

POPULATION CHARACTERISTICS OF *HALOXYLON AMMODENDRON* (C.A.MEY) BUNGE IN GURBANTÜNGGÜT DESERT, CHINA

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Abstract

Haloxylon ammodendron C.A. Mey Bunge is a desert shrub with ecological and economic importance. Because of the severe drought and the over-exploitation for firewood and livestock, the species is threatened. The survivor and mortality were studied in six populations distributed along the margin of Gurbantüנגgüt desert. The size structures, life tables and survivor curves were constructed for the studied populations. Populations were dominated by juvenile individuals and the seedling recruitment was extremely limited. Size distributions were skewed towards larger size classes in all populations. The survivorship curves approached Deevey type III in which the highest mortality occurs in the early life stages. The results indicated that the populations of *H. ammodendron* are threatened and efforts are required to minimize uncontrolled exploitation. Due to the very limited seedling recruitment, conservation efforts are required to protect and develop the extant populations. For this purpose, in situ and ex situ conservation of *H. ammodendron* populations are strongly recommended.

Key words: *Haloxylon ammodendron*, Chenopodiaceae, Population demography, Life table and survival curves, Deevey type III.

Introduction

The demographic study of plant population is important for reflecting the population's reality, to assess population stability, predicting successional trends, and implementing programs for the conservation and management of wild species (Lorimer 1980; Bonnicksen & Stone 1982; Menges, 1986; Silvertown *et al.*, 1993; Schemske *et al.*, 1994; Caswell, 2000; Manuel & Molles, 2002; Coates *et al.*, 2006). As it is generally infeasible to trace the whole life history, from birth to death, of a long-lived species, a static investigation on age structure of population was often accepted in population dynamic estimations (Harper, 1977; Stewart & Rose, 1986; Johnson & Fryer, 1989; Svensson & Jøglum, 2001). Population age structure may provide an insight into past and present regeneration (Agren & Zackarisson, 1990). Furthermore static life table, which estimates the age-specific survival and mortality from the age structure of a population at one moment in time, is used for long-lived 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).

Haloxylon ammodendron (C.A. Mey) Bunge is a perennial, xeric, desert shrub that occurs in a wide range of habitats. In Xinjiang Uygur Autonomous Region, northwest of China, it is widely distributed in the gap between fixed and semi-fixed sand dunes and the lower part of sand dunes, even grows into clay desert, gravel desert and saline land in Gurbantüנגgüt desert. As the dominant species in this arid region, it is often found in '*H. ammodendron* forests'. Since desert ecosystems have a simple physiognomic structure (Phillip & MacMahon, 1981) and have high environmental stress (Crisp & Lange, 1976), its great structural and economic importance are extremely important (Anon, 1947; McKell *et al.*, 1972). This species served as livestock feed and firewood, and was widely used in recent decades (Fu & Jin, 1992). Due to over-exploitation it resulted enlisting this

species as threatened in the Red Data Book of China Plants (Fu & Jin, 1992). With the development of local economy and the increasing of population, *H. ammodendron* degenerated rapidly and the quality of the extant forests is falling, resulted in the increasingly expanded desertification and worsened ecological environment (Huang, 2002). In the present study, the age and survival relationship of the tall shrub *Haloxylon ammodendron* C.A.Mey Bunge, is considered in conjunction with its spatial distribution indentifying population status and predicting future trends. It may provide strategies for restoration and conservation of *H. ammodendron* population.

Study area and Methods

Study area: The Gurbantüנגgüt desert (44°11'-46°20'N, 84°31'-90°00'E) is situated in the center of the Junggar Basin, Xinjiang Uygur Autonomous Region, China. It is the second largest desert in China with an area of 4.88×10^4 km². Because of the 'blocking effect' of the Himalayan range, moist air currents from the Indian Ocean fail to reach this area, resulting in a vast expansion of arid terrain. Mean annual precipitation is approximately 79.5 mm, falling predominantly in spring. In sharp contrast, mean annual pan evaporation is 2606.6 mm. Annual average temperature is 7.26 . Annual mean active accumulated temperature (≥ 10) is 3000–3500 . Mean relative air humidity ranges from 50% to 60%. Wind speeds are greatest during late spring, with average 11.17 m·s⁻¹, and are predominantly from the WNW, NW and N directions. Most of the sand dunes are stable and semi-stable. Natural vegetation in the area is dominated by *H. ammodendron* and *H. persicum* with a vegetation cover of less than 30% (Zhang *et al.*, 2007). Along the margin of Gurbantüנגgüt desert, the dominant species is *H. ammodendron*, and it is even formed pure forest in most vegetations. This species is found associated with many annual and perennial species such as *Artemisia arenaria*, *Calligonum leucocladum*, *Carex physodes*, *Ceratocarpus arenarius* *Erodium oxyrhynchum* and *Horanowia ulicina*.

Study species: *Haloxylon ammodendron* belongs to Chenopodiaceae family. It is a large shrub to a small tree about 1-10 m tall. It is covered with grey bark and green or glaucous-green, elongate, rather juicy Shoots 1.5-2 mm diameter, adpressed or drooping. Its leaves are underdeveloped, in a shape of opposite obtusate tubercles, with short hairs in axils. Its flowering and fruiting period are April and September respectively. Its flower is bisexual, very small, found in the axil. Tepals are ovate, scarious-translucent, forming obovate wings 8-10 spread. The seeds are dark green, have no endosperm and only a fully differentiated spiral seedling coated by pericarp. It develops strong root system, growing several meters down (Tobe *et al.*, 2000; Zhang, 2002; Sheng *et al.*, 2004).

H. ammodendron is found in arid region of central Asia, particularly in the Turkestan region and east of the Caspian Sea, as far as the Gobi, and also in many scattered areas of Iranian deserts. In china, it is distributed in Xinjiang Uygur Autonomous Region, Gansu, Ningxia Hui Autonomous Region and Inner Mongolia Autonomous Region. The Gurbantünggüt desert has the most extensive natural *H. ammodendron* forest in China. It is highly valued and called 'coal in the desert' because its woody stems and branches are an important fuel source for local people. The tender branches also provide good livestock fodder in winter and spring and *Cistanche deserticola*, a root parasite of *H. ammodendron* is prized in Chinese medicine as the 'ginseng of the desert'. Being highly drought-resistant, it has played an important role in the establishment of shelter belts and the fixation of sand dunes as a counter to desertification (McKee, 1993; Peng & Xu, 1996; Zhang, 2002a; Jia *et al.*, 2004).

Population demography: The variability and severity of the arid environment (Crisp & Lange, 1976) and great longevity of many shrub species, makes age estimations difficult in arid environment (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, 1980). JI(1930s) had noted that lines on the stem cross-section of *H. ammodendron* were normally thought as absence of rings, like in *H. ammodendron* forest of Karakum Desert. 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).

To undertake population dynamics six plots were set up. Plot 1 and 2 were kept in Karamay, the northwestern margin of The Gurbantünggüt desert. Plot 3, 4 and 5 were marked in Usu City, in the southwestern margin and plot 6 in Qitai County, in the southeastern margin (Fig. 1). The climates of the sampling plots were different (Table 1). Each plot having size of 0.3-0.4 ha was divided into quadrats of 25m² that measured the basal diameter, height and crown of each individual. For determining population structure and dynamics of *H. ammodendron*, static life-table and survival curve were used. The seedlings (basal diameter ≤ 1cm) and saplings (1cm ≤ basal diameter ≤ 3cm) were defined as the first and the second class respectively, while the adults were grouped into 3cm size classes based on basal stem diameter to give size-frequency distributions

of each plot. 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 (Table 2) sets out the estimated age in size class (x) and the second column list the corresponding numbers per cohort (N_x). 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 (l_x) was obtained as:

$$l_x = N_x/N_0 \quad (1)$$

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

$$d_x = l_x - l_{x+1} \quad (2)$$

Then, the stage-specific mortality rate (q_x) was calculated as:

$$q_x = d_x/l_x = 1 - (l_{x+1}/l_x) \quad (3)$$

The rate or intensity of mortality during any cohort, which reflects the killing power (K_x), was computed from the N_x values as:

$$K_x = \log_{10} N_x - \log_{10} N_{x+1} \quad (4)$$

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 (e_x) in age units was estimated as:

$$e_x = \sum_{j=x}^{\infty} l_j / l_x \quad (5)$$

Population spatial distribution: The spatial pattern of trees in a stand often reflects a species' mode of regeneration after disturbance. For example, clumped distributions at small to intermediate spatial scales may indicate gap-phase regeneration (Williamson, 1975), and random or regular distributions at larger scales may reflect intermittent regeneration after stand replacing disturbance (Veblen *et al.*, 1981). Mapping individuals in contiguous quadrats permits the use of nested-quadrat technique to detect scales of pattern. The type of spatial pattern was identified using Morisita's (1959) index:

$$I_s = q \sum n_i(n_i - 1) / N(N - 1) \quad (6)$$

where q is the number of 5 m × 5 m quadrats, n_i the number of individuals in the ith quadrat, and N is the total number of individuals in all quadrats. Morisita's index, I_s equals 1.0 when a population is randomly distributed, I_s > 1.0 if a populations is clumped, and I_s < 1.0 if a populations is regularly distributed. Each index value was tested with an F statistic to determine if it varied significantly (p < 0.01) from that of a random distribution (Morisita, 1959). The intensity of pattern was interpreted from the magnitude of the index value. The greater the index value the greater the intensity of clumping. The scale of pattern (m²) was identified by computing Morisita's index values for quadrats of varying size. Indices were calculated for square quadrats of successively larger size, whenever possible, to avoid fluctuations in I_s due to block shape (Pielou, 1977). I_s value was computed only for populations with >15 individuals because the index varies erratically when N is small.

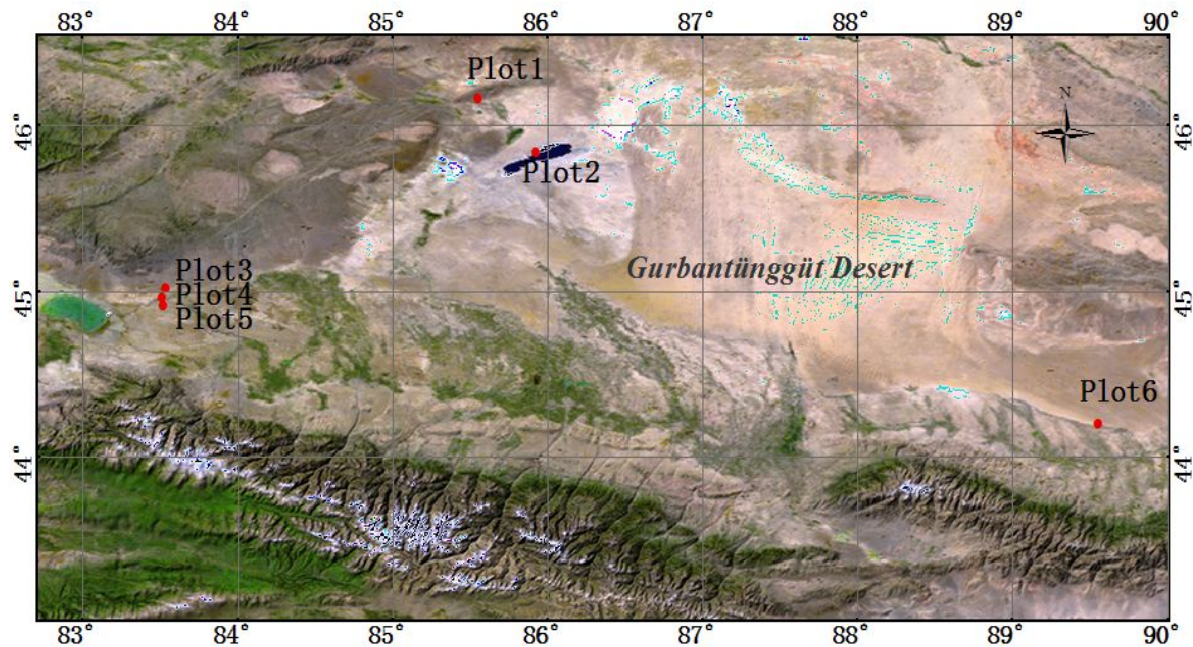


Fig. 1. The location of the *Haloxylon ammodendron* populations in studied plots

Table 1. Location of *Haloxylon ammodendron* populations in Gurbantünggüt desert.

Plot	Longitude (E)	Latitude (N)	Altitude (m)	Mean temperature °C				Mean annual rainfall (mm)			Mean annual evaporation (mm)
				Mean in Jan.	Mean in Jul.	Min in Jan.	Max in Jul.	Mean	Min.	Max.	
1.	85°33.087'	46°10.012'	419	□ 15.8	27.8	□ 40.2	43.8	96.4	56.0	117.8	3016.4
2.	85°55.593'	45°50.460'	252								
3.	83°32.268'	44°56.588'	231								
4.	83°32.368'	44°56.737'	219	□ 19.2	26.2	□ 42.1	43.7	150.0	97.2	180.0	2000.0
5.	83°32.553'	44°56.224'	208								
6.	89°33.632'	44°11.803'	648	—	—	□ 42.6	43.0	176.0	—	—	2141.0

Climatic data based on Anonymous (1999); Xu & Han (1996); Liu *et al.*, (2010)

Results

Population demographic structure: The size structure (age) of the studied populations is shown in Fig. 2. Seven diagrams represented the population structures in the six plots and the total of all plots together, respectively (Fig. 2). Among the studied plots, no seedling was found in plot 5. Juveniles were discovered in all plots with the highest values in plot 3 and 4 (46.48% and 31.96%, respectively). In the remaining plots, the percentage of juveniles' ranges varied between 9.45% in plot 6 and 32.87% in plot 1. All the size classes (cohorts) were represented in plot 2, 4, 5. The other plots lacked individuals in the larger size class. Simultaneously, the percentage of adult individuals per cohort decreased with cohort size. Taken together, all populations in the studied plots showed a deficit of individuals in the seedling class and the size structures were skewed towards larger size classes in all populations in the studied plots (Fig. 2). With the exception of plot 2 and 3, the most individuals were included in the juvenile and A1 size classes.

Life table and survive curve: The life tables of the studied populations are given in Table 2. The survivor individuals and survivor rate were decreased with the age increase (Fig. 3; Table 2). The age-specific mortality rate (q_x) varied in different size classes (ages). Comparatively, size classes S, J, A1, and A2 had a higher mortality rate, and size classes A3-10 had a lower mortality rate. A general trend was that mortality rate decreased with increase of age (Table 2). Specially, in some populations there were more individuals in the later class, class A1, than the preceding class, class S and J. Therefore negative deaths (d_x) and meaningless mortality rates were discovered. The mean expectation of future life (e_x) of the different stage-classes surviving to successive ages is shown in table 2. The e_x showed the highest values for seedling, but the values declined in older stages.

The survival curves (Fig. 3) showed the same tendency. There was a sharp decline in survival from juvenile to early adult stage and a plateau of low values in older plants. The shape of survivor curve of *H. ammodendron* was between Deevey II and III (Fig. 3) and seemed more closed to Type III than Type II.

Table 2. The static life table of *Haloxylon ammodendron* populations in Gurbantünggüt desert, northwest of China.

Size class(x)	N_x	l_x	d_x	q_x	$\text{Log}_{10} N_x$	K_x	e_x
Plot 1							
S	149	1.00000	-0.91946	-0.92	2.17	-0.28	5.84
J	286	1.91946	-0.06711	-0.03	2.46	-0.01	2.52
A1	296	1.98658	1.27517	0.64	2.47	0.45	1.47
A2	106	0.71141	0.53691	0.75	2.03	0.61	1.31
A3	26	0.17450	0.14765	0.85	1.41	0.81	1.27
A4	4	0.02685	0.02013	0.75	0.60	0.60	1.75
A5	1	0.00671	-0.00671	-1.00	0.00	-0.30	3.00
A6	2	0.01342	0.01342	1.00	0.30	-	1.00
A7	0	0.00000	0.00000	-	-	-	-
A8	0	0.00000	0.00000	-	-	-	-
A9	0	0.00000	0.00000	-	-	-	-
A10	0	0.00000	-	-	-	-	-
Plot 2							
S	10	1.00000	-2.10000	-2.10	1.00	-0.49	21.30
J	31	3.10000	-1.60000	-0.52	1.49	-0.18	6.55
A1	47	4.70000	0.00000	0.00	1.67	0.00	3.66
A2	47	4.70000	1.90000	0.40	1.67	0.22	2.66
A3	28	2.80000	1.10000	0.39	1.45	0.22	2.79
A4	17	1.70000	0.90000	0.53	1.23	0.33	2.94
A5	8	0.80000	0.30000	0.38	0.90	0.20	4.13
A6	5	0.50000	0.00000	0.00	0.70	0.00	5.00
A7	5	0.50000	0.30000	0.60	0.70	0.40	4.00
A8	2	0.20000	-0.30000	-1.50	0.30	-0.40	7.50
A9	5	0.50000	-0.30000	-0.60	0.70	-0.20	2.60
A10	8	0.80000	-	-	0.90	-	1.00
Plot 3							
S	86	1.00000	-8.81395	-8.81	1.93	-0.99	21.12
J	844	9.81395	2.79070	0.28	2.93	0.15	2.05
A1	604	7.02326	4.93023	0.70	2.78	0.53	1.47
A2	180	2.09302	1.43023	0.68	2.26	0.50	1.57
A3	57	0.66279	0.33721	0.51	1.76	0.31	1.79
A4	28	0.32558	0.20930	0.64	1.45	0.45	1.61
A5	10	0.11628	0.05814	0.50	1.00	0.30	1.70
A6	5	0.05814	0.04651	0.80	0.70	0.70	1.40
A7	1	0.01163	0.00000	0.00	0.00	0.00	2.00
A8	1	0.01163	0.01163	1.00	0.00	-	1.00
A9	0	0.00000	0.00000	-	-	-	-
A10	0	0.00000	-	-	-	-	-
Plot 4							
S	109	1.00000	-1.48624	-1.49	2.04	-0.40	7.78
J	271	2.48624	0.66972	0.27	2.43	0.14	2.73
A1	198	1.81651	0.77982	0.43	2.30	0.24	2.36
A2	113	1.03670	0.46789	0.45	2.05	0.26	2.39
A3	62	0.56881	0.15596	0.27	1.79	0.14	2.53
A4	45	0.41284	0.21101	0.51	1.65	0.31	2.11
A5	22	0.20183	0.06422	0.32	1.34	0.17	2.27

Table 2. (Cont'd.).

Size class(x)	N_x	l_x	d_x	q_x	$\text{Log}_{10} N_x$	K_x	e_x
A6	15	0.13761	0.06422	0.47	1.18	0.27	1.87
A7	8	0.07339	0.05505	0.75	0.90	0.60	1.63
A8	2	0.01835	0.00917	0.50	0.30	0.30	2.50
A9	1	0.00917	-0.00917	-1.00	0.00	-0.30	3.00
A10	2	0.01835	-	-	0.30	-	1.00
Plot 5							
S	0	-	-	-	-	-	-
J	99	1.00000	-1.16162	-1.16	2.00	-0.33	6.59
A1	214	2.16162	1.21212	0.56	2.33	0.36	2.58
A2	94	0.94949	0.19192	0.20	1.97	0.10	3.61
A3	75	0.75758	0.02020	0.03	1.88	0.01	3.27
A4	73	0.73737	0.36364	0.49	1.86	0.30	2.33
A5	37	0.37374	0.08081	0.22	1.57	0.11	2.62
A6	29	0.29293	0.15152	0.52	1.46	0.32	2.07
A7	14	0.14141	0.07071	0.50	1.15	0.30	2.21
A8	7	0.07071	0.00000	0.00	0.85	0.00	2.43
A9	7	0.07071	0.04040	0.57	0.85	0.37	1.43
A10	3	0.03030	-	-	0.48	-	1.00
Plot 6							
S	14	1.00000	-0.35714	-0.36	1.15	-0.13	14.36
J	19	1.35714	-4.50000	-3.32	1.28	-0.64	9.84
A1	82	5.85714	1.50000	0.26	1.91	0.13	2.05
A2	61	4.35714	2.85714	0.66	1.79	0.46	1.41
A3	21	1.50000	1.21429	0.81	1.32	0.72	1.19
A4	4	0.28571	0.28571	1.00	0.60	-	1.00
A5	0	0.00000	0.00000	-	-	-	-
A6	0	0.00000	0.00000	-	-	-	-
A7	0	0.00000	0.00000	-	-	-	-
A8	0	0.00000	0.00000	-	-	-	-
A9	0	0.00000	0.00000	-	-	-	-
A10	0	0.00000	-	-	-	-	-
Total (sum of 6 populations)							
S	368	1.00000	-3.21196	-3.21	2.57	-0.62	12.50
J	1550	4.21196	0.29620	0.07	3.19	0.03	2.73
A1	1441	3.91576	2.28261	0.58	3.16	0.38	1.86
A2	601	1.63315	0.90217	0.55	2.78	0.35	2.06
A3	269	0.73098	0.26630	0.36	2.43	0.20	2.38
A4	171	0.46467	0.25272	0.54	2.23	0.34	2.17
A5	78	0.21196	0.05978	0.28	1.89	0.14	2.56
A6	56	0.15217	0.07609	0.50	1.75	0.30	2.18
A7	28	0.07609	0.04348	0.57	1.45	0.37	2.36
A8	12	0.03261	-0.00272	-0.08	1.08	-0.03	3.17
A9	13	0.03533	0.00000	0.00	1.11	0.00	2.00
A10	13	0.03533	-	-	1.11	-	1.00

N_x , number per age class; l_x , proportion of original cohort surviving to the start of each age; d_x , proportion of original cohort dying during each age; q_x , stage-specific mortality rate; K_x , killing power; e_x , expectation for future life

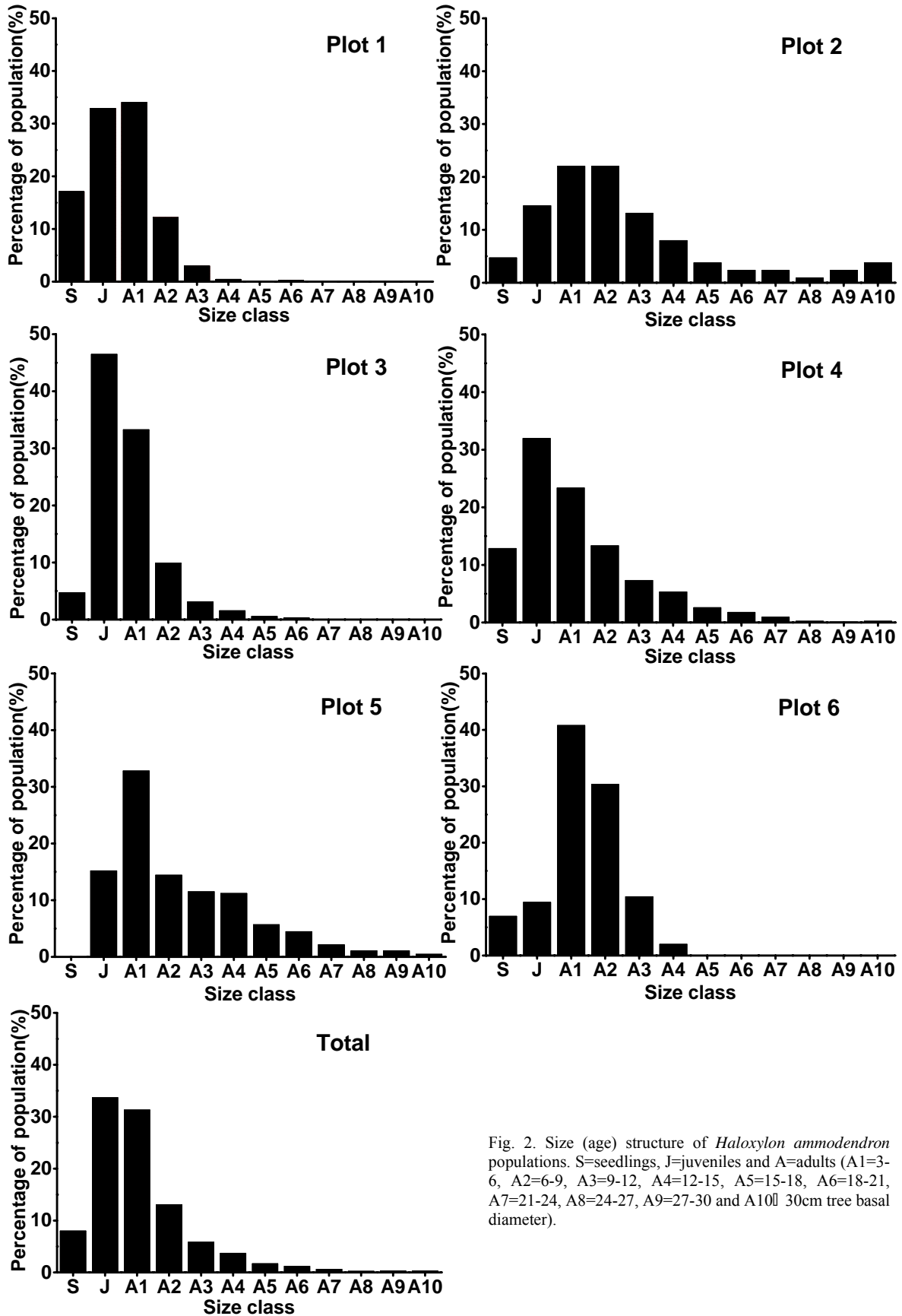


Fig. 2. Size (age) structure of *Haloxylon ammodendron* populations. S=seedlings, J=juveniles and A=adults (A1=3-6, A2=6-9, A3=9-12, A4=12-15, A5=15-18, A6=18-21, A7=21-24, A8=24-27, A9=27-30 and A10= 30cm tree basal diameter).

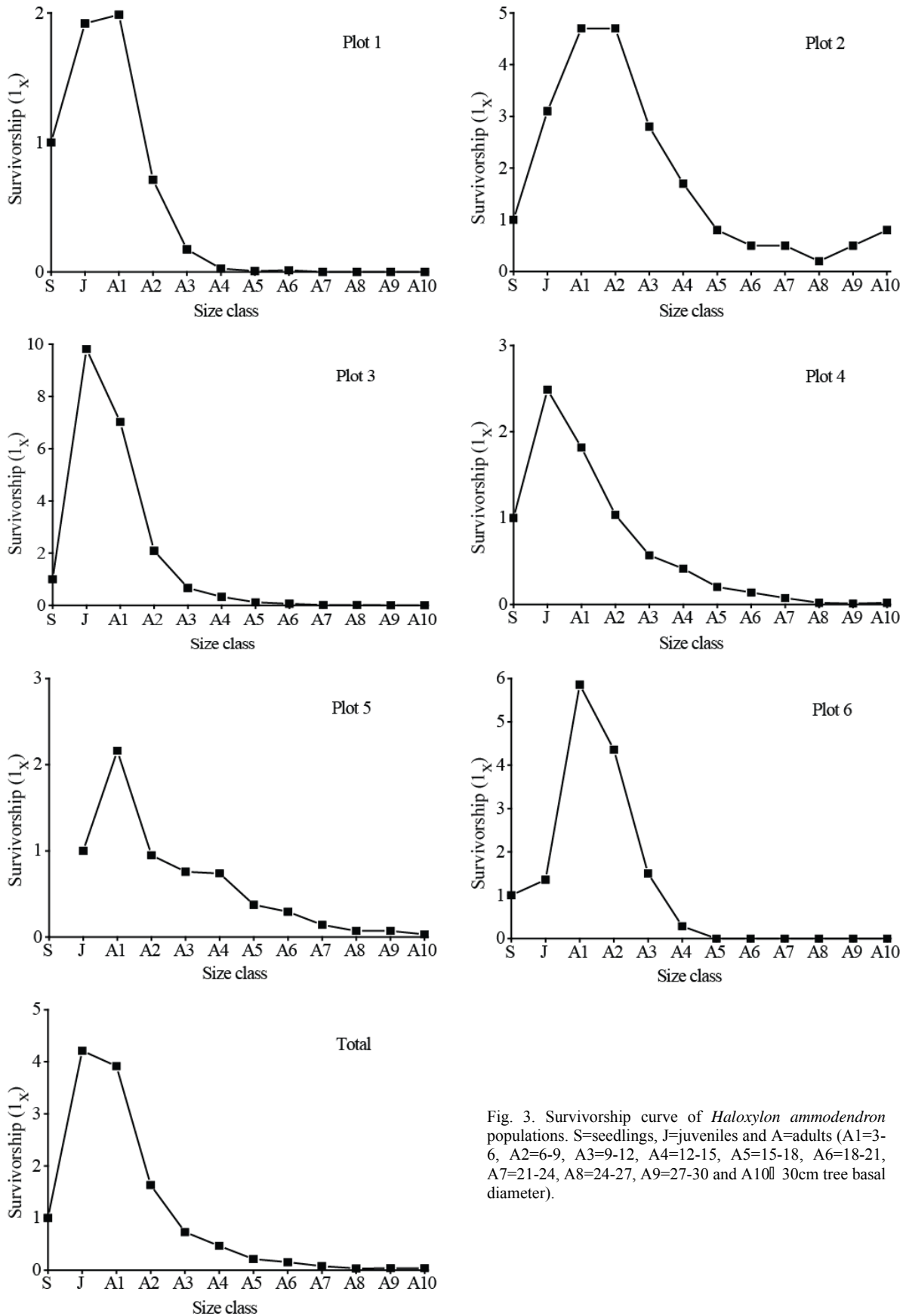


Fig. 3. Survivorship curve of *Haloxylon ammodendron* populations. S=seedlings, J=juveniles and A=adults (A1=3-6, A2=6-9, A3=9-12, A4=12-15, A5=15-18, A6=18-21, A7=21-24, A8=24-27, A9=27-30 and A10] 30cm tree basal diameter).

Distribution pattern: Analysis of the distribution patterns of *H. ammodendron* suggested that this species had a clumped distribution in all plots and all study areas together (Fig. 4). The intensity of aggregation represented by the value of I_s showed a rapid decline from the scale of 25m² to 100 m² and a plateau of low values in larger scales. The populations of plot 5 and 6 were even regularly distributed in larger scales (1600 m² and 900 m², respectively).

Discussion

The population structure of *H. ammodendron* was an irregular 'reversed-J shaped' in all plots in the Gurbantüggüt desert, i.e., most individuals were included in young classes and the number of seedlings was very small. Simultaneously, the static life-table proved that population size in the first three age classes varied greatly, i.e., seedlings, juveniles and small trees had a large mortality which was identical to 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 low mortality of older adults. These curves approached Deevey type III (Deevey, 1947), in which the highest mortalities occurred in the early life stages. This type of survivorship curve for perennials had also been observed by Valen (1975) and Hegazy (1992, 1997). According to Harper and White (1974), the survival pattern of *H. ammodendron* population in the Gurbantüggüt desert meant that selective forces in the habitat were acting on the weakest stages of the life cycle. 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.

The near lack of seedlings indicated the extremely low seedling recruitment that could be related to the adverse arid conditions prevailing in the region. In the Gurbantüggüt desert there were stable snow covers in winter and the stage of seed germination and seedling emergence was at the same time with the snow melt. This means good water condition at this stage. It was believed that the following rapid rising of temperature and drought in spring were the main reason resulted in the high mortality of seedlings and juveniles. Recruitment and mortality patterns may be closely tied to climatic fluctuations, with periods of abundant regeneration coinciding with periods of favorable weather conditions (Franklin *et al.*, 1971; Payette & Filion, 1985; Kullman, 1986). Further regeneration will be suppressed once a vigorously growing cohort of young plants has monopolized available resources (Hett & Loucks, 1976; Peet, 1981; Agren & Zackrisson, 1990). Also the Intraspecific competition and animal grazing had effect on survive of seedlings and juveniles. When they reached the adult stage, features relative to the early life stages, such as the development of deep roots that enable the plants to absorb water from the deep, permanently wet zone and the shedding of leaflets that reduces the transpiring surface, would have significant effect on their survivor.

These features allow the plants to cope with the high aridity characterizing the desert environments (Kassas & Batanouny, 1984; Hegazy *et al.*, 2008).

The general spatial distribution pattern of *H. ammodendron* population in the Gurbantüggüt desert was clumped which was consistent with other desert shrub species (Barbour, 1969; Crisp & Lange, 1976). The distribution pattern mainly depended on the biological features. Seeds were usually sprayed around their mother trees. It was believed that the stem flow of *H. ammodendron*, which was rainfall captured by the crown of tree, carried nutrients down into soils around tree stem. This volume of water and nutrient could contribute to the development of 'fertile island'. This effect of positive feedback on environment could enhance the water availability and nutrient content in the soil, which enabled plants to be more resistant to arid environment (Tromble, 1988; Meza, 1996; Whitford, 1997; Liu *et al.*, 1999; 2010) and was helpful to the recruitment of seedlings and establishment of saplings. Also the shading of the mother trees was helpful under the drought conditions due to high temperature and low rainfall, which is prevail in the desert environment. With the seedling growing, the need of resources was increased. In arid environments, established trees may be expected to suppress seedling and sapling growth through root competition (Romell & Malmström, 1945; Chapin *et al.*, 1989). Due to intraspecific competition the distributions of populations might turn to be random or even regular patterns in older adults (Sheng *et al.*, 2004; Song *et al.*, 2010).

Silander (1983) suggested that often the decline in a shrub species may not be detected until the remaining adults are moribund or have died, and new recruitment is unlikely. Lange and Purdie (1976) concluded similar predictions for *Acacia papyrocarpa*, which reproduces only from seed. By contrast, considerable number of individuals was in the early life stage of *H. ammodendron*, the deficit of seedlings and the high mortality of seedlings and juveniles were worrying. The population of *H. ammodendron* was threatened.

Prospects of conservation: Analysis of the demographic data by population structure and life tables is significantly important from the conservation management point of view, as they provide an understanding of the dynamics of the population and its life history characteristics. The Deevey type III survivorship curve suggests that seedling stages have the highest mortality risks in *H. ammodendron*. The population is in danger and its survival cannot be ensured without conservation management.

In China conservation efforts were curtailed by severe lack of money and dearth of information about individual species. Many sloppy works had done by the government officials who were Lack of awareness and professional knowledge of ecological protection. Demographic studies on survival, mortality and reproduction are the logical cost-effective studies to be undertaken. A thorough understanding of population dynamics and biology is critical for sound conservation management.

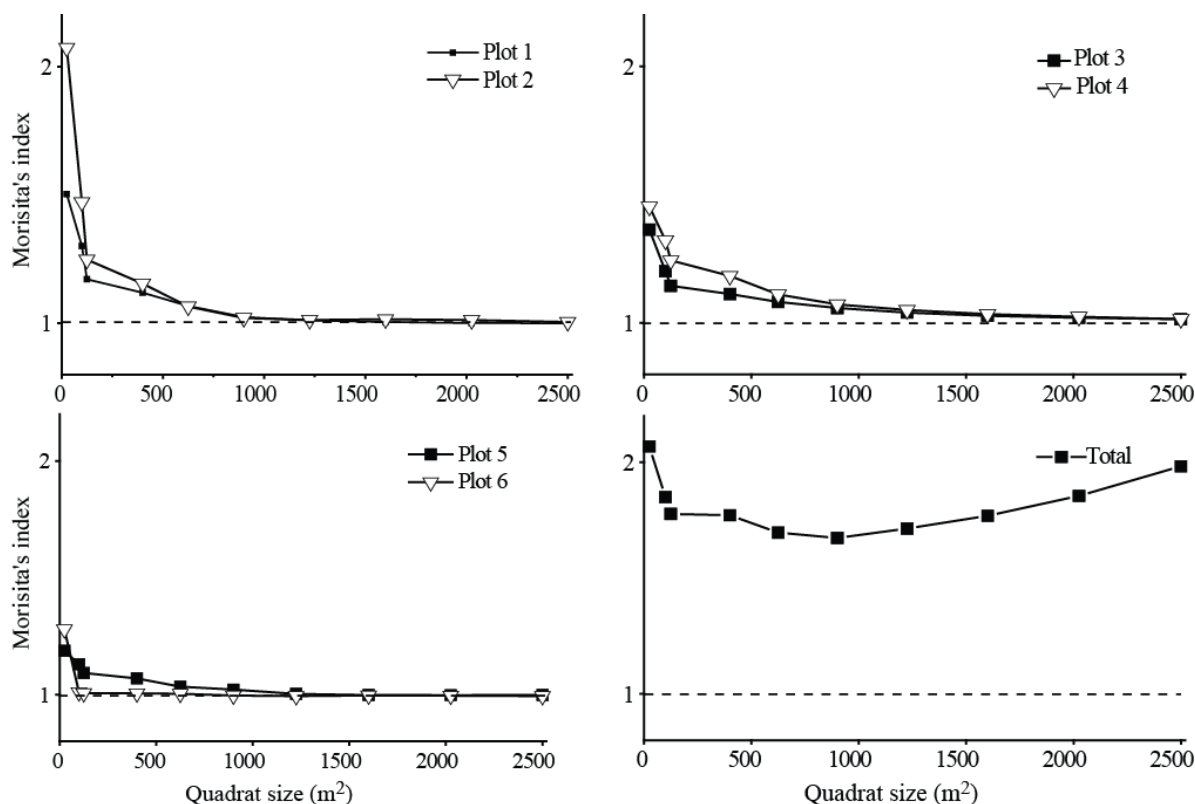


Fig. 4. Values of Morisita's (1959) index of *Haloxylon ammodendron* populations. A random distribution ($I^* = 1.0$) is shown by the dashed line.

The following recommendations may provide guidelines to conserve *H. ammodendron* and forestall its extinction: (1) in situ conservation of the existing populations; (2) creation of natural reserves to protect the diversity of plant population and habitat; (3) ecological research on in situ and ex situ populations for creating conditions conducive to optimum survival and reproductive strategies; (4) efforts should be made to increase the ecological awareness of the local people to reduce their dependence on the *H. ammodendron* for fuelwood and livestock feed; (5) measures should be taken to forbid the illegal collection of *Cistanche deserticola* since it will seriously hurt the root of *H. ammodendron*; (6) offering other resources and economic activities to the local people as alternatives to their dependence on *H. ammodendron* and on the natural vegetation in general as an income source, such as artificial cultivation of *Cistanche deserticola*; (7) preservations of seeds in a gene bank for maintenance of its valuable genetic resources; and (8) encouraging botanical gardens and research institutes to maintain ex situ populations.

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