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POPULATION STRUCTURE AND DYNAMICS OF AN ENDANGERED DESERT SHRUB ENDEMIC TO NORTHWESTERN CHINA

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Abstract

Information of population structure and dynamics can provide valuable insight for conservation and management of rare and threatened plant species. *Tamarix taklamakanensis* is an endangered shrub endemic to northwestern China. The abundance of this species has been substantially decreased over the past several decades. Size structure, static life table and survivor curve were analyzed to estimate the population demography. Within the 6 plots set up in the Taklimakan Desert, seedlings were scarce and juvenile individuals were dominant. Size distributions were skewed down towards larger size classes in all plots. The shape of survivorship curves was approximate Deevey type III, suggesting a high mortality in early life stages of this species. Based on hierarchical analysis of variance and Morisita's index, *T. taklamakanensis* had a clumped distribution pattern in all plots and in the species level. Based on time sequence analysis, survived individuals increased and decreased in abundance. The results indicated that young stages were at great risk before transforming to adult individuals, and the populations might finish with the elapse of time. Efforts are required to prevent the continuous loss in abundance. Conserving the groundwater in the basin is essential for the conservation of *T. taklamakanesis*, and in situ and ex situ conservation measures were strongly recommended. As well as, artificial tending should be performed on the young stages of the population.

Key words: *Tamarix taklamakanensis*, Age structure, Population demography, Conservation

Introduction

A better understanding of the population structure and dynamics is fundamental to the conservation and management of rare and threatened plant species (Synge, 1985; Hutchings, 1991; Peterken, 1993; Caswell, 2000; Coates *et al*., 2006; Monks *et al*., 2012). Usually, it is infeasible to trace the whole life history of a long lived species for longevity of the average individual, thus studying the population biology of tree or shrub species one could face with some special difficulties (Dong, 1987). However, in the absence of long-term records, surveying individuals of the population, performing a static investigation on age structure, and modeling demography in a chronological sequence, are valuable methods for giving insight into the age structure and dynamics of populations (Harper, 1977; Laven, 1982; Johnson & Fryer, 1989; Svensson & Jeglum, 2001). Within desert ecosystem, the dominated plant component is usually woody species that live for several decades or centuries, which played an important role in maintaining stability of the ecosystem (Beatley, 1980; Bowers *et al*., 1995; Aich, 1991). Nevertheless, in spite of its key role on desert biomes, most trees and shrubs have received little attention in terms of their natural history. For instance, little is known about population characteristics among shrubby species within the Tarim Basin, which covers approximately 530,000 km^2, and is the largest inland basin in the world (Liu & Qin, 2005). *Tamarix* species is an edificator in the ecosystem (Dang *et al*., 2002), and dune fixed by *Tamarix* species were found throughout the basin. *Tamarix* species has wide ecological amplitude, and is tolerant to drought, salinization, wind, and sand (Li, 1990), thus is an important shrub in the ecosystem within the Tarim Basin (Liu, 1987).

Among the *Tamarix* species within the Tarim Basin, *T. taklamakanensis* has a unique distribution pattern and non-overlapping ecological amplitude compared with other species of the genus, mainly distributing in interior of the Tarim Basin, the Taklimakan Desert. It has unique morphological characters, could be distinguished from the other species in *Tamarix*, with reduced leaves and the largest flowers in size (4-7mm in diameter) in China (Yang & Gaskin, 2007). As well as, it is much more tolerant to drought, high temperature, and sand burial than other species of *Tamarix* (Li, 1990; Liu, 1987). It is mainly distributed along the Hotan River, Tarim River, and Andir River systems, growing in sand dunes and lowland areas (Liu, 1987). However, it has been observed the population size continuously declined since the past several decades (Liu *et al*., 1996; Yang *et al*., 2013), and has been listed as endangered in the China Species Red List due to the depression status (Fu, 1992).

In spite of the depression status, there is no information about the population characteristics of the species. Population structure of plants may be described by classifying the individual either by age, size or their life stage (Rabotnov, 1969, 1985). Usually, it is impossible in practice to establish the age of each individual accurately, except by monitoring them persistently from germination onwards. However, plant size and age are correlated well, thus we can use size class frequency distributions of individuals to represent the age structures (Grice *et al*., 1994; Oostermeijer *et al*., 1994). This method was successfully used in studies of woody species, such as *Acacia victoriae* (Grice *et al*., 1994), *Acacia carnei* and *A. oswaldii* (Auld, 1990), and *Haloxylon ammodendron* (Lv *et al*., 2014). Here, we use size-class frequency distributions to examine the population structure of *Tamarix taklamakanensis* and predict its future trends dynamics, in order to provide conservation strategies for the populations.

Material and Methods

Study area: The Tarim basin is surrounded by the Pamir Plateau on the west, the Tianshan mountains on the north, the Kunlun and Altun Mountains on the south, and was opened to the eastern Kumtag Desert. Glaciers and snow hills on the surrounded mountains melt seasonally, feeding the ecosystem within the basin (Liu & Qin, 2005). Uplift of the Tibetan Plateau date from the Pliocene changed the atmospheric circulation in the basin intensely, causing widespread acidification across the entire basin (Zheng *et al*., 2003; Sun *et al*., 2008; Wang *et al*., 1996). The Taklimakan Desert, the world's second largest shifting-sand desert, is located in the center of Tarim Basin, covering approximately 3. 376 $\times 10^5$ km^2, and occuping nearly 60% of the entire area (Liu & Qin, 2005). In interior of the desert, annual maximum temperatures ranges from 40~46°C, annual minimum temperatures ranges from subzero 20~25°C, and mean annual temperature is 12.4°C. Mean annual precipitation is approximately 11.05 mm, falling mainly in spring and summer, and mean annual pan evaporation is 3 638.6 mm. Mean relative air humidity ranges from 10% to 30%, mean annual air humidity is 16.68%, and mean wind speeds is 2.3 $m \cdot s^{-1}$. Mean annual sandstorm weather approximately lasts above 30d, floating dust weather approximately lasts 200d, principally occurring in spring and summer (Peng, 2013; Wu *et al*., 2017).

Population demography: Accurate age estimation for plant individual is difficult for shrub, vine, and perennial herb, except for the temperate tree by annual ring (Yuan *et al*., 2011). In addition, it is impractical to sample annual ring for endangered species with a rare distribution. Moreover, it has been reported that the growth of ring was not continued in many shrubs in desert for the harsh arid environment, that is they produced multiple rings in some years but none or partial in others (Webber, 1936; Lange, 1965; Vasek, 1980). As well as, it has been reported in a congener, *Tamarix ramosissima*, annual ring is usually integral in individuals under 10 years old, but multiple and not integral in those beyond 10 years old (Xiao *et al*., 2005). Thus, it is infeasible to determine the age of *Tamarix taklamakanensis* using annual ring, therefore it, the size-class is used for the population dynamics analysis.

A total of 6 plots were set up in the Taklimakan Desert to learn the population dynamics. Of the 6 plots, plot 1 was from the northwest area of the desert, five (plots 2-6) were from the center of the desert (Table 1, Fig. 1). Climates of each sampled plots were presented in Table 1. Each plot covered an area of 0.3-0.4 ha, and was divided into 25m^2 quadrats. Within the quadrats, the basal diameter, height and crown were measured for each individual, using round number. Static life table and survival curve were used to determine the population structure and dynamics of *Tamarix taklamakanensis*. Seedlings with basal diameter ≤1cm were defined as the first size class, saplings with basal diameter greater than 1cm and less than 3cm were defined as the second class, and the adults were classified with a 3cm basal diameter ladder to give a size division for the populations. Static life table was created for each population following the methods of Pielou (1977) and Hegazy (1992). In the life table, size class (x) was present in the first column and the corresponding survived numbers (Nx) were present in the second column. The survived numbers in each class was standardized in the third column. With a started value of 1.0, the surviving proportion of each class to the originate cohort (lx) was obtained as:

$$lx = N_x/N_0 \qquad (1)$$

The numbers of died individuals from x stage to x+1 stage (dx) was calculated as:

$$dx = N_x - N_{x+1} \qquad (2)$$

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

$$qx = d_x/l_x \qquad (3)$$

The mortality rate index from x stage to x+1 stage, reflecting the killing power (Kx), was computed as:

$$Kx = lgN_x - lgN_{x+1} \qquad (4)$$

The expectation of remaining life (ex) in x stage was estimated as:

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

Population distribution pattern: All individuals were mapped in contiguous quadrats, then nested-quadrat technique was used to detect scales of distribution pattern. The type of population distribution pattern was verified using hierarchical analysis of variance according to Silvertown (1982). The index C was the ratio of variance (s^2) to the mean value (m), and was calculated as:

$$C = s^2/m \qquad (1)$$

The variance (s^2) was calculated as:

$$s^2 = \frac{\sum (f_i x_i)^2 - [(\sum f_i x_i)^2 / n]}{n-1} \qquad (2)$$

The mean value (m) was calculated as:

$$m = \frac{\sum f_i x_i}{n} \qquad (3)$$

The t value was calculated as: (4)

$$t = \frac{C-1}{\sqrt{\frac{2}{n-1}}}$$

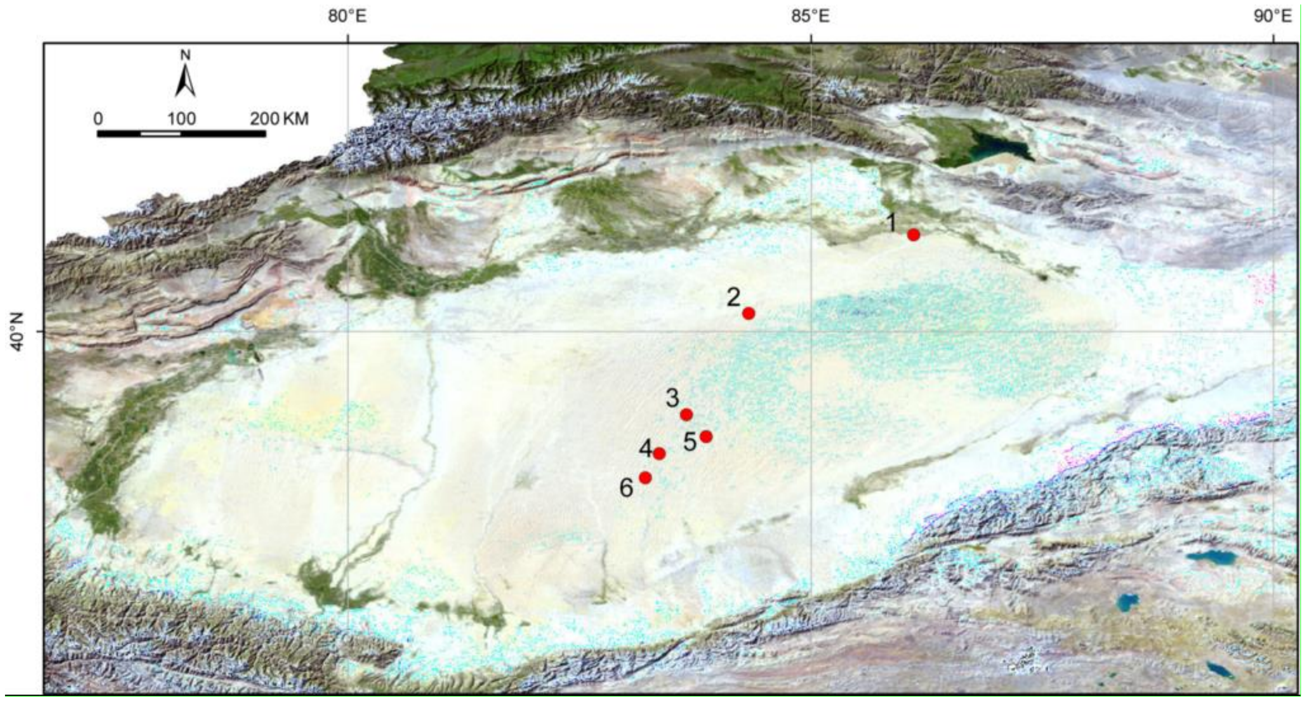

Fig. 1. The location of the *Tamarix taklamakanensis* populations in studied plots.

Table 1. Location of *Tamarix taklamakanensis* populations in Taklimakan Desert. Climatic data based on Dong (2012); Mu (2017); Peng (2013); Liu (2018).

Plot	Longitude	Latitude	Altitude	Mean temperature °C			Mean annual rainfall	Mean annual evaporation
	(E)	(N)	(m)	Annual mean	Min in Jan.	Max in Jul.	(mm)	(mm)
1	86.11	41.04	887	10.8	-30.9	43.6	17.4~42.0	2429~2910
2	84.34	40.20	935	10.6~11.5	-27.5	43.6	17.4~42.0	2671.4~2902.2
3	83.66	39.11	1070	12.1	-25	46	25.9	3812.3
4	83.37	38.69	1128	11.7	-20.8	40	17.8	1977.3
5	83.87	38.87	1096	12.1	-25	46	25.9	3812.3
6	83.22	38.43	1168	11.7	-20.8	40	17.8	1977.3

Where, n is the number of 5 m×5 m quadrats, x_i x_i is the number of individuals in the i th quadrat, and f_i is the frequency of the i th quadrat which have x individuals. If C < 1, it indicates the population is regularly distributed; if C = 1, it indicates the population is randomly distributed; and if C > 1 significantly, it indicates the population is clumped. The t value was used to estimate the significance level of the distribution pattern.

The Morisita's index I_δ was calculated as:

$$I_\delta = n\sum x_i(x_i - 1)\, x_i x_i / N(N-1) \quad (5)$$

Where n is the number of 5 m×5 m quadrats, x_i x_i is the individuals number in the i th quadrat, and N is the total individuals number of all quadrats. If $I_\delta < 1$, it indicates the population is regularly distributed; if $I_\delta = 1$, it indicates the population is randomly distributed; and if $I_\delta > 1$, it indicates the population is clumped. The χ^2 statistic was used to estimate the significance level ($p<0.01$) of the distribution pattern (Morisita, 1959).

The χ^2 was calculated as:

$$\chi^2 = I_\delta(N-1)+n-N \qquad (6)$$

Population dynamic prediction based on time sequence analysis: Using once moving average method of time sequence analysis, future population dynamic of *Tamarix taklamakanensis* was predicted as:

$$M_t^{(1)} = M_{t-1}^{(1)} + (X_t - X(t-n))/n \quad (7)$$

Where $Mt^{(1)}$ is the average of the n observed values at t moment, called moving average at the n_{th} period; X_t is the population size at t size class; and n is the individual number at different size class (Xie, 1990). Population development tendency were predicted at the 2th, 4th, and 6th generation respectively.

Results

Population age structure: Tree ages were determined in plots 1-6 and relative frequencies are presented in each year class (Fig. 2). Size class was complete in plots 3, 5, and 6, and were absent in older size classes within plots 1, 2, and 4. Within the 6 plots, seedlings made a small proportion in plots 1, 2, 4, 5, a high proportion in plot 3, and a moderate proportion in plot 6; Juveniles made the largest proportion in plots 1, 3, and 5; made a high proportion in plots 4 and 6, and a moderate proportion in plot 2; in each plot, the proportion of adult individuals has decreased with size class. In total individuals, seedlings were scarce, and juveniles made up the largest proportion; the size classes were ascending first, then skewed down towards larger size classes (Fig. 2).

Static life table and survivorship curve: The static life tables of the studied plots were presented in Table 2. The survivor individuals and survivor rate were declined with the increase of the age size (Table 2; Fig. 3). The age-specific mortality rate (qx) showed a multiple trend in age size classes in each plot. In total individuals, seedlings and juveniles had a negative or low mortality rate; during the transformation from young to adult class, A1 and A3 had a high mortality rate; at the adult status, size A4-A6 had a low mortality rate; when step in old class, class A7 had the highest mortality rate then fall to negative rate at A8 and A9 class. Seedling had the highest mean expectation of future life (ex) in plots 1, 2, 4, 5, and 6, and ex value was generally declined as the age size increased. The survivorship curves showed a sharp decline from juvenile to early adult stage and a plateau of low values in older sizes (Fig. 3). The shape of survivor curve was between Deevey II and III (Fig. 3), seemed to be more close to Type III than Type II.

Distribution pattern: Based on the ratio of variance to the mean value (C), populations in plots 1, 2, 3, 5, and 6 was clumped distributed, and populations in plot 4 was regularly distributed; based on the Morisita's index, populations in all the plots were clumped distributed. Taken together, *Tamarix taklamakanensis* had a clumped distribution in all studied plots (Fig. 4).

Population dynamic prediction: With the elapse of time (Fig. 4), size class with the maximum of survived individual in each plot became older; survived individuals increase in old sizes and decrease in young sizes; survived individuals decline as the age size increase in each time sequence. In short, the population might decay with the elapse of time if without sufficient supplement of seedling and juvenile.

Discussion

Within the sampled populations of *Tamarix taklamakanensis* in the Tarim Basin, the seedling number was small, and juvenile and young tree age states (A1-A3) were predominant, suggesting these were approximately described by an inverse-J type of curve. The static life-table, showed that the population size varied greatly in the first five classes, and a large mortality was detected within juveniles and small trees (A1-A3), that was consistent with the results in some other desert shrubs (Lv *et al*., 2014; Grice *et al*., 1994; Hegazy *et al*., 2008). The survivorship curves of the plots also showed a high mortality of young trees and a low mortality of elder adults. The shape of these curves approximately approaches Deevey type III (Deevey, 1947), in which a sharp number reduction occurred in the early life stages.

Soil moisture is speculated to be a critical factor influencing seedling survival and establishment. The climate in center of the Tarim Basin is very dry, with a fairly limited precipitation in spring when the seeds germinate. Although a large seed bank produced by *Tamarix taklamakanensis* adult trees (Ma, 2007), only a few seeds can germinate. Moreover, success in establishment of seedlings depended on subsequent weather conditions (Franklin *et al*., 1971; Kullman, 1986), whereas following rapidly rised temperature and drought in the habitats often lead to a high mortality of seedlings. As well as, animal grazing would reduce the number of seedlings. Once the seedlings can survive, they will vigorously grow in to the juvenile stage (Table 2). Whereas, from juvenile to A3 stage, further regeneration would be suppressed when the growing cohort of young trees monopolized limited resources (Peet, 1981; Agren & Zackrisson, 1990). Competition for water, mineral nutrients and light would induce a high mortarity of the young trees. Above all, young stages of *T. taklamakanensis* population encountered selective forces, and thus second to be the weakest stage of the life cycle. These stages were presumably at great risk before transforming to adult individuals, and were the bottleneck to the following successful regeneration. Similar thinning pattern during young stages were also ovserved in other species (Thomas & Polwart, 2003; Toft & Raizer, 2003; Boulan-ger-Lapointe, 2012; Nakatsubo *et al*., 2010; Cooper *et al*., 2004; Graae *et al*., 2011).

The spatial distribution pattern of *Tamarix taklamakanensis* population in the Tarim Basin was clumped, that was similar with other desert shrubs (Crisp & Lange, 1976; Holzapfel & Mahall, 1997, 1999; Lv *et al*., 2014). The clumped pattern mainly depended on the environmental heterogeneity. Distribution of *T. taklamakanensis* in the Tarim basin depended on the available underground soil water (He *et al*., 2014). Based on our field observations, *T. taklamakanensis* mainly occured along ephemeral waterways and low-lying areas among the sand dunes in the desert. Nonuniformity of the underground soil water could partially account for the clumped pattern. Sand dunes fluctuate in the desert, inducing the phreatic lines up-and-down, lead to an uneven distribution of the underground water. Furthermore, the universally clumped distribution pattern might relate to its biological feature. In a desert habitat with high temperature and low rainfall, mother trees would incubate a favorable micro-environment for the establishment of the seedlings. Shading of mother trees would be helpful to the survival of the seedlings, thus seedlings are apt to clump around the mother trees. Furthermore, crown of mother tree could capture rainfall and nutrients down into the soil that would develop a fertile island around mother tree stem. With the accessible water and nutrient, seedlings could be more resistant to harsh conditions and recruit in the arid desert (Tromble, 1988; Meza, 1996; Whitford, 1997; Liu *et al*., 2010; Lv *et al*., 2014). With the young trees growing, it is much harder for individuals to get resources for the root competition from the neighbors (Chapin *et al*., 1989; Golluscio *et al*., 1998); consequently the dispersion in populations might turn to be less aggregated or random in older adults.

Based on population dynamic prediction (Fig. 4), populations of *T. taklamakanensis* will decline inevitably with the elapse of time. Without artificial tending measures, population is hard to persist in future time. The continuous loss of *T. taklamakanensis* over the past several decades is believed to be caused by ground water depletion, either by agriculture diversion or excessive extraction from ground water (Liu *et al*., 1996; Yang *et al*., 2013). Thus, conserving the groundwater in the basin is primary in restoration of *T. taklamakanesis*. Unless water consumption from agriculture diversion and excessive extraction is curbed, conservation efforts for the population recovery will likely be undermined. To increase effective population size, we suggest natural reserves should be set up first to protect the populations and habitats. To mitigate the high mortality of seedlings observed in this study, establishment of a well designated ex situ conservation site is also strongly recommended, to propagate seedlings of local individuals for wild population augmentation. Furthermore, young stages of *T. taklamakanensis* were found to be the weakest stage of the life cycle done to the intense intraspecific competition, thus silvicultural activities should focus on moderate selective thinning in order to reduce the competition in the populations. Finally, a deeper understanding of population dynamics would be required to get the optimum survival and reproductive strategies for the recruitment of the species.

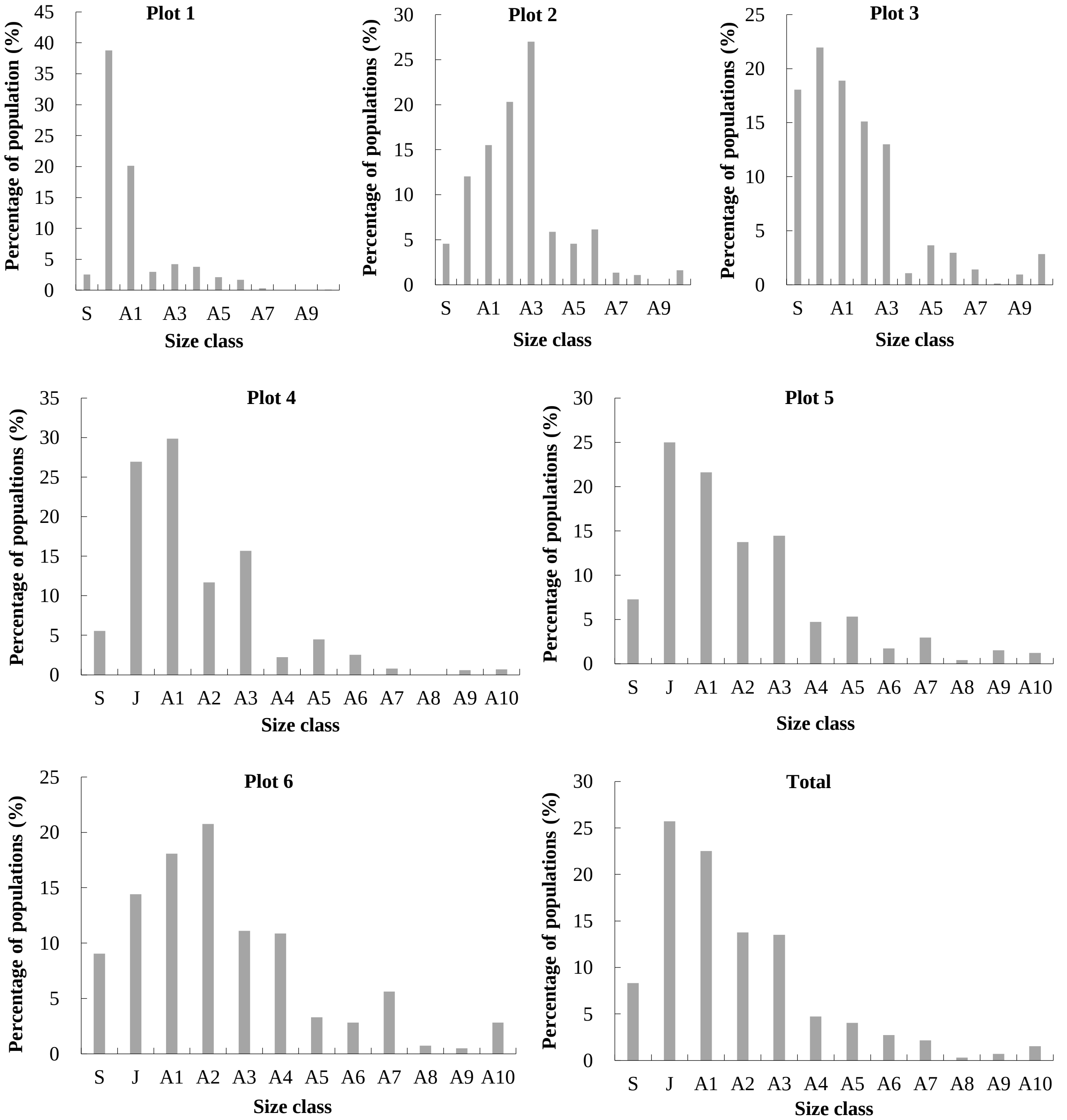

Fig. 2. Size (age) structure of *Tamarix taklamakanensis* populations. S=seedlings (≤2), J=juveniles (3-5) and A=adults (A1=6-8, A2=9-11, A3=12-14, A4=15-17, A5=18-20, A6=21-23, A7=24-26, A8=27-29, A9=30-32 and A10 ≥33 tree basal diameter).

Table 2. The static life table of *Tamarix taklamakanensis* populations in Taklimakan Desert, northwest of China.

Size class (x)	Nx	lx	dx	qx	Log$_{10}$ Nx	Kx	e_x
Plot 1							
S	24	1.0000	-14.2500	-14.25	1.38	-1.18	34.25
J	366	15.2500	7.3333	0.48	2.56	0.28	1.41
A1	190	7.9167	6.7500	0.85	2.28	0.83	1.26
A2	28	1.1667	-0.5000	-0.43	1.45	-0.15	4.64
A3	40	1.6667	0.1667	0.10	1.60	0.05	2.40
A4	36	1.5000	0.6667	0.44	1.56	0.26	1.61
A5	20	0.8333	0.1667	0.20	1.30	0.10	1.50
A6	16	0.6667	0.5417	0.81	1.20	0.73	0.75
A7	3	0.1250	0.1250	1.00	0.48		0.83
A8	0	0.0000	0.0000				
A9	0	0.0000	-0.0417				
A10	1	0.0417			0.00		0.50
Plot 2							
S	17	1.0000	-1.6471	-1.65	1.23	-0.42	21.50
J	45	2.6471	-0.7647	-0.29	1.65	-0.11	7.43
A1	58	3.4118	-1.0588	-0.31	1.76	-0.12	4.88
A2	76	4.4706	-1.4706	-0.33	1.88	-0.12	2.84
A3	101	5.9412	4.6471	0.78	2.00	0.66	1.26
A4	22	1.2941	0.2941	0.23	1.34	0.11	3.00
A5	17	1.0000	-0.3529	-0.35	1.23	-0.13	2.74
A6	23	1.3529	1.0588	0.78	1.36	0.66	1.15
A7	5	0.2941	0.0588	0.20	0.70	0.10	2.50
A8	4	0.2353	0.2353	1.00	0.60		2.00
A9	0	0.0000	-0.3529				
A10	6	0.3529			0.78		0.50
Plot 3							
S	153	1.0000	-0.2157	-0.22	2.18	-0.08	5.04
J	186	1.2157	0.1699	0.14	2.27	0.07	3.23
A1	160	1.0458	0.2092	0.20	2.20	0.10	2.68
A2	128	0.8366	0.1176	0.14	2.11	0.07	2.22
A3	110	0.7190	0.6601	0.92	2.04	1.09	1.50
A4	9	0.0588	-0.1438	-2.44	0.95	-0.54	11.72
A5	31	0.2026	0.0392	0.19	1.49	0.09	2.76
A6	25	0.1634	0.0850	0.52	1.40	0.32	2.30
A7	12	0.0784	0.0719	0.92	1.08	1.08	3.25
A8	1	0.0065	-0.0458	-7.00	0.00	-0.90	32.50
A9	8	0.0523	-0.1046	-2.00	0.90	-0.48	3.50
A10	24	0.1569			1.38		0.50
Plot 4							
S	57	1.0000	-3.6842	-3.68	1.76	-0.67	17.54
J	267	4.6842	-0.7018	-0.15	2.43	-0.06	3.14
A1	307	5.3860	3.2807	0.61	2.49	0.41	1.79
A2	120	2.1053	-0.7193	-0.34	2.08	-0.13	2.81
A3	161	2.8246	2.4211	0.86	2.21	0.85	1.22
A4	23	0.4035	-0.4035	-1.00	1.36	-0.30	4.54
A5	46	0.8070	0.3509	0.43	1.66	0.25	1.52
A6	26	0.4561	0.3158	0.69	1.41	0.51	1.31
A7	8	0.1404	0.1404	1.00	0.90		2.13
A8	0	0.0000	-0.1053				
A9	6	0.1053	-0.0175	-0.17	0.78	-0.07	1.67
A10	7	0.1228			0.85		0.50
Plot 5							
S	71	1.0000	-2.4366	-2.44	1.85	-0.54	13.25
J	244	3.4366	0.4648	0.14	2.39	0.06	3.21
A1	211	2.9718	1.0845	0.36	2.32	0.20	2.63
A2	134	1.8873	-0.0986	-0.05	2.13	-0.02	2.86
A3	141	1.9859	1.3380	0.67	2.15	0.49	1.74
A4	46	0.6479	-0.0845	-0.13	1.66	-0.05	3.30
A5	52	0.7324	0.4930	0.67	1.72	0.49	1.98
A6	17	0.2394	-0.1690	-0.71	1.23	-0.23	4.03
A7	29	0.4085	0.3521	0.86	1.46	0.86	1.57
A8	4	0.0563	-0.1549	-2.75	0.60	-0.57	7.25
A9	15	0.2113	0.0423	0.20	1.18	0.10	1.30
A10	12	0.1690			1.08		0.50
Plot 6							
S	74	1.0000	-0.5946	-0.59	1.87	-0.20	10.57
J	118	1.5946	-0.4054	-0.25	2.07	-0.10	5.81
A1	148	2.0000	-0.2973	-0.15	2.17	-0.06	3.74
A2	170	2.2973	1.0676	0.46	2.23	0.27	2.32
A3	91	1.2297	0.0270	0.02	1.96	0.01	2.90
A4	89	1.2027	0.8378	0.70	1.95	0.52	1.95
A5	27	0.3649	0.0541	0.15	1.43	0.07	4.28
A6	23	0.3108	-0.3108	-1.00	1.36	-0.30	3.93
A7	46	0.6216	0.5405	0.87	1.66	0.88	1.22
A8	6	0.0811	0.0270	0.33	0.78	0.18	5.00
A9	4	0.0541	-0.2568	-4.75	0.60	-0.76	6.25
A10	23	0.3108			1.36		0.50
Total							
S	396	1.0000	-2.096	-2.10	2.60	-0.49	11.54
J	1226	3.096	0.3839	0.12	3.09	0.06	3.07
A1	1074	2.7121	1.0555	0.39	3.03	0.21	2.43
A2	656	1.6566	0.0303	0.02	2.82	0.01	2.66
A3	644	1.6263	1.0581	0.65	2.81	0.46	1.70
A4	225	0.5682	0.0808	0.14	2.35	0.06	2.93
A5	193	0.4874	0.1591	0.33	2.29	0.18	2.33
A6	130	0.3283	0.0682	0.21	2.11	0.1	2.22
A7	103	0.2601	0.2222	0.85	2.01	0.83	1.67
A8	15	0.0379	-0.0454	-1.20	1.18	-0.34	7.57
A9	33	0.0833	-0.101	-1.21	1.52	1.52	2.71
A10	73	0.1843					0.50

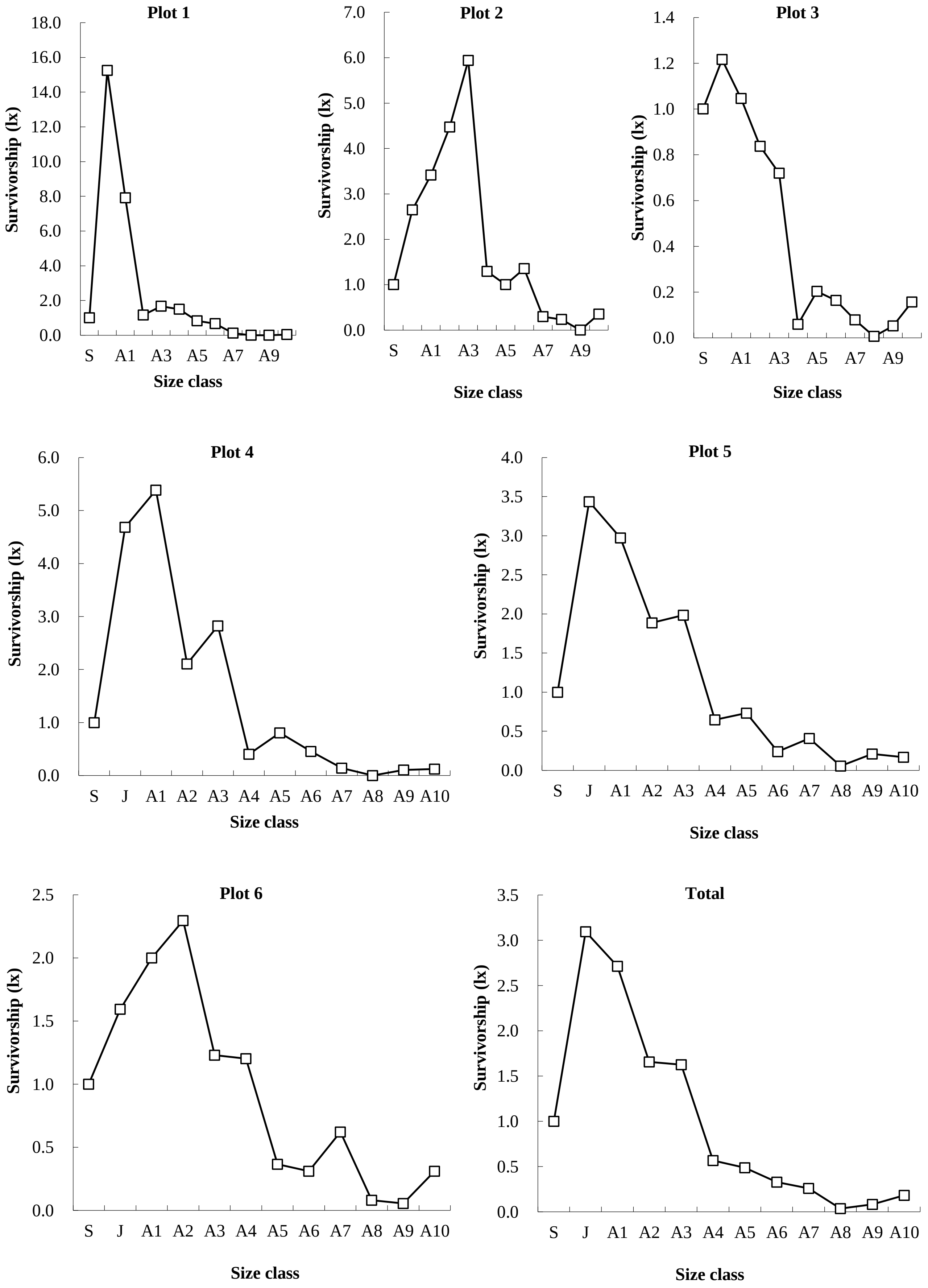

Fig. 3. Survivorship curve of *Tamarix taklamakanensis* populations. S=seedlings (≤2), J=juveniles (3-5) and A=adults (A1=6-8, A2=9-11, A3=12-14, A4=15-17, A5=18-20, A6=21-23, A7=24-26, A8=27-29, A9=30-32 and A10 ≥33 tree basal diameter).

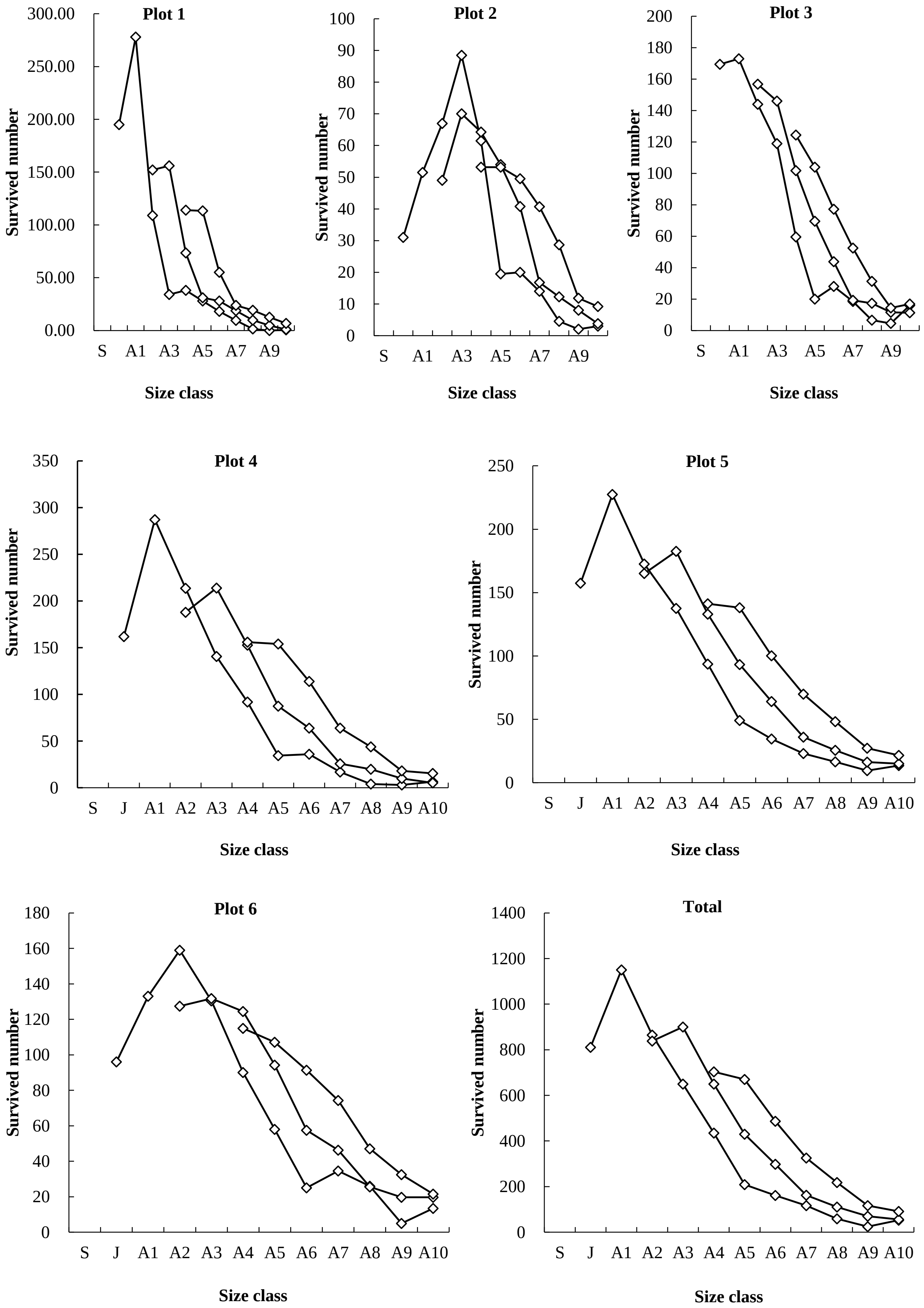

Fig.4. Time sequence prediction of population dynamics of *Tamarix taklamakanensis* at the 2th (M2), 4th (M4), and 6th (M6) generation respectively.

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