Age structure and static life tables of the endangered *Juniperus phoenicea* L. in North Sinai Mountains, Egypt: implication for conservation

Emad A. FARAHAT https://orcid.org/0000-0003-3115-1912; e-mail: emad23_1999@yahoo.com

Botany and Microbiology Department, Faculty of Science, Helwan University, Cairo, Egypt

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Abstract: Studying the population ecology of endangered plants provides important baseline information for its monitoring and conservation. *Juniperus phoenicea* L. is an endangered species in arid ecosystems in Africa and the Middle East. The static life tables, survival curve and age structure of *J. phoenicea* populations from two mountains in North Sinai, Egypt (Gabal (G.) El-Halal and G. El-Maghara) were investigated. In each mountain, fifteen plots were selected, and field measurements such as stand density, tree height, and crown diameter were conducted. Moreover, 44 trees were cored and cross-dated according to standard dendrochronological procedures. The results showed that the tree ages ranged from 50 to 262 years at G. El-Halal and 96 to 431 years at G. El-Maghara. Mature *J. phoenicea* individuals dominated the study area, with only a few individuals being younger than 100 years. Moreover, seedling recruitment was extremely limited. Since the studied *J. phoenicea* populations showed high mortality rates among both old and young individuals, there is an imminent need for establishing a conservation program to prevent its extinction in the future. Therefore, management and conservation efforts should be made to minimize human disturbance and protect the relic habitats of this endangered species at its southern distribution limits in Africa.

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Introduction

The spatial analysis of plant population structure can reflect the current status of the species and reveal the future population dynamics. For studying the population structure and its dynamics, life tables, survival function curves and time-series analyses are efficient tools for that (Li and Zhang 2015; Swart et al. 2019). *Juniperus phoenicea* L. (Ar'ar in Arabic, family: Cupressaceae) is an evergreen coniferous monoecious tree (Boulos 1999). It is native to the Canary Islands, Portugal, Saudi Arabia, Sinai (Egypt) and the coastal areas of the European Mediterranean region (EMR) such as in Yugoslavia (Vidakovic 1991). In North Africa, it occurs on hills and dunes, and in arid mountain regions (Boulos 1999). It is classified in Egypt as very rare species that suffered from over collection, destruction and degradation over the last few decades in North Sinai (El-Bana et al. 2010; Moustafa et al. 2016). Juniper has many ethnobotanical uses, including medicinal, veterinary and culinary uses such as treating diabetes, curing mild skin inflammations, as dilator for urinary tracts and laxative (Batanouny et al. 1999).

The species grows at elevations of up to 2200 m a.s.l. *J. phoenicea* is the only conifer species in Egypt that is restricted to three mountains located in the North Sinai province: Gabal (G.) El-Halal, G. El-Maghara and G. Yelleq. It grows mostly at high altitudes and in crevices of smooth-faced limestone outcrops (Tackholm 1974; Danin 1972). The International Union for Conservation of Nature and Natural Resources (IUCN) lists it as a threatened tree species, and it is included in a national list as a target for conservation and management (El-Bana et al. 2010). Furthermore, it is one of few species in Egypt that develop distinct annual rings (Waisel and Liphschitz 1968; Farahat and Gärtner 2019).

The current ecological status of *J. phoenicea* in North Sinai is like other Juniper species in arid areas, where regeneration of populations is limited to a few habitats where soils have high water storage capacity. It has been observed that juniper populations decline with increased drought stress in southern Saudi Arabia, Oman and Egypt (Fisher and Gardner 1995; Gardner and Fisher 1996; Fisher 1997; Youssef et al. 2014). Topography, soil physical properties, soil pH and salinity are the main limiting factors for the distribution of medicinal plants, such as Juniper, in North Sinai including our study area (Abd El-Wahab et al. 2008; Youssef et al. 2014). El-Bana et al. (2010) found that Juniper has generally poor conditions of vitality at higher elevation (600–960 m a.s.l.) in G. El-Halal, with high proportions of old and recently dead trees and a predominance of male individuals. In contrast, Juniper populations at lower elevation (350–470 m a.s.l.) of G. El-Halal were in better conditions with mostly living foliage and reproductive branches (El-Bana et al. 2010).

Life tables developed from field data provide information on age-specific probabilities of mortality and survival in the populations and can be used to estimate fitness as influenced by various biotic (e.g. human disturbances) and abiotic factors (e.g. climate conditions) (Svensson et al. 2001; Hegazy et al. 2008). There are two common types of life tables: (1) dynamic life tables, which are derived from following individuals in a cohort from birth until the last members of the cohort dies. Such life tables are commonly used for short-lived plants, and (2) static life table, which estimates the age-specific survival and mortality from the age structure of a population at a specific moment in time. Static life tables are used for long-lived plants where it is not practical to follow the demise of a cohort through time (Silvertown 1987; Hegazy et al. 2008). The analysis of age structures is a prerequisite for the understanding of ecological processes and the restoration of natural habitats. It gives a clear idea on the current ecological status of the plant species and its temporal and spatial dynamics. Eventually, this helps in determining the appropriate conservation and management plans for the target species under drought conditions in this extremely sensitive region that showing the effects of climate change (IPCC 2018). Understanding of the population dynamics of *J. phoenicea* trees, and consequently their sustained management, information on age and growth rates are required (Gourlay and Grime 1994). Age measurements are usually used to determine the age-class distribution of a tree population from which inferences on the dynamics of that population can be drawn (Fritts and Swetnam 1989). Moreover, age structure investigations provide insights into the processes of identifying the population structure back in time, which is crucial when reconstructing the environmental and/or human history of a region (Svensson and Jeglum 2001).

Therefore, the goal of this study was to estimate growth characteristics and the age-specific survival and mortality probabilities from the age structure of the populations of *J. phoenicea* at two mountains in North Sinai, Egypt. This was done to provide a baseline data on the structure of the populations of this species to help in the conservation management of the *J. phoenicea* at its southern distribution limit in Africa.

1 Material and Methods

1.1 Study area

The North Sinai province is a desert region characterized by an arid climate with hot summers, mild winters and annual rainfall of 20–100 mm (Ayyad and Ghabour 1986). Sinai falls within the great arid climatic belt crossing northern Africa and southwestern Asia. Temperatures during the warmest summer month (July) are around 34°C and during the coldest winter month (January) around 12°C. In the study area, the mean annual rainfall is less than 90 mm, mainly falling during the rainy season from December to March, while the summer months are almost rainless (Zahran and Willis 1992; Youssef et al. 2014).

The sampling was conducted in two mountain systems in North Sinai, Egypt: Gabal (G.) El-Halal, 892 m a.s.l. (30°41′ 39″ N, 34°04′ 08″ E) and G. El-Maghara, 738 m a.s.l. (30°43′01″ N, 33°28′06″ E; Figure 1**)**. The northern parts of the G. El-Maghara range extend almost to the Mediterranean coast and include broad tracts of sand dunes, which can reach heights of 90 m a.s.l. (Said 1990). Gebel Halal is characterized by large outcrops of smooth-faced limestone, whereas G. El-Maghara have fissured rocks with limestone and dolomite outcrops (Danin 1972). The northern Sinai arid anticlines contain vulnerable ecosystems due to their extreme ecological position, where plants must withstand the effects of drought, wind and erosion (Zahran and Willis 1992). The syncline valleys are filled with sand covered alluvium (Said 1990). El-Bana et al. (2010) identified four vegetation groups associated with Juniper in the northern Sinai mountains, where each were related to specific geomorphologic habitats along a topographic gradient in addition to wadis (i.e. valleys). at G. Halal, the vegetation groups associated with junipers consisted of *Chiliadenus montanus*, *Zygophyllum dumosum, Deverra tortuosa*, *Ephedra aphylla* and *Gymnocarpos decander*. In G. El- Maghara, where the trees were growing in the runnels of Wadi Arar, *Stachys aegyptiaca* and *Moricandia nitens* coexisted with the junipers. In general, the sampling site at G. El-Halal had the highest species diversity and Juniper density.

1.2 Field measurements

To get the general distribution of the trees in the study area, fifteen plots, each with a size of 5m × 20m, were assigned to each of the two sampling sites. In each plot, stand density was calculated as well as stem height, diameter and distance to the nearest tree neighbor (N=44 trees). The stem alignment (straight or tilting), in percentage, was calculated for all sampled tree individuals. The number of trees in the sampled plots with visible injuries, such as broken branches, open or closed

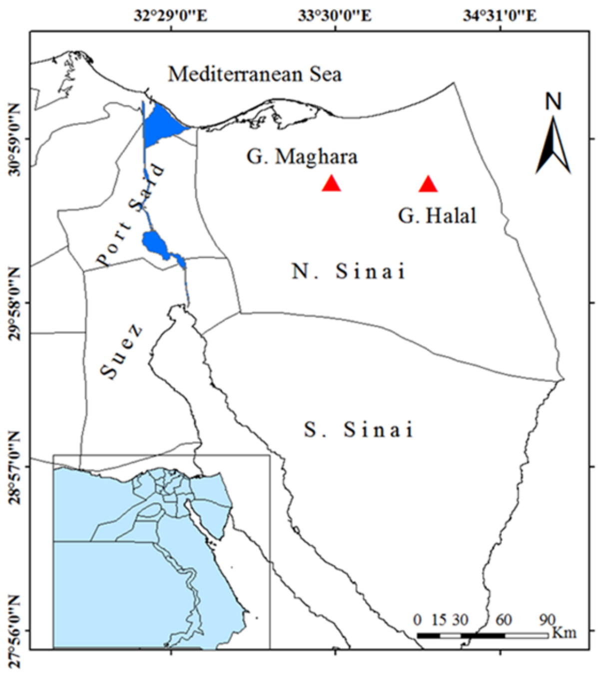

Figure 1 Location map of the studied area in G. Halal and G. Maghara mountains, North Sinai, Egypt. The left corner map is for the country.

wounds or dry crowns, was expressed as a percentage of the plot (Brisson et al. 1994). The populations were also classified into different size classes (cohorts) according to height (0–2 m, >2–4 m, >4–6 m and 6–8 m) and diameter at breast height (DBH) (< 10 cm, 10–20 cm, and > 20 cm). The total numbers of individuals mean height and DBH in each size class were then calculated (Shaltout and Ayyad 1988). Simple linear regression ($y = a + bx$) was used to estimate the relationship between DBH and height at the two sampled sites. The goodness of fit of the regression equations was assessed by calculating the correlation coefficient between each pair of X and Y variables. The variation in stem height (H) and DBH of Juniper trees between sites was tested using Kruskal-Wallis test using the statistical software IBM SPSS Statistics 21.0 (SPSS 2012).

1.3 Age structure, static life table and survivorship curve

For tree age estimation, 20 trees were sampled at an altitudinal range of 307–380 m a.s.l. at G. Halal and 24 trees at 348–506 m a.s.l. at G. El-Maghara, respectively. Sampling from both sites (two cores per tree) was done using a dry-wood increment borer (Rinntech, Germany) and an electric drill. Since the species is multi-stemmed, cores were taken below the stems or close to soil surface. The core samples were air-dried, mounted on wooden supports and sanded using successively finer sandpaper to make the rings clearly visible. The ages of the trees were determined by counting the average number of the rings in the two cores of each tree under microscope. Samples at higher elevations were inaccessible due to constrained safety.

The estimated tree ages were used to determine the age distribution and construct a static life table (Barbour et al. 1987). The age distribution of the studied populations was used as a predictive tool to determine if the *J. phoenicea* populations in North Sinai were healthy or not. The age structure of the populations consisting of multiple cohorts was used to estimate the survival patterns of the various age groups in a static life table (Sharitz and McCormick 1973; Dadamouny 2009)

The static life table was constructed for the individual populations as well as the whole, pooled, population following Pielou (1977), Hegazy (1992) and Zaghloul et al. (2008). The first column of the life table (Table 1) sets out the various estimated age classes (cohorts) of the population at each site. The second and third columns of the life table, lists the corresponding number of individuals per cohort (N_x) and the number of survivors at the beginning of the age interval x (a_x). 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:

Number of survivors at beginning of age interval x

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

The average proportion alive at the age x (L_x) was calculated as

$$L_x = (l_x + l_{x+1})/2 \quad (2)$$

Total number of living individuals at age class x and beyond (T_x) was calculated as

$$T_x = \Sigma L_{x-x\text{-}1} \text{ (e.g. } T_6 = L_6 + L_7 + L_8 + \text{....} + L_{max}) \quad (3)$$

The probability of living ' x ' number of years beyond a given age x (e_x) was calculated as

$$e_x = T_x/l_x \quad (4)$$

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

$$d_x = l_x - l_{x+1} \quad (5)$$

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

$$q_x = d_x/l_x \quad (6)$$

Survivorship curves, which summarize the patterns of survival in populations (Molles and Manuel 2002) of *J. phoenicea* trees were produced by plotting the *lx* at each age interval against time.

2 Results

2.1 Growth characteristics

The growth of *J. phoenicea* at both sites was confined to narrow valleys, starting from the ridges between two mountain peaks and progressing downwards, where running water was usually found. The width of these valleys was < 10 m in G. El-Maghara and < 5 m in G. El-Halal site, respectively. Some of the sampled trees had dead standing or tilting branches. In some cases, the main trunk was cut and new main branches with green crowns had developed. The stems of *J. phoenicea* at the sampling sites were mostly twisted rather than upright, and the stems were often fluted, and with increasing age, they develop a gray to reddish brown bark that shreds into shaggy longitudinal strips. The percentage of twisted stems was more notable in G. El-Maghara than in G. El-Halal (57.9 %, Table 1).

The stem height of the Juniper trees in G. El-Halal (4.71 ± 1.7 m) was two times higher than that

Table 1 Site characteristics of *J. phoenicea* populations (15 plots/site)

Location	Elevation (m a.s.l.)	Aspect	Stand density (ind/ha)	No. cored trees	Distance to nearest tree (m)	Stem habit (%)		Height (m)	DBH (cm)	Visual injury (%)
						Straight	Inclined/ Twisted			
G. Halal	307-380	East/North	152.7 ± 43.1^a	20	7-25^a	57.7^a	42.3^a	4.71 ± 1.7^a	17.7 ± 4.8^a	36.8
G. El-Maghara	348-506	East	86.3 ± 22.9^b	24	3-100^b	42.1^a	57.9^a	2.2 ± 0.6^b	15.8 ± 4.3^a	50

Notes: Different letters in columns showing significant differences at p = 0.05. DBH= diameter at breast height.

in G. EL-Maghara (2.2 ± 0.6 m; both p = 0.05). In contrast, there was only little difference in DBH between the two sites (17.7 ± 4.8 cm and 15.8 ± 4.3 cm, respectively, p = 0.05) (Table 1). The size frequency distribution of DBH showed that the middle DBH class (10-20 cm) was the most common, while DBH of > 20 cm or < 10 cm was weakly represented at both sites (Figure 2). On the other hand, the size frequency distribution of stem heights took bell-shaped and J-shaped patterns at G. El-Halal and G. El-Maghara, respectively (Figure 2). The relationship between stem height and DBH was weak and non-significant at both sites. The values of the coefficients of determination (R^2) were 0.36 and 0.23 at G. El-Halal and G. El-Maghara, respectively (Figure 2).

2.2 Age structure and static life table

The estimated oldest *J. phoenicea* individual was 262 years old, while the youngest tree was 50 years old at G. El-Halal. At G. El-Maghara, the oldest/ youngest *J. phoenicea* tree was 431/96 years old (Table 2). The age structure of *J. phoenicea* populations confirmed that most trees belong to the 101–250-year age class with an overall mean of 176.6 ± 80.1 years in the pooled population (Table 3). Most of the sampled trees belonged to the age class of 51–300 years, with only one individual aged below 51 years in G. El-Halal and a total absence of trees older than 300 years. Two trees (8.4%) at G. El-Maghara were older than 300 years (Table 3). Individuals that germinated during the last fifty years represented less than 5% in G. El-Halal accounting for 2.3% of the overall population since no new seedlings were found in G. El-Maghara. Moreover, during the last 100 years, only 4.2% of the individuals germinated while 29.25% started growing before AD 1900 (Table 3).

Based on the age structure and static life table of *J. phoenicea* in North Sinai, the oldest trees (≥ 250 years in G. Halal and ≥ 350 years in G. Maghara) have a high probability to die in a near future (qx = 1.00; Table 4). These trees represented 10% and 8.2% of the sampled trees at G. El-Halal and G. El-Maghara, respectively. The life table shows that only one tree was recruited in the last 50 years and 100 years in G. El-Halal and G. El-Maghara populations, respectively (Table 4).

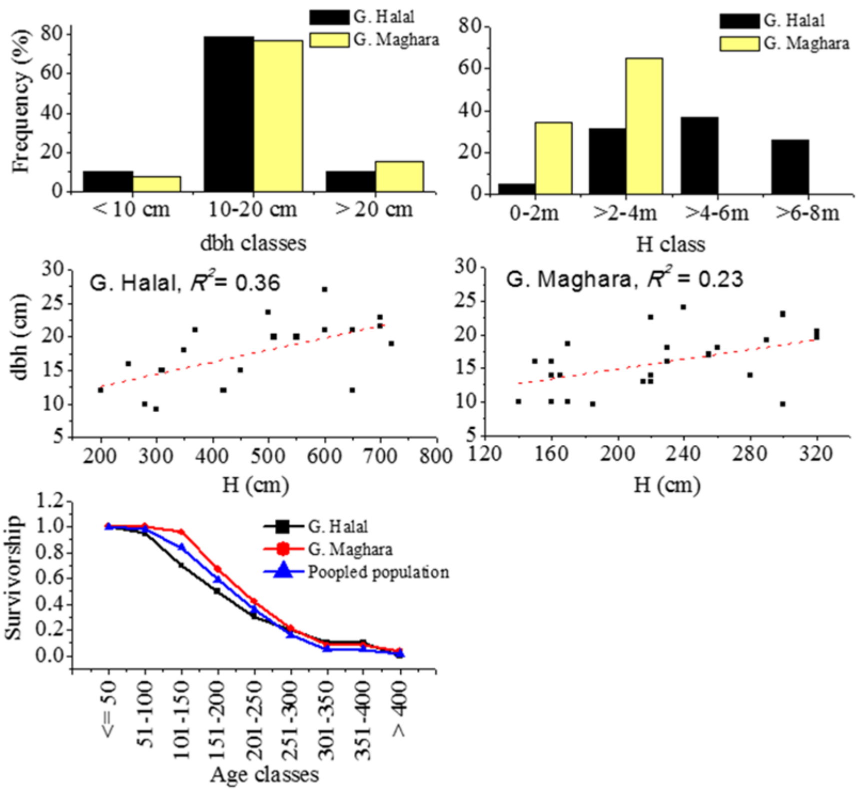

Figure 2 Size frequency distribution of stem height (H) and diameter at breast height (DBH), and relationship between H and DBH of *J. phoenicea* populations at G. Halal and G. Maghara Mountains, Sinai, Egypt, and its Survivorship curves.

Table 2 Age estimation of forty-four sampled trees in G. El-Halal and G. El-Maghara in North Sinai. DBH= diameter at breast height

G. El-Halal					G. El-Maghara				
Tree code	Tree height (m)	Tree DBH (cm)	No. of rings	Estimated age	Tree code	Tree height (m)	Tree DBH (cm)	No. of rings	Estimated age
41	2	12	50	1962-2012	3	1.5	16	96	1916-2012
46	3	9.2	66	1946-2012	19	1.4	10	105	1907-2012
28	4.5	15	77	1935-2012	10	2.2	13	108	1904-2012
34	2.5	16	84	1928-2012	9	3	9.6	113	1899-2012
32	6	21	87	1925-2012	12	3.2	20.4	115	1897-2012
39	7.2	19	87	1925-2012	4	2.2	13	122	1890-2012
52	2.8	10	104	1908-2012	8	2.2	14	128	1884-2012
33	7	22.8	108	1904-2012	18	2.2	22.5	133	1879-2012
51	6	27	136	1876-2012	13	1.65	14	165	1847-2012
50	3	15	145	1867-2012	16	1.7	10	170	1842-2012
47	5.1	20	151	1861-2012	5	2.6	18	172	1840-2012
38	7	21.5	169	1843-2012	11	2.9	19.1	175	1837-2012
44	5.5	20	179	1833-2012	25	1.6	10	179	1833-2012
36	6.5	21	182	1830-2012	15	2.8	14	199	1813-2012
48	5	23.7	209	1803-2012	20	2.6	18	207	1805-2012
49	3.5	18	209	1810-2012	23	3	23	213	1799-2012
35	6.5	12	240	1772-2012	24	1.6	16	217	1795-2012
31	4.2	12	242	1770-2012	27	1.6	14	217	1795-2012
45	3.1	15	257	1755-2012	14	2.55	17	240	1772-2012
43	3.7	21	262	1750-2012	21	2.3	18	275	1737-2012
					22	2.4	24	283	1729-2012
					17	2.3	16	289	1723-2012
					26	1.7	18.6	367	1645-2012
					1	1.85	9.7	431	1581-2012

Table 3 Age structure of *J. phoenicea* populations in G. Halal and G. El-Maghara mountains, North Sinai and pooled population

Rank	Age class	G. Halal				G. El-Maghara				Pooled population			
		Freq.	%	Cum.	%	Freq.	%	Cum.	%	Freq.	%	Cum.	%
1	≤ 50	1	5	19	95	0	0	24	100	1	2.3	43	97.7
2	51-100	5	25	14	70	1	4.2	23	95.8	6	13.6	37	84.1
3	101-150	4	20	10	50	7	29.2	16	66.7	11	25.0	26	59.1
4	151-200	4	20	6	30	6	25.0	10	41.7	10	22.7	16	36.4
5	201-250	4	20	2	10	5	20.8	5	20.8	9	20.5	7	15.9
6	251-300	2	10	0	0	3	12.5	2	8.3	5	11.4	2	4.5
7	301-350	0	0	0	0	0	0.0	2	8.3	0	0.0	2	4.5
8	351-400	0	0	0	0	1	4.2	1	4.2	1	2.3	1	2.3
9	> 400	0	0	0	0	1	4.2	0	0	1	2.3	0	0.0
	Total	20	100			24	100			44	100		
Age	Min-Max	50-262				96-431				50-431			
	Mean ±SD	152.6±68.1				196.6 ± 85.1				176.6±80.1			

Cum. = cumulative represents the percentage of individuals with age more than the upper limit of the specified class; Freq. = frequency represents the number of trees in each age class

According to the survivorship values (l_x), *J. phoenicea* populations in North Sinai have high mortality rates for both old and young trees. In the 51–100-year age class, the value of l_x started to decline in G. El-Halal (l_x= 0.95), while in G. El-Maghara, it started at the age class of 101–150 years (l_x= 0.96) (Figure 2).

3 Discussion

The lack of regeneration in the last 50 and 96 years in G. El-Halal and G. El-Maghara, respectively, indicates the unhealthy status of these *J. phoenicea* populations. The absence of young trees replacing older ones means that these populations are in rapid decline and will most probably facing extinction. This most likely natural stress affecting the *J. phoenicea* population is the prevailing aridity and infrequent precipitation in the study area (Yousef et al. 2014). Our preliminary analysis for the annual growth of *J. phoenicea* trees in the study area showed obvious decrease in the annual growth over the last four centuries. For instance, the ave rage annual ring-width was 1.04 mm from 1635-1735, 1.0 mm from 1736-1835, 0.95 mm from 1836-1935 and 0.86 mm during the last century (data are not shown here). In addition, over-cutting and over-grazing represent a great disturbance for the natural vegetation, threatening some rare species or leading consequently into their extinction (Yousef et al. 2014). Presence of older trees in G. El-Maghara compared to G. El-Halal could be explained by the presence of less anthropogenic disturbances in the mountain. The J-shape age structure indicated that environmental factors have had large effects on the age structures of *J. phoenicea*. The results also indicated that environmental conditions at the time of the establishment of the youngest individuals were more suitable for seedling survival and population regeneration than in recent years. This may be attributed to the anthropogenic disturbances in the study area and low annual precipitation. Age structure studies along higher altitudes will be helpful to understand the relationship between environmental factors and plant population dynamics.

The relationship between stem height and diameter is fundamental in determining community and ecosystem structure as well as for estimations of biomass and carbon storage. Hulshof et al. (2015) found that the stem height of angiosperms across the United States was more negatively influenced by increasing temperature variability, whereas gymnosperm height was negatively influenced by decreasing precipitation and increasing altitude. Trees are known to optimize growth strategies and other life-history traits depending on environmental conditions. The weak relationship between stem height and diameter in the present study may be attributed to the aridity of the study area. In arid environments, trees likely allocate more energy into belowground root structures at the cost of plant height (Schwinning and Ehleringer 2001). In other regions, reduced plant height (for a given diameter) has primarily been explained by aridity and cold temperatures (Lines et al. 2012), by winter coldness (northeast China, Wang et al. 2006), and by aridity and seasonality within tropical regions (Banin et al. 2012). Together, these results indicate a convergence of growth strategies in unfavorable environments (Grime 2002), and suggest that abiotic factors largely influence tree architecture and allometry at large spatial scales.

Table 4 A static life table for *J. phoenicea* populations at the populations in G. Halal and G. El-Maghara mountains, North Sinai and pooled population. X = age entered by time of census, N_x = number of individuals living in age x, a_x = number of individuals that survive to the age x, l_x = proportion of original cohort surviving to age x, L_x = the average proportion alive at the age, T_x = the total number of living individuals at age class x and beyond, e_x = the probability of living 'x' number of years beyond a given age, d_x is the number of individuals that die during stage x, and q_x = proportion of individuals entering age x that die during age x.

Age classes	N_x	a_x	l_x	L_x	T_x	e_x	d_x	q_x
	G. Halal mountain							
≤ 50	1	20	1.00	0.98	3.35	3.35	0.050	0.05
51-100	5	19	0.95	0.83	2.38	2.50	0.250	0.26
101-150	4	14	0.70	0.60	1.55	2.21	0.200	0.29
151-200	4	10	0.50	0.40	0.95	1.90	0.200	0.40
201-250	4	6	0.30	0.25	0.55	1.83	0.100	0.33
251-300	2	4	0.20	0.15	0.30	1.50	0.100	0.50
301-350	0	2	0.10	0.10	0.15	1.50	0.000	0.00
351-400	0	2	0.10	0.05	0.05	0.50	0.100	1.00
> 400	0	0	0.00	0.00	0.00	0.00	-	-
	G. El-Maghara							
≤ 50	0	24	1.00	1.00	3.96	3.96	0.000	0.00
51-100	1	24	1.00	0.98	2.96	2.96	0.042	0.04
101-150	7	23	0.96	0.81	1.98	2.07	0.292	0.30
151-200	6	16	0.67	0.54	1.17	1.75	0.250	0.38
201-250	5	10	0.42	0.31	0.63	1.50	0.208	0.50
251-300	3	5	0.21	0.15	0.31	1.50	0.125	0.60
301-350	0	2	0.08	0.08	0.17	2.00	0.000	0.00
351-400	1	2	0.08	0.06	0.08	1.00	0.042	0.50
> 400	1	1	0.04	0.02	0.02	0.48	-	-
	Pooled population							
≤ 50	1	44	1.00	0.99	3.55	3.55	0.023	0.02
51-100	6	43	0.98	0.91	2.56	2.62	0.136	0.14
101-150	11	37	0.84	0.72	1.65	1.96	0.250	0.30
151-200	10	26	0.59	0.48	0.93	1.58	0.227	0.38
201-250	9	16	0.36	0.26	0.45	1.25	0.205	0.56
251-300	5	7	0.16	0.10	0.19	1.21	0.114	0.71
301-350	0	2	0.05	0.05	0.09	2.00	0.000	0.00
351-400	1	2	0.05	0.03	0.05	1.00	0.023	0.50
> 400	1	1	0.02	0.01	0.01	0.44	-	-

4 Implications for Conservation

Under the harsh climate conditions in Sinai, *J. phoenicea* has a high ecological value in relation to its soil-retaining ability and other economic and medicinal purposes. It is a key species for the associated endemic, rare, vulnerable and endangered flora (Boulos and Gibali 1993). The absence of new individuals for Juniper trees and its unhealthy population status should encourage stakeholders and interested investigators to establish conservation and rehabilitation programs by which the current individuals are kept safe from burning, cutting and grazing. In addition, new seedlings should be cultivated *in situ* under controlled conditions to increase the stand density and hence, secure future reproduction rates. The local people should be involved in any conservation and in situ programs for protecting this important endangered species. This has been reported to be an efficient method in conservation and rehabilitation of similar desert trees such as *Acacia* (Moustafa et al. 2000). Higher protection together with immediate conservation can protect this keystone species and its associated endemic, rare, vulnerable and endangered flora such as *Ifloga spicata*, *Origanum isthmicum*, *Bufonia multiceps* and *Anarrhinum pubescens*.

5 Conclusions and Recommendations

Analysis of the demographic data by life tables is 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 present study revealed that mature individuals dominate the studied *J. phoenicea* populations in North Sinai, Egypt, and the seedling recruitment was extremely limited. Few individuals are being less than 100 years. *J. phoenicea* populations in North Sinai showed high mortality rates of both old and young individuals. This suggests that the populations of *J. phoenicea* are declining and their survival cannot be ensured without rapid conservation measures to prevent the species extinction in the coming future. Further research is needed to help in conservation of the species through more detailed ecological studies on the reproductive fitness of the species and dendroecological analysis for wood cores. Moreover, participation of local people in any conservation programs should be a priority.

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