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Anthropogenic impacts on population structure and floristic composition of Black Saxaul (*Haloxylon aphyllum* Minkw.) woodlands in Ili Delta region, Kazakhstan

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ABSTRACT

Haloxylon aphyllum Minkw. (Black Saxaul) is the main forest forming species in Kazakhstan. While the latter is a rain fed shrub distributed on sand dunes, the former is a phreatophyte, which uses groundwater as water source. Therefore, Black Saxaul is mainly distributed on current and Ancient river terraces. Saxaul played and still plays an important role as fodder plant and fuel wood for herders in the Turanian Deserts. Due to over-grazing and over-exploitation for fuel wood during the past fifty years, the Saxaul dominated vegetation has been considerably degraded. *Haloxylon* woodlands which grow in desert ecosystems suffer from anthropogenic effect severely. Our study concerned human impact on woodland structure and biodiversity of populations. In the study it was done a distribution of trees by classes according to root collar diameter, density, regeneration, and analysis of floristic composition of plots with various level of anthropogenic effect. All sites suffered from human activity, and were on different stage of regeneration. As a result of clean cuttings in the past the majority of woodlands present homogeneous size structure. The most disturbed plots show random structure of populations and very low level of regeneration or lack of it. When plots are disturbed reasonably regeneration of Saxaul populations goes well, especially on plots with density equal to up to 1000 shrubs/ha. The plot which is located very far from residential areas was studied having the most sustainable structure under favourable growth conditions. Biodiversity level is higher on plots with less anthropogenic effect. Nevertheless, both sites show intrusion of weed and ungrazed plants.

***Key words** : Haloxylon aphyllum, Density dynamics, Woodland regeneration, Biodiversity*

Introduction

Saxaul (*Haloxylon aphyllum* Minkw.) is the main forest forming species in Kazakhstan which grows in desert ecosystems. Saxaul forests directly affect environmental situation creating favorable conditions for human life and farming (Tokmurzin 1982).

Saxaul forests serve the following functions of ecosystem: biomass production, sand stabilization; minimization of soil drifting; microclimate mitiga-

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tion which ensures growth and development of associated plants (for example, *Carex physodes* M. Bieb.); setting habitat conditions for animals. And, desert forests are a food supply for farming and energy-efficient biofuel for local population (Buras *et al.,* 2012).

According to the data published by Forest and Hunting Management Committee under the Ministry of Environmental protection of the Republic of Kazakhstan the area of state forest fund comprised 4.4 mln. ha covered by Saxaul on the 1st of January, 2013 (Committee on Forestry and Hunting of the Ministry of Environment of the Republic of Kazakhstan, 2015). Among all Saxaul woodlands the most common ones are channel Black Saxaul woodlands located on clay sand and loam soil (49.5%) and Black Saxaul woodlands located on sand deposits (29.2%). Channel Black Saxaul woodlands located on clay sand and loam soil plains are the most productive Saxaul woodlands having the best growth conditions (Nurkhanov 1978-2013). Black Saxaul woodlands grow in lowland area where ground waters are 3-10 m below surface. The most common associations of this formation are Black Saxaul woodlands with *Artemisia terrae-albae* Krasch. and *Salsola orientalis* S.G. Gmel. Each of these associations covers up to 30% of all territory (Gvozdeva 1960).

Currently, as a result of human impact it was identified that Saxaul is spread only on 25% of potential areal in Kazakhstan. About three thirds of potential areal of Saxaul forests were destroyed or they deteriorated comparing to potential areal (Thevs *et al.,* 2013).

As a result of widespread extermination of woodlands of Black Saxaul the Government of the Republic of Kazakhstan prohibits any type of cuttings in Saxaul woodlands of state forest fund of Kazakhstan until 31 December 2018 (Resolution of the Government of the Republic of Kazakhstan, 2013). This is the reason why there was a necessity to identify the present state of Saxaul woodlands, and make forecasts on regeneration of woodland associations of plants with limited anthropogenic impact. Studying age structure and regeneration can help understanding processes which are fundamental for populations with the course of time (Svensson and Jeglum 2001) and can become an measures of environmental changes.

To study dynamics of forest vegetation it is definitely necessary to analyze structure and gradation of populations, density, regeneration, and biodiversity (Lingua *et al.,* 2008; Wangda and Ohsawa 2006; Wang *et al.,* 2006; Wang *et al.,* 2004).

However, there is not enough information on age structure and regeneration of Saxaul woodlands. Different changes in Saxaul woodlands testify change in their structure, composition and density as a result of uncontrolled cuttings, Saxaul breaking, shrub clearance, cattle grazing (Bijanova, 1998) as well as natural forces (Bedareva, 2009). Population responds in different ways depending on type, size, severity and frequency of disturbances (Antos and Parish 2002; Nakashizuka, 1991).

Poor sustainability of desert ecological systems determines the necessity to monitor their state, receive data on dynamics and changes of desert vegetation (Bedareva, 2009, Bijanova, 1998). Identification of principles of age structure change will help to analyze processes of regeneration and forest ecosystem management (Wangda & Ohsawa 2006, Mast *et al.,* 1999).

The purpose of the present study was to identify structure of *Haloxylon* population, state of trees reproduction as well as floristic composition and biodiversity on the plots which underwent different levels of anthropogenic impact.

Materials and Methods

Study area

This study was carried out in Black Saxaul woodlands representative for the region of the Ili Delta and downstream section of the Ili River, because this region represents riparian and delta regions of the Turanian Deserts. Therefore, sites were selected near Bakanas (east of the Ili Delta), Karoi (northern part of the delta), and in Kuigan (southern part of the delta). The study area is located in the Almaty District, in the south-eastern part of Kazakhstan (Fig. 1).

The Ili River is the largest river draining into Lake Balkhash. The Ili Delta and Lake Balkhash are embedded in the deserts Saryesik-Atyrau, Moinkum, Taukum, and Lyukkum. There, the Ili River has formed the Ili Delta. This delta is a mosaic of submerged reed beds, riparian terraces, and sand dunes. Bakanas Plain is more than 250 km long covering more than 1 mln. ha of desert area. On the territory of the Plain there is an old coulee which comes from the main bed of the Ili River and then is divided into numerous dry beds (Naryn-bakanas,

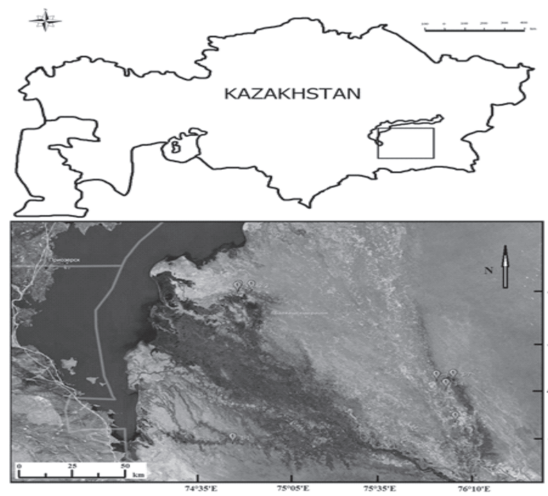

Fig. 1. Location of the study area

Kara-bakanas, Shet-bakanas, etc.). Black Saxaul mainly is distributed on the riparian terraces so that the study sites were selected on such riparian terraces (Table 1).

The climate of the study area is sharply continental and arid (Table 2).

Site 1, Present Ili river delta, is located on a terrace adjacent to the Ili River with groundwater levels of 3-5 m. The main accompanying species are: *Halimodendron halodendron* Voss, *Tamarix ramosissima* L., and *Populus euphratica* Oliv. The second site (Ancient Ili rivet delta) is located on a Ancient river terrace with groundwater depths from 5-6 m. Accompanying species are *Salsola rigida* Pall. and *Artemisia terrae albae* Krasch (Babyev 1986, Lobova 1960).

Data collection and processing

Reconnaissance Survey

Preliminary survey was carried out in Saxaul forest of the Ili river delta to define vegetation segments based on its homogeneity and disturbance intensity. The study area was divided into two study sites on the basis of disturbance gradient – distance from settlement i.e. highly disturbed (Present Ili river delta) area, mildly disturbed (Ancient Ili river delta) area for studying the status of size and age community structures, plant diversity of the study area (Table 3).

Table 2. The climatic characteristics of the study area (Ile–Balkhash region. Climate 2015)

Climatic feature	Meteorological data
Average annual air temperature	7,5 ° C
Absolute minimum temperature	-44 ° C
Absolute maximum temperature	42 ° C
Average temperature in July	25,1 ° C
Average temperature in January	-13,6 ° C
Last spring frosts	25 April
First autumn frosts	26 September
Duration of frost-free period	153 d
Average annual precipitation	135 mm

The field measurements were carried out in 2013 and 2014. At the three sites, in total 600 shrubs were investigated. Thereby, at Kuigan, Karoi, and Bakanas, one, three, and four plots were selected, respectively. In each plot, 40 shrubs were selected using the PCQ (Point Centered Quarter method) after Mueller-Dombois and Ellenberg (Mueller–Dombois & Ellenberg 1974), whereby the age range of each Site was covered. At each shrub the following items were measured: age of the shrub, height, diameter of the root collar, diameter of the crown. The tree species includes all the saplings and seedling.

Age tree determination

Age determination by a number of annual growth rings is not applicable to Saxaul as it produces more than one annual growth ring in different parts of a trunk per a year. Artsihovskiy's method was applied in order to determine age of young trees of Saxaul (Lavrenko and Korchagin 1960). V.M. Artsihovskiy proposed to use forking of Saxaul for its age determination. According to him, Saxaul annually develops several apex shoots and only two or three (more rarely) of them stay by autumn, and the rest apex shoots exfoliate. Furthermore, apiculus

Table 1. Relief, soils of research site

	Site	Relief	Soils	Name of divided site
1	Kuigan	Hills and ridges	Grey, grey-brown soils	Present Ili river delta
2	Karoi	The river valleys, depression of coasts	Clay-loam, clay sand	
3	Bakanas	Plain and hills	Grey-brown, takyr like soils	Ancient Ili river delta

stops growing, and the following spring several new lateral branches grow out of it. Thus, forked verticillus is annually formed. V.M.Artsihovskiy suggests counting forks from the top down to the base of root collar. The number of forks corresponds to the age of a tree. The age of stands of mature trees was identified according to the data of Forestry Department (Nurkhanov 1978 – 2013).

Due to the fact that desert vegetation is very thinned all species of plants were collected regarding PCQ (Point Centered Quarter method). Furthermore, groundwater levels (GWL) were determined with a soil auger at site one, in the second ground water measurement in accordance with the depth of a well. All those groundwater levels were verified with data on the hydrology of the Southern Balkhash region (Akhmedsafin 2003).

Vegetation Sampling Procedures

All plants were identified to species level when it was possible in the field, otherwise specimens of plant species that were not easily identified in the field, specimens were collected, pressed and taken to the herbarium in the Department of Biodiversity and bioresources, Al-Farabi Kazakh national university for identification by matching with the herbarium specimens and/or keying using relevant floras such as Flora of Kazakhstan (Pavlov 1956-1966).

Quantitative analysis

Shrub densities and basal area were calculated after (Mitchell 2007):

$$Absolute\ \ density = \frac{10.000m^2 / ha}{(\bar{x})^2 / tree},$$

where $(\bar{x})$ - mean distance between shrubs [m].

$$\text{Basal area} = A \times \frac{Density}{ha} \times \frac{1m^2}{10.000cm},$$

where A - mean basal area of shrub [cm^2].

$$A = \pi d^2 / 4,$$

where d^2 - diameter of root collar of shrub [cm^2].

The species richness of the plants was calculated by using the method 'Margalef's index of richness' (D_{mg}) (Magurran 1988) and evenness (E) (Sheldon 1969):

$$D_{mg} = (S–1)/\ln(N),$$

$$E = H/\ln(S),$$

where N = Total number of individuals, S=Total number of species in a community, H=Shannon index. Species diversity and dominance were evaluated by using the following methods. Shannon's diversity index and Simpson's index of dominance were calculated using important value index (IVI) of species.

Shannon–Weaver index (H) of diversity (Shannon 1948):

The formula for calculating the Shannon diversity index is

$$H = -\Sigma p_i \ln p_i,$$

where, H = Shannon index of diversity

p_i = the proportion of important value of the species ($p_i = n_i$ / N, n_i is the important value index of species and N is the important value index of all the species).

Table 3. Age, height, diameter of root collar, and crown diameter of H. aphyllum at the three sites with mean, standard deviation (std. dev.), minimum (min.), and maximum (max.). At each plot, 40 shrubs were measured

Plot	Age [years]	Height [m]			Diameter of root collar [cm]			Crown diameter [m]		
		max	min	mean± Std.dev.	max	min	mean± Std.dev.	max	min	mean± Std.dev.
Site 1- Present Ili river delta										
I	10-12	2.2	0.7	1.6±0.4	15	2	7.5±3.2	2.2	0.5	1.4±0.4
II	15-18	3.6	1.2	2.51±0.55	23.8	4.5	11.41±4.89	3.9	0.9	2.34±0.76
III	18-20	4.5	2	3.41±0.72	28	7.9	15.85±5.16	5	2	3.16±0.72
IV	15-18	5.5	2.1	3.03±0.64	28.2	6.4	13.3±5.19	5.1	1.9	2.97±0.72
Site 2 - Ancient Ili river delta										
V	15	2.9	1.3	2.3±0.411	14	7	9.95±2.29	3.8	1.2	2.25±0.54
VI	10-15	2.1	1.7	1.9±0.182	10	8	9.25±0.957	2	1.5	1.7±0.206
VII	25	6.2	2.5	3.6±0.944	30	14	19.12±4.997	4.5	2.5	3.2±0.541
VIII	23	5.4	1.7	2.94±0.782	60	5	12.9±8.983	6.5	1.1	2.56±0.992

Simpson (Simpson 1949) index of Dominance:

The equation used to calculate Simpson's index was

$$D = \Sigma (p_i)^2$$

where, D = Simpson index of dominance

p_i = the proportion of important value of the species ($p_i = n_i$ /N, n_i is the important value index of species and N is the important value index of all the species).

Results

Age composition of populations varies in sites (Table 3). Age structure analysis indicates that Saxaul shrubs at the site Present Ili delta were significantly younger than those at the site Ancient Ili river (ANOVA, $P \leq 0.05$). The site Present Ili river delta represented an age of 10 to 20 years. Saxaul shrubs from the site Ancient Ili river delta covered an age range from 10 to 25 years. The youngest trees (from 10 to 12 years old) are represented on plot I. Age of trees on plot VII is of 25 years. There are the oldest trees of all survey plots.

In spite of the fact that the trees on site Present Ili delta are in average 5 years younger medium height of trees on two plots differs insignificantly (ANOVA, $P \leq 0.05$). However, maximum heights of trees (5.4 m and 6.2 m) on plots VIII and VII exceed ones on site Present Ili river delta. There is the same situation with diameter of root collar and crown. On site 1 the maximum root collar diameter is 23.8 cm, on site 2 it is 60 cm. Two sites do not show quite difference in maximum crown diameter with 5.1 m (site 1) and 6.5 m (site 2).

Groundwater levels in Present Ili river delta were up to 5 m below soil surface, while the plots of Ancient Ili rivet delta had groundwater levels deeper than 5 m below soil surface. Population density of plot I and VIII varies from 780 shrubs/ha up to 2000 shrubs/ha. Density and basal area of Saxaul trees at the Ancient Ili delta are significantly higher than that at Present Ili delta (ANOVA, $P \leq 0.05$). However, basal area of plot III and VII is virtually the same with different age and ground water level.

All survey sites were exposed to anthropogenic effect. During the Soviet Union period there were clean cuttings of Saxaul on the studied territory. New Saxaul trees were set out on cutting sites with assistance to regeneration. Thus, there were two sites identified with anthropogenic effect on Saxaul woodlands (Table 4). Plots of Present Ili river delta are in a short distance from residential areas (up to 7 km). These plots represent illegal cuttings, cattle-posts, back roads, sealed roads as well as dumping sites and open fire sites. Plot IV is village outermost and has less anthropogenic effect as it is protected by Forestry Department. Trees of this plot are used for seed harvesting and further planting of Saxaul trees.

Plots of Ancient Ili river delta are far from population area (more than 40-65 km). This site is exposed to cuttings though restricted by Forestry Department. Plot V and VI represent the most typical Saxaul woodlands on plains of Ancient Ili river delta covering a vast territory. Plot VIII was not available

Table 4. Main characteristic of Haloxylon populations at two sites of Ili river delta

Plot	GWL [m]	Density [shrubs/ha]	Basal area [m^2/ha]	Anthropogenic inûuence	Distance to the nearest settlement
Site 1- Present Ili river delta					
I	4.6	780	5.006	Tree belt area along asphalt roads	10 km
II	4.3	1055	13.018	Cutting, grazing, dump, fires, deadwood	Within the settlement
III	5	1242	27.029	Grazing, cutting, country road	1,5 km
IV	4.5	975	15.551	Seed tree, protected by Forestry Department	7 km
Site 2 - Ancient Ili river delta					
V	6	891	7.269	The plot is near the well	40 km
VI	7.9	1050	6.172	The most typical plot of Saxaul forests	60 km
VII	6.3	911	27.905	The plot is in relief depression	65 km
VIII	5.5	2000	38.54	The site inaccessible to machinery for cutting, after cutting 1997	55 km

for cuttings in 1997 as equipment for clean cutting of Saxaul was not designed for highlands. Thus, this plot preserved the most natural woodland structure.

Floristic composition of populations is studied in order to identify biodiversity of varied associations of Saxaul woodlands. Site 1 is characterized by *Haloxylon-Halimodendron* association where shrub *Halimodendron halodendron*, subshrub *Eurotia ceratoides*, herbs *Atriplex tatarica, Chorispora tenella, Koelpinia linearis* dominate (Table 5). *Haloxylon- Artemisia terrae-albae* association is mostly spread on site Ancient Ili river delta. Subshrub *Artemisia terrae-albae* is the essential one in this population. It creates almost a background on several plots. Also such species as *Eurotia ceratoides, Salsola rigida, Ceratocarpus turkestanicus, Carex physodes, Schismus arabicus* were dominating ones (Table 6).

The association growing on site Ancient Ili delta contained 31 species which belonged to 12 families. A little less number of species (26) was identified in association of site Present Ili delta. Biodiversity index and evenness was higher in *Haloxylon-Halimodendron* association (2.622 and 0.805) (Table 7).

Distribution of trees by crown diameter is a scale-down (5-cm root collar diameter class). The smallest diameter (<5 cm) was identified on two plots (plot I – 32.5%, plot II – 2.5%) on site Present Ili delta while site Ancient Ili delta had it only on plot VIII (5%). Starting from 6-10-cm root collar diameter class both sites represente reduction of trees quantity in every next class. Only plot III show small quantity of trees

Table 5. Life form and abundance of species (Drude Scale) of the most important species of the inventoried Haloxylon-Halimodendron association of Present Ili delta forest

Family	Species	Life form	Abundance of species
Asteraceae	*Koelpinia linearis* Pall.	Herb	Sparsae
	Schischkinia albispina (Bunge) Iljin	Herb	Solitariae
Boraginaceae	*Nonea picta* (M. Bieb.) Fisch. & C.A. Mey.	Herb	Solitariae
Brassicaceae	*Chorispora tenella* (Pall.) DC.	Herb	Sparsae
Chenopodiaceae	*Atriplex tatarica* L.	Herb	Solitariae
	Eurotia ceratoides (L.) C. A. Mey	Subshrub	Sparsae
	Haloxylon aphyllum Minkw.	Tree	Copiosae 3
	Petrosimonia sibirica (Pall.) Bunge	Herb	Solitariae
Fabaceae	*Halimodendron halodendron* Voss.	Shrub	Copiosae 2
	Trigonella arcuata C.A. Mey.	Herb	Solitariae
Zygophyllaceae	*Peganum harmala* L.	Herb	Solitariae

Table 6. Life form and abundance of species (Drude Scale) of the most important species of the inventoried Haloxylon-Artemisia terrae-albae association of Ancient Ili delta forest

Family	Species	Life form	Abundance of species
Asteraceae	*Artemisia terrae-albae* Krasch.	Subshrub	Copiosae 3
	Koelpinia linearis Pall.	Herb	Solitariae
Boraginaceae	*Arnebia grandiflora* (Trautv.) Popov	Herb	Solitariae
	Nonea picta (M. Bieb.) Fisch. & C.A. Mey.	Herb	Solitariae
Brassicaceae	*Lepidium perfoliatum* L.	Herb	Solitariae
Chenopodiaceae	*Atriplex tatarica* L.	Herb	Solitariae
	Carex physodes M. Bieb.	Herb	Sparsae
	Ceratocarpus turkestanicus Sav.-Rycz. ex Iljin	Herb	Copiosae 2
	Eurotia ceratoides (L.) C. A. Mey	Subshrub	Copiosae 1
	Haloxylon aphyllum Minkw.	Tree	Copiosae
	Kirilowia eriantha Bunge	Herb	Sparsae
	Salsola rigida Pall.	Subshrub	Sparsae
Poaceae	*Eremopyrum orientale* (L.) Jaub. & Spach	Herb	Solitariae
	Schismus arabicus Nees	Herb	Solitariae
Solanaceae	*Hyoscyamus pusillus* L.	Herb	Solitariae

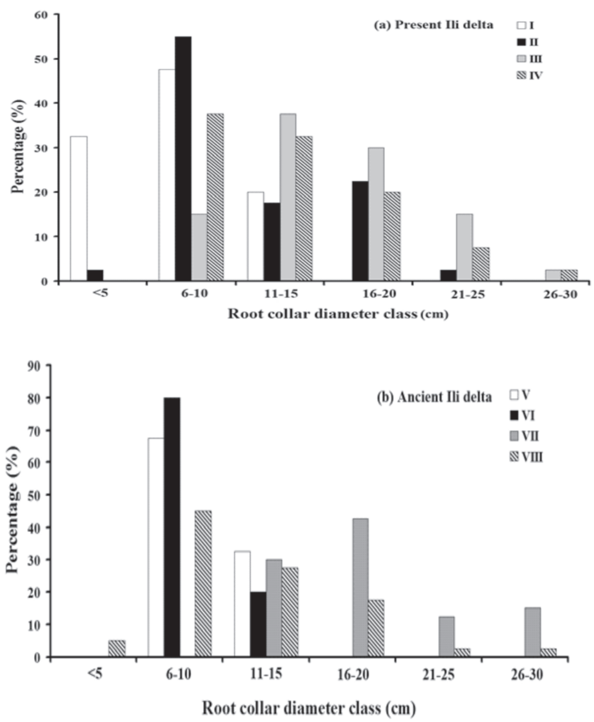

Fig. 2. Size class distributional of Haloxylon aphyllum populations at different forest growth conditions: Present Ili delta (a), Ancient Ili delta (b)

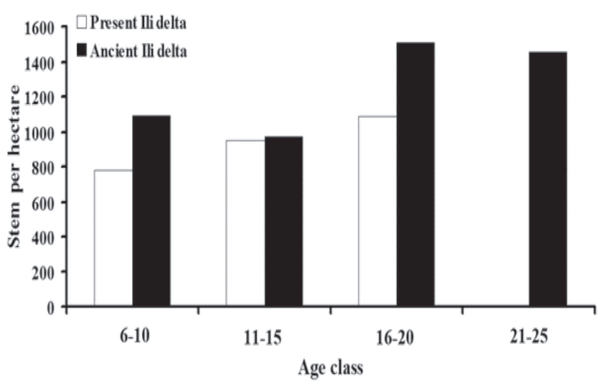

Fig. 3. Age structure by 5-year interval of Haloxylon aphyllum trees at Present Ili delta and Ancient Ili delta forest

of this class (15 %) while in other plots it is much higher (50-80%). Distribution pattern reveals that the number of big trees with a diameter more than 16-20 cm decreased slowly. The biggest trees were found on plots III, IV, VI, VII (Figure 2 a, b).

Density distribution according to age showed its thickening with aging (Fig. 3). 6-10-year age class represented sapling trees. Population density of site Ancient Ili delta is higher in all age classes.

Plot II having density level of 1055 shrubs/ha and plot VIII having density level of 2000 shrubs/ha do not show signs of regeneration (Fig. 4). The number of seedling trees on Present Ili delta is very small comprising 27-335 shrubs/ha. Positive regeneration tendency was identified on site 2 - 119-730 shrubs/ha. The correlation between seedling quantity and density was found out as well. Seedling quantity decreases with thickening of stands.

Discussion

Research on regularities of population distribution is vital for vegetation dynamics study. Studying long lifespan plants provides an opportunity to observe dynamics of populations as well as environmental changes (Camarero *et al.*, 2005; Wang *et al.*, 2004).

Age-class composition, size structure and regeneration of population are used to evaluate dynamics of wood plants (Dang *et al.*, 2010; Wangda and Ohsawa, 2006; Svensson and Jeglum, 2001; Brubaker 1986). Information on location of a particular tree which can be acquired from age and size distributions is required as well. This data is applicable to research on impact of various environmental factors on population dynamics. It can be used as an index of vegetation condition modification as well (Motta and Nola, 2001; Harcombe, 1987).

Unfortunately, authors did not find any studies on structural change of *Haloxylon aphyllum* populations caused by anthropogenic effect. Therefore, research data on structure of other species of plants was used.

Populations of Present Ili delta mainly belong to 6-10-cm root collar diameter class (Figure 2a). The germination of the population can be seen on plot I as it belongs to windbreakers located along sealed roads. Previously, the plot underwent clear cutting

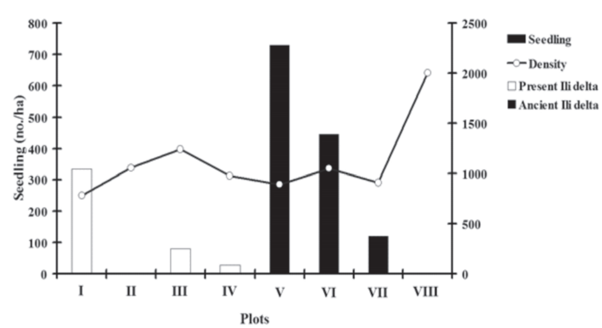

Fig. 4. Relationship between density of the Haloxylon stand and seedling

as there are only three diameter classes. According to the data (Galanin and Belikovich, 2004), after clean cutting the process of woodland formation starts, and there is a formation of canopy. It can be deduced that there were limited influence of human activity (except garbage pollution) on the plot and more favorable growth conditions as the plot is located in a low land. During precipitations as well as spring floods the plot has conditions for successful recovery and growth. Sapling trees make 32.5%.

Plot II shows high level of anthropogenic effect such as illegal cuttings, cattle-posts, and other disturbances. This coenotic structure along the root collar diameter is not only a product of competitive interaction and outside influence but a result of genetic potential of endogenetic diversity of population (Moslakov, 2001). This proves that there are trees of almost all diameter classes but their location is occasional. Probably, if human intervention in ecosystem is limited it will restore as there are saplings in the population.

Plots III and IV are quite far from residential area. As trees of this plot are older they belong to the last diameter class (26-30 cm). The majority of trees are of 6-10-cm root collar diameter class. Number of the rest of the trees decreases with every other class. Such population structure is of non-homogeneous type where trees pass to the next coenotic group according to root collar diameter without getting new elements in form of forest thinners. This type proves further woodland degradation (Galanin and Belikovich 2004; Vasilenko, 2001; Galanin, 2000).

On plot IV (a protected area) trees are arranged according to diameter classes. It shows that this plot is artificial woodland. According to (Vasilenko 2008) this artificial system is unstable and over the years it will change its eco-coenotic structure to optimal one according to these conditions.

Size structure of site Ancient Ili river delta is almost not affected by human influence. As the trees are located far from residential areas their structure is primarily affected by age and growing conditions. However, these plots represent very good reproduction process. It is connected with stand density and lack of competition and interference. Thus, trees on plots V and VI are only of two diameter classes (Fig. 2b). Firstly, the woodland stand of the plot is 10-15 years old. This regularity is supported by many studies saying that initially woodland stand is homogeneous and non-discrete according to root collar diameter (Uspenskij and Popov, 1974; Moiseev 1971; Polikarpov, 1962). Secondly, this happens because here soil-hydrological conditions are poor having no additional moistening, and ground water level is 6 m and 7.9 m down.

The structure of these woodland stands (Vasilenko, 2008) refers to identification of these plant associations in bifurcation point. It is that state of confusion which all these systems and subsystems have, and where every structure demands individual approach. Unfavourable environmental conditions, human activity as well as natural decay of woodland stands are responsible for making studied woodlands and separate cenopopulations to be in such a condition. Some woodland can exist in such a condition for a long time, sometimes even through a lifetime of a woodland.

Plot VII represents relatively mature woodland stands with trees of 3-5 diameter classes. This fact is explained by favorable growth conditions. The plot is located in topographic low. It is the only plot which has trees of all diameter classes. This population has enough quantity of seedlings, saplings and young trees what proves successful regeneration. This structure is the most stable and can be referred to as sustainable woodland ecosystem. These ex-

Table 7. The diversity indices and structural characteristics of Haloxylon-Halimodendron association (Present Ili delta) and Haloxylon-Artemisia terrae-albae association (Ancient Ili delta)

Variables	*Haloxylon-Halimodendron* association	*Haloxylon-Artemisia terrae-albae* association
Number of species	26	31
Number of genera	24	29
Number of families	10	12
Shannon index	2,622	2,391
Simpson index	0,122	0,148
Evenness	0,805	0,696
Margalef index	4,983	4,935

amples show that woodland stands with one dominant tree species also represent all functional parts in the form of various discrete tree groups according to root collar diameter. Further maintenance and self-complication of such a diversity of internal structure of woodlands become possible provided that there will be new elements in form of regrowth in cenopopulation (Vasilenko, 2008).

Plot VIII represented the most productive Saxaul plant association. This plot is the most distant one from residential area (65 km). Density is very high here – 2000 shrubs/ha. However, it completely lacks regeneration, and this is the reason why this plant association can be referred to as naturally deteriorating (Galanin *et al.,* 2004). Other studies support this fact as well stating that high-density stands of Saxaul almost lack seed regeneration, and field stratum is underdeveloped there. In fact, such plant association is a monostratous one (Bedareva, 2009).

According to Korovin (Korovin, 1961), the distribution of Saxaul trees can vary, and under optimal conditions they grow as a complete stand. However, due to peculiar features of crown architectonics and leafless shoots they cover maximum 50% of the area. According to our data, Saxaul woodland density increases with age (Fig. 3). It is explained by the fact that trees in population sprout as shoots, i.e. new tree develops from tip buds on the spot of felled tree. Under favorable conditions when a tree reaches reproductive age (5-7 years), regrowth starts developing. Thus, with aging woodland stand becomes dense and simultaneously forms structure to diameter. In future, when it becomes fully dense (in our research it is 2000 shrubs/ha) regeneration stops (Fig. 3). Models of Saxaul natural thinning (Bedareva 2006) acquired the state of full density at the age of 5-10 years. Then, gradual retrogradation starts and since the age of 25 the level of density is almost the same. The obtained results have different data what can be explained by worse growth conditions of populations studied (Bedareva, 2006) in desert communities of Black Saxaul.

As a whole, regeneration on undisturbed plots is much higher than on disturbed ones (Dang *et al.,* 2010). There is a very low level of regeneration on site Present Ili delta on all plots which are close to residential area. The number of seedlings is highly influenced by cattle grazing (Imani *et al.,* 2015; Jimenez *et al.,* 2005, Stern *et al.,* 2002). Plots with low density show the highest rate of regeneration (McEvoy *et al.,* 2006). On site Ancient Ili delta the plots with the least favorable growth conditions have the highest regeneration rate (plots V and VI).

Thus, in spite of the fact that site Present Ili delta has more favorable soil-hydrological growth conditions for Saxaul woodlands our research identified that anthropogenic effect reduces ability of woodland communities for successful regeneration.

Woodland biodiversity depends on climatic, soil and biotic factors. Every soil mantle is characterized by floristic composition and biodiversity. Domination of species and families in *Haloxylon-Artemisia terrae-albae* association proves that species diversity is affected by human activity. Literary sources (Kurochkina, 1978; Gvozdeva, 1960) state that channel Saxaul woodlands of *Haloxylon-Halimodendron* association have rich species diversity. Cattle grazing on the survey plots resulted in change of population species composition, replacement of grazed plants with weed and poisonous ones which increase covering area. Thus, *Haloxylon-Halimodendron* association acquired such species as *Peganum harmala* L., *Zygophyllum lexmannianum* Bge., *Z. fabagoides* M. Ror., etc.

Regardless the lack of direct anthropogenic effect on site Ancient Ili river delta there is a change of community structure. Thus, weed species *Ceratocarpus arenarius* L. is widely spread. According to Bedareva (2009) (Bedareva, 2009) *Haloxylon-Ceratocarpus* association - woodlands symbolize a closing stage of degradation and belong to ebelek (*Ceratocarpus arenarius*) type of weed infestation. Probably, our studies prove the theory of intermediate disturbance. It states that disturbance of old woodlands can lead to enrichment due to growth of additional species during succession though extreme disturbance can lead to decline in species diversity (Sheil and Burslem, 2003).

Conclusions

All survey sites represent plots which underwent anthropogenic effect in the past or it is happening now. Size structure of populations show state of plant association at different times. Thus, the most disturbed populations have unequal distribution in root collar diameter classes. Such structure has coenotic groups of trees according to root collar diameter. However, it cannot develop as a result of low rate of regeneration or lack of it. On studied territory the most typical structure of Saxaul woodland is homogenic one, stage of formation of crop. Ecosystem of artificial stands or stands after clear cutting is unstable one and acquires optimal structure after some time. Besides anthropogenic factors the reason of confusion of structure is a natural decay of woodland stand which is presented on a highly dense plot. Degradation of woodland stand happened as a result of lack of young trees caused by high density and competition. Only one studied plot has a stable system. The population grows in favorable conditions; the structure is heterogeneous; there is a constant supply of young trees.

Research outcomes show the most productive density equal to 900-1000 shrubs/ha as it provides favorable growth and regeneration conditions. Biodiversity also shows the level of influence of human activity. Thus, there is abundance of species on site Ancient Ili delta though both sites represent implantation of weed and ungrazed plants as well as invasion of associations.

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