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Ontogenetic spectrum of rare Linaria cretacea Fisch ex Spreng coenopopulations in the Aktobe region

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Abstract. The article is devoted to the assessment of the state of coenopopulations of the plant Linaria cretacea, a rare species that needs special protection, by botanical methods. To study the age structure and ontogenetic state of rare species in the Aktobe region. L. cretacea coenopopulations, test sites were built for Akkudyksai, Kopaly, and Utek coenopopulations in the populations of the Ishkargantau chalk massif. The age structure and ontogenetic state of the registered individuals of the species were determined, and the demographic situation in the coenopopulations, the values of the age index and the energy efficiency index, i.e., "delta-omega", and the indicators of recovery, exchange, and aging were calculated. In the results obtained, the average density of the species around coenopopulations and the average number of plants in different age states in the sample sites were calculated. According to coenopopulations, indicators were determined to determine changes in the demographic situation. The soil cover of the coenopopulation consists of gravelly chalk formed by sedimentary rocks of the Cretaceous period. In the soil where L. cretacea plant populations are found, facultative calcefites are twice as dominant as obligate calcefites. Studied rarely, the base spectra of L. cretacea coenopopulations are of a single and mature type. In the future, based on the results obtained, it will be possible to make recommendations for the conservation and protection of this rare species.
Keywords: L. cretacea, botanical methods, coenopopulations, ontogenetic state, age structure

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Introduction

The destruction of a certain biological species on Earth disrupts the stability of ecosystems and the integrity of the biosphere. This is one of the dangerous changes that are currently developing at a rapid pace in nature [1]. In most cases, anthropogenic factors are the cause of the decline and disappearance of plant populations within the ecosystem [2]. In the last edition of the Red Book of our republic (2014), 387 species with a reduced number are under state protection. In the Aktobe region, located at the crossroads of Europe and Asia, Mountain suffixes of the Cretaceous and Mesozoic were formed [3]. One of the oldest species preserved in the landscape and climatic zones is the Volga - West Kazakhstan endemic *Linaria cretacea* Fisch ex Spreng, which is listed in the Red Book of Kazakhstan.

In order to preserve these species, populations are monitored and, if possible, conservation and restoration work is established. Nevertheless, the list of rare plant species is constantly updated, because today's methods for accurately determining the number and distribution area of a particular species still require in-depth study. Therefore, the issue of improving various methods of assessing and preserving rare species at the population level in different regions of the country is relevant [4,5].

One of the pressing issues in the preservation of rare plant species is the question of the number in the coenopopulation sufficient for life in the protected area. The study of coenopopulation plays an important role in determining the organization and dynamics of phytocenoses [6-8]. The properties of coenopopulations are determined by the number, age, and vital conditions of the plants included in their composition, their ecological and genetic heterogeneity [9,10].

In some cases, the deterioration of abiotic living conditions of plants in coenopopulations is associated not with climatic characteristics, but with changes in local conditions caused by human activity, including economic changes, albeit at a considerable distance from the research site [11-13].

It is important to note that in plants of the same coenopopulation, the requirements for environmental conditions may differ in different ontogenetic States. In the pregenerative period (juvenile and immature states), plants are sensitive to fluctuations in temperature and humidity, which is caused by the fact that powerful root and shoot systems do not have time to form.

Other reasons for the deterioration of the coenopopulation of protected plant species may be related to the generative sphere. This includes, for example, a decrease in the viability of plants, which is a consequence of hybridization, which is closely related to the spatial isolation of small areas and coenopopulations. Regardless of the factors leading to the destruction of the coenopopulation, it is important to determine the question of the number of plants sufficient for successful development in these specific conditions in order to plan possible steps to restore it [14].

Plant coenopopulation refers to a dynamic phenomenon that is constantly changing and evolving. The habitat of plants is distinguished by factors affecting coenopopulations. Depending on the climatic conditions of the environment and soil moisture, changes and signs in the external structure of plants are formed. The influence of abiotic factors, along with anthropogenic factors, on the reduction of the species number of the *Linaria cretacea* plant, which is the subject of research, may be present. For this reason, the study of the age status, density and demographic status of the rare *Linaria cretacea* cenopopulations is relevant.

Materials and research methods

According to the population of Ishkargantau in the Aktobe region of the rare species *Linaria cretacea*, 3 coenopopulations were studied: Akkudyksai, Kopaly and Utek populations. Test sites were built every 10-20 meters for each of the three coenopopulations taken in the study, that is, a total of 30 individuals of *Linaria cretacea* from the test sites were calculated, and life States were determined [15-18]. The age status of 459 individuals of the *Linaria cretacea* plant found in 3 cenopopulation (CP) zones found in the Ishkargantau chalk massif was determined by the classification of T. A. Rabotnov (1950) in Table 1 and a set of criteria proposed by A. A. Uranov (1975) [19,20] (Table 1).

Table 1

Classification of the state of life according to T. A. Rabotnov (1950)

Stages of ontogenesis	State of plants	Age index
Latent	Seed in a state of rest	sm
Pregenerative	Sprouted	pl
	Juvenile	j
	Immaturly	im
	Virginil	v
Generative	Young	g1
	Mature	g2
	Old age	g3
Postgenerative	Subsenil	ss
	Senile	s
	Withered	sc

The density of coenopopulations of Linaria cretacea was calculated by the number of individuals in the test sites [21-23]. The age structure and ontogenetic state of individuals of the species, calculated from the sample sites of 3 coenopopulations (CP) in the populations of the *Linaria cretacea* plant in the Ishkargantau chalk massif in the Aktobe region, were determined. To determine the demographic situation of the studied coenopopulations, the values of the age index (Δ) and the energy efficiency index (ω), i.e., "delta-omega", and the indicators of recovery, exchange, and aging were calculated [24-27]. Statistical processing was performed using the MS EXCEL 2010 program and Statistica 5.0 statistical software package.

Results

It is known that the soils of the Akshatau and Ishkargantau mountains, where populations of the *Linaria cretacea* plant are the subject of research, are mainly chalky. As a general substrate, chalk has its own characteristics. The specific microclimate regime, physical and chemical properties of chalky soils, a low content of humus and an excessive excess of calcium affect plants. Several species have been formed that have adapted to such soils of the mentioned chalk mountains. Plants in such an unusual chalky substrate are divided into obligatory and

facultative calcefites.

In the mountains of Akshatau and Ishkargantau, where populations of the Linaria cretacea plant are found, there is mainly chalk soil. The specific order of the microclimate, physicochemical properties of the soil of the region studied as a substrate for growth, the low content of humus, the peculiarities of chalk and an excessive excess of calcium cannot help but affect the plants themselves. The flora of obligate and facultative calcefites, adapted to the chalky soils of the Ishkargantau chalk massif, is formed.

The *Linaria cretacea* plant has a high dependence on a chalky substrate. Among the plants included in the studied populations, we can note the real calcefites *Anthemis trotzkiana, Limonium cretaceum, Crambe tataria, Anabasis cretacea, Achillea nobilis, Echinops meyeri, Zygophyllum pinnatum*, which are found exclusively in cretaceous soils of carbonate rocks. Facultative calcefites include the rest of the species, which are better adapted to other soils than chalky ones [19,21,28].

Facultative calcefites predominate over obligate calcefites in the Ishkargantau chalk soil studied by us, where populations of the *Linaria cretacea* plant are found: 23.4% of obligate calcefites are adapted only to chalky soils and 76.6% of facultative calcefites are registered, typical of desert areas that can grow on other soils (Figure 1).

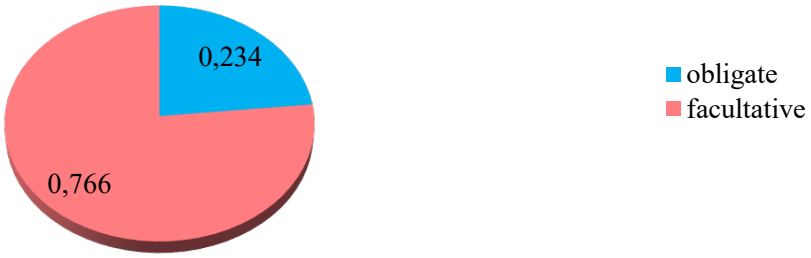

Figure 1. Flora of obligate and facultative calcefites in the Ishkargantau chalk massif, %

In the study, the average density of the species in the area of coenopopulations (PCs/m2) and the average number of individuals in different age states in the sample areas (PCs/M2) were calculated (Figure 2).

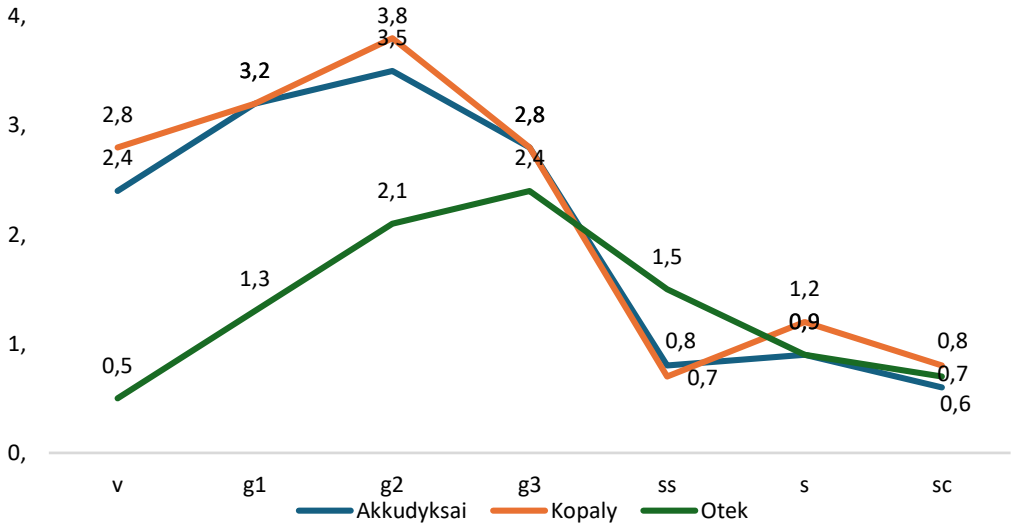

Figure 2. Ontogenetic state of L. cretacea cenopopulations

On the territory of Akkudyksai of the Ishkargantau chalk massif, the average density of *L. cretacea* individuals is 11.3 PCs/M2. In the coenopopulation, individuals of the pre-generative period v-18.9%, the generative period g - 74.8% and the post-generative period ss -6% were recorded (Figure 3).

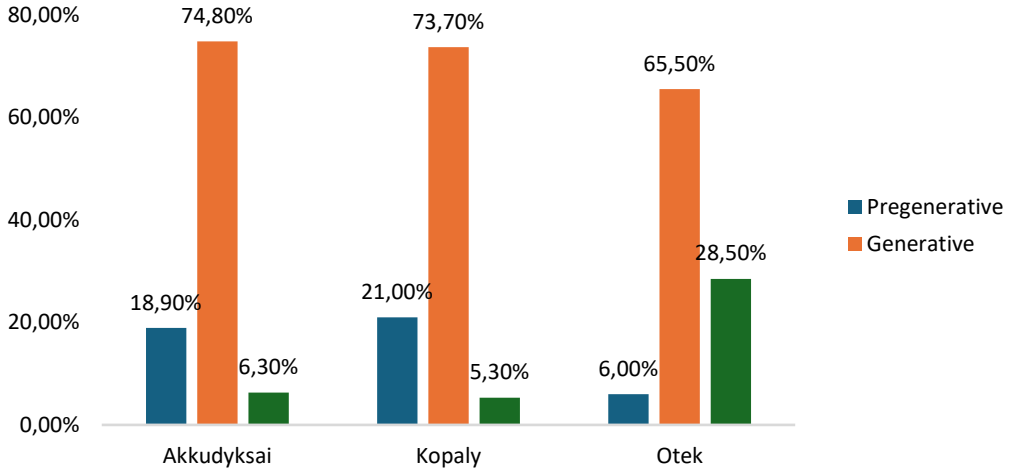

Figure 3. Ontogenetic stages of Linaria cretacea coenopopulations, (%)

The average density of individuals of the species in the area of copular coenopopulation was 10.2 pieces/M2, individuals of the pre-generative period V-21% of the plant, g-73.7% of the generative period and subsenile individuals of the postgenerative period ss - 5.3%.

The average density of individuals of the species on the territory of the Otek coenopopulation is 7.1 PCs/M2. Individuals of the pre-generative period (v) consist of 6%, individuals of the generative period G-65.5% and subsenile individuals of the post generative period (ss) 28.5%. In addition, our study revealed indicators of the demographic situation according to the listed coenopopulations (Table 2).

Table 2

Demographic status of mature Linaria cretacea coenopopulations

Cenopopulation	Akkudyksai	Kopaly	Otek
Age index, Δ	0,56± 1.4	0,44± 0.5	0,42± 1.3
Energy efficiency index, ω	0,71± 0.9	0,62± 1.0	0,58 ±1.1
Recovery index, Ir, %	31,3± 1.0	28,5± 0.5	20,2 ±0.9
Exchange index, Ie, %	42,1± 1.3	38,3±0.7	17,4± 0.6
Aging index, Ia %	0,25± 0.2	0,05± 0.5	0,06 ±1.1

The Kopaly and Otek populations were approximate in terms of Δ and ω, forming the values Δ = 0.44, ω = 0.62 and Δ = 0.42, ω = 0.58, respectively.

Discussion

We see that these values are much higher in the Akkuduksai coenopopulation (Δ = 0.56, ω = 0.71). In the bile, virginil individuals are smaller in comparison with Otek and Kopaly coenopopulations. However, the number of generative individuals in the Akkudyksai and

Kopaly coenopopulations was approximately the same, and the number of generative individuals was recorded in the bile. At the same time, 15 senile plants were observed in this Otek coenopopulation, and 7-8 senile plants were observed around the Akkudyksai and Kopaly coenopopulations.

In these populations, Δ and ω have almost the same indicator, and the higher of these indicators in the Whitefish is due to the fact that the two previous coenopopulations contain more than the number of middle-aged generative individuals. As for the indicators of the age index (ω) and energy efficiency index (ω) of the studied coenopopulations, the registration of individuals in the senile (s) state together with subsenile (ss) individuals in the post generative period of all coenopopulations affects the low indicator of the age indexΔ.

Population-based studies are based not only on visual assessments. The success of the analysis of the obtained data is also determined by the use of quantitative indicators that assess the number, density, fitness, ontogenetic spectra and other characteristics of coenopopulations.

In this study, the Δω classification made it possible to additionally identify coenopopulations of the "transitional" type, and from the "young" cenopopulations, it was possible to identify "maturing" ones, i.e., cenopopulations with a high proportion of generative individuals. These classifications are based on different criteria, so they can evaluate the age status of *Linaria cretacea* cenopopulations in different ways. Thus, the indicators presented in the article make it possible to quantify the state of *Linaria cretacea* cenopopulations based on data on ontogenetic spectra and identify their temporal and spatial dynamics in different environmental conditions.

Conclusion

In the coenopopulations of Akkudyksai, Kopaly and Otek, the state of growth and germination of the *L. cretacea* plant is normal. There are a few young virginil individuals in the testicular coenopopulation. The whitefly coenopopulation was distinguished by the predominance of the number of generative individuals of a rare species over other coenopopulations, and the presence of a small number of post generative individuals. Plants in the subsenile (ss) and senile (s) state predominate in the Otek coenopopulation. Thus, the quantitative indicators of aging and recovery indices presented in the results of the study showed that all studied coenopopulations have the potential to expand the distribution areas of the species. The basic spectra of the studied coenopopulations are of a single and mature type. The main ontogenetic spectrum of coenopopulations is concentrated in the middle of the spectrum, from the abundance of young and middle-aged generative individuals. In coenopopulations, differences are observed only in the density of individuals. The highest average density of individuals at the test sites was recorded in the Akkudyksai coenopopulation of 11.3 (PCs / M2), the lowest in the Otek coenopopulation of 7.1 (PCs/m2). We attribute the reason for the low Exchange index and aging rate in the Otek coenopopulation to the predominance of plants in the subsenile and senile states here.

Author Contributions

M.K., B.Sh.– concept and supervision of the work; **M.B.** – conducting the experiments; **N.A.** – discussion of the research results; **M.B.** – writing the text; **A.B.** and **T.A.** – editing the text of the article.

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Conflicts of Interest

The authors declare no conflicts of interest.

Compliance with ethical standards

This article does not contain a description of studies performed by the authors involving people or using animals as objects.

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Ақтөбе облысындағы сирек кездесетін *Linaria cretacea* Fisch ex Spreng ценопопуляцияларының онтогенетикалық спектрі

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Аңдатпа. Мақалада ерекше қорғауды қажет ететін сирек түр *Linaria cretacea* өсімдігінің ценопопуляциялары жағдайын ботаникалық әдістермен бағалауға арналған. Ақтөбе облысындағы сирек кездесетін *L. cretacea* ценопопуляцияларының жастық құрылымы мен онтогенетикалық күйін зерттеу үшін Ешқырғантау борлы массиві популяциялары ішіндегі Аққұдықсай, Қопалы және Өтек ценопопуляцияларына сынақ алаңдары салынды. Тіркелген түр дараларының жастық құрылымы мен онтогенетикалық күйі анықталып,

ценопопуляциялардағы демографиялық жағдайды анықтау үшін жастық индексі мен энергетикалық тиімділік индексі, яғни «дельта-омега» мәндері және қалпына келу, алмасу, қартаю көрсеткіштері есептелді. Алынған нәтижелерде ценопопуляциялар ауданындағы түрдің орташа тығыздығы мен үлгі алаңдарындағы әртүрлі жастық күйлеріндегі өсімдіктердің орташа саны есептелді. Ценопопуляциялар бойынша демографиялық жағдайдың өзгерістерін анықтайтын көрсеткіштер анықталды. Ценопопуляцияның топырақ жамылғысы бор дәуірінің шөгінді жыныстарынан түзілген қиыршықты бордан тұрады. *L. cretacea* өсімдігі популяциялары кездесетін топырақта облигатты кальцефиттерге қарағанда факультативті кальцефиттер екі есе басым екенін көрсетті. Зерттелген сирек кездесетін *L. cretacea* ценопопуляцияларының базалық спектрлері бір шыңды және жетілген типке жатады. Келешекте, алынған нәтижелерге сүйеніп осы сирек түрді сақтау мен қорғауға ұсыныстар жасауға болады.

Түйін сөздер: *L. cretacea*, ботаникалық әдістер, ценопопуляциялар, онтогенетикалық күйі, жастық құрылымы

Онтогенетический спектр редких ценопопуляций Linaria cretacea Fisch ex Spreng в Актюбинской области

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Аннотация. Статья посвящена оценке состояния ценопопуляций редкого вида растения Linaria cretacea, требующего особой защиты, ботаническими методами. Для изучения возрастной структуры и онтогенетического состояния ценопопуляций редкого вида *L. cretacea* в Актюбинской области были построены испытательные площадки для ценопопуляций Аккудыксай, Копалы и Отек в популяциях мелового массива Ишкаргантау. Были определены возрастная структура и онтогенетическое состояние зарегистрированных особей вида, а для определения демографической ситуации в ценопопуляциях были рассчитаны значения индекса молодости и индекса энергетической эффективности, то есть «дельта-омега», а также показатели восстановления, обмена, старения. По полученным результатам была рассчитана средняя плотность вида в районе ценопопуляций и среднее количество растений в различных возрастных состояниях на участках образцов. Определены показатели, определяющие изменения демографической ситуации по ценопопуляциям. Почвенный покров ценопопуляций состоит из гравийного мела, образованного осадочными породами мелового периода. В почве, где встречаются популяции растений *L. cretacea*, факультативные кальцефиты преобладают над облигатными кальцефитами в 2 раза. Базовые спектры ценопопуляций исследуемого редкого растения *L. cretacea* относятся к одиночному и зрелому типу. На основании полученных результатов, в будущем можно дать рекомендации по сохранению и защите этого редкого вида.

Ключевые слова: *L. cretacea*, ботанические методы, ценопопуляции, онтогенетическое состояние, возрастная структура

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