Cenopopulation dynamics of Cisbaikalia medicinal plants

Elena Khudonogova^{1,*}, Svetlana Polovinkina¹, Bimba-Tsyren Namzalov^{2,3}, Nikolai Dubrovsky⁴, and Sergey Ondar⁴

¹Irkutsk State Agrarian University named after A.A. Ezhevsky, 664038, Molodezhny settlement, 1, Irkutsk District, Irkutsk Region, 664038, Russia

²Banzarov Buryat State University, 670000, st. Smolina, 24a, Ulan-Ude, Russia

³Buryat Scientific Research Institute of Agriculture, 670045, st. Tretyakov, 25z, Ulan-Ude, Russia

⁴Tuva State University, 667000, Russian Federation, Kyzyl, st. Lenina, 5, Republic of Tuva, Russia

Abstract. The article provides information on the study of the dynamic processes occurring in cenopopulations of 16 species of medicinal plants used both in scientific and folk medicine (*Achillea asiatica* Serg., *Artemisia frigida* Willd., *Chamaenerion angustifolium* (L.) Holub, *Comarum palustre* L., *Geranium pratense* L., *Dasiphora fruticosa* (L.) Rydb., *Fragaria orientalis* Losinsk., *Mentha arvensis* L., *Pulmonaria mollis* Wulfen ex Hornem., *Potentilla anserina* L., *Potentilla bifurca* L., *Ribes spicatum* E. Robson, *Rosa majalis* Herrm., *Rubus matsumuranus* Levl. Et Vaniot, *Spiraea salicifolia* L., *Vaccinium uliginosum* L.): age coefficient, recovery index, development rate. Identification of the population confinement of species to existing ecological and coenotic conditions, determination of demographic parameters, study of the development dynamics, methods of self-maintenance and survival strategies serve as the basis for the rational use of plant resources. The stable and dynamically developing medicinal plant cenopopulations, with a high recovery index, with a tendency to develop towards rejuvenation, include the cenopopulations of *Geranium pratense* of the Ziminsky region, *Pulmonaria mollis* of the Alar and Irkutsk regions, *Rubus matsumuranus* of the Irkutsk region. The results of the analysis of the cenopopulation dynamics of the studied species made it possible to identify stable, dynamically developing cenopopulations and recommend them for use.

1 Introduction

The study of plant resources of Baikal Siberia for the purpose of their rational use and protection remains one of the main tasks of modern biology and medicine. The development of resource industries in the pharmaceutical and food industries implies the expansion of the range of medicinal types, taking into account the experience of traditional and Tibetan medicine. The search for new medicinal and food plants requires a comprehensive study of flora and vegetation, comprehensive ecological and biological

* Corresponding author: doky2015@yandex.ru

research on the basis of generalization, clarification and addition of theoretical, methodological and practical recommendations.

Population studies can be considered one of the priority areas of ecological and biological research. Identification of the population confinement of species to existing ecological and coenotic conditions, determination of demographic parameters, study of the development dynamics, methods of self-maintenance and survival strategies serve as the basis for the rational use of plant resources.

The work of many authors is devoted to the study of medicinal plants used in scientific and folk medicine. Resource science, ontogenetic and cenopopulation, introduction studies, identification of thickets of industrial importance, recommendations on scientifically grounded volumes of raw materials procurement, ecological-biological, biochemical and pharmacognostic studies, study of the technology of drying and processing of plant materials while preserving the maximum amount of biologically active substances, study the impact of recreational activities on the components of biocomplexes and other aspects considered by the authors will help to solve the problem of biodiversity conservation [1-24].

When developing the problems of preserving the biological diversity of wild-growing medicinal plants, the question inevitably arises about the criteria for an approach to the procurement of raw materials for valuable plant species. The dynamic structure of cenopopulations of medicinal plants, as a rule, is not taken into account when collecting and preparing raw materials. In this connection, the aim of our research was to study the dynamic structure of wild medicinal plant cenopopulations in the conditions of Cisbaikalia.

2 Materials and Methods

Study of cenopopulations of 16 species of medicinal plants (*Achillea asiatica* Serg., *Artemisia frigida* Willd., *Chamaenerion angustifolium* (L.) Holub, *Comarum palustre* L., *Geranium pratense* L., *Dasiphora fruticosa* (L.) Rydb., *Fragaria orientalis* Losinsk., *Mentha arvensis* L., *Pulmonaria mollis* Wulfen ex Hornem., *Potentilla anserina* L., *Potentilla bifurca* L., *Ribes spicatum* E. Robson, *Rosa majalis* Herrm., *Rubus matsumuranus* Levl. et Vaniot, *Spiraea salicifolia* L., *Vaccinium uliginosum* L.) conducted by us on the territory of Cisbaikalia (Alar, Bokhansky, Ziminsky, Irkutsk, Nizhneudinsky, Olkhonsky regions) from 1999-2012.

The determination of the age composition and number of cenopopulations of medicinal plants was carried out in accordance with the method of T.A. Rabotnov, taking into account the methodology for studying the age structure of the populations that make up the community of V.D. Aleksandrova, criteria for identifying age states and features of the course of ontogenesis in plants of various biomorphs of L.I. Vorontsova, L.E. Gatsuk, V.N. Egorova and others, L.B. Zaugolnova, L.A. Zhukova, A.S. Komar, O.V. Smirnova, as well as the principles and methods of studying the age structure of cenopopulations by Yu.A. Zlobina, E.L. Nukhimovsky [25].

When assessing each age state, three groups of features were taken into account (according to the classification of life forms of Rabotnov-Uranov): a) morphostructure of individuals and its change in ontogenesis; b) the state of integration of elements; c) the sequence of passing the stages of morphogenesis. The age state was determined mainly by the aboveground parts: the number, shape and size of leaves, the number and length of shoots, the presence of flowers and fruits. Sometimes, to clarify the age state, they dug up individual shoots or dug up the whole plant [25].

Individuals belonging to the same age state were combined into one age group. The selection of age groups of individuals was carried out in accordance with the classification of age states of T.A. Rabotnov, indexes of age states were proposed by A.A. Uranov [25].

When assessing the dynamic structure of cenopopulations, we relied on the theory of A.A. Uranova, L.A. Zhukova, including with co-authors, according to which the dynamic processes occurring in populations reflect the age coefficients, recovery index, development rate [25]. The age index was determined by the formula:

$$\Delta = \sum k_i m_i / \sum k_i, \text{ where}$$

k_i is the size of each age group,
 m_i is the “weight” of the age of one individual in each age group:

$$m_i = 1 / 1 + e^{-x},$$

The development rate of cenopopulations was determined by the formula proposed by L.A. Zhukova:

$$UA = \Delta_2 - \Delta_1 / t_2 - t_1, \text{ where}$$

Δ_1 is initial age, Δ_2 is final age, $t_2 - t_1$ is time interval.

The recovery index ($J_R, \%$) was calculated to characterize the dynamics of self-maintenance:

$$J_B = \sum j \rightarrow v / \sum g_1 \rightarrow g_3 \times 100\%.$$

3 Results

Cisbaikalia is a region of the south of Eastern Siberia, located in the center of the Asian continent. The territory of Cisbaikalia, according to the botanical-geographical zoning, belongs to the Eurasian coniferous-forest region, the Euro-Siberian subregion and is characterized by a plain or plateau relief, the predominance of pine forests. Dark coniferous forests with the participation of spruce, cedar, fir and larch are located in elevated areas. Birch and aspen forests, as well as mixed forests with the participation of small-leaved species, are common at the site of fires.

The results of the ontogenetic structure studies of cenopopulations of the studied medicinal plants are shown in Table 1.

According to theory of A.A. Uranova and L.A. Zhukova, the dynamic processes taking place in populations reflect the age coefficients, recovery index and development rate (Table 2).

The plant communities of medicinal plants in all regions were identical, and therefore, the experimental data on the studied cenopopulations of 16 species were summarized by us and presented for the studied regions of the study.

Table 1. Dynamics of raw material stocks and age structure of medicinal plant cenopopulations.

View	Research area	Plant Communities	Year	Ontogenetic structure,%										
				p	j ₁	j ₂	im	v	g ₁	g ₂	g ₃	ss	s	
<i>Achillea asiatica</i>	Alar	Pine-birch forest, forb, forb meadow	2005	0.1	0.2	1.4	3.8	12.5	29.0	38.3	13.6	1.1	-	
			2011	0.3	0.3	0.6	1.5	13.0	20.1	37.6	24.3	2.3	-	
	Irkutsk		2005	0.8	1.0	1.2	1.5	16.0	32.5	30.1	15.9	1.0	-	
			2010	0.4	0.2	0.5	1.1	27.0	28.9	23.4	17.5	1.0	-	
	Ziminsky		2005	0.3	0.9	1.1	1.9	10.0	50.6	30.2	4.7	0.3	-	
			2011	0.3	1.4	0.5	1.7	7.6	67.3	18.4	1.3	1.5	-	
	Nizhneudinsky		2005	0.6	0.8	1.5	2.0	17.1	45.5	20.6	10.3	1.6	-	
			2011	0.1	0.5	1.0	1.3	26.2	39.6	22.7	6.2	2.4	-	
<i>Artemisia frigida</i>	Olkhonsky	Grass-forb real steppes	2000	1.2	1.6	1.6	2.0	2.3	51.2	25.2	10.2	4.7	-	
			2011	0.2	0.3	0.4	0.7	0.8	29.5	29.7	28.9	9.5	-	
<i>Chamaener</i>	Irkutsk	Berezhnyak,	2000	0.6	2.0	6.5	10.3	13.2	18.4	40.0	7.0	-	2.0	

View	Research area	Plant Communities	Year	Ontogenetic structure,%									
				p	j ₁	j ₂	im	v	g ₁	g ₂	g ₃	ss	s
<i>ion angustifolium</i>		mixed fireweed forest, grass-fireweed meadow	2006	1.0	4.6	8.8	9.2	9.7	26.9	33.8	5.0	-	1.0
			2011	0.9	3.8	8.5	8.7	10.4	20.0	42.4	4.2	-	1.1
<i>Comarum palustre</i>	Irkutsk	Bereznayak rotational, horsetail; soddy sedge meadow	2006	0.6	0.6	0.8	4.4	11.0	23.2	30.6	25.9	2.3	0.6
			2012	0.6	0.6	0.6	2.3	3.3	9.7	42.5	35.4	4.0	1.0
<i>Dasiphora fruticosa</i>	Alar	Yernik forb	2005	1.4	1.6	2.0	3.2	8.0	46.1	35.8	1.3	0.6	-
	Irkutsk		2012	2.1	2.4	3.8	5.6	6.3	41.1	37.6	0.7	0.4	-
			1999	0.1	0.5	0.3	3.7	15.0	40.2	36.9	2.4	0.9	-
			2005	0.2	0.7	2.3	5.0	12.4	39.8	35.5	2.5	1.6	-
			2011	0.3	0.3	1.1	3.6	10.7	38.2	40.4	3.6	1.8	-
			2006	0.1	0.2	1.6	2.8	5.2	40.6	39.3	7.7	2.5	-
	Olkhonsky		2011	0.6	1.3	1.3	2.2	2.2	31.8	47.8	9.6	3.2	-
<i>Fragaria orientalis</i>	Alar	Grass-strawberry-forb meadow	2000	1.0	1.8	2.5	3.8	6.4	29.5	48.6	3.7	2.0	0.7
	Ziminsky		2005	1.3	1.5	1.7	1.5	10.2	32.0	40.4	6.5	3.7	1.2
			2012	0.8	1.0	1.2	1.4	1.8	34.7	58.0	0.8	0.2	0.1
			2005	0.6	1.3	2.0	2.5	4.5	22.2	45.5	10.9	10.3	0.2
			2011	0.1	0.5	0.6	0.9	1.1	19.2	43.0	18.6	15.0	1.0
			Irkutsk	2005	0.5	0.8	1.4	2.1	8.2	53.3	27.7	5.0	1.0
	2010			0.3	0.6	1.0	1.3	3.7	52.4	29.5	9.5	1.7	-
<i>Geranium pratense</i>	Alar	Grain-geranium-forb meadow	2000	1.5	4.2	5.0	1.33	27.9	40.1	16.9	2.4	0.6	-
	Ziminsky		2005	1.0	2.8	3.5	16.5	20.4	31.0	20.0	4.0	0.8	-
			2012	4.4	2.6	4.4	14.8	16.5	27.4	19.1	9.0	1.7	0.1
			2005	0.6	0.9	8.3	0.4	25.2	30.7	30.2	3.4	0.3	-
			2011	1.3	2.0	15.6	3.7	17.3	36.5	16.3	6.5	0.8	-
			Irkutsk	2000	1.7	3.4	6.7	9.9	14.4	38.8	22.0	1.6	1.5
	2005			3.0	4.6	6.3	1.5	9.3	38.1	30.2	5.8	1.2	-
	2010			6.2	9.3	3.1	5.2	17.0	33.4	22.5	2.9	0.3	0.1
<i>Mentha arvensis</i>	Alar	Yernik forb. sedge-horsetail meadow	2005	0.3	1.5	1.4	1.7	7.6	56.3	26.0	3.5	1.7	-
	Irkutsk		2012	1.4	2.3	2.7	3.6	4.1	52.2	23.9	5.8	4.0	-
			2006	0.8	0.9	3.1	8.8	30.3	45.6	8.6	1.4	0.5	-
			2010	0.4	1.6	4.5	1.2	5.8	47.4	38.5	2.8	0.8	-
			Olkhonsky	2006	0.1	0.1	0.6	1.7	9.3	58.4	27.9	1.6	0.3
	2011			1.0	2.0	4.0	4.0	6.7	50.5	26.0	4.8	1.0	-
<i>Potentilla anserina</i>	Irkutsk	Grass-geese-leaved meadow	2001	0.02	1.2	1.2	4.88	29.4	24.4	24.4	12.2	2.3	-
			2010	0.02	0.05	0.06	0.85	10.69	44.35	24.3	16.52	3.16	-
<i>Potentilla bifurca</i>	Olkhonsky	Forb-cold wormwood mountain steppes	2006	0.1	0.1	0.3	4.7	8.0	39.0	43.0	4.0	0.8	-
			2011	0.2	0.5	1.6	2.9	5.6	35.2	46.2	6.5	1.3	-
<i>Pulmonaria mollis</i>	Alar	Bereznayak forb	2005	0.3	1.9	2.8	11.6	17.5	38.0	23.9	3.0	-	1.0
	Ziminsky		2012	0.4	4.0	5.0	9.9	21.5	30.0	22.0	5.5	-	1.7
			2005	0.6	2.0	1.8	3.8	29.2	22.6	22.4	16.2	-	1.4
			2011	0.2	1.1	1.6	2.5	28.7	26.0	19.7	18.0	-	2.2
			1999	0.5	2.7	3.2	16.9	14.2	37.2	23.1	2.0	-	0.2
			Irkutsk	2005	0.8	3.0	6.6	13.5	15.2	33.8	25.2	1.7	-
	2010			0.9	5.1	8.3	14.1	8.9	38.4	21.5	2.3	-	0.5
<i>Ribes spicatum</i>	Alar	Yernik forb	2005	0.3	3.5	7.2	10.2	10.4	27.8	33.0	7.0	0.6	-
			2012	0.6	1.3	4.6	5.3	6.0	19.9	56.3	5.3	0.7	-

View	Research area	Plant Communities	Year	Ontogenetic structure,%									
	p			j ₁	j ₂	im	v	g ₁	g ₂	g ₃	ss	s	
	Irkutsk		2005	0.1	4.0	5.5	10.1	10.6	24.7	41.0	3.8	0.2	-
			2012	0.1	2.8	4.6	7.4	10.7	25.5	46.5	1.4	0.5	0.5
<i>Rosa majalis</i>	Alar	Bereznnyak cereal. sedge	2001	0.7	1.2	3.5	9.0	26.3	22.1	18.2	18.0	1.0	-
			2005	0.2	0.8	0.7	10.6	15.9	30.3	25.6	13.6	2.0	0.3
			2012	0.4	0.1	0.5	3.0	8.3	21.9	39.4	21.2	4.5	0.7
	Ziminsky		2001	0.1	0.1	2.4	4.6	17.0	18.3	20.3	19.5	9.8	7.9
			2005	0.3	0.9	1.5	1.5	6.6	20.0	19.5	29.7	9.6	10.4
			2011	0.1	0.5	0.6	2.0	3.0	8.0	22.2	40.4	10.1	13.1
	Irkutsk		2001	0.7	2.6	5.4	10.9	21.9	33.7	21.5	2.6	0.7	-
			2005	0.2	1.8	5.3	5.0	21.4	26.0	38.5	1.3	0.5	-
			2012	0.5	3.9	6.1	7.7	16.6	19.4	43.7	1.6	0.5	-
	Nizhneudinsky		2000	0.3	0.3	1.5	15.4	18.0	32.5	24.3	4.8	2.0	0.9
			2005	0.4	1.7	3.6	12.5	10.1	21.6	37.6	7.2	3.9	1.4
			2012	0.2	2.5	5.0	7.5	8.3	19.2	42.5	9.1	4.1	1.6
<i>Rubus matsumuranus</i>	Alar	Mixed grass-forb forest	2001	2.6	2.9	6.4	10.6	18.2	20.0	24.3	10.8	3.7	0.5
	Irkutsk		2010	4.3	6.3	6.7	7.5	13.5	17.5	19.0	14.0	9.1	2.1
			2001	1.8	1.5	2.4	6.0	18.0	22.2	41.5	4.2	2.0	0.4
			2010	2.6	3.5	3.8	5.5	20.6	25.6	32.0	3.2	2.6	0.6
<i>Spiraea salicifolia</i>	Alar	Yernik forb	2006	0.6	0.8	2.8	9.6	23.3	39.3	19.5	4.0	0.1	-
	Irkutsk		2011	0.3	0.4	3.3	8.4	19.1	37.6	24.1	6.7	0.1	-
			2006	0.9	0.7	1.5	7.0	12.0	43.5	30.6	2.1	1.7	-
			2011	1.4	1.8	4.7	9.7	10.4	32.4	34.4	2.9	2.2	0.1
<i>Vaccinium uliginosum</i>	Irkutsk	Blueberry pine forest	1999	0.3	0.4	1.6	2.3	10.0	22.0	56.5	3.9	2.2	0.8
			2005	1.2	1.5	2.0	3.9	13.7	36.5	37.3	2.5	1.0	0.4
			2011	1.5	2.6	4.2	6.3	6.5	20.7	52.7	4.0	1.0	0.5
	Olkhonsky		2000	0.1	0.4	0.9	5.3	14.4	30.1	40.6	6.4	1.8	-
			2005	0.1	0.2	1.6	3.9	8.4	34.0	35.3	11.6	4.7	0.2
			2010	0.7	0.8	1.7	3.4	10.1	28.5	35.9	13.5	5.2	0.2

Note: p - seedlings (shoots), j (j₁, j₂) - juvenile, im - immature, v - virginal (young vegetative, adult vegetative), g₁ - young generative, g₂ - middle-aged generative, g₃ - old generative, ss - subsenile (old vegetative), s - senile.

Table 2. Dynamics of medicinal plant cenopopulations.

Research area	Coefficients of cenopopulation dynamic						
	Age of cenopopulation, Δ			Recovery index, J _R		Development rate, U	
Achillea asiatica							
Research year	2000	2005	2010-2011.	2000	2005	2010-2011	2000-2011
Alar	-	0.396	0.456	-	22.1	18.8	1.00
Ziminsky	-	0.335	0.314	-	16.1	12.8	- 0.35
Irkutsk	-	0.385	0.375	-	25.6	41.4	- 0.22
Nizhneudinsky	-	0.337	0.319	-	28.5	40.4	- 0.30
Artemisia frigida							
Research year	2000	2005	2011	2000	2005	2011	2000-2011
Olkhonsky	0.385	-	0.526	8.6	-	2.4	1.28
Chamaenerion angustifolium							
Research year	2000	2006	2011	2000	2006	2011	2000-2011
Irkutsk	0.343	0.434	0.399	49.6	50.5	48.5	0.50
Comarum palustre							
Research year	2000	2006	2012	2000	2006	2012	2000-2012

Research area	Coefficients of cenopopulation dynamic						
	Age of cenopopulation, Δ			Recovery index, J_R		Development rate, U	
Irkutsk	-	0.446	0.366	-	20.8	9.8	1.33
<i>Dasiphora fruticosa</i>							
Research year	1999	2005-2006	2011-2012	1999	2005-2006	2011-2012	1999-2012
Alar	-	0.328	0.346	-	19.8	25.4	0.25
Irkutsk	0.128	0.335	0.361	24.7	26.7	19.5	1.94
Olkhonsky	-	0.551	0.426	-	6.5	8.5	- 2.48
<i>Fragaria orientalis</i>							
Research year	2000	2005	2010-2012	2000	2005	2010-2012	2000-2012
Alar	0.384	0.394	0.396	17.9	18.9	5.8	0.10
Ziminsky	-	0.467	0.547	-	13.3	3.8	1.33
Irkutsk	-	0.339	0.379	-	14.5	7.2	0.78
Nizhneudinsky	-	0.348	0.418	-	15.2	11.4	1.17
<i>Geranium pratense</i>							
Research year	2000	2005	2010-2012	2000	2005	2010-2012	2000-2012
Alar	0.252	0.253	0.326	64.4	78.5	68.9	0.61
Ziminsky	-	0.294	0.259	-	53.9	65.3	- 0.56
Irkutsk	0.264	0.316	0.253	55.2	29.7	58.6	- 0.11
<i>Mentha arvensis</i>							
Research year	2000	2005-2006	2010-2012	2000	2005-2006	2010-2012	2005-2012
Alar	-	0.333	0.346	-	14.0	15.4	0.19
Irkutsk	-	0.258	0.353	-	24.8	11.4	2.36
Olkhonsky	-	0.324	0.319	-	13.7	20.0	-0.09
<i>Potentilla bifurca</i>							
Research year	1999	2006	2011	1999	2006	2011	2006-2011
Irkutsk	-	0.368	0.395	-	15.0	11.9	0.52
<i>Potentilla anserina</i>							
Research year	2001	2005-2006	2010	2001	2005-2006	2010	2001-2010
Irkutsk	0.387	-	0.403	60.0	-	13.7	0.17
<i>Pulmonaria mollis</i>							
Research year	1999	2005	2010-2012	1999	2005	2010-2012	1999-2012
Alar	-	0.281	0.280	-	43.0	71.2	- 0.005
Ziminsky	-	0.328	0.359	-	61.3	53.5	0.50
Irkutsk	0.258	0.257	0.252	58.2	64.4	60.0	- 0.02
<i>Ribes spicatum</i>							
Research year	2001	2005	2012	2001	2005	2012	2001-2012
Alar	-	0.316	0.390	-	46.4	21.1	1.05
Irkutsk	-	0.320	0.338	-	43.4	34.8	0.25
<i>Rosa majalis</i>							
Research year	2000-2001	2005	2011-2012	2000-2001	2005	2011-2012	2000 – 2012
Alar	0.329	0.355	0.470	68.4	40.5	14.5	1.27
Ziminsky	0.481	0.564	0.650	41.6	27.2	8.7	1.69
Irkutsk	0.256	0.305	0.322	73.9	51.0	52.9	0.59
Nizhneudinsky	0.300	0.365	0.399	57.2	42.0	32.9	0.82
<i>Rubus matsumuranus</i>							

Research area	Coefficients of cenopopulation dynamic						
	Age of cenopopulation, Δ			Recovery index, J_R			Development rate, U
Research year	2001	2005	2010	2001	2005	2010	2001 – 2010
Alar	0.322	-	0.410	68.7	-	67.1	0.98
Irkutsk	0.345	-	0.309	41.0	-	55.0	-0.38
<i>Spiraea salicifolia</i>							
Research year	2000	2006	2011	2000	2006	2011	2006 – 2011.
Alar	-	0.267	0.300	-	58.2	45.7	0.65
Irkutsk	-	0.318	0.319	-	27.8	38.1	0.005
<i>Vaccinium uliginosum</i>							
Research year	1999-2000	2005-2006	2010-2011	1999-2000	2005-2006	2010-2011	1999 – 2011
Irkutsk	0.411	0.334	0.375	17.3	27.8	25.3	- 0.30
Olkhonsky	0.366	0.408	0.417	27.3	17.4	20.5	0.50

4 Discussion

The results of the analysis of the cenopopulation dynamics of medicinal plants for the studied period from 1999 to 2012, showed that the cenopopulation of *Achillea asiatica* in the Alar region is normal, long-lived, but slowly developing, with a tendency towards aging ($U = 1$). Gradual aging is also observed in the coenopopulation of *Rubus matsumuranus* ($U = 0.98$) of the Alar region, *Fragaria orientalis*, *Rosa majalis* and *Spiraea salicifolia* ($U = 0.005-0.65$) ($U = 0.59-1.69$) of the Alar, Ziminsky, Irkutsk and Nizhneudinsky regions ($U = 0.1-1.33$); *Artemisia frigida* ($U = 1.28$) of the Olkhonsky region; *Comarum palustre* ($U = 1.33$), *Mentha arvensis* ($U = 2.36$), *Potentilla bifurca* ($U = 0.52$), *Potentilla anserina* ($U = 0.17$) of the Irkutsk region; *Pulmonaria mollis* ($U = 0.50$) of the Ziminsky region; *Ribes spicatum* ($U = 0.25-1.05$), *Rosa acicularis* ($U = 0.30-1.29$) of the Alar and Irkutsk regions; *Vaccinium uliginosum* ($U = 0.50$) of the Olkhonsky region.

The cenopopulation of *Chamaenerion angustifolium* is stable and rapidly developing ($J_R = 48.5 - 50.5$), the species is regenerated both by seed and vegetative means. A high recovery index was also noted in *Pulmonaria mollis* ($J_R = 43-71.2$). Fluctuations in the dynamics of age and recovery index for *Geranium pratense* ($J_R = 29.7-78.5$), *Potentilla anserina* ($J_R = 13.7-60$), *Pulmonaria mollis* ($J_R = 43-71.2$), *Rosa majalis* ($J_R = 8.7-73.9$), *Rubus matsumuranus* ($J_R = 41-68.7$), *Spiraea salicifolia* ($J_R = 27.8-58.2$) and other species over the studied period of time, can be associated with biomorphological features of the species, for example, with the ability of the rhizomes of *Chamaenerion angustifolium* and other species to partially die off, fall out of the clone structure and quickly replace the fallen shoots with young vegetative particles, as well as with climatic features of the year (dry growing season), anthropogenic (irrational procurements of raw materials, pasture digression) and pyrogenic factors.

The cenopopulation of *Dasiphora fruticosa* is quite stable, periodically renewing by seed. The moderately pronounced seed renewal of *Dasiphora fruticosa* ($J_R = 6.5-26.7$) is possibly associated with the weak ability of seeds to germinate in a dry climatic period. Development towards rejuvenation is observed in the Olkhonsky cenopopulation of *Dasiphora fruticosa* ($U = - 2.48$), a fairly young Alar cenopopulation ($U = 0.25$).

Gradual rejuvenation is also observed in the cenopopulation of *Achillea asiatica* of the Ziminsky, Irkutsk and Nizhneudinsky regions ($U = - 0.22 - 0.35$), *Geranium pratense* of the Ziminsky and Irkutsk regions ($U = - 0.11-0.56$), *Rubus matsumuranus* ($U = - 0.38$) of the Irkutsk region. The Irkutsk coenopopulations of *Vaccinium uliginosum* ($U = - 0.30$) and others stable and dynamically developing coenopopulations of *Pulmonaria mollis* are

developed with rejuvenation, while development towards rejuvenation, with good seed renewal, is observed in cenopopulations of *Pulmonaria mollis* of the Alar (U = - 0.005) and Irkutsk regions (U = - 0.02).

5 Conclusions

The stable and dynamically developing cenopopulations of medicinal plants, with a high recovery index ($J_R \geq 50$), with a tendency to develop towards rejuvenation, include the cenopopulations of *Geranium pratense* of the Ziminsky region; gradual rejuvenation is observed in the cenopopulations of *Pulmonaria mollis* of the Alar and Irkutsk regions, *Rubus matsumuranus* of the Irkutsk region. Irkutsk cenopopulations of *Chamaenerion angustifolium*, *Rosa majalis*, Ziminsky cenopopulations of *Pulmonaria mollis*, Alar cenopopulations of *Geranium pratense*, *Rubus matsumuranus*, *Spiraea salicifolia* develop with a tendency towards aging.

The results of the analysis of the cenopopulation dynamics of the studied species for the studied period of time (1999-2012) made it possible to identify stable, dynamically developing cenopopulations and recommend them for use. Determining the demographic parameters of useful plants, studying the dynamics of development, methods of self-maintenance and survival strategies of species serve as the basis for the rational use of plant resources.

References

1. A.Y. Astashenkov, V.A. Cheryomushkina, A.B. Myrzagaliyeva, B.Z. Medeubayeva, Ontogenesis, estimation of cenopopulation state and component composition in *Nepeta densiflora* Kar. Et Kir. (Lamiaceae) individuals of East Kazakhstan. International, *Journal of Environmental Studies*, **76**(4), 634-647 (2019). doi: 10.1080/00207233.2018.1509496.
2. I.L. Bukharina, K.E. Vedernikov, A.S. Pashkova Morphophysiologic traits of spruce trees in conditions of Izhevsk, *Contemporary Problems of Ecology*, **9**(7), 853-862. (2016).
3. E.A. Efremov, I.D. Zyкова, A.A. Efremov Component composition of essential oil and some extractives *Pulmonaria mollis* Hornem, *Siberian Medical Journal*, **122** (7), 125-128 (2013).
4. M.M. Ishmuratova, A.R. Ishbirdin, M.M. Cherosov, N.I. Baryshnikova, E.N. Suleimanova Ecological-phytocenotic, population, resource characteristics of *Valeriana alternifolia* Ledeb. *Bulletin of the Ammosov North-Eastern Federal University*, **6** (62), 17-24 (2017).
5. T.V. Krasnova, M.A. Safonov, Z.N. Ryabinina Bioresource potential of the Central Orenburg region, Publishing house: *Publishing and printing complex "University"*, (2014).
6. E. G. Khudonogova, M. A. Rachenko, N. G. Dubrovsky, O. A. Popova, T. T. Taisayev, Stocks of raw materials of wild medicinal plants in the Western Baikal Region, In: *IOP Conference Series: Earth and Environmental Science*, **315** (2019). <https://doi.org/10.1088/1755-1315/7/072002>.
7. E. Khudonogova, S. Tretyakova, A. Mikhlyaeva Ecological features of useful plants in natural populations of the Western Baikal Region. In: *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM*, **19**, 301–306 (2019). <https://doi.org/10.5593/sgem2019/5.2/S20.037>.

8. E. Khudonogova, O. Zatsepina, S. Polovinkina, M. Rachenko, Seed germination of woody and shrubby introduced species. *IOP Conference Series: Earth and Environmental Science*, **316** (2019). <https://doi.org/10.1088/1755-1315/316/1/012021>.
9. E.G. Khudonogova, A.A. Mikhlyaeva, S.V. Polovinkina, Ontogenetic development of *Hedysarum alpinum* L. in Prebaikalia. *Global Journal of Science Frontier Research*, **20**(3), 35-40, (2020)
10. E.B. Kolegova, V.A. Cheryomushkina, Ontogenetic structure and assessment of state of *Thymus mongolicus* (Lamiaceae) coenopopulations in Southern Siberia, *Contemporary Problems of Ecology*, **8** (2), 155-161 (2015). DOI: 10.1134/S1995425515020079.
11. A.V. Kuritsyn, V.D. Belonogova, G.I. Oleshko, *Resources of medicinal plant materials in the southern regions of the Perm Territory*, **3**, 11-13 (2007).
12. B.B. Namzalov, S.V. Zhigzhitzhapova, N.G. Dubrovsky Wormwoods of Buryatia: diversity analysis, ecological-geographical features, and chemotaxonomy of section abrotanum, *Acta Biologica Sibirica*, **5**(3), 178-187 (2019). doi: 10.14258/abs.v5.i3.6589.
13. N.A. Nikolaeva, I.A. Parygin, S.V. Tretyakova, Ecological characteristics of useful plants in the Baikal region, *Topical issues of agricultural science*, **21**, 27-34 (2016).
14. Yu.A. Plotnikova, E.S. Barysheva, I.V. Mikhailova, The effect of anthropogenic load on the pharmacological activity of medicinal herbs growing on the territory of the Orenburg region (review), *Problems of ecology of the Southern Urals. Collection of materials of the IX All-Russian scientific-practical conference with international participation*. 229-233 (2019).
15. T.V. Polozova, T.P. Antsupova, Natural resource potential of wild plants in the Republic of Buryatia. In the collection: State and development of production and processing of livestock products, hunting and fishing, *Materials of the international scientific and practical conference dedicated to the 80th anniversary of the Faculty of Technology*, 153-156 (2018).
16. E.A. Ponomarenko, O.V. Ryabinina, The impact of recreational activities on the components of biocomplexes in the Olkhon region and Olkhon island, *Bulletin of IrGSKhA*, **78**, 13-18 (2017).
17. G.O. Osmanova, S.V. Kozyreva, O.P. Vedernikova, The role of ontogenetic herbarium in studying intrapopulation biodiversity, *Pakistan Journal of Botany*, **48**(4), 1495-1500 (2016).
18. J.S. Sattarov, S.Kh. Vyshegurov, R.R. Galeev Monitoring the species diversity of medicinal plants typical for the south slope of Hissar Ridge, *Agronomy Research*. **18**(2), 543-553 (2018).
19. E.B. Talovskaya, Ontogenetic structure of coenopopulations of *Thymus baicalensis* (Lamiaceae) in the south of Siberia. *Bulletin of Tomsk State University*, **1** (33), 39-49 (2016).
20. S.A. Kholboeva, B.B. Namzalov, E.V. Bukharova, O.V. Imetkhenova, On the diversity of shrub communities in the vegetation of the Selenga midlands (Western Transbaikalia), *The flora of Asian Russia*, **1** (17), 55-63 (2015).
21. I.A. Khudonogov, Resource-saving principles of IR-power supply control in the processes of processing medicinal plants into health-improving tea. *Bulletin of KrasGAU*, **1** (28), 127-131 (2009).
22. I.A. Khudonogov, E.G. Khudonogova, Classification and energy technology system for processing wild and cultivated raw materials by infrared heating. In the collection:

Joint activities of agricultural producers and scientific organizations in the development of the agro-industrial complex of Central Asia. Collection of materials of the international scientific and practical conference: 4 parts. Ministry of Agriculture of the Russian Federation, Department of Science and Technology Policy and Education, 112-116 (2008).

23. E.G. Khudonogova, Medicinal plants of Cisbaikalia for tea and health drinks, *Bulletin of the Russian Academy of Agricultural Sciences*. **1**, 87-89 (2009).
24. E.G. Khudonogova, N.A. Nikolaeva, N.Yu. Chernigovskaya, Raw materials of wild medicinal plants in Cisbaikalia, *Topical issues of agricultural science*, **3**, 13-21 (2012).
25. E.G. Khudonogova, Biology, ecology and productivity of useful plants in Cisbaikalia: analysis, forecasting and optimization of use: abstract of doctors of biological sciences thesis (2015).