# SUSTENTABILIDADE DA VEGETAÇÃO DE YAKUTIA SOB INFLUÊNCIA TECNOGÊNICA

# PERSISTENCE OF YAKUTIA VEGETATION UNDER THE TECHNOGENIC IMPACT

# УСТОЙЧИВОСТЬ РАСТИТЕЛЬНОСТИ ЯКУТИИ ПРИ ТЕХНОГЕННОМ ВОЗДЕЙСТВИИ

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## RESUMO

São dados os resultados de estudos de longo prazo da vegetação de paisagens tecnogênicas de Yakutia pelo método de ordenação de espécies ao longo do tempo de sucessão. Os objetos de pesquisa são depósitos de rochas residuais de campos de ouro na Yuzhnaya Yakutia; cronócrinas ordenadas por modo dos primeiros implementadores em sucessão em depósitos jovens para os tipos estabelecidos de depósitos mais antigos (mais de 20 anos). Isto revelou um padrão geral na mudança de espécies e o tempo de aparecimento de diferentes espécies em sucessão, a duração de sua permanência na composição de comunidades seriadas. Cinco grupos de espécies foram obtidos: 1) um grupo de espécies de distribuição “subjacente”; 2) um grupo de espécies que estão expostas aos estágios iniciais da sucessão; 3) um grupo de espécies que estão expostas aos estágios intermediários; 4) um grupo de espécies que estão expostas aos estágios posteriores; 5) um grupo com distribuição bimodal. Os grupos selecionados de espécies por idade de depósitos de rochas residuais em depósitos minerais determinam o grau de auto-crescimento da vegetação dependendo das condições naturais e climáticas da região e a tecnologia de extração. Os autores identificaram padrões de formação de vegetação nos depósitos de campos de ouro na Yuzhnaya Yakutia, a fim de determinar o potencial de recultivo das terras perturbadas.

**Palavras-chave**: *depósitos de campos de ouro, sucessão, método de ordenação, paisagem, tipos de depósitos antigos.*

## ABSTRACT

This research presents the results of long-term studies into the vegetation of technogenic landscapes of Yakutia using the method of the ordination of species along successional time. The objects of the research are refuse heaps of gold deposits in South Yakutia; chronoclines, arranged by mode values from the earliest intruders into succession on young heaps to the established species on older heaps (over 20 years). The research discovered a general pattern in changes of species and time of appearance of various species in the succession, the duration of their presence as part of seral communities. 5 groups of species were identified: 1) the group of species of "flow-through" spread; 2) the group of species gravitating towards early stages of succession; 3) the group of species gravitating towards middle stages; 4) the group of species gravitating towards later stages; 5) the group with bimodal distribution. Groups of species selected by age of refuse heaps on mineral deposits determine the degree of vegetation overgrowth because of the climate of a region and mining technology. The authors identified patterns in revegetation of gold deposits heaps in South Yakutia in order to determine the reclamation potential of disturbed lands.

**Keywords**: *heaps of gold deposits, succession, method of ordination, landscape, types of old deposits.*

## АННОТАЦИЯ

Приводятся результаты многолетних исследований растительности техногенных ландшафтов Якутии методом ординации видов вдоль сукцессионного времени. Объекты исследований – отвалы пустых пород месторождений золота Южной Якутии; хроноклинов, упорядоченных по положению моды от первых внедренцев в сукцессию на молодых отвалах до установившихся видов более старых отвалов (более 20 лет). Это выявило общую закономерность смены видов и времени появления разных видов в сукцессии, длительность их пребывания в составе серийных сообществ. Получено 5 групп видов: 1) группа видов "сквозного" распространения; 2) группа видов, тяготеющих к ранним стадиям сукцессии; 3) группа видов, тяготеющих к средним стадиям; 4) группа видов, тяготеющих к более поздним стадиям; 5) группа с двухвершинным распределением. Выделенные группы видов по возрасту отвалов пустых пород на месторождениях полезных ископаемых определяют степень самозарастания растительности от природно-климатических условий региона и технологии добычи. Авторами выявлены закономерности формирования растительности отвалов месторождений золота Южной Якутии в целях определения рекультивационного потенциала нарушенных земель.

**Ключевые слова:** *отвалы месторождений золота, сукцессия, метод ординации, ландшафт, виды старых отвалов.*

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## INTRODUCTION

Intensive industrial development of Yakutia territory brought awareness to the need to identify the degree of impact on its nature. Vegetation is sensitive to environmental disturbances and quickly reacts to changing the environmental situation of the territory (Nikolayeva and Pinigin, 2016). Therefore, it can be used as an indicator of the level of persistence of disturbed ecosystems.

The most informative parameters of forest vegetation for ecological regulation could be – total stock of forest stands (relative density, quality of stands, medium height and diameter of the dominant species), the percentage of dead wood in stock, weight of coarse woody debris, productivity of forest stands, density of undergrowth, sprouts and natural seeding of dominant species. In grassland ecosystems, the degree of natural disbalance can be assessed based on the changes in the species composition of grass stands, expressiveness of canopies, biological spectrum and plant communities, similarities between species composition and background communities, as well as morphological changes of various plant parts (leaves, needles, roots, etc). Changes in vegetation structure (reduction in the area of primary associations, changes in forest cover), as well as changes on the level of plant communities and individual species (populations) also happen on forage lands (Golovatin *et al.*, 2012; Vasiliev *et al.*, 2009).

Among unique features of the environment of the North is the small capacity of biota, a weak link between vegetation and mineral substrate, the stunted biological cycle of organic matter, extremely weak self-restoration ability and being easily destructible under technogenic loads (Varlamova and Solovyev, 2010; Eastman *et al*, 2013; Lukiyanova, 2014; Garms, 2017; Zhuravleva *et al.*, 2018; Esatelles *et al.*, 2018). All these factors require the establishment of scientifically grounded criteria for marginal loads.

Industrial heaps serve as a location of anthropogenic spontaneous evolution, which results in the emergence of phytogenesis, previously absent in nature. The revegetation process lasts for hundreds of years and does not reach its climax state.

The purpose of this research is to identify patterns of revegetation of gold deposits heaps in South Yakutia and to analyze the recovery potential of the vegetation of different technogenic habitats. To resolve this problem, the following tasks were set:

- to study the flora and vegetation of heaps;

- to determine succession status of species involved in the process of self-recovery (Mironova and Ivanov, 2004);

- to identify technogenic succession systems.

## MATERIALS AND METHODS

Direct and indirect methods were used to study the dynamics of vegetation on heaps, where it is possible to accurately determine the age of a dump of any plot. (Aleksandrova, 1964). However, researchers note that indirect (extrinsic) methods are highly convenient (Fedorov and Goryukhin, 1987).

At the beginning of this century, L.G. Ramensky formulated the idea about the persistence of vegetation cover (Whittaker, 1980; Mirkin and Naumova, 1998). This led to creation of a new method of ordination, i.e. arrangement of objects (species, communities) along any axes that define the vegetation variation (Aleksandrova, 1966; McIntosh, 1978; Vasilevich, 1969; Ramensky, 1971; Whittaker, 1973; Mirkin and Rosenberg, 1978; Whittaker, 1980; Mirkin, 1984). It is preferred in cases where the leading factor is clearly expressed and is not hard to measure.

The authors used one variant of ordination – the analysis of chronoclines, i.e. gradient analysis along the axis of successional time (Mirkin *et al.*, 1968; Mirkin, 1970;). The only condition to perform the gradient analysis is the requirement of independence of selection of description points from the ordination gradient value and the vegetation pattern.

Selection for the ordination analysis was performed on ore heaps of the Kuranakh mine and dredge fields on the lowlands of the Seligdar river. For ordination, heaps were divided into 2 levels: upper (surface and slopes of heaps) and lower (pockets and shores of artificial reservoirs). The age of heaps was determined using surveying maps M: 25000.

Ordination was performed in accordance with the methodology of B.M. Mirkin and G.S. Rosenberg (1978). The analysis of changes in persistency of species along the time axis consists of two stages: identifying the degree of influence of ordination factor (one-factor dispersion analysis) and constructing the species distribution curve along the gradation of upper and lower levels of heaps.

## RESULTS AND DISCUSSION:

The result of the ordination – arrangement of species along the time axis – is called a chronocline. Chronoclines allows us to describe the succession. On the heaps of a certain age, successional rows were split into 5 stage-classes. Researchers received 2 versions of chronoclines: upper and lower heap levels. All species were given syntaxonomic association in accordance with the list of classes of the vegetation of the USSR.

The results of the analysis are presented in tables 1 and 2. Species in chronoclines tables are arranged by mode values from the earliest intruders into succession on young heaps to the established species on older heaps (over 20 years). The research discovered a general pattern in changes of species and time of appearance of various species in the succession, the duration of their presence as part of seral communities (Fedorova *et al.*, 2013; Popp, 2006; Compton *et al.*, 2001).

For statistical analysis species with selection concentration over 10% occurrence were picked. 5 groups of species were identified:

1 – the group of species of "flow-through" spread;

2 – the group of species gravitating towards early stages of succession;

3 – the group of species gravitating towards middle stages of succession;

4 – the group of species gravitating towards later stages of succession;

5 – the group with a bimodal distribution.

At the upper level of heaps, 104 species are included in processing, 31 of them are definitely not associated with the ordination factor. Table 1 presents the results of the ordination.

All species associated with the time gradient are also split into 5 groups.

The group of "flow-through" spread consists of perennials with a broad ecological amplitude. It is predominated by representatives of meadow communities of the order Arrhenatheretalia (*Elymus kronokensis*, *Astragalus schelichowii*, *Vicia cracca*) and the ruderal class Epilobietea (*Chamerion angustifolium*).

The group of species gravitating towards the early stage of succession includes 12 species with a predominance of perennials (*Tanacetum vulgare, Agrostis sibirica, Potentilla supina, Trifolium repens*) and with the participation of annual ruderal species (*Spergula sativa, Lappula squarrosa*). Overgrowth occurs with great intensity. Species of ruderal class Chenopodietea (*Tanacetum vulgare, Sonchus arvensis*) are replenished by species of classes Puccinellio-Hordeetea (*Puccinellia hauptiana, Beckmannia *syzigachne*), Plantaginetea (*Trifolium repens, Rumex crispus*) and the ruderal class Chenopodietea (*Tanacetum vulgare, Sonchus arvensis*). From meadow communities of the order Arrhenatheretalia, *Agrostis sibirica* can be found.

The group of species gravitating towards the middle stage of succession consists of 17 species. It is predominated by meadow species of the order Arrhenatheretalia (Trifolium pratense, *Euphrasia jacutica, Equisetum arvense, Poa pratensis, Inula britannica, Agrostis gigantea*) as well as the typical for Yakutian meadows species *Calamagrostis langsdorffii*.

The appearance of sprouts of tree and shrub communities of the class Salicetea purpureae (*Salix viminalis, Salix hastata, Chosenia arbutifolia, Populus tremula*) and the order Vaccinio-Pinetalia (*Larix gmelinii*) was observed.

The group of species gravitating towards the later stage of succession is the largest and includes 34 species. It is predominated by perennial plant species (*Cirsium setosum, Taraxacum ceratophorum, Achillea millefolium, Astragalus fruticosa, Dracocephalum nutans*).

The high persistence is observed among meadow plants of the order Arrhenatheretalia (*Ranunculus borealis, Plantago media, Potentilla anserina, Veronica longifolia, Thalictrum simplex, Festuca rubra*) and ruderal species – perennials of the class Artemisietea (*Linaria acutiloba, Galatella dahurica, Achillea millefolium, Carduus crispus, Chelidonium majus*). Steppe species of the class Cleistogenetea (*Astragalus fruticosa, Atriplex patula, Gentianopsis barbata*) begin appearing in the grass stands. Ruderal species of the class Plantaginetea (*Taraxacum ceratophorum, Polygonum aviculare*) persist. The composition of tree and shrub species of the class Salicetea (*Rubus sachalinensis, Rosa jacutica*) and the order Vaccinio-Pinetalia (*Pinus sylvestris*) also get enriched.

The group of species with bimodal distribution includes species whose persistence is quite high in the early stages, then it declines, sometimes disappearing and reappearing again at 15-20 years. As was already noted, at the middle stage of succession these species are replaced by meadow species, reappearing with secondary technogenic disruption (construction of residential areas and their infrastructure). These include eurytopic ruderal species *Elytrigia repens, Silene repens, Chenopodium album*.

28 rare species were identified, 10 of them gravitate towards early stages of succession (species of classes Artemisietea, Molinio-Arrhenatheretea), 8 – towards medium stages (species of classes Molinio-Arrhenatheretea, Salicetea) and 10 – towards later stages (species of classes Salicetea, Secaletea, Festuco-Brometea).

From the conducted analysis it is evident that the upper level of heaps is dominated by species gravitating towards later stages of succession (34 species), and the numbers in a ratio of species gravitating to early and middle stages are almost equal (12 and 17).

Table 2 shows the distribution of species of the lower level of heaps. Processing included 102 species, 14 of them have an inaccurate value of impact intensity. It should be noted that dredge heaps, compared to opencast spoil heaps, are low and their vegetation converges with vegetation of the upper level during succession.

Species are divided, as in the previous table, into 5 groups.

The group of species of "flow-through" spread includes 8 eurytopic perennials of ruderal classes Chenopodietea (*Tanacetum vulgare, Lactuca sibirica*), Artemisietea (*Artemisia mongolica, Trifolium repens*) and meadow species of the order Arrhenatheretalia (*Elymus kronokensis, Agrostis sibirica*). Ruderal classes Plantaginetea (*Plantago major*) and Epilobietea (*Chamerion angustifolium*) each represent one species.

The group of species gravitating towards the early stage of succession is represented by 4 perennials of ruderal class Puccinellio-Hordeetea (*Puccinellia hauptiana, Hordeum jubatum*), as well the meadow class Calamagrostetea (*Lathyrus pilosus*) and the order Arrhenatheretalia (*Agrostis gigantea*).

The group of species gravitating towards the middle stage of succession includes 9 species. The main is meadow species of the order Arrhenatheretalia (*Astragalus schelichowii, Equisetum arvense, Galium davuricum, Galium boreale*). Classes Secaletea (*Spergula sativa*), Plantaginetea (*Taraxacum ceratophorum*), Artemisietea (*Melilotus albus*) and the order Phragmitetalia (*Polygonum amphibium*) have one representative each. Shrubs are intruded by *Salix hastata*.

The group of species gravitating towards the later stage of succession is the largest one and consists of 64 species (more than 60% of the total list). Species composition is quite diverse – among them, there are 11 higher syntax of an order – class rank. Secondary (as already noted) technogenic impact enables subsequent intrusion of species of the ruderal orientation (Volpert and Shadrina, 2010). The group is widely represented by species of proper meadows of the order Arrhenatheretalia (*Vicia cracca, Trifolium pratense, Euphrasia jacutica, Ranunculus borealis, Galatella dahurica, Thalictrum simplex*, 22 species in total), ruderal communities of classes Artemisietea (*Elytrigia repens, Achillea millefolium, Geum aleppicum, Linaria acutiloba*) and Chenopodietea (*Sonchus arvensis, Silene repens, Galeopsis bifida, Cirsium setosum, Chenopodium album*). Massive development can be observed in shrubs of the class Salicetea purpureae (*Salix viminalis, Betula fruticosa, Duschekia fruticosa, Pentaphylloides fruticosa*, 16 species in total) and trees of the order Vaccinio-Pinetalia (*Larix gmelinii, Picea obovata, Pinus sibirica, Chosenia arbutifolia, Populus suaveolens, Populus tremula, Sorbaria sorbifolia*).

11 rare species were identified, most of which gravitate towards middle stages of succession.

Thus, on the lower level of heaps, there is a prevalence of species gravitating towards later stages of succession (62% of their total number), the number of shrub and tree species increases.

On the basis of selected groups of species, a classification of species-indicators was created, that allowed to easily determine the stage of overgrowth (table 3).

## CONCLUSIONS:

In summary, on refuse heaps of gold deposits in South Yakutia, the ordination analysis of species along the successional time was conducted. Species were arranged by mode values from the earliest intruders into succession on young heaps to the established species on older heaps (over 20 years). The research discovered a general pattern in changes of species and time of appearance of various species in the succession, the duration of their presence as part of seral communities. 5 groups of species were identified: 1) the group of species of "flow-through" spread; 2) the group of species gravitating towards early stages of succession; 3) the group of species gravitating towards middle stages; 4) the group of species gravitating towards later stages; 5) the group with bimodal distribution.

Ordination of species and the ecological-floristic classification of vegetation helped to assemble technogenic successional systems of heap overgrowth, which can be used to accurately determine the extent of vegetation self-recovery. The obtained data are the scientific basis for the compilation of normative indicators of heap overgrowth (Mironova *et al*., 2001).

Groups of species selected by age of refuse heaps on mineral deposits determine the degree of vegetation overgrowth depending on the climate of a region, as well as the reclamation potential of the disturbed lands.

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*Table 1. Chronocline of recovery succession of heaps in South Yakutia (upper level)*

| Species | Class, order | $\eta^2$ | Succession stage | | | | |
|---|---|---|---|---|---|---|---|
| Age | | | up to 5 | 6-10 | 11-15 | 16-20 | >20 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Species of "flow-through" spread | | | | | | | |
| *Elymus kronokensis* | Arr. | 0.27 | 0.86 | 0.46 | 0.50 | 0.88 | 0.20 |
| *Asrtagalus schelichowii* | Arr. | 0.45 | 0.84 | 0.70 | 0.26 | 0.84 | 0.02 |
| *Vicia cracca* | Arr. | 0.09 | 0.82 | 0.44 | 0.56 | 0.70 | 0.46 |
| *Chamerion angustifolium* | Ep. | 0.34 | 0.48 | 0.80 | 1.00 | 0.76 | 0.20 |
| *Artemisia mongolica* | Art. | 0.03* | 0.98 | 0.86 | 0.92 | 0.94 | 0.94 |
| *Trifolium lupinaster* | Arr. | 0.03* | 0.12 | 0.10 | 0.14 | 0.08 | 0.26 |
| Species gravitating towards early stages of succession | | | | | | | |
| *Agrostis stolonifera* | Arr. | 0.30 | 0.88 | 0.22 | 0.70 | 0.20 | 0.34 |
| *Potentilla supina* | P-H. | 0.48 | 0.84 | 0.20 | 0 | 0.34 | 0 |
| *Trifolium repens* | Pl. | 0.37 | 0.78 | 0.06 | 0.04 | 0.16 | 0.36 |
| *Sonchus arvensis* | Ch. | 0.26 | 0.46 | 0.02 | 0 | 0.02 | 0.20 |
| *Puccinellia hauptiana* | P-H. | 0.44 | 0.50 | 0 | 0 | 0 | 0 |
| Species gravitating towards middle stages of succession | | | | | | | |
| *Equisetum arvense* | Arr. | 0.25 | 0.32 | 0.02 | 0.56 | 0.04 | 0.12 |
| *Salix viminalis* | Sal. | 0.17 | 0.14 | 0.52 | 0.54 | 0.50 | 0.10 |
| *Calamagrostis langsdorffii* | Cal. | 0.21 | 0 | 0.16 | 0.32 | 0.48 | 0.02 |
| *Salix schwerinii* | Sal. | 0.10 | 0 | 0 | 0 | 0.14 | 0.02 |
| *Agrostis gigantea* | Arr. | 0.07 | 0 | 0 | 0 | 0.08 | 0 |
| Species gravitating towards later stages of succession | | | | | | | |
| *Linaria acutiloba* | Art. | 0.23 | 0.10 | 0 | 0 | 0 | 0.36 |
| *Ranunculus borealis* | Arr. | 0.20 | 0.04 | 0 | 0 | 0 | 0.28 |
| *Pinus sylvestris* | V-P. | 0.20 | 0 | 0.08 | 0.12 | 0.06 | 0.44 |
| *Achillea millefolium* | Art. | 0.63 | 0 | 0.02 | 0 | 0.12 | 0.80 |
| *Astragalus fruticosa* | Cl. | 0.61 | 0 | 0 | 0 | 0 | 0.66 |
| Species with a bimodal distribution | | | | | | | |
| *Elytrigia repens* | Art. | 0.40 | 0.78 | 0.22 | 0.06 | 0.14 | 0.74 |
| *Silene repens* | Ch. | 0.05 | 0.18 | 0.10 | 0 | 0.06 | 0.16 |
| *Populus suaveolens* | Sal. | 0.08 | 0.12 | 0 | 0 | 0 | 0.12 |
| *Carex spaniocarpa* | Cl. | 0.06 | 0.10 | 0.02 | 0 | 0.12 | 0 |
| *Chenopodium album* | Ch. | 0.09 | 0.10 | 0 | 0 | 0 | 0.16 |
| *Duschekia fruticosa* | Sal. | 0.06 | 0 | 0.10 | 0 | 0.02 | 0.12 |
| Total number of species in the succession stages (gamma diversity) | | | 54 | 41 | 28 | 42 | 79 |
| Average number of species in the description ( alpha diversity) | | | 15 | 11 | 12 | 13 | 15 |
| Average cover-abundance | | | 25 | 50 | 60 | 70 | 80 |
| Number of descriptions | | | 0 | 50 | 50 | 50 | 50 |

***Table 2.*** *Chronocline of recovery succession of dumps in South Yakutia (lower level)*

| **Species** | **Class, order** | **$\eta^2$** | **Succession stage** | | | | |
|---|---|---|---|---|---|---|---|
| **Age** | | | **up to 5** | **6-10** | **11-15** | **16-20** | **>20** |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Species of "flow-through" spread | | | | | | | |
| *Tanacetum vulgare* | Ch. | 0.16 | 0.72 | 0.36 | 0.26 | 0.52 | 0.78 |
| *Artemisia mongolica* | Art. | 0.17 | 0.60 | 0.90 | 0.94 | 0.96 | 0.60 |
| *Trifolium repens* | Art. | 0.22 | 0.42 | 0.08 | 0.64 | 0.10 | 0.50 |
| *Chamerion angustifolium* | Ep. | 0.09 | 0.38 | 0.08 | 0.20 | 0.34 | 0.48 |
| *Elymus kronokensis* | Arr. | 0.16 | 0.24 | 0.52 | 0.44 | 0.86 | 0.52 |
| Species gravitating towards early stages of succession | | | | | | | |
| *Puccinellia hauptiana* | P-H. | 0.09 | 0.16 | 0 | 0 | 0 | 0.06 |
| *Beckmannia syzigachne* | P-H. | 0.05 | 0.10 | 0.08 | 0.12 | 0 | 0 |
| *Lathyrus pilosus* | Cal. | 0.07 | 0 | 0.08 | 0 | 0 | 0 |
| *Agrostis gigantea* | Arr. | 0.05 | 0 | 0.06 | 0 | 0 | 0 |
| Species gravitating towards middle stages of succession | | | | | | | |
| *Asrtagalus schelichowii* | Arr. | 0.22 | 0.22 | 0.52 | 0.06 | 0.46 | 0.02 |
| *Equisetum arvense* | Arr. | 0.05 | 0.16 | 0.02 | 0.20 | 0.04 | 0.08 |
| *Melilotus albus* | Art. | 0.15 | 0.02 | 0.04 | 0.44 | 0.20 | 0.20 |
| *Salix hastata* | Sal. | 0.05 | 0.02 | 0.28 | 0.24 | 0.16 | 0.20 |
| *Polygonum amphibium* | Phr. | 0.04 | 0.02 | 0.02 | 0.12 | 0 | 0.08 |
| Species gravitating towards later stages of succession | | | | | | | |
| *Vicia cracca* | Arr. | 0.08 | 0.34 | 0.36 | 0.38 | 0.50 | 0.72 |
| *Sonchus arvensis* | Ch. | 0.16 | 0.26 | 0.20 | 0.12 | 0.10 | 0.58 |
| *Elytrigia repens* | Art. | 0.27 | 0.14 | 0 | 0 | 0.18 | 0.54 |
| *Trifolium pratense* | Arr. | 0.28 | 0.14 | 0.16 | 0.66 | 0.52 | 0.80 |
| *Salix viminalis* | Sal. | 0.16 | 0.08 | 0.14 | 0.18 | 0.34 | 0.56 |
| Species with a bimodal distribution | | | | | | | |
| *Potentilla supina* | Art. | 0.07 | 0.26 | 0.18 | 0.12 | 0.24 | 0. |
| *Achillea cartilaginea* | Arr. | 0.11 | 0.24 | 0.06 | 0.04 | 0. | 0.28 |
| *Potentilla tanacetifolia* | Arr. | 0.14 | 0 | 0.22 | 0 | 0 | 0.20 |
| Total number of species in the succession stages (gamma diversity) | | | 35 | 44 | 48 | 42 | 84 |
| Average number of species in the description ( alpha diversity) | | | 10 | 14 | 18 | 20 | 27 |
| Average cover-abundance | | | 20 | 30 | 45 | 55 | 60 |
| Number of descriptions | | | 50 | 50 | 50 | 50 | 50 |

**Table 3.** *Classification of species*

| Groups of species | The upper level of heaps | The lower level of heaps |
|---|---|---|
| "Flow-through" species | *Elymus kronokensis, Asrtagalus schelichowii, Vicia cracca, Chamerion angustifolium, Artemisia mongolica, Trifolium lupinaster, Elytrigia repens* | *Tanacetum vulgare, Artemisia mongolica, Trifolium repens, Chamerion angustifolium, Elymus kronokensis, Agrostis stolonifera, Lactuca sibirica, Plantago major, Crepis tectorum, Inula britannica* |
| Early stages of succession | *Tanacetum vulgare, Agrostis stolonifera, Potentilla supina, Trifolium repens, Sonchus arvensis, Puccinellia hauptiana, Spergularia marina, Lappula squarrosa,* | *Puccinellia hauptiana, Beckmannia syzigachne, Lathyrus pilosus, Agrostis gigantea* |
| Middle stages of succession | *Trifolium pratense, Crepis tectorum, Euphrasia jacutica, Equisetum arvense, Salix viminalis, Lactuca sibirica, Poa pratensis, Inula britannica, Chosenia arbutifolia, Salix hastata, Calamagrostis langsdorffii,* | *Asrtagalus schelichowii, Equisetum arvense, Melilotus albus, Salix hastata, Polygonum amphibium, Taraxacum ceratophorum,* |
| Later stages of succession | *Cirsium heterophyllum, Linaria acutiloba, Rhinanthus vernalis, Taraxacum ceratophorum, Ranunculus borealis, Plantago media, Pinus sylvestris, Veronica longifolia, Achillea millefolium, Thalictrum simplex, Galeopsis bifida, Astragalus fruticosa, Scutellaria galericulata, Dracocephalum nutans, Erodium cicutarium, Festuca rubra, Populus suaveolens, Larix gmelinii.* | *Vicia cracca, Sonchus arvensis, Elytrigia repens, Trifolium pratense, роð Salix, Calamagrostis langsdorffii, Plantago media, Euphrasia jacutica, Ranunculus borealis, Chosenia arbutifolia, Galatella dahurica, роð Populus, Galeopsis bifida, Thalictrum simplex, Sorbaria sorbifolia, Betula fruticosa, Carex juncella, Pentaphylloides fruticosa, Geum aleppicum, Rubus sachalinensis.* |