Concerning the main directions of biological diversity ex situ and in situ conservation providing by the Botanical Garden of Samara University

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Abstract. The article presents information on the results achieved by the Botanical Garden of Samara University in the field of biological diversity conservation in ex situ and in situ directions. The composition of 4 parts of living plants collection in open ground and greenhouse, together estimated over 4.5 thousand of seed plants taxa, is briefly characterized. The information on the seed bank development is given, about the implementation of experimental rare plants reintroduction into natural communities. The results gained by integration of ground-based monitoring and RS data, including operational surveying of target plant communities using UAVs, is briefly described also.

1 Introduction

Basing on statistic data, over the past half century our planet's population has doubled, the global economy has quadrupled, and global trade has grown tenfold [1]. Under these conditions, many plant species around the world are facing extinction threats due to natural ecosystems degradation as a result of human activities. Over 50% of the world's flora species are endemic to 34 so-called global biodiversity hotspots (GBH), the area of which previously occupied 15.7% of the land surface, but has now decreased to 2.3%. The majority of endemic species are concentrated here and are increasingly threatened with extinction [2]. Unfortunately, compared to the conservation of fauna species, plant conservation has received less human attention [3]. The species rarity or extinction results from a combination of a number of anthropogenic and evolutionary factors. We must briefly list some of them: they are habitat destruction, fragmentation, loss of pollinators, instability of reproduction, low ability of seeds to germinate, loss of genetic diversity, overexploitation, competition, pathogens and diseases, environmental conditions, climate change, natural disasters etc. [4]. The widely used term “biological diversity”, which includes a huge variety of ecosystems, species, genomes, emerging from official documents of the United Nations and governments, has become a basic concept in organizing practical activities for the protection wildlife [5, 6, 7].

As well known, the measures aimed to biological diversity (biodiversity) conservation, including flora conservation, are implemented within two general directions - *in situ* and *ex situ*. The most effective option for preserving rare plant species is to preserve their populations *in situ* - in nature, within the boundaries of their natural habitats. This problem is effectively solved by specially protected natural areas of "highest status" - nature reserves and national parks, while the status of less valuable categories ("pamyatnik prirody", in RF) often does not ensure the safety of natural objects. In addition, in protected areas we cannot exclude the possibility of unfavourable events that could destroy rare components of the vegetation cover (natural fires, etc.). This highlights the actual necessity for plant conservation through cultivation – *ex situ* conservation. In this case, collection funds, essentially representing field banks of biodiversity objects, can act as sources of materials for other forms of conservation (seed banks, pollen banks, tissue cultures), plant reintroduction, and work in the field of breeding [8].

2 Research methodology

Analysing a number of publications devoted to these problems, in particular, [9, 10, 11, 12, 13], we have compiled overview diagram aimed to reflect the specifics of each of the areas, including their advantages and disadvantages (Figure 1).

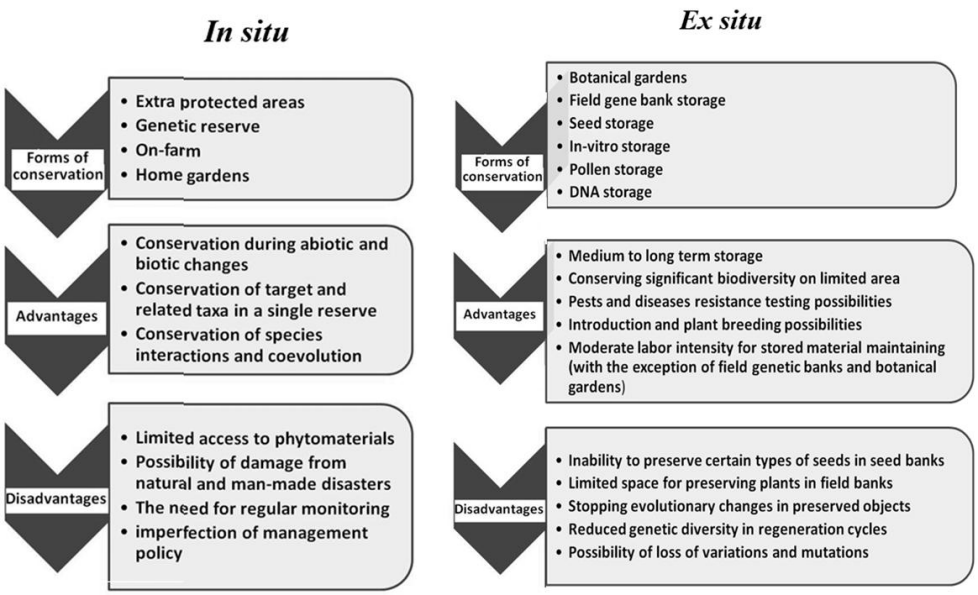

Fig. 1. *Ex situ* and *in situ* flora conservation directions: conservation forms, their advantages and disadvantages

3 Results and discussion

Speaking about the work of botanical gardens as specialized institutions that directly implement work of phytodiversity conservation, we can use the example of the Botanical Garden of Samara University to show how it carries this work in *ex situ* and *in situ* directions.

The first and most important area of activity, undoubtedly, is the formation, maintenance and development of valuable bioresource collections. First of all, these are collections of living plants, representatives of local and foreign flora.

The collection funds of the Botanical Garden, which by 2024 include more than 4.5 thousand taxa, are represented by 4 blocks of living plants collections in open and indoor ground. Their collection, maintenance and replenishment are carried out in the work of 4 departments. We shall name them and give some data about each of departments:

The Dendrology Department: the collection includes 1338 taxa (species, forms, varieties) of trees, shrubs, woody vines and fruit plants. Of the 657 species of dendroflora, 255 species are included in the International Red Book (The IUCN Red List of Threatened Species), 21 species are included in the Red Book of the Russian Federation, 5 species are included in the Samara Region Red Book.

The Tropical and Subtropical Crops Department: the number of taxa in the collection list is 1240 units, including 326 species listed in the IUCN Red List of Threatened Species.

The Flora Department: the collection includes 1115 taxa (herbaceous perennials, perennials and biennials). The core of the collection is protected species: 416 plant species of various rarity categories are presented in the collection and exhibition areas, including 53 listed in the Red Book of the Russian Federation, 67 in the Samara Region Red Book.

The Floriculture Department: the collection contains 871 taxa from 50 families. The most widely represented in the collection are the families Peaeonia (150 taxa), Iris (126 taxa), Asphodelaceae (84 taxa), Asteraceae (52 taxa), Asparagaceae (40 taxa), and Saxifragaceae (36 taxa). 17 species of floral and ornamental plants have varying status of rarity.

Some quantitative data related to the dynamics of the formation of department collections are presented in Figure 2, 3.

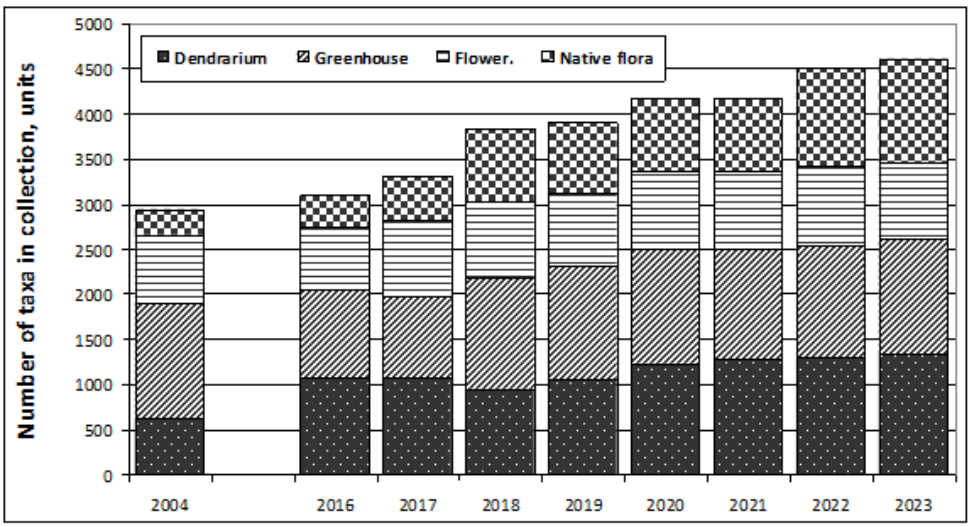

Fig. 2. Dynamics of changes in collection funds of Botanical Garden of Samara University

Unfortunately, the dynamics of changes in the number of collection funds taxa is not always characterized by unidirectional growth. We can illustrate such thesis, for example, using the data on the collection funds of the floriculture department (Figure 3). Thus, the weather conditions of 2009–2010, when after an exceptionally dry autumn the Samara region was faced by very strong and deep soil freezing, and the extreme drought was observed in the summer the following year. Such conditions led to the loss of many woody

and herbaceous taxa in open ground. Another year, some plants of greenhouse collection fund were lost due to disruption in the heat supply and the ventilation system in winter, which also required efforts to restore the losses.

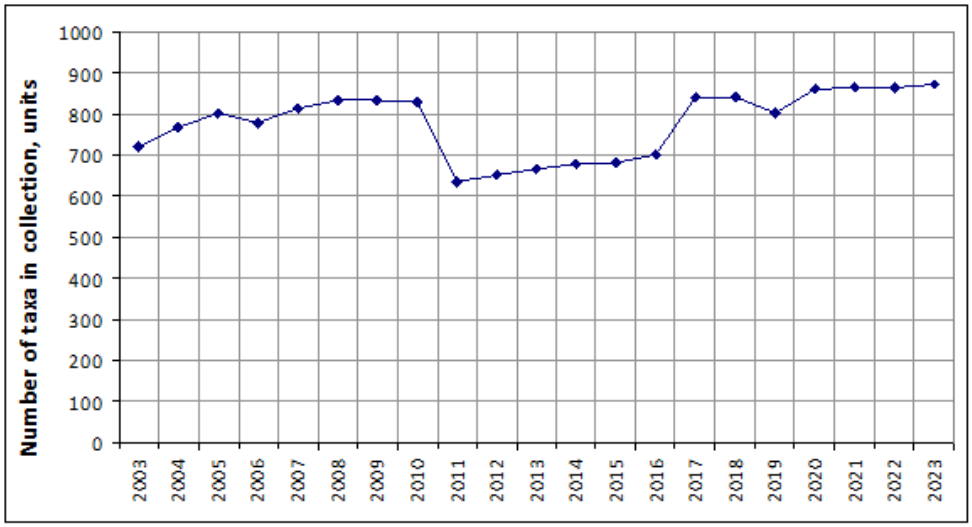

Fig. 3. Dynamics of changes in the collection funds of the Floriculture Department of the Botanical Garden of Samara University

Along with the field banks (collections of living plants), the botanical gardens often develop other types of banks (seeds, pollen, tissue cultures).

The Botanical Garden of Samara University in accordance with the implementation plan for the regional Conservation Strategy of Biological diversity [7] since the end of 2020 works on the formation of a seed bank of rare plants of natural flora and promising introduced species. The storage units of our seed bank are samples of diaspores collected in natural conditions and in the collections of the Botanical Garden. The placement of storage units in the bank is preceded by multi-stage sample processing, including X-ray quality assessment with subsequent rejection of defective diaspores. At the beginning of 2024, the seed bank contained 90 seed samples belonging to 44 taxa of flowering and gymnosperm plants. The representation of taxa ranges from 1 sample (18 species) to 16 samples (1 species – *Iris aphylla* L., represented by samples of different years of formation and origin). The number of rare species of the Samara region in the seed bank was 25 (54 storage samples).

The transition from *ex situ* conservation to restoration and maintenance of the numbers of rare species in situ is the reintroduction of plants [14, 15]. The Botanical Garden of Samara University has been carrying out reintroduction work since 2008, initially due to our participation in grants from the Botanic Gardens Conservation International (BGCI), later under government contracts with the Ministry of Forestry, Environmental Protection and Natural Resources Management of Samara regions (2011-2014, 2022-present). During this time, an experimental reintroduction of 11 rare species of local flora was carried out into natural biotopes that satisfy their ecological needs (*Juniperus sabina* L., *Paeonia tenuifolia* L., *Iris pumila* L., *I. sibirica* L., *I. aphylla* L., *I. halophila* Pall., *Euonymus europaea* L., *Lilium martagon* L., *Polemonium caeruleim* L., *Dictamnus gymnostylis* Stev., *Clematis integrifolia* L.). Among the named species are *Paeonia tenuifolia* L., *Euonymus europaea* L., *Iris halophila* Pall. were mentioned in the first edition of the Red Book of the Samara Region in the list of those that have disappeared over the past 50 years. It must be

noted that "new" plantings are carried out periodically, in connection with contracts, whereas the state of previously created reintroduction population groups of plants are monitored annually according to seasonal phases of plants development.

An important aspect of activities aimed at biological diversity conservation, both *in situ* and *ex situ*, is monitoring of rare plants populations, carried out in various ways.

The monitoring of rare plants reintroduced into natural ecosystems we mentioned earlier is an example of the "ground-based" research that we conduct in the traditional form. At the same time, thanks to collaboration with colleagues – specialists in the field of geoinformatics, the Botanical Garden is implementing the practice of supporting ground monitoring using Earth Remote Sensing (ERS) methods (working with satellite images, surveying using unmanned aerial vehicles (UAVs). At the same time, reintroduction sites and collection areas funds of the Botanical Garden become new reference (etalon) plots, gives the information for training programs development that increase the efficiency of recognition of regional remote sensing materials. Thus, we first tested remote monitoring using UAVs at reintroduction sites in August 2020 in addition to ground-based surveys of rare plants. Special markers were placed near each specimen of the *Paeonia tenuifolia* L. plant, which facilitated the identification of plants in the photographs at the end of their growing season. In the spring of 2021, a drone photographs were taken for Botanical Garden (the dendrarium and the area with the population group of *P. tenuifolia* L. at the exposition of the steppe site). In 2022, the state of the population groups of *P. tenuifolia* L. reintroduced into nature was again monitored, in combination with ground surveys and UAV surveys. Our mutual work with remote sensing materials continued in 2023 both for population groups of plants in the Botanical Garden and in natural biotopes, including reintroduction sites. We continue to develop targeted information support for the integration of monitoring data, including within the framework of the RSF grant.

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