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Review

BIOBANKS AS A WAY TO CONSERVE BIODIVERSITY IN THE CONTEXT OF THE CONTINUING DECLINE IN THE SPECIES DIVERSITY OF WILD FLORA AND FAUNA

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ABSTRACT

To date, human actions have significantly changed 75% of the Earth's surface. This has resulted in an unprecedented increase in the rate of biodiversity loss in human history. According to the International Union for Conservation of Nature and Natural Resources, over the past 500 years, as a result of direct or indirect influence of the anthropogenic factor, 774 animal species and 123 plant species have become extinct. To prevent further loss of biodiversity, in the context of the ongoing «crisis of biodiversity», all over the world, including Kazakhstan, there is a need for reliable conservation of the available genetic resources of plants and animals, primarily rare and endangered species. In this regard, specialized biobanks of organized collections of living biomaterials are successfully used worldwide for the conservation and restoration of populations of rare and endangered species of flora and fauna. The article presents information about some of the largest biobanks and their importance in solving this global problem. The experience of scientific centers of Kazakhstan in the field of biobanking of biomaterials of wild flora and fauna, including rare and endangered species, is given, and the results of the National Center for Biotechnology in this area are summarized.

Keywords: biodiversity, biodiversity decline, biodiversity conservation, flora, fauna, biobank, biobanking.

INTRODUCTION

Biodiversity, despite its greatness, is at the same time a very fragile structure. Since the appearance of the first living creature on Earth, at least 3.7 billion years ago [1], the biodiversity of living organisms has not ceased to change due to natural evolutionary processes. However, man, as an inseparable part of all life on Earth, has a significant impact on biodiversity. Over the past 50 years, the world's population has doubled, the global economy has quadrupled, and world trade has increased tenfold [2]. These circumstances have led to a concomitant increase in human demand for natural resources, the consumption of which has a serious impact on the environment, which is reflected in climate change and biodiversity decline [3,4].

To date, human actions have significantly changed 75% of the Earth's surface. This has resulted in an unprecedented increase in the rate of biodiversity loss in human history [2]. The scientific and popular media are already warning us that we are facing a «biodiversity crisis» [5] and heading towards the sixth great extinction [6,7].

The conservation of biodiversity of wild flora and fauna is one of the most important tasks facing humanity, especially in recent years, due to the increasing anthropogenic pressure on the environment. The most fragile component of biodiversity, and the most sensitive integrated indicator of its unfavorable changes, is rare and endangered species of flora and fauna [8]. Thanks to these species, we can judge the quality of the environment. The disappearance and extinction of any species has serious consequences for the natural balance of ecosystems. At the same time, each individual species, in addition to its role in the ecosystem, is also a source of valuable genes and resources that are already being used or may be in demand in the future, as potential sources of medicines, food, etc.

According to the International Union for Conservation of Nature and Natural Resources (IUCN), over the past 500 years, as a result of direct or indirect influence of the anthropogenic factor, 774 animal species and 123 plant species have become extinct [9]. According to some scientists, over the past 250 years, about 571 plant species have died out, and, likely, this figure is significantly underestimated [10]. In the last 50 years alone, from 30 to 50% of all mangrove forests have died or been destroyed [11]. In general, plant biomass has decreased by approximately 50% compared to the period before the appearance of humans [12], while about 40% of all plant species growing on Earth are threatened with extinction [13]. The disappearance of plant diversity has serious consequences for the well-being of humanity and our planet [14]. Two out of five plant species are estimated to be threatened with extinction [15]. The main threats to plants in situ as assessed by the IUCN for the Red List of Threatened Species are as follows: agriculture and aquaculture (32.8%), use of biological resources (21.1%), change in natural systems (10.8%), residential and commercial development (10.5%), invasive species, genes and diseases (6.5%), pollution (5.4%) and climate change (4.1%) [16]. For example, in Chile, about 46% of flora species are in a critical state or under the threat of extinction [17]. And in Mexico, one of the world's richest countries in terms of flora, there are 249 species of endangered trees alone [18]. Today, more than 142,577 species of plants and animals are included in the IUCN Red List, of which more than 40,000 are endangered [9].

Animal populations are rapidly declining. Climate change and global food demand could lead to the loss of up to 23% of all natural animal habitats by the end of this century [19]. According to forecasts, if the current rate of biodiversity decline continues, up to 600 species of mammals may disappear from the face of the Earth by 2100. According to some scientists, signs of global extinction of biodiversity are already observed in Australia and the Caribbean [20]. The Food and Agriculture Organization (FAO) estimates that almost a third of the world's fish stocks are overfished, and a third of freshwater fish species assessed are considered endangered [21]. Many species of vertebrates from the classes of amphibians and reptiles are threatened with extinction as a result of habitat loss and increased anthropogenic impact on the environment. More specifically, 32% of amphibian species and 20% of reptile species are endangered [22]. During the current biodiversity extinction crisis, it is estimated that 200 amphibian species have already become extinct [23], and about 950 species need some form of captivity to prevent their extinction [24-26]. According to some estimates, one in five reptile species is endangered, but for some groups, such as turtles and crocodiles, the threat of extinction can be as high as 50% [27,28]. Insect populations are rapidly declining due to the loss of natural habitats, the intensification of agriculture with the widespread use of pesticides, global warming, and displacement by invasive alien species [29]. Recent studies show a significant decline in the entomofauna, both in terms of abundance and extinction of species in temperate and tropical regions and even in the Arctic [30-35].

Based on the foregoing, it is not difficult to conclude that the problem of preserving the biodiversity of flora and fauna remains extremely relevant, the solution of which depends on the well-being of life on Earth.

Today, the creation, development and use of the opportunities of wildlife biobanks is one of the most effective measures along with other conservation measures, such as: creation of specially protected natural territories (SPNT); improvement of legislation to ensure the protection of the environment and biodiversity; combating invasive alien species that pose a threat to the biodiversity of ecosystems and other measures.

For more than 30 years, the scientific community around the world has been successfully using the possibilities of wildlife biobanks to preserve and restore populations of rare and endangered species of flora and fauna. Examples of successful use of the possibilities of plant biobanks can be: the experience of Finnish scientists in the conservation and reintroduction into natural conditions of the plant population once saved from destruction – *Rubus humulifolius* [36]; reintroduction in China of endangered trees of the species *Bretschneidera sinensis* [37]; successful implementation of the «Saving threatened forests of Hispaniola» project in the Dominican Republic to save endangered forests in Hispaniola, as a result of which seeds of at least 100 tree species were saved and 25 tree species propagated for reforestation [37,38]; the experience of the Millennium Seed Bank Partnership (MSBP) in implementing a pilot project under the revolutionary Great Green Wall Initiative, which resulted in the planting of more than 1 million seedlings of 55 woody and herbaceous species of wild plants in dry regions of the Sahel in Africa [37,39].

Through the genetic resources of biobanks (cryobanks) of wild animals, populations of rare and endangered animal species are successfully preserved and restored, in particular: the population of *Elephas maximus* is recovering [40]; healthy offspring were obtained from an endangered subspecies of equids – the Persian onager (*Equus hemionus onager*) [41]; the well-known giant panda (*Ailuropoda melanoleuca*), in China mainly reproduces using artificial insemination, using sperm samples obtained from cryobanks [42]; the black-footed ferret, once considered an endangered species in North America, has also been restored through a combination of natural mating and artificial insemination, including semen frozen and stored for two decades [43,44]; a litter of cheetah cubs was obtained at the North American Zoo using samples of frozen sperm from a wild-caught male cheetah in Africa [45].

Summarizing the above information, we can come to the obvious conclusion that the problem of reducing the biodiversity of flora and fauna will remain an extremely urgent problem in the near future. This will be facilitated not only by the growth of the human population and its ever-growing need for natural resources, but also by the problem of global warming. Therefore, the collection and conservation of biomaterials of wild flora and fauna, primarily rare and endangered species, is of extremely high importance throughout the world. In this regard, the role of biobanks and their capabilities can hardly be overestimated. This can be proved by examples of the excellent results achieved by scientists in the conservation and restoration of populations of some rare and endangered species of plants and animals.

Relevance. The previous examples support the argument that wildlife biobanks are one of the effective tools in the field of conservation and restoration of plant and animal populations, including rare and endangered species. Therefore, the creation of new and development of existing biobanks, including in Kazakhstan, remains an urgent task today. At the same time, we consider it necessary to note that biobanks are not a substitute for existing environmental protection measures. Biobanks are one of the progressive scientific tools through which humanity is given the opportunity to solve a global environmental problem - to stop and reverse the process of degradation of the biodiversity of flora and fauna on Earth.

Materials and methods. The literature review of scientific papers was carried out using the resources of the following search engines: Web of Science, Scopus, PubMed, Wiley Online Library, Google Academy, eLibrary.ru. The search for the necessary literature was carried out by keywords. To solve the purpose and objectives of the article, we used literature data containing questions related to biobanks and biobanking of biomaterials of plants and animals, including rare and endangered species.

Purpose. To analyze the available literature data on the world biobanks of flora and fauna, including those of Kazakhstan, and to summarize the results of the work of the National Center for Biotechnology in the field of biobanking of biomaterials of local flora and fauna, including rare and endangered species.

Objectives. The following objectives were set to achieve the purpose of the work:

– to generalize the concept of the term «biobank»;

– give examples of some of the largest biobanks of wild flora and fauna, including those in the Commonwealth of Independent States (CIS);

– give examples of some scientific centers of Kazakhstan that carry out work, including in the field of biobanking of biomaterials of wild flora and fauna;

– to summarize the results of the work of the National Center for Biotechnology in the field of biobanking of biomaterials of wild flora and fauna of Kazakhstan, including rare and endangered species.

Main part

The concept of the term «biobank» and the role of biobanks in society

The term «biobank» (biological bank) has many definitions [46-48]. However, both in domestic and foreign legislation [49-51] there is still no single interpretation of it.

According to the legislation of the Republic of Kazakhstan, the term biobank is «a specialized repository of biological materials for scientific and biomedical purposes (including samples of cells, tissues, deoxyribonucleic, ribonucleic acids of the genetic material of humans and (or) animals and (or) plants, and other biological and genetically modified substances and organisms)» [52].

By the international standard ISO 20387:2018 Biotechnology – Biobanking – General requirements for biobanking, the term «biobank» means «a legal entity or part of a legal entity that performs biobanking». In turn, the term «biobanking» means the «process of acquisition and storing, together with some or all of the activities related to collection, preparation, preservation, testing, analyzing and distributing defined biological material as well as related information and data» [53].

In this paper, the term «biobank» means a specialized organization or subdivision in an organization engaged in the collection, storage, study, and provision for the scientific use of biological materials of plants and (or) animals and related data, including germplasm banks (seed banks, genebanks), cryobanks, *in vitro* cell line banks, DNA banks (Figure 1).

Today, there are quite a lot of biobanks in the world. Most of them are located at large medical and scientific centers [54,55]. For example, in Italy, most biobanks and biological resource centers are located in structures or institutions that are part of the National Health Service or associated with it [56].

Mostly, biobanks have a medical focus, specializing in the collection, storage, and provision of human biological material (blood, plasma, DNA, RNA, tissue materials, etc.) for scientific and clinical use. This is reflected in the number of sci-

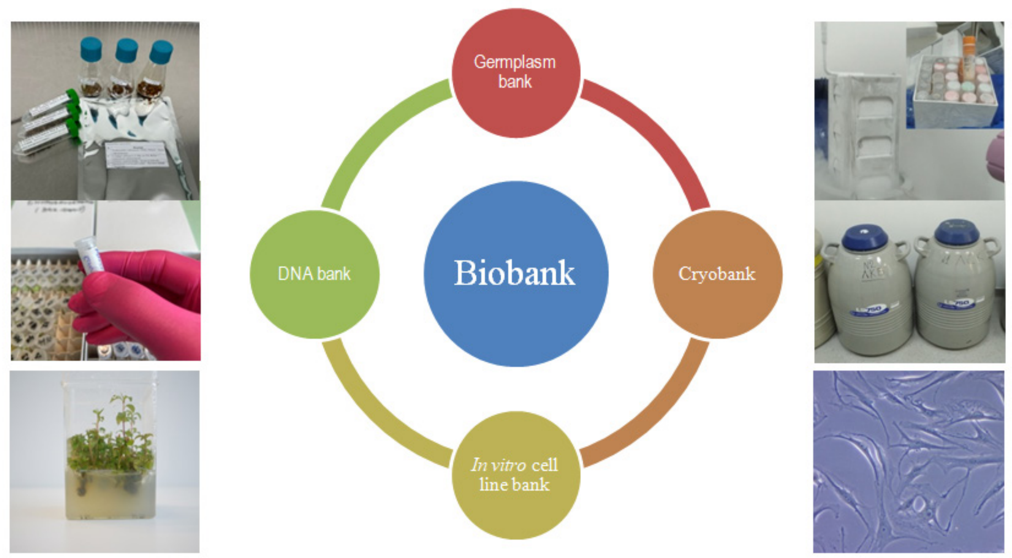

Figure 1 – Types of biobanks

Table 1 – Number of publications in some major databases of peer-reviewed scientific literature and the Google Academy search engine containing the term «biobank»

Database	Period	Number of publications				
		Total	Of these, in the direction of «Medicine»	% of total	Of these, in the direction of «Environmental Studies», including «Plants» and «Animals»	% of total
Web of Science	1996-2023	25,389	20,136	79.3	463	1.8
Scopus	1985-2023	57,785	45,695	79.1	1995	3.5
PubMed	1945-2023	33,823	27,220	80.5	2848	8.4
Wiley Online Library	1995-2023	11,131	8510	76.5	117	1.1
Google Academy		259,000	169,000	65.3	81,300	31.4
Note: Information is current as of January 2023						

entific publications in medicine in which the term «biobank» occurs (Table 1).

As mentioned earlier, most biobanks in the world are focused on medicine. This can be noticed by examining the electronic directories of biobanks available on the Internet. In particular, the website of the Biobank Resource Center https://biobanking.org contains a list of 328 biobanks that are focused on the collection, storage and study of human biosamples. In this directory you can find information about the world's biobanks such as: *Alberta Cancer Research Biobank* (Canada), *Australian Breast Cancer Tissue Bank* (Australia), *Liverpool Research Eye Bank* (United Kingdom), *National Liver Disease Biobank* (India) and others [57]. The Global Biobank Directory, Tissue Banks and Biorepositories https://specimencentral.com contains information on 327 biobanks in the field of medicine, of which 171 biobanks are located in the United States [58].

At the same time, in addition to biobanks of human biomaterials, there are also wildlife biobanks in the world specializing in the collection, storage and distribution of plant and animal biomaterials. These genetic resources are essential for the study and maintenance of biodiversity. For example, the previously mentioned Global Biobank Directory, Tissue Banks and Biorepositories https://specimencentral.com also has a list of 22 biobanks specializing in the collection and storage of plant and (or) animal biomaterials, for example: *Israel Plant Gene Bank* (Israel), *Marbank – National Marine Biobank* (Norway) and others [58]. Figure 2 shows the distribution of biobanks of flora and (or) fauna in accordance with this directory.

Examples of some large foreign biobanks of flora

An effective way to conserve biodiversity species is to conserve species in *ex-situ* conditions, which means the conservation of components of biological diversity outside their natural habitats [59]. Through this strategy, it becomes possible to protect the components of biodiversity (populations, species, and genes) outside the environment in which they naturally grow. Plant *ex situ* conservation includes collections

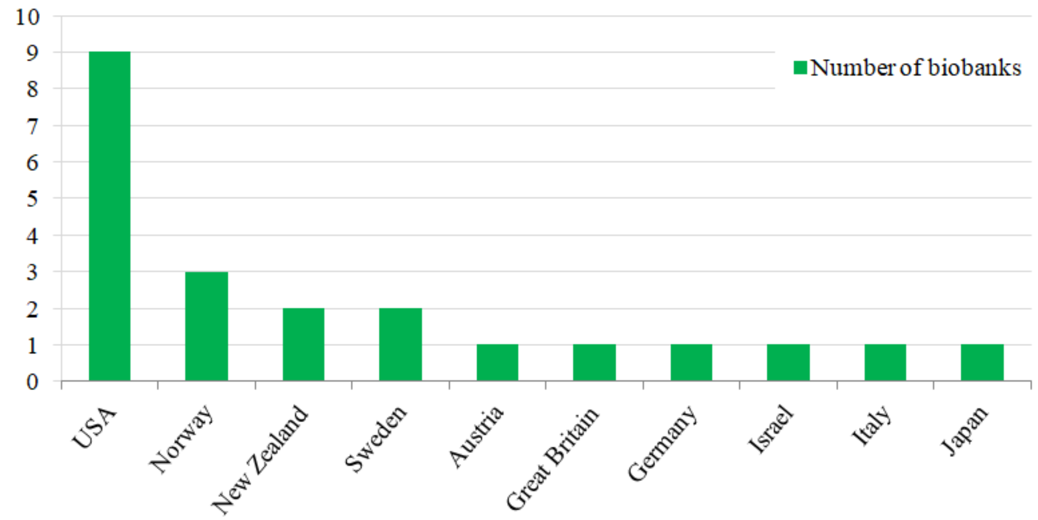

Figure 2 – Biobanks of plants and (or) animals by country according to the Internet resource Global Directory of Biobanks, Tissue Banks and Biorepositories

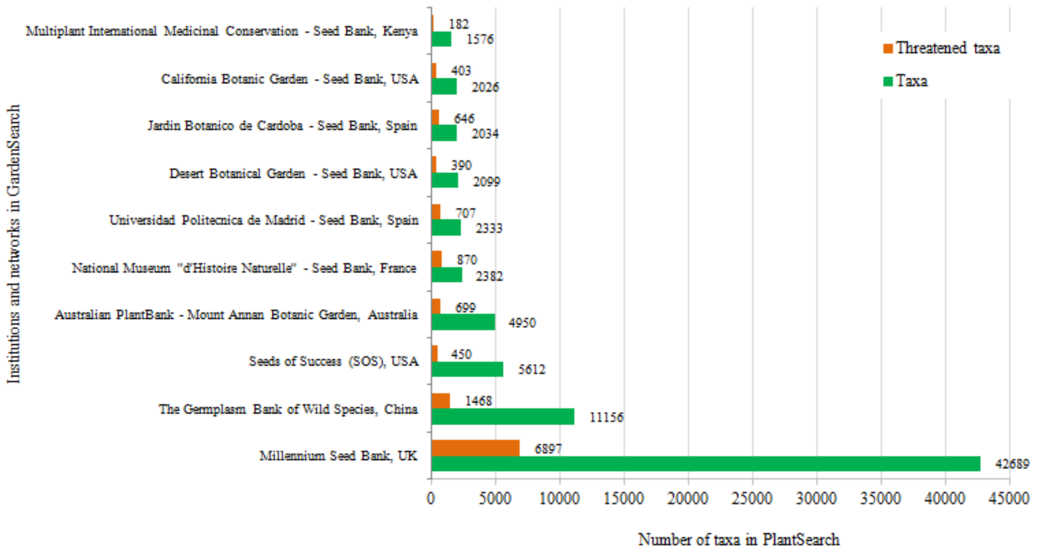

Figure 3 – Seed collection holdings of the largest ten wild plant seed banks by the number of taxa stored based on PlantSearch data. Threatened taxa includes species categorized as threatened (including global, regional and national assessments) from data in ThreatSearch (Adapted from Breman et al. 2021)

in botanical gardens and arboretums, *in vitro* cultivation, cryopreservation of seeds, embryos, or other tissues in liquid nitrogen, and storage of genetic material (for example, seeds, cuttings, bulbs, tubers, pollen) in germplasm banks [16,60,61].

Today, there are more than 3000 botanical gardens in the world located in 185 countries of the world, in which more than 105,000 species of wild plants are preserved as seeds and (or) living collections [37]. They contain collections of at least 30% of all known plant species on Earth, including 41% of endangered species [62,63]. These *ex situ* collections are conserved in various ways, but today the main method of *ex situ* conservation of plant genetic resources is the creation of a seed bank [64]. About 350 botanical gardens have their seed banks, and they contain the genetic resources of 57,000 wild plant species [62,63]. Although the function and name of the seed bank (genebank, germplasm bank, biobank) may vary, the general concept remains the same to use of controlled environments (drying and cooling) to preserve a wide variety of plant germplasm for immediate and future use [37].

In addition to over 350 wild plant seed banks established by botanical gardens, more than 1,750 genebanks are containing up to 7.4 million samples of plant genetic resources in the form of seeds, *in vitro*, DNA, and cryopreserved collections that are used for food production and agricultural management [37]. Plant accessions maintained in agricultural genebanks are of real or potential value as food crops and are important resources for developing more resilient (e.g., pest and disease or drought tolerant) and productive varieties that are critically needed to feed a growing world population [64-66].

To date, the largest seed banks of wild plants by several taxa include The Millennium Seed Bank (MSB) of the Royal Botanic Gardens, Kew, in the UK, Germplasm Bank of Wild Species (GBOWS) in China, Seeds of Success (SOS) program in the USA, Australian PlantBank at Mount Annan Botanic Garden in Australia, National Museum «d'Histoire Naturelle» – Seed Bank in France, Universidad Politécnica de Madrid – Seed Bank in Spain, Desert Botanical Garden – Seed Bank in the USA, Jardin Botanico de Cordoba – Seed Bank in Spain, California Botanic Garden – Seed Bank in the USA and Multiplant International Medical Conservation – Seed Bank in Kenya (Figure 3) [37].

The Germplasm Bank of Wild Species (GBOWS) located at the Kunming Institute of Botany (KIB) of the Chinese Academy of Sciences (hereinafter referred to as the Germplasm Bank) currently holds samples of more than 11,000 species of wild plants [37]. The Germplasm Bank consists of three repositories – a seed bank, an in vitro plant germplasm bank, and a plant DNA bank. At the same time, the subsidiaries of the Germplasm Bank are the microbial germplasm bank and the animal germplasm bank, which are located at Yunnan University and the Kunming Institute of Zoology CAS, respectively [67].

The Australian PlantBank of the Mount Annan Botanic Garden in Australia holds a collection of more than 12,000 seed samples from nearly 5,300 wild plant species, 437 of which are endangered [37,64].

The Desert Botanical Garden – Seed Bank in the US, located at the Ahearn Desert Conservation Laboratory, contains over 4000 seed specimens, some of the rarest plants in the world. The botanical garden's collection is primarily focused on the conservation of desert plants, especially those of the cactus and agave families. The Botanical Garden also works in partnership with the Smithsonian Institution and the North American Orchid Conservation Center (NAOCC) to conserve the seeds of numerous orchid species in the US Southwest, some of which are extremely rare [68,69].

The Seeds of Success (SOS) Program (the SOS Program) is a national seed collection program led by the Bureau of Land Management in the United States. The SOS Program is the most comprehensive repository of native seeds in the United States, supporting the restoration, management, and research of native plants. The SOS Program was established in 2000, and since then the seeds of more than 24,400 native plant populations representing about 5,600 taxa have been collected under this program in 43 US states. These collections include species important to wildlife, pollinators, and indigenous peoples, with over 10,000 collections donated for restoration and research use. The SOS Program enables scientists to understand the changes taking place in natural populations and represents the most important repository of native plant genetic resources for conservation and future use [70].

The most prominent examples of seed banks are the Millennium Seed Bank Partnership in the UK, which conserves wild plant seeds, and the Svalbard Global Seed Vault in Norway, which serves as a backup repository for crop seed collections from around the world [64].

Millennium Seed Bank of Royal Botanic Gardens Kew (hereinafter – MSB Seed Bank) was founded in 2000 as a result of more than three decades of research into seed biology and conservation. Today, the MSB Seed Bank collection includes more than 97,000 individual seed collections with 997,000 plant accessions representing more than 40,000 species belonging to more than 6,100 genera and 350 families. In total, the MSB Seed Bank holds the genetic material of more than 10% of all known plant species on Earth.

The mission of the MSB Seed Bank is to conserve plant biodiversity and ensure its sustainable use through a global partnership. To this end, the Millennium Seed Bank Partnership (MSBP), made up of seed banks affiliated with botanical gardens, agricultural, forestry, and research institutions, and government organizations around the world are working together to conserve native flora. To date, 97 countries and more than 250 organizations around the world are participating in the project.

The advantage of the MSB Seed Bank in the long-term conservation of wild plant diversity is the ability to store seed samples in a relatively small space (about 40,000 species are preserved in a 300 sqm area), at a relatively low cost compared to other *ex situ* conservation options (for example, *in vitro* collections, field genebanks, etc.). At the same time, the premises in the MSB Seed Bank are designed for 500 years, and the seed samples stored there must remain viable for decades to centuries. The presence of well-documented collections provides great opportunities to use this valuable resource now and use it in the future [37].

In the issue of plant diversity conservation, it is extremely important to pay attention to the provision of backup storage facilities for storing duplicate samples in case of emergencies, man-made or global disasters (earthquakes, fires, floods, etc.), as a result of which valuable samples of biomaterials, patiently accumulated and carefully preserved for years, can suddenly disappear from the face of the Earth. A good example is the Svalbard Global Seed Vault (SGSV) (hereinafter – Vault), which is a backup Vault for over 1 million crop samples from around the world.

The Vault is located on the island of Svalbard (Norway) in the middle of the Arctic Ocean. It was built by Norway in 2008 to prevent the destruction of seed samples of the main crops, as a result of possible global catastrophes, such as an asteroid strike, nuclear war, or global warming. Therefore, some call it the «Doomsday Vault» [71,72]. The Vault serves as a backup store for over 1700 crop genebanks located around the world. If any genebank is deprived of its seed collections in the event of a natural disaster or human factor, then it has the right to request from the Vault for a return transfer of duplicates of its seeds, through which it can safely restore its collections and continue breeding work [73,74]. The Vault is built in such a way that it can store up to 4.5 million seed samples in three separate rooms (caverns) dug into the mountain and located at the end of a 100-meter tunnel. If we take into account the fact that each plant sample transferred for storage contains an average of 500 seeds, then up to 2.5 billion seeds can be stored in the Vault at the same time [75].

Since the opening of the Vault, the number of seed samples deposited in it has exceeded 1.1 million [76]. Most of the samples, about two-thirds, are deposited by major international agricultural research centers, four of which have deposited more than 100,000 samples each, in particular: International Maize and Wheat Improvement Center (CIMMYT) in Mexico, International Rice Research Institute (IRRI) in the Philippines, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India and The International Center for Agriculture Research in the Dry Areas (ICARDA).

Table 2 – Examples of wild animal species biobanks worldwide

Institution/ Consortium	Country	Started	Sample number and type	References/Access
Smithsonian Institution	USA	1970	>1,000,000 DNA samples, cell lines and germplasm samples from >18,000 species	Smithsonian Institution. Available at: https://www.si.edu/ (Access in January 2023) (Comizzoli & Wildt, 2017)
Frozen Zoo ® San Diego Zoo Global Wildlife Conservancy	USA	1976	Over 10,000 living cell cultures, oocytes, sperm, and embryos representing nearly 1,000 taxa	Frozen Zoo ® San Diego Zoo Wildlife Alliance. Available at: https://science.sandiegozoo.org/ (Access in January 2023)
Kunming Wild Animal Cell Bank	China	1986	1455 cell lines from 298 animal species (4 insects, 24 fishes, 17 amphibians and reptiles, 25 birds, 228 mammals). About 1200 pieces of tissues from over 200 animal species, 45 sets animal chromosome-specific probes	Kunming Wild Animal Cell Bank. Available at: http://english.kiz.cas.cn/ gre/skl_Facility/ (Access in January 2023)
The Frozen Ark Consortium	International consortium based in United Kingdom	1996	48,000 samples from >5500 species	The Frozen Ark Consortium. Available at: https://www.frozenark. org/impact-and-outcomes (Access in January 2023)
American Museum of Natural History	USA	2001	>28,000 tissue and DNA samples	American Museum of Natural History. Available at: https://www.amnh.org/. (Access in January 2023) (Comizzoli & Wildt, 2017)
Conservation Genome Resource Bank for Korean Wildlife	Korea	2002	13,475 tissue and DNA samples from 407 species	Conservation Genome Resource Bank for Korean Wildlife. Available at: http://www.cgrb.org/. (Access in January 2023) (Comizzoli & Wildt, 2017)
Biodiversity Biobanks South Africa	Consortium based in South Africa	2003	>80,000 germplasm samples, cell lines, DNA samples from 500 species	Biodiversity Biobanks South Africa. Available at: https://bbsa.org.za/. (Access in January 2023) (Comizzoli & Wildt, 2017)

At the same time, the largest depositors of the Vault among national biobanks are such countries as the USA, Germany, Canada, Australia, the Netherlands, South Korea, and Switzerland. The Vault contains samples of about 5000 plant species. Crops such as rice and wheat are represented by over 150,000 seed samples each. In addition, 15 major kinds of cereal, vegetables, and fodder crops are represented by more than 10,000 seed samples [75].

The Vault is located in a place favorable for the long-term storage of seeds for several reasons:

– Located in the area of permafrost, where the average temperature ranges from -3ºC to -4ºC. Through this, the seed material is protected from damage, even if the refrigeration equipment that maintains a low temperature on the premises -18ºC fails;

– Seed storage facilities are located inside the mountain, at a depth of 150 meters above the surface, while well above sea level, which protects the seeds from flooding even in the worst-case scenario of sea level rise;

– The storage area is geologically stable, and the level of humidity in it is extremely low, which favorably affects the safety of seed material;

– Located in the world's northernmost settlement of Longyearbyen (Norway), with a permanent population of more than a thousand people, and where the world's northernmost airport with regular flights – Svalbard Airport is located. Through the presence of the airport, it becomes possible to deliver seeds to the Vault from any corner of the world.

Seed samples are stored in custom-made three-layer foil bags, which are sealed in boxes stored on the shelves of the Vault. As mentioned earlier, the reliable preservation of seeds in the Vault is ensured by the operation of special refrigeration units that maintain a constant temperature of -18ºC in the seed storage rooms. Due to the combination of low temperature and limited oxygen access, low metabolic activity is ensured and seed viability is maintained for a long period [76].

The storage of seed collections of crops, including their wild relatives, and taxa of wild plants genetically related to crops, is an important component of ensuring global food security. Such seed banks protect the genetic resources of crops from degradation and extinction and provide breeders with the necessary material [77].

Along with biobanks that preserve and distribute plant genetic resources, there are also specialized biobanks in the world for storing biomaterials of animal origin. In biobanks of wild animals, along with germ cells, tissues, cell lines, blood products, and DNA are also stored, which are of great importance for the study and maintenance of biodiversity [78]. Examples of wild animal species biobanks worldwide are presented in Table 2.

Collections of biomaterials carefully preserved in such biobanks find a wide variety of applications in science [79,80], medicine [81-83], breeding [84,85], and biodiversity conservation, by creating and maintaining viable cell cultures of various animal species, including rare and endangered species [22,26,86-92].

The Frozen Zoo cryobank at the Beckman Center for Conservation Research in the United States is the world's largest animal tissue cryobank. It was established in 1975, making it the oldest wild animal specimen cryobank in the world [93]. The cryobank collection includes more than 10,000 live samples of cell cultures, eggs, sperm, and embryos, representing about 1000 different taxa [86,94,95]. Germplasm stored in a cryobank is capable of producing offspring when used for *in vitro* maturation and fertilization of eggs, as well as during artificial insemination and embryo transfer. This irreplaceable collection of living cell lines, germ cells, and animal embryos is an invaluable resource for faunal biodiversity conservation, reproduction, evolutionary biology, and wildlife medicine. One of the partners of the Frozen Zoo cryobank is the Altyn-Emel State National Natural Park in Kazakhstan, which cooperates with the biobank in the field of reintroduction of Przewalski's horses [96,97].

CryoArks is a UK-based animal biobanking consortium for research and conservation. It is funded by the UK's Biotechnology and Biological Sciences Research Council (BBSRC), and coordinated by Cardiff University in partnership with the National History Museum of London, the National Museums of Scotland, the Royal Zoological Society of Scotland, The Frozen Ark, the University of Nottingham and the University of Edinburgh. This consortium aims to create the first unified British animal biobank, uniting several institutions and linking their collections through a common database [98,99].

The bio-cryobank of the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW) in Germany specializes in the storage of live specimens of endangered and other species of wild animals. The Department of Reproduction Biology holds samples of sperm, testicular tissue, eggs, ovarian tissue, and embryos from 105 different animal species, including samples from 20 felids species. In addition to these samples, the Department of Reproduction Management maintains semen samples from 45 species of wild animals and fibroblast cell lines cultured from 118 animal species. At the same time, 14 of these 118 animal species are on the verge of extinction, and three species have already become extinct in the wild. The value of Leibniz-IZW sperm banks has been repeatedly demonstrated by the use of elephant and rhinoceros sperm samples in artificial insemination (AI) and *in vitro* fertilization (IVF) programs [94,100,101]. Leibniz-IZW works closely with international organizations such as the Frozen Ark Consortium to improve specimen conservation and storage methods. Leibniz-IZW is also a member of the Association of German Cryobanks (Gemeinschaft Deutscher Kryobanken, GDK), whose goal is to globally unite all existing bio-cryobanks into a single network. This is the only way to ensure that valuable wild animal genetic and genomic samples are stored in a coordinated manner and to high standards [102].

The Israel-German Ark of Life (IGAL) is a joint project of the Zoological Center Tel Aviv-Ramat Gan Safari in Israel, which holds the largest collection of wild animals in the Middle East, and the Department of Reproduction Management of the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW) in Germany. The project was created in 2017 and is aimed at preserving tissues and cell cultures of animals and birds collected in the clinic of the zoological center.

The Israeli-German Ark of Life is a frozen zoo where animal DNA samples are stored in special test tubes in liquid nitrogen tanks at a constant temperature of -196ºC. Tissue samples are collected when animals are admitted for treatment at the Wildlife Clinic at the Zoological Center Tel Aviv-Ramat Gan, which annually treats about 4,000 animals and birds. Each animal DNA sample obtained is duplicated and sent to the Leibniz-IZW for safekeeping. According to the scientists of the center, DNA samples can be stored for up to 3000 years [103].

The Biorepository of the National Museum of Natural History (NMNH) in the United States began its work in 2011 and is considered the largest biorepository of natural history based in the museum. Big storage capacity exceeds 4.2 million standard 2 ml cryotubes with potential expansion to 5 million cryotubes. The biostorage contains samples of birds, amphibians, fish, mammals, reptiles, insects, and plants. NMNH researchers have been collecting material for projects in biodiversity, phylogenetics, population genetics, toxicology, and environmental monitoring since the early 1970s [104].

The Ambrose Monell Cryo-Collection (AMCC) in the United States is the centralized cryogenic repository for animal tissue and DNA samples from the American Museum of Natural History (AMNH). The collection was created in 2001 and includes tens of thousands of tissue and DNA samples from animals, including endangered ones [105].

The Biobank of Nature's SAFE (Saving Animals from Extinction) charity in the UK is one of the first specialized biobanks of animal tissue in Europe. The activity of the biobank is aimed at the long-term storage of living cells of those animal species that are most threatened with extinction. Preservation of the collection of animal tissue samples (somatic cells and gametes) in the biobank is carried out using modern technologies of cryogenic freezing of samples at a temperature of -196ºC. The biobank collection is used by scientists in the programs of reproduction and restoration of populations of rare and endangered species of animals [106,107].

The Ocean Genome Legacy Center (OGLC) Genebank at Northeastern University in the United States is engaged in marine research and the conservation of biological samples (DNA, tissues) of marine organisms. The genebank collection includes 29,323 DNA samples belonging to 1126 marine families of organisms [108,109]. Reliable preservation of valuable biological samples in the genebank is ensured by cryopreservation. At the same time, during the operation of the genebank, scientists of the center discovered 3814 new species of marine organisms [109].

The countries of the Commonwealth of Independent States (CIS) also have plant and (or) animal biobanks, but, as in the rest of the world, most of them conserve genetic resources of valuable crops and (or) animal breeds. Perhaps the most famous biobank, not only on the scale of the CIS countries but throughout the world, is the Collection of Genetic Resources of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (VIR Plant Genetic Resources Gene Bank) (hereinafter – VIR PGR Collection).

The VIR PGR Collection is a systematized and documented collection (genebank) of living specimens and herbarium references of the world diversity of cultivated plants and their wild relatives. The VIR PGR Collection on the genetic diversity of wheat is one of the five leading in the world, along with Mexico, the USA, Italy, and Australia; in terms of the number of barley samples is the fourth (after Great Britain, Canada, and the USA); oats, cotton, peanuts - the third; sunflower is the second; buckwheat, flax is the first in the world. The hemp collection is the only one in the world. For example, the wheat collection has more than 54,000 samples. It maintains the genetic resources of the genus *Triticum* L., including wild species, varieties, forms, and cultivated varieties from over 70 countries. The collection of oats, rye, and barley includes more than 36,000 seed samples, constantly maintained in a viable state: barley – 20,000 (24 species) [110], oats – 13,000 (21 species), rye – 3000 (4 species) [111]. The VIR PGR Collection contains separate collections of genetic resources: grain legumes, cereals, fodder, oilseeds, spinning, vegetables, melons, and fruit crops, as well as potato crops [112,113].

Similar biobanks of genetic resources (genebanks) of cultivated plants on a national scale exist or work is underway to create them in many CIS countries, in particular in: Azerbaijan [114,115], Armenia [116], Ukraine [117,118], Belarus [119,120], Kyrgyzstan [121], Moldova [122], Tajikistan [123], Uzbekistan [124], Turkmenistan [125], and Kazakhstan [126-130].

At the same time, with wildlife biobanks in the CIS countries, as well as throughout the world, the situation is different. Wildlife biobanks of a national scale are available in Russia and Belarus. Separate collections of biomaterials of wild plants and (or) animals are available in research institutions in Kazakhstan, Kyrgyzstan, and other countries.

In Russia, Moscow State University named after M.V. Lomonosov (MSU) since 2015, the «Noah's Ark» project has been implemented, which is dedicated to the study of biodiversity and is the largest Russian project in the field of life sciences. During the implementation of the project, several hundred new species of living beings were discovered, and a comprehensive genetic and biochemical certification of new and already stored specimens in the collections of MSU was carried out. As part of the project, work is underway to combine the maximum possible number of biological collections in a single information space, which is designed as an information system – the National Depository Bank of Live Systems «Noah's Ark» (https://depo.msu.ru/) [131]. As of 2022, the database of the depositary bank contains 1,255,740 plant samples (herbarium samples, DNA samples) [132] and 198,630 animal samples [133].

Based on the *A.V. Zhirmunsky National Scientific Center* of *Marine Biology Far Eastern Branch*, the *Russian Academy* of *Sciences* operates a unique Center for Collective Use (CCU) – the only one in Russia – the Resource Collection «Marine Biobank» (hereinafter – CCU RK «Marine Biobank»), which provides storage of biomaterial of marine organisms for subsequent biochemical, molecular biological and genetic research. CCU RK «Marine Biobank» was established in 2017 to ensure scientific research using existing collections and equipment by international protocols for the collection, cataloging, maintenance, and storage of biological samples of marine origin. At present, the biobank has concentrated its activities on biobanking and the cultivation of marine microorganisms [134,135].

In Belarus, based on the Institute of Genetics and Cytology of the National Academy of Sciences of Belarus, the Republican DNA Bank of Humans, Animals, Plants, and Microorganisms (hereinafter – Republican DNA Bank) operates. One of the priority activities of the Republican DNA Bank is the inventory and conservation of genetic resources of rare and endangered plant and animal species of the Republic of Belarus [119,136]. In 2016, the Republican DNA Bank received the status of a national treasure [137].

Since 2008, based on the Laboratory of Molecular Biology of the State Research and Production Association «Scientific and Practical Center of the National Academy of Sciences of Belarus for Bioresources» (SRPA «SPC NAS of Belarus for Bioresources»), work has been carried out to form a genetic bank (genebank) of wild fauna. The purpose of creating a genebank of wild fauna was the accumulation of original samples obtained both from the territory of Belarus and from the territory of other countries to perform diverse genetic studies. There are about 6000 samples of birds, mammals, fish, and aquatic invertebrates in the genebank of the SRPA «SPC NAS of Belarus for Bioresources» [138].

In Kyrgyzstan, based on the Laboratory of Plant Biotechnology of the Institute of Biotechnology of the National Academy of Sciences of the Kyrgyz Republic, there is the first and only wild flora seed bank in the country (Table 3).

Table 3 – State of the seed bank of wild flora of the Institute of Biotechnology of the National Academy of Sciences of the Kyrgyz Republic

	Total number of species	Number of widespread	Number of subendemics	Number of endemics	Number of species included in the Red Book	Number of species included in the list of rare and endangered
Grows in Kyrgyzstan	3870	1767	1669	356	78	375
Stored in a seed bank	1090	616	523	96	41	133

The main purpose of creating this seed bank is to preserve and study endemic and rare plant species in Kyrgyzstan. At the same time, seed samples of 1039 species of wild flora of Kyrgyzstan are stored in the Millennium Seed Bank, Kew Gardens, UK [139,140].

Biobanks of flora and fauna in Kazakhstan

Kazakhstan has a rich biodiversity of flora and fauna, numbering according to the latest data 5754 species of higher vascular plants [141,142] and 890 species of vertebrates, about 100,000 species of invertebrates, including at least 50,000 species of insects [142], today does not have a National Wildlife Biobank. This is despite the fact that the issue of the need for its creation has been repeatedly raised at the government level [143,144] and the country's scientific community [145,146]. At the same time, a high level of endemism is observed in the country, up to 14% of all flora species are endemic species, that is, they are not found anywhere else in the world in a wild state [142]. For example, a relic endemic species is the *Niedzwedzkia semiretschenskia* B. Fedtsch., whose age is almost 30 million years [141]. At the same time, rare and endangered species are 387 species of plants [142,147] and 128 species and subspecies of vertebrates, including 18 species and subspecies of fish and fish-like ones; 3 types of amphibians; 10 species of reptiles; 57 species of birds and 40 species and subspecies of mammals [148].

Despite the absence of the National Biobank of Wildlife in Kazakhstan, the work on biobanking of biomaterials of wild plants and animals, including rare and endangered species, is carried out by several research organizations in the country, in particular: the National Center for Biotechnology, Institute of Botany and Phytointroduction, Institute of Plant Biology and Biotechnology, Institute of Zoology, botanical gardens of the country and other organizations (Figure 4).

In the Laboratory of Seed Research and Plant Protection of the Institute of Botany and Phytointroduction (IBP), since 2013, the Bank of Seeds of Natural Flora of Kazakhstan (hereinafter, Seed Bank) has been functioning. To date, the Seed Bank has 4,438 accessions belonging to 970 plant species. The Seed Bank uses two types of seed storage for storage: long-term, in refrigerated chambers at a temperature of -18ºC, and short-term, at a temperature from 0 to +4ºC [148]. The data of each sample is entered into a special database. Every year the collection of the Seed Bank is replenished by 200-250 samples. In the collection, seed samples of rare and endangered plant species are of particular value. There are more than 60 species in the collection. The IBP Seed Bank has received international recognition, as a result of which it successfully cooperates with similar seed banks in China, Korea, and European countries [149].

The IBP includes the botanical gardens of Kazakhstan, in particular the Main Botanical Garden, the Zhezkazgan Botanical Garden, the Ili Botanical Garden, and the Astana Botanical Garden, where a rich gene pool of Kazakhstan and world flora is preserved *ex situ*. In the Main Botanical Garden (GBS), along with the preservation and replenishment of *ex situ* collection funds of living plants, work is also underway to replenish the collections of the herbarium (AA) and the IBP Seed Bank [149]. The IBF herbarium fund includes more than 258,000 specimens of vascular plants [150]. There is an exchange of seed samples, also known as delectus exchange, with many botanical gardens in the world. In 2021, GBS received 316 seed samples from 13 countries through the delectus exchange [151].

The Astana Botanical Garden (ABS) is currently working on the creation of a seed genebank [152]. According to the Herbarium Index (Index Herbariorum), the ABS herbarium

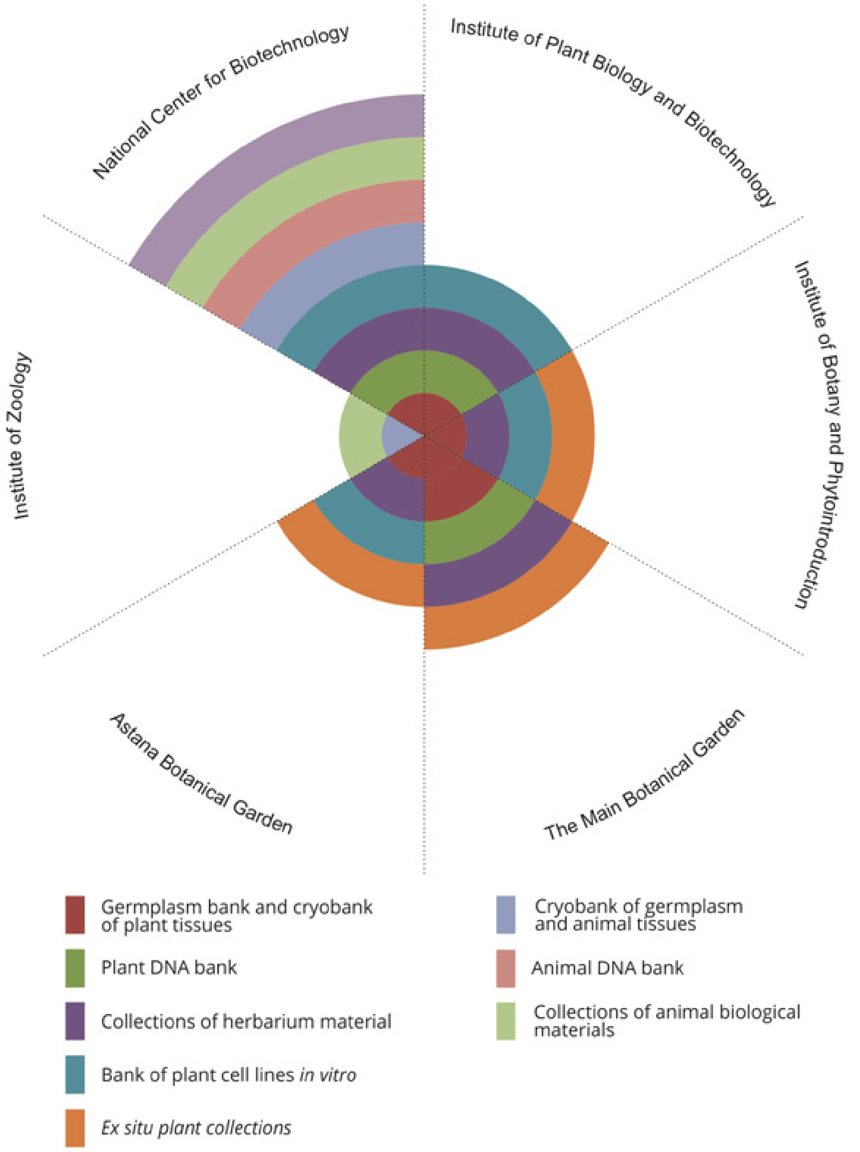

Figure 4 – Scientific organizations of Kazakhstan with collections of biomaterials of wild plants and animals

fund contains 18,500 accessions, including 8,060 accessions of seed plants and 2,500 accessions of algae [153].

One of the oldest botanical gardens in Kazakhstan is the Altai Botanical Garden which has collections of living plants, consisting of 3250 names of taxa of species and intraspecific levels, and an herbarium fund, including more than 70,000 herbarium sheets. Employees of the botanical garden pay great attention to the study of rare and endangered plants of East Kazakhstan and carry out work on their introduction. At the same time, the only collection of orchids from the genus Cypripedium in Kazakhstan is located in the Altai Botanical Garden [154].

The Laboratory of germplasm cryopreservation of the Institute of Plant Biology and Biotechnology (IPBB) created the first plant cryobank in Kazakhstan. The germplasm (seeds, apical meristems) of economically important, rare, and endangered plant species in a cryobank is stored in liquid nitrogen at two temperature regimes at -20°C and at an ultra-low temperature of -196°C [155-157]. Work continues on the cultivation of rare and endangered plant species in *in vitro* collections at a temperature of 24°C and an average temperature of +4°C (cold storage) [155,157,158]. For the first time in Kazakhstan, a collection of *in vitro* promising varieties and wild-growing forms of walnut has been created. A primary DNA bank has also been created, consisting of 121 samples. Biotechnological regulations for micropropagation have been developed and regulations for cryopreservation of germplasm of walnut and hazelnut varieties and wild forms have been optimized [158].

In the Laboratory of Molecular Genetics of the IPBB, a DNA bank of about 500 endemic, rare and endangered species of the wild flora of Kazakhstan has been created. The study of the genetic diversity of species of the wild flora of Kazakhstan is being carried out using DNA markers [160]. Genetic passports of plant species are being documented based on the use of DNA barcoding markers, ITS, and *matK* [161]. An information system (database Biodiversity of flora in Kazakhstan) has been created (https://kazflora.kz/), according to the genetic and botanical description of endemic, rare, endangered, and economically useful species of the flora of Kazakhstan. This information system was created for cataloging information, conservation, and rational use of plant genetic resources in Kazakhstan [159,162].

In addition to the above, IPBB, together with the Kazakh

Research Institute of Plant Protection and Quarantine named after Zhazken Zhyembayev, is working on the production and sale of elite planting material of *Turanga* and hybrids of *Populus* of Kazakhstan selection. The work is carried out based on the use of biotechnological methods of clonal micropropagation and agrotechnical methods of cultivation with an integrated system of protection against pests and diseases [163].

The Institute of Zoology, the only scientific zoological organization in Kazakhstan that coordinates and conducts fundamental and applied research on the study of the country's fauna, has collected a large collection of materials that are important for an in-depth study of the taxonomy and zoogeographic distribution of animals in Kazakhstan. The collection of mammals of the Institute of Zoology has more than 20,000 carcasses, skins, and skulls, and the collection of birds has more than 20,000 skins [164].

Based on the Biotechnology and Eco-Monitoring Research Park of Karaganda University named after academician E.A. Buketov, work is being carried out on the microclonal reproduction of rare, endangered, food, and medicinal plants. Methods for cryopreservation of plant and animal material are being developed [165-167].

Experience of the National Center for Biotechnology in the field of biobanking of biomaterials of wild flora and fauna of Kazakhstan, including rare and endangered species

National Center for Biotechnology (hereinafter – NCB) is the leading scientific institution of biological and biotechnological profile in Kazakhstan. The NCB was established by the Decree of the Government of the Republic of Kazakhstan dated August 02, 2005 No. 802 «On some measures for the development of biotechnology in the Republic of Kazakhstan» [168,169]. The Center has a reputation as a leader in conducting fundamental and applied scientific research in the field of biotechnology related to solving urgent problems of healthcare, agriculture, and ecology of the Republic of Kazakhstan.

One of the priorities of the NCB is to conduct scientific research in the field of biodiversity conservation in Kazakhstan using advanced methods in biotechnology. To this end, since 2014, the NCB has been actively conducting research aimed at preserving and restoring populations of rare and endangered plant species in the country. Below are some significant results in the field of biodiversity conservation obtained in the period 2014-2020:

– An *in vitro* collection of cells and tissues of rare and endangered plant species of Kazakhstan has been created: *Berberis iliensis*, *Berberis karkaralensis*, *Malus niedzwetzkyana* [170], *Malus sieversii*, endemic onion species (*Allium* sp.) [171], medicinal plant *Rhodiola rosea* [172] and *Cistanche deserticola* [173]. The deposited collection consists of 150 samples of *Berberis iliensis*, 200 samples of *Berberis karkaralensis*, 450 samples of *Malus niedzwetzkyana*, 300 samples of *Malus sieversii*, 247 cultures of *Allium altaicum* (13 populations), 26 cultures of *Allium ledebourianum* (2 populations), 44 cultures of *Allium microdictyon*, 31 cultures of

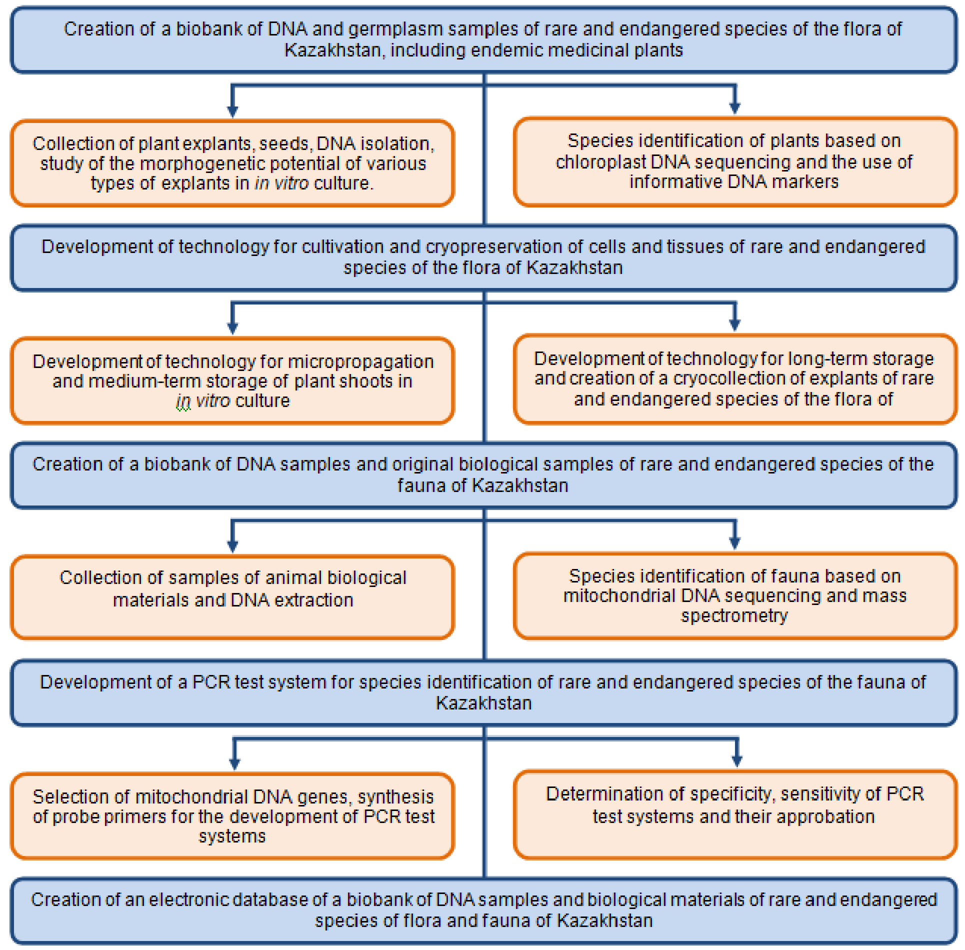

Figure 5 – Flowchart for the implementation of the scientific and technical program «Biobanking for rare and endangered species of flora and fauna for the conservation of biodiversity in Kazakhstan» for 2021-2022

Rhodiola rosea (2 populations) [174].

– *In vitro* technologies for micropropagation of rare and endangered plant species of Kazakhstan have been developed: *Berberis iliensis*, *Berberis karkaralensis*, *Malus niedzwetzkyana* [175], *Malus sieversii*, and a valuable medicinal plant – *Rhodiola rosea* [176].

– A genetic characterization of endemic onion species (*Allium* sp.) represented by populations growing in the territory of Kazakhstan Altai was carried out [177,178].

Since 2021, with the financial support of the Ministry of Education and Science of the Republic of Kazakhstan, the NCB has been implementing the targeted scientific and technical program OR11465422 «Biobanking for rare and endangered species of flora and fauna for the conservation of biodiversity in Kazakhstan» (hereinafter – Program) [179].

As a result of the implementation of the Program, for the first time in Kazakhstan, work was carried out to create a specialized biobank of DNA samples, germplasm (seeds, cultures of isolated meristems, cells, tissues) of rare and endangered plant species, including endemic medicinal plants, DNA samples and biomaterials of rare and endangered species of the fauna of Kazakhstan. Within the framework of the Program, the genetic characteristics of rare and endangered species of plants and animals were studied, their identification was carried out based on the use of modern molecular-genetic technologies and mass spectrometry methods (Figure 5).

During the implementation of the Program, the following significant results were obtained:

– Identified natural populations of rare and endangered species of wild flora of Kazakhstan, including valuable medicinal plants, such as: *Tulipa greigii*, *Tulipa kaufmanniana*, *Tulipa turkestanica*, *Tulipa alberti*, *Tulipa dubia*, *Tulipa tarda*, *Fraxinus sogdiana*, *Artemisia glabella*, *Alnus glutinosa*, *Iris lactea*, *Allium karataviense*, *Juniperus sabina*, *Rosa majalis* [180], *Sibiraea altaensis*, *Rhodiola quadrifolia*, *Erythronium sibiricum*, *Paeonia hybrida*, *Paeonia anomala*, *Betula kirghisorum*, *Pulsatilla patens*, *Adonis villosa*, *Stipa pennata*, *Juno coerulea*, *Juno orchioides*, *Euonymus koopmannii*.

– A germplasm bank of rare and endangered flora species of Kazakhstan, including endemic and valuable medicinal plants, has been created. Seeds were collected from 60 rare and endemic plant species growing in different regions of Kazakhstan (Figure 6).

In the NCB germplasm bank, seeds are stored for long-term storage at a temperature of -20°C in accordance with the standards of plant seed gene banks (Figure 7).

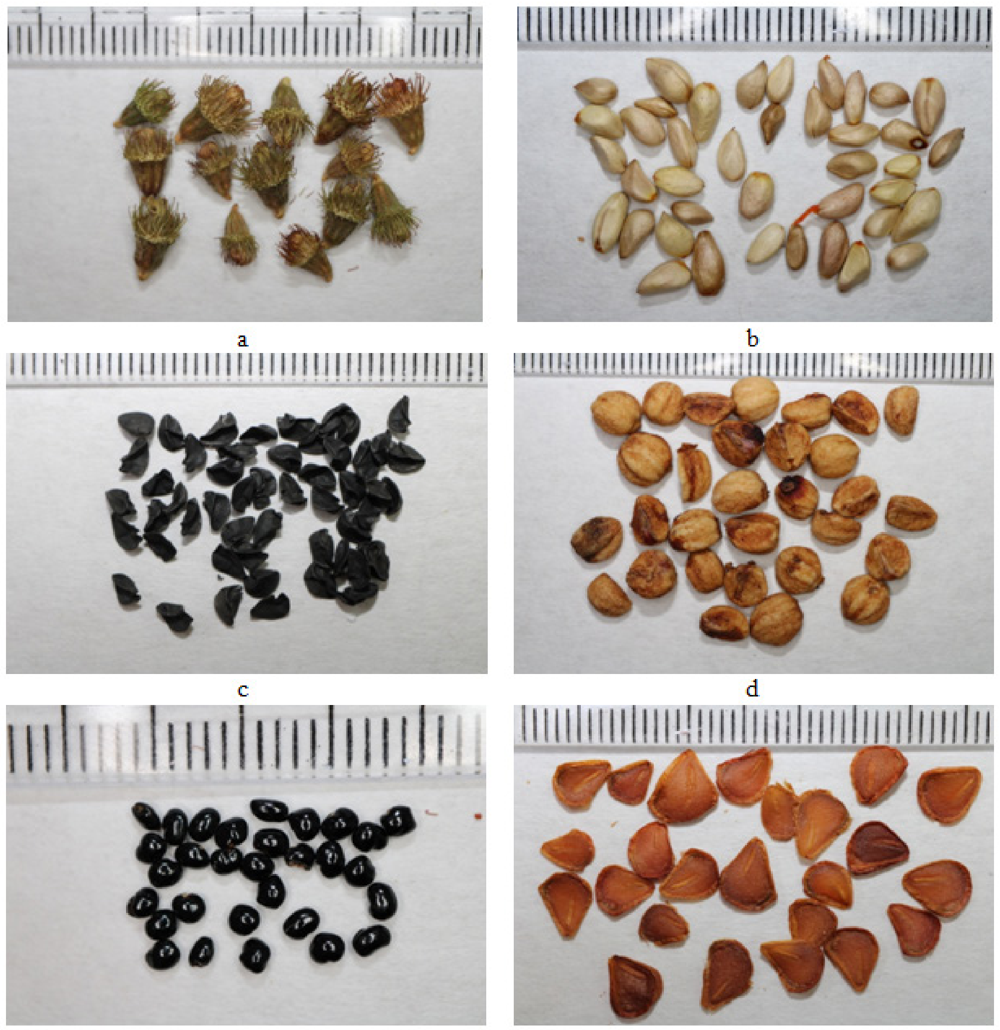

Figure 6 – Seed samples in the germplasm bank of the National Center for Biotechnology:
a) *Agrimonia asiatica* Juz.; b) *Rosa fedtschenkoana* Regel; c) *Allium altaicum* Pall.;
d) *Crataegus tianschanica* Pojark.; e) *Corydalis semenovii* Regel; f) *Tulipa alberti* Regel

Figure 7 – Germplasm bank of rare and endangered flora species of Kazakhstan: a) seed samples placed in a sealed foil bag with a desiccant inside; b) containers with seed samples in a refrigeration unit

Also, the technology of cryopreservation of seeds at low and ultra-low temperatures has been developed at the NCB: -20ºC, -70ºC, -196ºC. The conditions of cryopreservation, defrosting, sterilization, stratification, and germination for each type of seeds are selected. There is also an active collection of seeds (medium-term storage) under storage conditions of 5-10°C for research at the moment.

– Species identification of rare and endangered flora species of Kazakhstan was carried out based on chloroplast DNA sequencing and the use of informative DNA markers, including *Malus sieversii*, *Malus niedzwetzkyana*, *Tulipa alberti*, *Tulipa greigii*, *Tulipa kaufmanniana*, *Tulipa patens*, *Tulipa dubia*, *Allium karataviense*, *Allium karelinii*, *Allium nutans,* and other species [181]. At the same time, the complete sequence of the chloroplast DNA genome of *Malus niedzwetzkyana* was obtained. Nucleotide sequences are being deposited in the database of the National Center for Biotechnological Information (NCBI). DNA samples and original biological samples (plant fragments) were placed for long-term storage by cryopreservation (storage temperature -80ºC).

– The technologies for introducing into the culture *in vitro* and micropropagation of explants of 18 rare and endangered species of the flora of Kazakhstan have been optimized: *Alnus glutinosa*, *Iris lactea, Tulipa schrenkii*, *Tulipa greigii, Juniperus seravschanica*, *Allium ivasczenkoae*, *Rhaponticum carthamoides* [182,183], *Malus niedzwetzkyana* [184], *Paeonia anomala* and other species. These technologies consist of the stages of preliminary sterilization of explants, obtaining sterile seedlings, and induction of adventitious shoot formation for subsequent microcloning.

– Technologies for medium-term storage in culture *in vitro* of rare and endangered species of the flora of Kazakhstan, including endemic medicinal plants, have been developed. The conditions for medium-term storage and direct cultivation of 16 cultures were optimized to create an *in vitro* culture bank: *Fraxinus sogdiana*, *Juniperus seravschanica*, *Euonymus koopmannii*, *Sorbus persica*, *Crataegus ambigua*, *Rhaponticum carthamoides*, *Malus niedzwetzkyana* [185] and other species.

– Cryoprotective agents have been selected, modes of freezing and thawing of explants of 15 rare and endangered species of flora of Kazakhstan, including endemic medicinal plants, have been worked out. In particular, a technology for cryopreservation of cells of a suspension culture of a medicinal plant, *Cistanche deserticola*, has been developed. Cryopreservation technologies based on droplet vitrification, vitrification and encapsulation in sodium alginate have been developed for *Juniperus seravschanica*, *Euonymus koopmannii*, *Crataegus ambigua* and other species.

– A cryocollection of 220 explants (without thawing in liquid nitrogen) of rare and endangered flora species of Kazakhstan, including endemic medicinal plants, has been created: suspension culture cells of *Cistanche deserticola*, apexes of *Juniperus seravchanica*, *Euonymus koopmannii*, *Crataegus ambigua*, *Fraxinus sogdiana*, *Malus niedzwetzkyana*, *Viburnum opulus*, *Rosa fedtschenkoana*, *Alnus glutinosa*, *Rhaponticum carthamoides*, microbulbs of *Lilium martagon*, *Allium nutans*, *Allium obliquum*, *Allium ivasczenkoae*.

– A biobank of DNA and original biological samples of rare and endangered species of the fauna of Kazakhstan has been created. In total, more than 70 samples of biomaterials (blood, pieces of meat, fragments of bones, horns, skins, feathers, needles) of wild animals were collected, in particular: *Saiga tatarica*, *Equus przewalskii caballus*, *Cervus elaphus sibiricus*, *Cervus nippon*, *Ovis ammon*, *Haliaeetus albicilla*, *Aquila nipalensis*, *Anthropoides virgo*, *Pelecanus crispus* and other species. From the collected biomaterial, scientists of the NCB isolated DNA, which was stored for long-term storage by cryopreservation (storage temperature -80ºC). Original biological samples (blood leukocytes, pieces of meat from carcasses) from which DNA was isolated are also stored for long-term storage.

– Species identification of rare and endangered species of fauna of Kazakhstan based on mitochondrial DNA (mtDNA) sequencing was carried out. DNA sequencing (NGS – Next Generation Sequencing and Sanger sequencing) was carried out and the nucleotide sequences of mtDNA of the following animal species were studied: *Falco cherrug*, *Aquila chrysaetos*, *Aquila nipalensis*, *Bubo bubo* [186], *Capreolus pygargus* and *Hystrix indica*. The mtDNA nucleotide sequences have been deposited in the GenBank database.

The protein profile of collagen obtained from the bone remains of rare and endangered species of fauna was studied using mass spectrometry methods: *Saiga tatarica*, *Cervus elaphus*, *Capreolus pygargus*, *Ursus arctos isabellinus*, *Hystrix indica* and other animals.

– PCR test systems have been developed for species identification of rare and endangered fauna species of Kazakhstan by the Cytb gene: *Capreolus pygargus*, *Cervus elaphus*, *Saiga tatarica* and *Ovis ammon* [187,188].

– An electronic database of a biobank with open access for viewing has been created, containing passport data of DNA samples and biomaterials of rare and endangered species of flora and fauna. The database is available at https://kzgenbank.com [189].

As a result of the implementation of the Program, a biobank of DNA and germplasm samples (seeds, cultures of isolated meristems, cells and tissues) of rare and endangered plant species, including endemic medicinal plants, was created at the NCB. A biobank of DNA samples and biomaterials from rare and endangered species of the fauna of Kazakhstan has been created. The genetic characteristics of rare and endangered species of plants and animals have been studied and their identification based on the use of modern molecular-genetic technologies and mass spectrometry methods has been carried out.

CONCLUSION

For several decades, scientists around the world have been successfully using the possibilities of wildlife biobanks to conserve and restore populations of rare and endangered species of flora and fauna. A number of excellent results on the restoration of populations of some species of plants and animals that are on the verge of extinction are a clear confirmation of this. Today it is already obvious that the well-being of mankind directly depends on the state of the environment, including the biodiversity of flora and fauna. Therefore, the creation and development of wildlife biobanks around the world seems to be quite justified, including in Kazakhstan.

A wide range of works carried out by Kazakh scientists in the field of biobanking of biomaterials of wild flora and fauna inspire confidence that endangered species of plants and animals inhabiting the territory of the country will be preserved and successfully restored.

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REFERENCES

1. Pearce B.K.D., Tupper A.S., Pudritz R.E., Higgs P.G. Constraining the time interval for the origin of life on Earth // Astrobiology. - 2018. - Vol. 18, No. 3. - P. 343-364. DOI: https://doi.org/10.1089/ast.2017.1674.

2. **Diaz S., Settele J., Brondizio E., Ngo H.T., Gueze M., Agard J., Arneth A., Balvanera P., Brauman K., Butchart S., Chan K., Garibaldi L.A., Ichii K., Liu J., Subramanian S.M., Midgley G.F., Miloslavich P., Molnar Z., Obura D., Pfaff A., Polasky S., Purvis A., Razzaque J., Reyers B., Chowdhury R.R., Shin Y.J., Visseren-Hamakers I., Willis K., Zayas C.** *IPBES: Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; **IPBES secretariat, Bonn, Germany, 2019. ISBN: 978-3-947851-13-3.** Available at: https://ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf.

3. World Meteorological Organization. State of the Global Climate 2020 (WMO-No. 1264); WMO: Geneva, Switzerland, 2021. ISBN: 978-92-63-11264-4. Available at: https://library.wmo.int/doc_num.php?explnum_id=10618.

4. Portner H.O., Scholes R.J., Agard J., Archer E., Arneth A., Bai X., Barnes D., Burrows M., Chan L., Cheung W.L., Diamond S., Donatti C., Duarte C., Eisenhauer N., Foden W., Gasala M.A., Handa C., Hickler T., Hoegh-Guldberg O., Ichii K., Jacob U., Insarov G., Kiessling W., Leadley P., Leemans R., Levin L., Lim M., Maharaj S., Managi S., Marquet P.A., McElwee P., Midgley G., Oberdorff T., Obura D., Osman E., Pandit R., Pascual U., Pires A.P.F., Popp A., Reyes-Garcia V., Sankaran M., Settele J., Shin Y.J., Sintayehu D.W., Smith P., Steiner N., Strassburg B., Sukumar R., Trisos C., Val A.L., Wu J., Aldrian E., Parmesan C., Pichs-Madruga R., Roberts D.C., Rogers A.D., Diaz S., Fischer M., Hashimoto S., Lavorel S., Wu N., Ngo H.T. Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change; IPBES secretariat, Bonn, Germany, 2021. DOI: https://doi.org/10.5281/zenodo.4659158.

5. Watts J. Destruction of nature as dangerous as climate change, scientists warn // The Guardian. - 23 March, 2018. [Online] Available at: https://www.theguardian.com/environment/2018/mar/23/all.

6. Ceballos G., Ehrlich P.R., Dirzo R. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines // Proceedings of the National Academy of Sciences. - 2017. - Vol. 114, No. 30. - P. E6089-E6096. DOI: https://dx.doi.org/10.1073%2Fpnas.1704949114.

7. Roe D., Seddon N., Elliott J. Biodiversity loss is a development issue: a rapid review of evidence. 2019. IIED Issue Paper. IIED, London. Available at: https://pubs.iied.org/17636iied.

8. Sokhranenie i vosstanovlenie bioraznoobraziya (Conservation and restoration of biodiversity). Series of training manuals «Conservation of biodiversity». Authors: Flint V.V., Smirnova O.V., Zaugolnova L.B., Khanina L.G., Bobrovskij M.V., Toropova N.A., Melekhova O.P., Sorokin A.G. Moscow: Izdatelstvo Nauchnogo i uchebno-metodicheskogo tsentra. - 2002. - 286 pp. Available at: http://www.nature.air.ru/biodiversity/pdf/book2.pdf. [in Russian]

9. The IUCN Red list of threatened species. [Online] Available at: https://www.iucnredlist.org/statistics. Accessed: 11 May 2022.

10. Humphreys A.M., Govaerts R., Ficinski S.Z., Lughadhs E.N., Vorontsova M.S. Global dataset shows geography and life form predict modern plant extinction and rediscovery // Nature Ecology & Evolution. - 2019. - Vol. 3. - P. 1043-1047. DOI: https://doi.org/10.1038/s41559-019-0906-2.

11. Grooten M., Almond R.E.A. (Eds). Living planet report - 2018: Aiming higher, WWF, 2018. Available at: https://www.wwf.org.uk/sites/default/files/2018-10/LPR2018_Full%20Report.pdf.

12. Bar-On Y.M., Phillips R., Milo R. The biomass distribution on Earth // Proceedings of the National Academy of Sciences of the United States of America. - 2018. - Vol. 115, No. 25. - P. 6506-6511. DOI: https://doi.org/10.1073/pnas.1711842115.

13. Lughadha E.N., Bachman S.P., Leao T.C.C., Forest F., Halley J.M., Moat J., Acedo C., Bacon K.L., Brewer R.F.A., Gateble G., Goncalves S.C., Govaerts R., Hollingsworth P.M., Krisai-Greilhuber I., de Lirio E.J., Moore P.G.P., Negrao R., Onana J.M., Rajaovelona L.R., Razanajatovo H., Reich P.B., Richards S.L., Rivers M.C., Cooper A., Iganci J., Lewis G.P., Smidt E.C., Antonelli A., Mueller G.M., Walker B.E. Extinction risk and threats to plants and fungi // Plants, People, Planet. - 2020. - Vol. 2, No. 5. - P. 389-408. DOI: https://doi.org/10.1002/ppp3.10146.

14. Walters C., Pence V.C. The unique role of seed banking and cryobiotechnologies in plant conservation // Plants, People, Planet. - 2021. - Vol. 3, No. 1. Special Issue: A world of plants. - P. 83-91. DOI: https://doi.org/10.1002/ppp3.10121.

15. Antonelli A., Smith R.J., Fry C., Simmonds M.S.J., Kersey P.J., Pritchard H.W., Abbo M.S., Acedo C., Adams J., Ainsworth A.M., et al. State of the World's Plants and Fungi; Research Report; Royal Botanic Gardens (Kew); Sfumato Foundation: London, UK, 2020. Available at: https://www.bioversityinternational.org/e-library/publications/detail/state-of-the-worlds-plants-and-fungi-2020/.

16. Ebert A.W., Engels J.M.M. Plant biodiversity and genetic resources matter! // Plants. - 2020. - Vol. 9, No. 12. - Article number: 1706. DOI: https://doi.org/10.3390/plants9121706.

17. Panitrur-De la Fuente C., Ibanez S.T., Leon M.F., Martinez-Tilleria K., Sandoval A. Conservation of native plants in the seed base Bank of Chile // Conservation Science and Practice. - 2020. - Vol. 2, No. 11. - Article number: e292. DOI: https://doi.org/10.1111/csp2.292.

18. Tellez O., Mattana E., Diazgranados M., Kuhn N., Castillo-Lorenzo E., Lira R., Montes-Leyva L., Rodrigues I., Mateo Flores Ortiz C., Way M., Davila P., Ulian T. Native trees of Mexico: diversity, distribution, uses and conservation // PeerJ. - 2020. - Vol. 8. - Article number: e9898. DOI: https://doi.org/10.7717/peerj.9898.

19. Beyer R.M., Manica A. Historical and projected future range sizes of the world's mammals, birds, and amphibians // Nature Communications. - 2020. - Vol. 11, No. 1. - Article number: 5633. DOI: https://doi.org/10.1038/s41467-020-19455-9.

20. Andermann T., Faurby S., Turvey S.T., Antonelli A., Silvestro D. The past and future human impact on mammalian diversity // Science Advances. - 2020. - Vol. 6, No. 36. - P. 1-17. DOI: https://doi.org/10.1126/sciadv.abb2313.

21. The state of the World's biodiversity for food and agriculture. Food and Agriculture Organization of the United Nations, 2019. https://www.fao.org/3/CA3129EN/CA3129EN.pdf.

22. Strand J., Thomsen H., Jensen J.B., Marcussen C., Nicolajsen T.B., Skriver M.B., Sogaard I.M., Ezaz T., Purup S., Callesen H., Pertoldi C. Biobanking in amphibian and reptilian conservation and management: opportunities and challenges // Conservation Genetics Resources. - 2020. - Vol. 12. - P. 709-725. DOI: https://doi.org/10.1007/s12686-020-01142-y.

23. Alroy J. Current extinction rates of reptiles and amphibians // PNAS. - 2015. - Vol. 112, No. 42. - P. 13003-13008. DOI: https://doi.org/10.1073/pnas.1508681112.

24. Bishop P.J., Angulo A., Lewis J.P., Moore R.D., Rabb G.B., Garcia Moreno J.G. The amphibian extinction crisis – what will it take to put the action into the amphibian conservation action plan? // S.A.P.I.E.N.S. - 2012. - Vol. 5, No. 2. [Online] Available at: https://journals.openedition.org/sapiens/1406#entries.

25. Clulow J., Trudeau V., Kouba A. Amphibian declines in the twenty-first century: why we need assisted reproductive technologies. In «Reproductive Sciences in Animal Conservation» // Advances in Experimental Medicine and Biology. - 2014. - Vol. 753. - P. 275-316. DOI: https://doi.org/10.1007/978-1-4939-0820-2_12.

26. Clulow J., Clulow S. Cryopreservation and other assisted reproductive technologies for the conservation of threatened amphibians and reptiles: bringing the ARTs up to speed // Reproduction, Fertility and Development. - 2016. - Vol. 28, No. 8. - P. 1116-1132. DOI: https://doi.org/10.1071/rd15466.

27. Bohm M., Collen B., Baillie J.E.M., Bowles P., Chanson J., Cox N., Hammerson G., Hoffmann M., Livingstone S.R., Ram M., et al. The conservation status of the world's reptiles // Biological Conservation. - 2013. - Vol. 157. - P. 372-385. DOI: https://doi.org/10.1016/j.biocon.2012.07.015.

28. Grigg G., Kirshner D. Biology and evolution of crocodylians. CSIRO Publishing: Melbourne, 2015. ISBN 978-1-4863-0067-9. Available at: http://71.248.165.151/Books-Mags/Birds%20&%20Animals/Biology%20and%20Evolution%20of%20Crocodylians.pdf.

29. Jactel H., Imler J.-L., Lambrechts L., Failloux A.-B., Lebreton J.D., Maho Y.L., Duplessy J.-C., Cossart P., Grandcolas Ph. Insect decline: immediate action is needed // Comptes Rendus. Biologies. - 2020. - Vol. 343, No. 3. - P. 267-293. DOI: https://doi.org/10.5802/crbiol.37.

30. Wagner D.L. Insect declines in the Anthropocene // Annual Review of Entomology. - 2020. - Vol. 65. - P. 457-480. DOI: https://doi.org/10.1146/annurev-ento-011019-025151.

31. Hallmann C.A., Zeegers T., van Klink R., Vermeulen R., van Wielink P., Spijkers H., Jongejans E. Declining abundance of beetles, moths and caddisflies in the Netherlands // Insect Conservation and Diversity. - 2020. - Vol. 13, No. 2 - P. 127-139. DOI: https://doi.org/10.1111/icad.12377.

32. Seibold S., Gossner M.M., Simons N.K., Bluthgen N., Muller J., Ambarl D., Ammer Ch., Bauhus J., Fischer M., Habel J.C., Linsenmair K.E., Nauss T., Penone C., Prati D., Schall P., Schulze E.-D., Vogt J., Wollauer S., Weisser W.W. Arthropod decline in grasslands and forests is associated with landscape-level drivers // Nature. - 2019. - Vol. 574, No. 7780. - P. 671-674. DOI: https://doi.org/10.1038/s41586-019-1684-3.

33. Lister B.C., Garcia A. Climate-driven declines in arthropod abundance restructure a rainforest food web // Proceedings of the National Academy of Sciences. - 2018. - Vol. 115, No. 44. - P. E10397-E10406. DOI: https://doi.org/10.1073/pnas.1722477115.

34. Stepanian Ph.M., Entrekin S.A., Wainwright C.E., Kelly J. Declines in an abundant aquatic insect, the burrowing mayfly, across major North American waterways // Proceedings of the National Academy of Sciences. - 2020. - Vol. 117, No. 6. - P. 2987-2992. DOI: https://doi.org/10.1073/pnas.1913598117.

35. Powney G.D., Carvell C., Edwards M., Morris R.K.A., Roy H.E., Woodcock B.A., Isaac N.J.B. Widespread losses of pollinating insects in Britain // Nature Communications. - 2019. - Vol. 10. - Article number: 1018. DOI: https://doi.org/10.1038/s41467-019-08974-9.

36. Hyvarinen M.-T. *Rubus humulifolius* rescued by narrowest possible margin, conserved *ex situ*, and reintroduced in the wild // Journal of Nature Conservation. - 2020. - Vol. 55. - Article number: 125819. DOI: https://doi.org/10.1016/j.jnc.2020.125819.

37. Breman E., Ballesteros D., Castillo-Lorenzo E., Cockel Ch., Dickie J., Faruk A., O'Donnell K., Offord C.A., Pironon S., Sharrock S., Ulian T. Plant diversity conservation challenges and prospects - the perspective of botanic gardens and the Millennium Seed Bank // Plants. - 2021. - Vol. 10, No. 11. - Article number: 2371. DOI: https://doi.org/10.3390/plants10112371.

38. Mattana E., Manger K.R., Way M.J., Ulian T., Garcia R., Encarnacion W., Clase T., Peguero B., Jimenez F. A new seed bank for Hispaniola to support the conservation and sustainable use of the Caribbean native flora // Oryx. - 2017. - Vol. 51, No. 3. - P. 394-395. DOI: https://doi.org/10.1017/S0030605317000692.

39. Sacande M., Berrahmouni N. Community participation and ecological criteria for selecting species and restoring natural capital with native species in the Sahel // Restoration Ecology. - 2016. - Vol. 24, No. 4. - P. 479-488. DOI: https://doi.org/10.1111/rec.12337.

40. Thongtip N., Mahasawangkul S., Thitaram C., Pongsopavijitr P., Kornkaewrat K., Pinyopummin A., Angkawanish T., Jansittiwate S., Rungsri R., Boonprasert K., Wongkalasin W., Homkong P., Dejchaisri S., Wajjwalku W., Saikhun K. Successful artificial insemination in the Asian elephant (*Elephas maximus*) using chilled and frozen-thawed semen // Reproductive Biology and Endocrinology. - 2009. - Vol. 7, No. 75. - DOI: https://doi.org/10.1186%2F1477-7827-7-75.

41. Schook M.W., Wildt D.E., Weiss R.B., Wolfe B.A., Archibald K.E., Pukazhenthi B.S. Fundamental studies of the reproductive biology of endangered persian onager (*Equus hemionus onager*) result in first wild equid offspring from artificial insemination // Biology of Reproduction. - 2013. - Vol. 89, No. 2. - Article number: 41. DOI: https://doi.org/10.1095/biolreprod.113.110122.

42. Howard J.G., Huang Y., Wang P., et al. Role and efficiency of artificial insemination and genome resource banking: In: Wildt D.E., Zhang A., Zhang H., Janssen D.L., Ellis S. (eds). Giant pandas: biology, veterinary medicine and management. Cambridge University Press, New York, 2006. - P. 469-494. ISBN: 9780521832953.

43. Howard J.G., Wildt D.E. Approaches and efficacy of artificial insemination of felids and mustelids // Theriogenology. - 2009. - Vol. 71, No. 1 - P. 130-148. DOI: https://doi.org/10.1016/j.theriogenology.2008.09.046.

44. Comizzoli P. Biobanking efforts and new advances in male fertility preservation for rare and endangered species // Asian Journal of Andrology. - 2015. - Vol. 17, No. 4. - P. 640-645. DOI: https://doi.org/10.4103%2F1008-682X.153849.

45. Wildt D.E., Rall W.F., Crister J.K., Monfort S.L., Seal U.S. Genome resource banks: living collections for biodiversity conservation // Bioscience. - 1997. - Vol. 47. - P. 689-698. https://repository.si.edu/handle/10088/4433.

46. Hewitt R., Watson P. Defining biobank // Biopreservation and Biobanking. - 2013. - Vol. 11, No. 5. - P. 309-315. DOI: https://doi.org/10.1089/bio.2013.0042.

47. Loft S., Poulsen H.E. Cancer risk and oxidative DNA damage in man // Journal of Molecular Medicine. - 1996. - Vol. 74, No. 6. - P. 297-312. DOI: https://doi.org/10.1007/bf00207507.

48. Creation and governance of human genetic research databases, OECD, Paris, 2006. DOI: https://doi.org/10.1787/9789264028531-en.

49. Act on Biobanks No. 110/2000, Iceland. [Online] Available at: https://www.personuvernd.is/information-in-english/greinar/nr/439. Accessed: 5 May 2022.

50. Comitato Nazionale per la Biosicurezza e le Biotecnologie. Linee guida per la certificazione delle biobanche, Presidenza del Consiglio dei Ministri, 2006. [Online] Available at: https://cnbbsv.palazzochigi.it/media/1629/2006-19-aprile-biobanche_1.pdf. Accessed: 6 May 2022.

51. **The Royal Decree of 9 January 2018 on biobanks, published in the Belgian Official Gazette on 05.02.2018 in implementation of Article 22 of the Law of 19 December 2008 regarding the procurement and use of human substances destined for human medical applications or for scientific research purposes, enters into force on 01.11.2018.** [Online] Available at: https://www.famhp.be/en/news/new_royal_decree_on_biobanks. Accessed: 13 May 2022.

52. Order of the Acting Minister of Healthcare of the Republic of Kazakhstan dated December 24, 2020 no. ҚР ДСМ-328/2020 «On approval of the Rules for creation and activities of biobanks». Available at: https://adilet.zan.kz/rus/docs/V2000021927.

53. ISO 20387:2018 «Biotechnology – Biobanking – General requirements for biobanking». Available at: https://www.iso.org/ru/standard/67888.html. Accessed: 28 May 2022.

54. Sterckx S., Assche K.V. The new Belgian law on biobanks: some comments from an ethical perspective // Health Care Analysis. - 2011. - Vol. 19. - Article number: 247. DOI: https://doi.org/10.1007/s10728-011-0181-0.

55. Lalova T., Negrouk A., Dolle L., Bekaert S., Debucquoy A., Dereze J.-J., Valcke P., Kindt E.J., Huys I. An overview of Belgian legalization applicable to biobank research and its interplay with date protection rules // GDPR and Biobanking. Law, Governance and Technology Series. - 2021. - Vol. 43. - P. 187-213. DOI: https://doi.org/10.1007/978-3-030-49388-2_10.

56. Cannovo N., Cingolani M., Guarino R., Fedeli P. Regulation of biobanks in Italy // Frontiers in Pediatritics. - 2020. - Vol. 8. - Article number: 415. DOI: https://dx.doi.org/10.3389%2Ffped.2020.00415.

57. Biobank Locator. [Online] Available at: https://biobanking.org/locator. Accessed: 25 January 2023.

58. Global Biobank Directory, Tissue Banks and Biorepositories. [Online] Available at: https://specimencentral.com/biobank-directory. Accessed: 13 May 2022.

59. Declaration of the United Nations Conference on the Human Environment, Stockholm, 16 June 1972. [Online] Available at: https://legal.un.org/avl/ha/dunche/dunche.html.

60. Li D.Z., Pritchard H.W. The science and economics of *ex situ* plant conservation // Trends in Plant Science. - 2009. - Vol. 14, No. 11. - P. 614-621. DOI: https://doi.org/10.1016/j.tplants.2009.09.005.

61. Abeli T., Dalrymple S., Godefroid S., Mondoni A., Müller J.V., Rossi G., Orsenigo S. (2020). *Ex situ* collections and their potential for the restoration of extinct plants // Conservation Biology. - 2020. - Vol. 34, No. 2. - P. 303-313. DOI: https://doi.org/10.1111/cobi.13391.

62. O'Donnell K., Sharrock S. The contribution of botanic gardens to *ex situ* conservation through seed banking // Plant Diversity. - 2017. - Vol. 39, No. 6. - P. 373-378. DOI: https://doi.org/10.1016/j.pld.2017.11.005.

63. O'Donnell K., Sharrock S. Botanic gardens complement agricultural gene bank in collecting and conserving plant genetic diversity // Biopreservation and Biobanking. - 2018. - Vol. 16, No. 5. - P. 384-390. DOI: https://doi.org/10.1089/bio.2018.0028.

64. Merritt D.J., Whitehouse K.J., Hoyle G.L., Crawford A., Wood J.A., Satyanti A., Norton S., Errington G., Martyn Yenson, A.J. Seed banking: Orthodox seeds. In Plant Germplasm Conservation in Australia; Martyn Yenson, A.J., Offord, C.A., Meagher, P.F., Auld, T., Bush, D., Coates, D.J., Commander, L.E., Guja, L.K., Norton, S.L., Makinson, R.O., et al., Eds.; Australian Network for Plant Conservation: Canberra, Australia, 2021. - P. 119-158. ISBN 978-0-9752191-4-0 (online). Available at: https://www.anpc.asn.au/wp-content/uploads/2021/09/GermplasmGuidelinesThirdEdition_FINAL_210902.pdf.

65. Yu X., Xianran L., Guo T., Zhu C., Wu Y., Mitchell S.E., Roozeboom K.L., Wang D., Wang M.L., Pederson G.A., Tesso T.T., Schnable P.S., Bernardo R., Yu J. Genomic prediction contributing to a promising global strategy to turbocharge gene banks // Nature Plants. - 2016. - Vol. 2. - Article number: 16150. DOI: https://doi.org/10.1038/nplants.2016.150.

66. Fu Y.-B. The vulnerability of plant genetic resources conserved *ex situ* // Crop Science. - Vol. 57, No. 5. - P. 2314-2328. DOI: https://doi.org/10.2135/cropsci2017.01.0014.

67. Cai J. Seed conservation of China's flora through The Germplasm Bank of Wild Species // BGjournal. - 2015. - Vol. 12, No. 1. - P. 22-24. Available at: https://www.jstor.org/stable/bgj.12.1.22.

68. Desert Botanical Garden. Seed Bank and Seed Photography Laboratory. Available at: https://dbg.org/research-conservation/programs/. Accessed: 3 June 2022.

69. Hultine K.R., Majure L.C., Nixon V.S., Arias S., Búrquez A., Goettsch B., Puente-Martinez R., Zavala-Hurtado A. The role of botanical gardens in the conservation of *Cactaceae* // BioScience. - 2016. - Vol. 66, No. 12. - P. 1057-1065. DOI: https://doi.org/10.1093/biosci/biw128.

70. Barga S.C., Olwell P., Edwards F., Prescott L., Leger E.A. Seeds of Success: a conservation and restoration investment in the future of U.S. lands // Conservation Science and Practice. - 2020. - Vol. 2, No. 7. - Article number: e209. DOI: https://doi.org/10.1111/csp2.209.

71. Duggan J. Inside The «Doomsday» Vault // Time, April 08, 2017. [Online] Available at: https://time.com/doomsday-vault.

72. Vaughan A. Svalbard doomsday vault gets first big seed deposit since upgrade // NewScientist. Environment. - 2020. - No. 3271. [Online] Available at: https://www.newscientist.com/article/2235116-svalbard-doomsday-vault-gets-first-big-seed-deposit-since-upgrade/.

73. Wolff L. The past shall not begin: frozen seeds, extended presents and the politics of reversibility // Security Dialogue. - 2021. - Vol. 52, No. 1. - P. 79-95. DOI: https://doi.org/10.1177%2F0967010620912961.

74. Westengen O.T., Lusty C., Yazbek M., Amri A., Asdal A. Safeguarding a global seed heritage from Syria to Svalbard // Nature Plants. - 2020. - Vol. 6, No. 11. - P. 1311-1317. DOI: https://doi.org/10.1038/s41477-020-00802-z.

75. Asdal A., Guarino L. The Svalbard Global Seed Vault: 10 years - 1 million samples // Biopreservation and Biobanking. - 2018. - Vol. 16, No. 5. - P. 391-392. DOI: https://dx.doi.org/10.1089%2Fbio.2018.0025.

76. CropTrust. Svalbard Global Seed Vault. [Online] Available at: https://www.croptrust.org/our-work/svalbard-global-seed-vault. Accessed: 18 June 2022.

77. Kallow S., Mertens A., Janssens S.B., Vandelook F., Dickie J., Swennen R., Panis B. Banana seed genetic resources for food security: status, constraints, and future priorities // Food and Energy Security. - 2022. - Vol. 11, No. 1. - Article number: e345. DOI: https://doi.org/10.1002/fes3.345.

78. Comizzoli P., Wildt D.E. Cryobanking biomaterials from wild animal species to conserve genes and biodiversity: relevance to human biobanking and biomedical research. In: Hainaut P., Vaught J., Zaltoukal K., Pasterk M. (eds) Biobanking of human biospecimens. Springer, Cham, 2017. DOI: https://doi.org/10.1007/978-3-319-55120-3_13.

79. Walter I., Burger S., Stargardt M., Kummer S., Wieser M. VetBiobank, Vetmeduni Vienna: a bioresource for clinical

animal biospecimens // Open Journal of Bioresources. - 2020. - Vol. 7, No. 9. - P. 1-6. DOI: http://dx.doi.org/10.5334/ojb.60.

80. Groeneveld L.F., Gregusson S., Guldbrandtsen B., Hiemstra S.J., Hveem K., Kantanen J., Lohi H., Stroemstedt L., Berg P. Domesticated animal biobanking: land of opportunity // PLOS Biology. - 2016. - Vol. 14, No. 7. - Article number: e1002523. DOI: https://doi.org/10.1371%2Fjournal.pbio.1002523.

81. Lieberman-Cribbin W., Tuminello S., Gillezeau C., van German M., Brody R., Mulholland D.J., Horton L., Sisco M., Prophete C., Zelikoff J., Lee H.-W., Park S.-H., Chen L.-C., Cohen M.D., Taioli E. Complementary biobank of rodent tissue samples to study the effect of World Trade Center exposure on cancer development // Journal of Transnational Medicine. - 2019. - Vol. 17. - Article number: 342. DOI: https://doi.org/10.1186/s12967-019-2089-7.

82. Witham C., Wells S. Nonhuman primate's tissue banks: resources for all model organism research // Mammalian Genome. - 2022. - Vol. 33, No. 1. - P. 241-243. DOI: https://doi.org/10.1007/s00335-021-09925-w.

83. Abbott A. An inside look at the first pig biobank // Nature. - 2015. - Vol. 519. - P. 397-398. DOI: https://doi.org/10.1038/519397a.

84. Matson, T. Post-mortem epididymal sperm extraction, BEVA - Annual Congress - Birmingham, 2018. Available at: https://www.ivis.org/library/beva/beva-annual-congress-birmingham-2018/post-mortem-epididymal-sperm-extraction.

85. Blackburn H.D. Genetic selection and conservation of genetic diversity // Reproduction in Domestic Animals. - 2012. - Vol. 47, No. S4. - P. 249-254. DOI: https://doi.org/10.1111/j.1439-0531.2012.02083.x.

86. Ryder O.A., Onuma M. Viable cell culture banking for biodiversity characterization and conservation // Annual Review of Animal Biosciences. - 2018. - Vol. 6. - P. 83-98. DOI: https://doi.org/10.1146/annurev-animal-030117-014556.

87. De Oliveira L.R.M., Praxedes E.A., Silva M.B., Ribeiro L.R., Silva H.V.R., Pereira A.F. Comparative effect of cryoprotectant combinations on the conservation of somatic cells derived from jaguar, panther onca, towords the formation of biological banks // Anais da Academia Brasileira de Ciencias. - 2021. - Vol. 93, No. 4. - Article number: e20190314. DOI: https://doi.org/10.1590/0001-3765202120190314.

88. O'Brien J.K., Steinman K.J., Montano G.A., Dubach J.M., Robeck T.R. Chicks produced in the magellanic penguin (*Spheniscus magellanicus*) after cloacal insemination of frozen-thawed semen // Zoo Biology. - 2016. - Vol. 35, No. 4. - P. 326-338. DOI: https://doi.org/10.1002/zoo.21304.

89. Howell L.G., Johnston S.D., O'Brien J.K., Frankham R., Rodger J.C., Ryan S.A., Beranek C.T., Clulow J., Hudson D.S., Witt R.R. Modeling genetic benefits and financial costs of integrating biobanking into the captive management of koalas // Animals. - 2022. - Vol. 12, No. 8. - Article number: 990. DOI: https://doi.org/10.3390/ani12080990.

90. Howell L.G., Frankham R., Rodger J.C., Witt R.R., Clulow S., Upton R.M., Clulow J. Integrating biobanking minimizes inbreeding and produces significant cost benefits for a threatened frog captive breeding programme // Conservation Letters. - 2020. - Vol. 14, No. 2. - Article number: e12776. DOI: https://doi.org/10.1111/conl.12776.

91. Zippel K., Johnson K., Gagliardo R., Gibson R., McFadden M., Browne R., Martinez C., Townsend E. The Amphibian Ark: a global community for *ex situ* conservation of amphibians // Herpetological conservation and biology. - 2011. - Vol. 6, No. 3. - P. 340-352. ISSN: 1931-7603. https://www.cabdirect.org/cabdirect/abstract/20123201417.

92. Hermes R., Hildebrandt T.B., Göritz F., Fasel N.J., Holtze S. First cryopreservation of phyllostomid bat sperm // Theriogenology. - 2019. - Vol. 131. - P. 28-31. DOI: https://doi.org/10.1016/j.theriogenology.2019.03.014.

93. Benirschke K. The Frozen Zoo concept // 1984. - Vol. 3, No. 4. - P. 325-328. DOI: https://doi.org/10.1002/zoo.1430030405.

94. Hildebrandt T.B., Hermes R., Goeritz F., Appeltant R., Colleoni S., de Mori B., Diecke S., Drukker M., Galli C., Hayashi K., Lazzari G., Loi P., Payne J., Renfree M., Seet S., Stejskal J., Swegen A., Williams S.A., Zainuddin Z.Z., Holtze S. The ART of bringing extinction to a freeze – history and future of species conservation, exemplified by rhinos // Theriogenology. - 2021. - Vol. 169. - P. 76-88. DOI: https://doi.org/10.1016/j.theriogenology.2021.04.006.

95. Prisco J. Back from the brink: how «frozen zoos» could save dying species // CNN, March 31, 2022. [Online] Available at: https://edition.cnn.com/2022/03/31/world/frozen-zoo-save-species-scn-c2e-spc-intl/index.html.

96. Frozen Zoo. San Diego Zoo Wildlife Alliance. Science. [Online] Available at: https://science.sandiegozoo.org/resources/frozen-zoo%C2%AE. Accessed: 26 May 2022.

97. How we're helping to save the Przewalski's horse // San Diego Zoo Wildlife Alliance. Science. [Online] Available at: https://science.sandiegozoo.org/species/przewalskis-horse. Accessed: 26 May 2022.

98. Perez-Espona S., the CryoArks Consortium. Conservation-focused biobanks: a valuable resource for wildlife DNA forensics // Forensic Science International: Animals and Environments. - 2021. - Vol. 1. - Article number: 100017. DOI: https://doi.org/10.1016/j.fsiae.2021.100017.

99. BBR-CryoArks: Enhancing frozen collections for non-model and endangered animal taxa. Cardiff University. Research Grant, 2018-2022. [Online] Available at: https://gtr.ukri.org/projects?ref=BB%2FR015260%2F1#/tabOverview.

100. Hildebrandt T.B., Hermes R., Saragusty J., Potier R., Schwammer H.M., Balfanz F., Vielgrader H., Baker B., Bartels P., Göritz F. Enriching the captive elephant population genetic pool through artificial insemination with frozen-thawed semen collected in the wild // Theriogenology. - 2012. - Vol. 78, No. 6. - P. 1398-1404. DOI: https://doi.org/10.1016/j.theriogenology.2012.06.014.

101. Hermes R., Hildebrandt T.B., Göritz F. Cryopreservation in rhinoceros – setting a new benchmark for sperm cryosurvival // PLoS One. - 2018. - Vol. 13, No. 7. - Article number: e0200154. DOI: https://doi.org/10.1371%2Fjournal.pone.0200154.

102. Bio-cryobank. Leibniz Institute for Zoo and Wildlife Research. [Online] Available at: https://www.izw-berlin.de/en/bio-cryobank.html. Accessed: 10 June 2022.

103. Viva Sarah Press. «Frozen zoo» preserves DNA of animals at risk of extinction // Israel21c, February 16, 2017. [Online] Available at: https://www.israel21c.org/frozen-zoo-preserves-dna-of-animals-at-risk-of-extinction/.

104. National Museum of Natural History. Biorepository. [Online] Available at: https://naturalhistory.si.edu/research/biorepository. Accessed: 5 June 2022.

105. Corthals A., Desalle R. An application of tissue and DNA banking for genomics and conservation: The Ambrose Monell Cryo-Collection (AMCC). Points of view // Systematic Biology. - 2005. - Vol. 54, No. 5. - P. 819-823. DOI: https://doi.org/10.1080/10635150590950353.

106. The living biobank. Animal cell & tissue preservation for future regeneration. [Online] Available at: https://www.natures-safe.com/science. Accessed: 18 June 2022.

107. Cryopreservation and biobanking could save the World's rarest species from extinction // Biobanking.com, May 23, 2022. [Online] Available at: https://www.biobanking.com/cryopreservation-and-biobanking-could-save-the-worlds-rarest-species-from-extinction/. Accessed: 26 May 2022.

108. Imbler S. Finding a retirement home for 466 frozen flatworm fragments // The New York Times, March 08, 2022. [Online] Available at: https://www.nytimes.com/2022/03/08/science/frozen-flatworm-retriement.html. Accessed: 12 May 2022.

109. The Ocean Genome Legacy Center. Northeastern University. [Online] Available at: https://ogl.northeastern.edu/about/. Accessed: 12 May 2022.

110. Temirbekova S., Afanasyeva Y., Beloshapkina O., Postnikov D. Barley genetic resources from Global Vavilov Seed Bank to use in plant breeding // Journal of Biochemical Technology. - 2020. - Vol. 11, No. 2 - P. 123-127. ISSN 0974-2328. https://jbiochemtech.com/article/barley-genetic-resources-from-the-global-vavilov-seed-bank-to-use-in-plant-breeding.

111. Safonova I.V., Anis'kov N.I., Kobylyansky V.D. The database of genetic resources in the VIR winter rye collection as a means of classification of genetic diversity, analysis of the collection history and effective study and preservation // Vavilov Journal of Genetics and Breeding. - 2019. - Vol. 23, No. 6. - P. 780-786. DOI: https://doi.org/10.18699/VJ19.552.

112. VIR Plant Genetic Resources Gene Bank. [Online] Available at: https://www.vir.nw.ru/unu-kollektsiya-vir. Accessed: 10 May 2022.

113. Riaz A., Hathorn A., Dinglasan E., Zeims L., Richard C., Singh D., Mitrofanova O., Afanasenko O., Aitken E., Godwin I., Hickey L. Into the vault of the Vavilov wheats: old diversity for new alleles // Genetic Resources and Crop Evolution. - 2017. - Vol. 64, No. 3. - P. 531-544. DOI: https://doi.org/10.1007/s10722-016-0380-5.

114. Akparov Z.I., Mammadova S.A., Mammadov A.T. Mobilization and conservation of the seed pool of plant genetic resources in Azerbaijan // Vavilov Journal of Genetics and Breeding. - 2012. - Vol. 16, No. 3. - P. 655-659. DOI: https://vavilov.elpub.ru/jour/article/view/136.

115. Rafiyeva G., Majidova G. Study of S. segetale (Zhuk) accessions from different regions of Azerbaijan in conditions of Absheron // Proceedings of the Genetic Resources Institute of Azerbaijan National Academy of Sciences. - 2021. - Vol. 10, No. 2. - P. 14-19. ISSN 2223-5817. Available at: http://genresjournal.az/Docs/elmi_eser_10_2.pdf. [in Russian]

116. Navasardyan Ye.M., Elbakyan A.H., Shcherbakova Y.N., Nersesyan A.A. The seed viability of the *Poaceae* family from collections of the Seed Bank of Armenian Flora of the Institute of Botany after A. Takhtajyan NAS RA // Collection of scientific works. Flora, vegetation and plant resources. Takhtajania. - 2020. - Vol. 6. - P. 102-110. ISBN: 978 -99941-2-564-7. Available at: https://arar.sci.am/publication/287165#-description. [in Russian]

117. The Plant Production Institute named after V.Ya. Yuriev National Academy of Agrarian Sciences of Ukraine. Laboratory of Introduction and Preservation of Plant Genetic Resources. Available at: https://yuriev.com.ua/en/pro-institut/struktura-institutu/naukovi-pidrozdili/viddil-teoretichnih-doslidzhen-v-roslinnictvi-ta-genetichnih-resursiv-roslin/laboratoriya-introdukcii-ta-zberigannya-genetichnih-resursiv-roslin/. Accessed: 20 June 2022.

118. Pozniak O.V. The breeding aspect of the distribution of okra in Ukraine // Proceedings of the International scientific-practical conference «Actual problems of agro-science in the context of adaptation to global climate change» devoted to the 75[th] anniversary of the Doctor of Agricultural Sciences, Professor, Academician of National Academy of Sciences and Academy of Agricultural Sciences of the Republic of Kazakhstan Meiirman Galiolla, Almalybak, 17-18 June 2021. - Almaty: LLP «Asyl kitap», 2021. - P. 248-250. Available at: https://kazniizr.kz/wp-content/uploads/2021/06/Sbornik-konf.-75-let.-Mejrman-G.T.-08.06.21.pdf. [in Russian]

119. Privalov F., Grib S., Matys I. Genofond rastitelnykh resursov v Belarusi (Gene pool of plant resources in Belarus) // Nauka i innovatsii. - 2019. - Vol. 198, No. 8. - P. 7-9. Available at: https://cyberleninka.ru/article/n/genofond-rastitelnyh-resursov-v-belarusi. [in Russian]

120. Privalov F.I., Grib S.I., Matys I.S., Dmitrieva S.A., Lavnikevich A.S. On the national strategy for conservation and sustainable use of plant genetic resources in the Republic of Belarus // Proceedings of the International scientific-practical conference «Actual problems of agro-science in the context of adaptation to global climate change» devoted to the 75[th] anniversary of the Doctor of Agricultural Sciences, Professor, Academician of National Academy of Sciences and Academy of Agricultural Sciences of the Republic of Kazakhstan Meiirman Galiolla, Almalybak, 17-18 June 2021. - Almaty: LLP «Asyl kitap», 2021. - P. 250-255. Available at: https://kazniizr.kz/wp-content/uploads/2021/06/Sbornik-konf.-75-let.-Mejrman-G.T.-08.06.21.pdf. [in Russian]

121. KyrgGen. Plant Gene Bank of the Kyrgyz Republic. [Online] Available at: https://agro.gov.kg/language/ru/5511/. Accessed: 5 June 2022.

122. Spivachenko A.B., Borozan P.A., Mistrets S. Achievements of the Crop Institute Porumbeni in areas of breeding corn hybrids adapted to changing climatic conditions and implementing them into production // Proceedings of the International scientific-practical conference «Actual problems of agro-science in the context of adaptation to global climate change» devoted to the 75[th] anniversary of the Doctor of Agricultural Sciences, Professor, Academician of National

Academy of Sciences and Academy of Agricultural Sciences of the Republic of Kazakhstan Meiirman Galiolla, Almalybak, 17-18 June 2021. - Almaty: LLP «Asyl kitap», 2021. - P. 289-295. Available at: https://kazniizr.kz/wp-content/uploads/2021/06/Sbornik-konf.-75-let.-Mejrman-G.T.-08.06.21.pdf. [in Russian]

123. Regionalnaya Programma po ustojchivomu razvitiyu selskogo khozyajstva v Tsentralnoj Azii i Yuzhnom Kavkaze. Rabochij otchet № 14 «Selskokhozyajstvennoe nauchno-issledovatelskoe sotrudnichestvo v Tadzhikistane» (Regional program for sustainable agricultural development in Central Asia and the South Caucasus. Working Paper No. 14 «Agricultural Research Collaboration in Tajikistan». ICARDA, 2013. ISBN: 92_9127_449_6. Available at: http://www.cac-program.org/files/wokring_paper_14_ru.pdf). [in Russian]

124. Mansurov Kh.G., Abdullaev F.Kh. Ispolzovanie mirovoj kollektsii geneticheskikh resursov masha (*Vigna radiate* (L.) Wilczek) (Using the world collection of mung bean (*Vigna radiate* (L.) Wilczek) genetic resources) // Materials of the International scientific and practical conference «Priorities of the agroindustrial complex: scientific discussion», dedicated to the 30th anniversary of the Independence of the Republic of Kazakhstan. - Petropavlovsk: M. Kozybayev North Kazakhstan University, 2021. - P. 152-155. ISBN: 978-601-223-388-9. Available at: https://www.researchgate.net/publication/351230176_Ispolzovanie_mirovoj_kollekcii_geneticeskih_resursov_masa_Vigna_radiata_L_Wilczek_Utilization_of_Global_Collection_of_Genetic_Resources_of_Mung-bean_Vigna_radiata_L_Wilczek. [in Russian]

125. Strategiya i plan dejstvij po sokhraneniyu bioraznoobraziya Turkmenistana (Strategy and action plan for the conservation of biodiversity of Turkmenistan). Editor Razhapov M., Ashgabat, 2002. - 116 pp. Available at: https://www.cbd.int/doc/world/tm/tm-nbsap-01-ru.pdf. [in Russian]

126. Abildaeva D.B., Didorenko S.V., Saikenova A.Zh., Kanatkyzy M., Kassenov R. Characteristic collections of soybeans as a source material for various directions of breeding // Proceedings of the International scientific-practical conference «Actual problems of agro-science in the context of adaptation to global climate change» devoted to the 75th anniversary of the Doctor of Agricultural Sciences, Professor, Academician of National Academy of Sciences and Academy of Agricultural of Sciences of the Republic of Kazakhstan Meiirman Galiolla. - Almaty: «Asyl kitap» (Baspa үji) LLP, 2021. - P. 61-63. ISBN: 978-601-7667-08-5. Available at: https://kazniizr.kz/wp-content/uploads/2021/06/Sbornik-konf.-75-let.-Mejrman-G.T.-08.06.21.pdf. [in Russian]

127. Esimbekova M.A., Mukin K.B. The state of Kazakhstan fodder crops genetic resources // Proceedings of the International scientific-practical conference «Actual problems of agro-science in the context of adaptation to global climate change» devoted to the 75th anniversary of the Doctor of Agricultural Sciences, Professor, Academician of National Academy of Sciences and Academy of Agricultural of Sciences of the Republic of Kazakhstan Meiirman Galiolla. - Almaty: «Asyl kitap» (Baspa үji) LLP, 2021. - P. 147-150. ISBN: 978-601-7667-08-5. Available at: https://kazniizr.kz/wp-content/uploads/2021/06/Sbornik-konf.-75-let.-Mejrman-G.T.-08.06.21.pdf. [in Russian]

128. Esimbekova M.A., Shtefan G.I., Kobernitskij V.I., Ajtymbetova K.Sh., Espanov A.M., Kiseleva N.A., Krasavin V.F., Podolskikh A.N., Umbetaev I., Gerasimova E.T., Gavrilova O.A., Ortaev A.K., Tsygankov V.I., Kulinich V. Mobilizatsiya i sokhranenie geneticheskikh resursov selskokhozyajstvennykh rastenij Respubliki Kazakhstan (Mobilization and conservation of genetic resources of agricultural plants of the Republic of Kazakhstan) // Proceedings of the International scientific-practical conference «Achievements and prospects of agriculture and plant growing development», dedicated to the 85th anniversary of the Kazakh scientific research institute of Agriculture and Plant growing (15-16 August 2019). - Almaty: «Asyl kitap» (Baspa үji) LLP, 2019. - P. 35-41. ISBN: 978-601-7962-44-9. Available at: https://kazniizr.kz/wp-content/uploads/2019/08/sbornik-konferentsii-85.pdf. [in Russian]

129. Dolinnyj Yu.Yu. Plant genetic resources are the basis of food and technological security of the Republic of Kazakhstan. A.I. Barayev Research and Production Centre for Grain Farming. Available at: https://baraev.kz/glavnaya/2676-geneticheskie-resursy-rasteniy-osnova-prodovolstvennoy-i-tehnologicheskoy-bezopasnosti-respubliki-kazahstan.html.

130. Creation of a genebank of agricultural plants. NJSC «National Agrarian Scientific and Educational Center». News, April 29, 2022. Available at: http://nasec.kz/ru/news/sozdanie-genbanka-selskokhozyaystvennykh-rasteniy. Accessed: 31 May 2022.

131. Kalyakin M.V., Seregin A.P., Solovchenko A.E., Kamenskij P.A., Sadovnichij V.A. Proekt «Noev kovcheg» promezhutochnye itogi i perspektivy razvitiya klassicheskikh kollektsij (Project «Noah›s Ark» intermediate results and prospects for the development of classical collections) // Acta Naturae. - 2018. - Vol. 10, No. 4 (39). - P. 49-58. Available at: https://cyberleninka.ru/article/n/proekt-noev-kovcheg-promezhutochnye-itogi-i-perspektivy-razvitiya-klassicheskih-kollektsiy. [in Russian]

132. Seregin A.P. (Ed.). 2022. Moscow Digital Herbarium: Electronic resource. - Moscow State University, Moscow. - Available at: https://plant.depo.msu.ru/. Accessed: 01 February 2023.

133. National Depository Bank of Live Systems. Animals. Available at: https://animal.depo.msu.ru/. Accessed: 01 February 2023.

134. The Resource Collection «Marine Biobank». Available at: http://marbank.dvo.ru/index.php/en/. Accessed: 05 June 2022.

135. Skriptsova A.V., Kalita T.L. The first record of the brown endophytic alga *Laminariocolax aecidioides* (Rosenvinge) A.F. Peters, 1998 (Ectocarpales: *Phaeophyceae*) in the Russian far-eastern seas // Biologiya morya. - 2020. - Vol. 46, No. 1. - P. 45-52. DOI: https://doi.org/10.31857/S013434752001009X. [in Russian]

136. Republican DNA Bank. Institute of Genetics and Cytology of the National Academy of Sciences of Belarus. Available at: https://igc.by/ru/2016/08/18/dna-bank-1-ru/. Accessed: 05 June 2022. [in Russian]

137. Decree of the Council of Ministers of the Republic of Belarus dated August 13, 2016 No. 629 «On the declaration of the Republican DNA Bank of Humans, Animals, Plants and Microorganisms as a National Treasure». Available at: https://abs.igc.by/wp-content/uploads/2020/04/Postanovlenie-SM-bank-DNK.pdf. Accessed: 06 June 2022. [in Russian]

138. Homel K.V., Shpak A.V., Kheidorova E.E., Nikiforov M.E., Gajduchenko H.S., Yurchenko D.G., Golovenchik V.I., Slivinska K., Larchanka A.I., Mahan'ko O.V., Dombrovski V.C. Genetic bank of wild fauna as a basis for the development of molecular genetic studies in zoology // Actual problems of zoological science in Belarus: Collection of articles of the XI Zoological International Scientific and Practical Conference dedicated to the tenth anniversary of the founding of the SRPA «SPC NAS of Belarus for Bioresources», Belarus, Minsk, 1-3 November, 2017 - Minsk: Publisher A.N. Varaksin, 2017. - P. 47-60. ISBN 978-985-7186-33-4. Available at: https://www.researchgate.net/publication/321245369_Genetic_bank_of _wild_fauna_as_a_basis_for_the_development_of_molecular_genetic_studies_in_zoology. [in Russian]

139. Biotechnology Institute National Academy of Science of Kyrgyz Republic. Available at: https://naskr.kg/ru/2019/06/23/institut-biotexnologii/. Accessed: 31 January 2023. [in Russian]

140. Project: «Conservation and use of germplasm of Kyrgyzstan's wild flora for management of genetic-selectional and economical tasks» - ISTC project #KR-973. Plant and Fungi Biotechnology Laboratory of the Institute of Biotechnology National Academy of Sciences of the Kyrgyz Republic. Available at: http://www.plant-biotech.kg/index.php/projects. Accessed: 01 June 2022.

141. Ivashchenko A.A. Rastitelnyj mir Kazakhstana (Flora of Kazakhstan). - Popular science edition. - Almaty: «Almaty kitap» LLP, 2006. - 176 pp. Available at: https://www.almaty-kitap.kz/upload/files/91439_346781_16.pdf. [in Russian]

142. The sixth national report on biological diversity in the Republic of Kazakhstan. - Astana, 2018. Available at: https://www.cbd.int/doc/nr/nr-06/kz-nr-06-en.pdf.

143. Ajtzhanova B. Biobanki planiruyut sozdat v Kazakhstane (Biobanks are planned to be created in Kazakhstan) // TengriNews, November 07, 2018. [Online] Available at: https://tengrinews.kz/kazakhstan_news/biobanki-planiruyut-sozdat-v-kazahstane-357201/. Accessed: 08 June 2022. [in Russian]

144. Sabekov S. Razvivat biobanki dlya khraneniya geneticheskogo materiala planiruyut v Kazakhstane (It is planned to develop biobanks for the storage of genetic material in Kazakhstan) // KazInform, November 07, 2018. [Online] Available at: https://www.inform.kz/ru/razvivat-biobanki-dlya-hraneniya-geneticheskogo-materiala-planiruyut-v-kazahstane_a3449437. Accessed: 08 June 2022. [in Russian]

145. Isaeva R.B., Kozhamkulov U.A., Isabayeva K.K., Dyujsenova Zh.S., Zhabagin M.K., Abzaliyeva S.A., Aliakparova A.K. Na puti k sozdaniyu Natsionalnogo biobanka Respubliki Kazakhstan: pravovoe i eticheskoe regulirovanie (On the way to the creation of the National Biobank of the Republic of Kazakhstan: legal and ethical regulation) // Proceedings of the VII Congress and Associate Simposiums of Vavilov Society of Geneticists and Breeders on the 100th Anniversary of the Department of Genetics of Saint Petersburg State University, 18-20 July, 2019. - 2019. - P. 421. Available at: https://www.elibrary.ru/item.asp?id=39156558. [in Russian]

146. Nurullin E. Biobank predlozhili sozdat v Kazakhstane (Biobank was proposed to be created in Kazakhstan) // Ekspress K, March 25, 2022. [Online] Available at: https://exk.kz/news/848/biobank-priedlozhili-sozdat-v-kazakhstanie. Accessed: 08 June 2022. [in Russian]

147. Krasnaya kniga Kazakhstana (Red Book of Kazakhstan). - 2nd edition, revised and enlarged. - Vol. 2. Plants. - Astana: «Арт Print XXI» LLP, 2014. - 452 pp.

148. The Red Data Book of the Republic of Kazakhstan. 4th edition, revised and uptadet. Volume I.: Animals; Part 1: Vertebrates. (authors' collective) - Almaty, «DPS», 2010. - 324 pp. ISBN 9965-32-738-6. [Online] Available at: https://zool.kz/wp-content/uploads/2021/02/red-data-book-rk_v1_1_2010.pdf.

149. Laboratory of seed-research and plant protection. Institute of Botany and Phytointroduction. [Online] Available at: https://www.botsad.kz/en/labs/view/laboratoriya_semenovodstva. Accessed: 21 June 2022.

150. Sitpayeva G.T. The role of the main Botanical garden of Kazakhstan in preservation of botanical diversity of the republic // Materials of the XVII International Scientific and Practical Conference «Problems of Botany of Southern Siberia and Mongolia», 24-27 May 2018, Barnaul, Altai Krai. - Barnaul, 2018. - P. 509-512. Available at: http://elibrary.asu.ru/xmlui/bitstream/handle/asu/6216/509-512.pdf?sequence=1&isAllowed=y. [in Russian]

151. Otchet Glavnogo botanicheskogo sada Respublikanskogo gosudarstvennogo predpriyatiya «Institut botaniki i fitointroduktsiI» Komiteta nauki Ministerstva obrazovaniya i nauki Respubliki Kazakhstan (Report of the Main Botanical Garden of the Republican State Enterprise «Institute of Botany and Phytointroduction» of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan) // Informatsionnyj byulleten. - 2017. - Vol. 30, No. 7. - P. 41-52. Available at: https://sbsgbsad.files.wordpress.com/2017/09/7-vip.pdf. [in Russian]

152. Delektus exchange. The Main Botanical Garden. [Online] Available at: https://www.botsad.kz/ru/news/view/delektusnii_obmen. Accessed: 10 June 2022. [in Russian]

153. Laboratory of seed production and plant protection. The Astana Botanical Garden. [Online] Available at: https://astana-botsad.kz/ru/laboratorii/6. Accessed: 12 June 2022. [in Russian]

154. Index Herbariorum. Astana Botanical Garden. [Online] Available at: http://sweetgum.nybg.org/science/ih/herbarium-details/?irn=260124. Accessed: 09 June 2022.

155. Danilova A.N. Opyt i napravleniya raboty Altajskogo gosudarstvennogo botanicheskogo sada KN MON RK (Experience and directions of work of the Altai State Botanical Garden SC MES RK) // Collection of reports of the International scientific-practical conference «Creation and development prospects of the Botanical Garden of the city of Astana under condition of sharply continental climate. Theory and practice». - Astana: Institute of Botany and Phytointroduction, 2017. - P. 71-73. Available at: https://www.botsad.kz/storage/58/58bb3fb5295c22b84802c062c94dfeec.pdf. [in Russian]

156. Laboratory of Germplasm Cryopreservation. Institute of Plant Biology and Biotechnology. Available at: http://ipbb.kz/eng/laboratory-of-germplasm-cryopreservation/. Accessed: 08 June 2022.

157. Romadanova N.V., Mishustina S.A., Matakova G.N., Kuhsnarenko S.V., Rakhimbaev I.R., Reed B.M. *In vitro* collection of *Malus* shoot cultures for cryogenic bank development in Kazakhstan // Acta Horticulturae. - 2016. - V. 1113. - P. 271-277. DOI: https://doi.org/10.17660/ActaHortic.2016.1113.40.

158. Romadanova N.V., Karasholakova L.N., Makhmutova I.A., Ishmuratova M.Yu., Kopytkova L.A., Kabylova F.D., Kushnarenko S.V. Preservation of barberry (some species) genetic material in a cryobank // Bulletin of the Karaganda university. Biology. Medicine. Geography series. - 2019. - Vol. 95, No. 3. - P. 20-26. Available at: https://biollogy-medcine-geography-vestnik.ksu.kz/apart/2019-95-3/3.pdf. [in Russian]

159. Romadanova N.V., Mishustina S.A., Karasholakova L.N., Aralbaeva M.M., Kabulova F.D., Abidkulova K.T., Kushnarenko S.V. Introduction of wild berberis species of Kazakhstan and Uzbekistan flora into *in vitro* culture // KazNU Bulletin. Biology series. - 2015. - Vol. 65, No. 3. - P. 346-354. Available at: https://bb.kaznu.kz/index.php/biology/article/view/1137. [in Russian]

160. Natsionalnyj doklad o sostoyanii okruzhayushchej sredy i ob ispolzovanii prirodnykh resursov Respubliki Kazakhstan za 2019 god (National report on the state of the environment and on the history of natural resources of the Republic of Kazakhstan for 2019). Available at: https://ecogosfond.kz/kz-2019-zhyl-a-arnal-an-orsha-an-ortany-zhaj-k-ji-turaly-zh-ne-r-tabi-i-resrstaryn-pajdalanu-turaly-ltty-bajandama-ru-nacionalnyj-doklad-o-sostojanii-okruzhajushhej-sredy-i-ob-ispolzovanii-prirodnyh-r/. [in Russian]

161. Almerekova S., Lisztes-Szabo Z., Mukhitdinov N., Kurmanbayeva M., Abidkulova K., Sramko G. Genetic diversity and population genetic structure of the endangered Kazakh endemic *Oxytropis almaatensis* (Fabaceae) // Acta Botanica Hungarica. - 2018. - V. 60, No. 3-4. - P. 263-278. DOI: https://doi.org/10.1556/034.2018.1.

162. Abugalieva S., Volkova L., Genievskaya Y., Ivaschenko A., Kotukhov Y., Sakauova G., Turuspekov Y. Taxonomic assessment of *Allium* species from Kazakhstan based on ITS and *matK* markers // BMC Plant Biology. - 2017. - Vol. 17, No. 2. - P. 51-60. DOI: https://doi.org/10.1186/s12870-017-1194-0.

163. Laboratory of Molecular Genetics. Institute of Plant Biology and Biotechnology. Available at: http://ipbb.kz/eng/laboratory-of-molecular-genetics/. Accessed: 08 June 2022.

164. Natsionalnyj doklad o sostoyanii okruzhayushchej sredy i ob ispolzovanii prirodnykh resursov Respubliki Kazakhstan za 2020 god (National report on the state of the environment and on the use of natural resources of the Republic of Kazakhstan for 2020). Available at: https://www.gov.kz/memleket/entities/ecogeo/press/news/details/300999?lang=ru. [in Russian]

165. History of the Institute of Zoology. Institute of Zoology Republic of Kazakhstan. Available at: https://zool.kz/ob-institute/istoriya/obshhij-ocherk/. Accessed: 12 June 2022. [in Russian]

166. Biotechnology and Eco-Monitoring Research Park. Karaganda University named after Academician E.A. Buketov. Available at: https://buketov.edu.kz/ru/page/laboratory/science13. Accessed: 12 June 2022.

167. Ishmuratova M.Yu., Tleukenova S.U., Atikeyeva S.N., Auelbekova A.K., Zhuzbayeva G.O., Zhumagaliyeva Zh.Zh. Cryopreservation of *Calendula officinalis* seeds // EurAsian Journal of BioSciences. - 2020. - Vol. 14, No. 1. - P. 501-505.

168. Romadanova N.V., Aralbaeva M.M., Rymkhanova N.K., Baigaraev D.Sh., Ramazanov A.K., Ishmuratova M.Iu., Kushnarenko S.V. Cryopreservation as a way to improve laboratory germination and germination energy of seeds // Bulletin of the Karaganda university. Biology. Medicine. Geography Series. - 2022. - Vol. 105, No. 1. - P. 86-95. DOI: http://dx.doi.org/10.31489/2022BMG1/86-95. [in Russian].

169. Decree of the Government of the Republic of Kazakhstan dated August 2, 2005 No. 802 «On some measures for the development of biotechnology in the Republic of Kazakhstan». Available at: https://adilet.zan.kz/rus/docs/P050000802_. Accessed: 31 May 2022. [in Russian]

170. Charter of the Republican State Enterprise on the Right of Economic Management «National Center for Biotechnology» of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan, Astana, 2010.

171. Nurtaza A., Magzumova G., Yessimseitova A., Karimova V., Shevtsov A., Silayev D., Lutsay V., Ramankulov Ye., Kakimzhanova A. Micropropagation of the endangered species *Malus niedzwetzkyana* for conservation biodiversity in Kazakhstan // In Vitro Cellular and Developmental Biology - Plant. - 2021. - Vol. 57. - P. 965-976. DOI: https://doi.org/10.1007/s11627-021-10174-4.

172. Novakovskaya A.P., Raizer O.B., Danilova A.N., Khapilina O.N. *In vitro* cultivation of rare and endemic *Allium* sp. species // Eurasian Journal of Applied Biotechnology. - 2018. - No. 2. - P. 1-12. DOI: https://doi.org/10.11134/btp.2.2018.6.

173. Khapilina O.N., Kupeshev Z.S., Danilova A.N., Kalendar R.N. *In vitro* culture of *Rhodiola rosea* L. // Biotechnology Theory and Practice. - 2016. - No. 4. Available at: https://biotechlink.org/index.php/journal/article/view/183. [in Russian]

174. Bekkuzhina S.S., Rakhimzhanova A.O., Talkanbayeva A.K., Manabayeva S.A. Induction of callusogenesis in a culture of isolated seeds of *Cistanche Deserticola* // Bulletin of L.N. Gumilyov ENU. Bioscience Series. - 2020. - Vol. 133, No. 4. - P. 44-52. Available at: https://bulbio.enu.kz/article/archive/view?id=induction-of-callusogenesis-in-a-culture-of-isolated-seeds-of-cistanche-deserticola-2. [in Russian]

175. Research report BR05236334 «Organization of a biobank for microorganisms, cell cultures, genomic and genetically engineered materials for a preservation of a biodiversity and provision of a basis of biotechnology resources» for 2018-2020 (final report). - Hur-Sultan, 2020. - 246 pp.

176. Nurtaza A.S., Magzumova G.K., Yessimseitova A.K., Dyussembekova D.A., Baktybay B., Turganbayeva A.K., Kakimzhanova A.A. Micropropagation for the conservation of rare and endangered *Malus niedzwetzkyana* // Eurasian Journal of Applied Biotechnology. - 2019. - No. 2. - P. 121-131. DOI: https://doi.org/10.11134/btp.2.2019.12.

177. Method for obtaining sterile seedlings of *Rhodiola rosea* L. for explantation into *in vitro* culture // Authors: Khapilina O.N., Kupeshev Zh.S., Novakovskaya A.P., Tagimanova D.S., Kalendar R.N., Ramankulov Ye.M. - Patent of the Republic of Kazakhstan No. 1912 dated December 30, 2016

178. Khapilina O., Turzhanova A., Danilova A., Tumenbayeva A., Shevtsov V., Kotukhov Y., Kalendar R. Primer binding site (PBS) profiling of genetic diversity of natural populations of endemic species *Allium ledebourianum* Schult. // BioTech. - 2021. - Vol. 10, No. 4. - Article number: 23. DOI: https://doi.org/10.3390/biotech10040023.

179. Khapilina O., Raiser O., Danilova A., Shevtsov V., Turzhanova A., Kalendar R. DNA profiling and assessment of genetic diversity of relict species *Allium altaicum* Pall. on the territory of Altai // PeerJ. - 2021. - Vol. 9. - Article number: e10674. DOI: https://doi.org/10.7717/peerj.10674.

180. Report about scientific research work OR11465422 «Biobanking for rare and endangered species of flora and fauna for the conservation of biodiversity in Kazakhstan» (final). Cod of the program: O.0957. - Astana, 2021. - 216 pp.

181. Muranets A.P., Yessimseitova A.K., Dyussembekova D.A., Nurtaza A.S., Kalybayev K.R., Kozhanov K.Z., Kakimzhanova A.A. Study of the biodiversity of wild plants of the genus *Rosa* L. in Kazakhstan and their molecular-genetic identification // Bulletin of L.N. Gumilyov ENU. Bioscience Series. - 2022. - Vol. 139, No. 2. - P. 44-60. DOI: 10.32523/2616-7034-2022-139-2-44-60. Available at: https://bulbio.enu.kz/article/archive/view?id=study-of-the-biodiversity-of-wild-plants-of-the-genus-rosa-l-in-kazakhstan-and-their-molecular-genetic-identification-2. [in Russian]

182. Sarsen A., Saginova M., Aktayeva S., Akishev Zh., Kiribayeva A., Mussakhmetov A., Manabayeva Sh., Kakimzhanova A., Khapilina O., Akhmetollayev I., Khassenov B. DNA barcoding of rare and endangered plant species of the Republic of Kazakhstan // Eurasian Journal of Applied biotechnology. - 2022. - No. 2. - P. 19-24. DOI: https://doi.org/10.11134/btp.2.2022.3.

183. Raizer O.B., Khapilina O.N. Introduction to the *in vitro* culture of the medicinal plant *Rhaponticum carthamoides* // Collection of the International scientific and practical conference «Modern problems of biotechnology: from the laboratory researches to production», dedicated to the 80th anniversary of outstanding scientist, microbiologist, academician of Kazakhstan National Academy of Natural Sciences, the best teacher of the university - 2007, doctor of biological sciences, professor Zhubanova Azhar Akhmetovna, 4-5 June, 2021. - Almaty, 2021. - P. 43-46.

184. Method for obtaining adventitious shoots of safflower leuzea (*Rhaponticum carthamoides*) in *in vitro* culture // Authors: Khapilina O.N., Raiser O.B., Kotukhov Yu.A., Danilova A.N., Ramankulov Ye.M. - Patent of the Republic of Kazakhstan for invention No. 35836 dated September 09, 2022.

185. Nurtaza A., Karimova V., Magzumova G., Muranets A., Kakimzhanova A. Effect of pH, light intensity, and fertilizers on acclimatization of endangered rooted plantlets *Malus niedzwetzkyana* for restoration in nature // Journal of Plant Nutrition. - 2022. - P. 1-15. DOI: https://doi.org/10.1080/01904167.2022.2160756.

186. Nurtaza A.S., Dyussembekova D.A., Kakimzhanova A.A. Optimization of the medium-term storage protocol for the endangered *Malus niedzwetzkyana* // Bulletin of L.N. Gumilyov ENU. Bioscience Series. - 2022. - Vol. 139, No. 2. - P. 107-122. DOI: 10.32523/2616-7034-2022-139-2-107-122. Available at: https://bulbio.enu.kz/article/archive/view?id=optimization-of-the-medium-term-storage-protocol-for-the-endangered-malus-niedzwetzkyana-3. [in Russian]

187. A method for determining the complete genome of mitochondrial DNA of birds of the owl order // Authors: Zholdybayeva E.V., Shevtsov A.B., Amirgazin A.O., Akhmetollayev I.A., Chimiruk A.S., Mukanov K.K., Ramankulov Ye.M. - Application for a patent of the Republic of Kazakhstan for an invention No. 2022/0158.1 dated March 14, 2022.

188. Specific primers for identification of roe deer, saiga, maral and argali by the cytochrome b gene // Mukantayev K.N., Mukanov K.K., Tursunov K.A., Kanayev D.A., Ramankulov Ye.M. - Application for a patent of the Republic of Kazakhstan for an invention No. 2022/0127.1 dated February 28, 2022.

189. Mukantayev K., Kanayev D., Zhumabekova Sh., Shevtsov A., Tursunov K., Mukanov K., Ramankulov Ye. Optimization of polymerase chain reaction for the identification of roe deer, saiga, and siberian stag living in Kazakhstan // Veterinary World. - 2022. - Vol. 15. - P. 2067-2071. DOI: www.doi.org/10.14202/vetworld.2022.2067-2071.

190. Plant collection. National Center for Biotechnology. [Online] Available at: http://kzgenbank.com/AdminPlant/Index. Accessed: 31 January 2023.

БИОБАНКИ, КАК СПОСОБ СОХРАНЕНИЯ БИОРАЗНООБРАЗИЯ В УСЛОВИЯХ ПРОДОЛЖАЮЩЕГОСЯ СОКРАЩЕНИЯ ВИДОВОГО РАЗНООБРАЗИЯ ДИКОЙ ФЛОРЫ И ФАУНЫ

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АБСТРАКТ

На сегодняшний день, действия человека значительно изменили 75% поверхности Земли, и привели к беспрецедентному в истории человечества увеличению темпов утраты биоразнообразия. По данным Международного союза охраны природы и природных ресурсов за последние 500 лет в результате прямого или косвенного влияния антропогенного фактора вымерло 774 вида животных и 123 вида растений. В целях не допущения дальнейшей утраты биоразнообразия, в условиях продолжающегося «кризиса биоразнообразия», во всем мире, и в Казахстане в том числе, возникает необходимость надежного сохранения имеющихся генетических ресурсов растений и животных, в первую очередь редких и исчезающих видов. В этом отношении, на себя обращает внимание успешный мировой опыт использования специализированных биобанков дикой природы – организованных коллекций живых биоматериалов – для сохранения и восстановления популяций редких и исчезающих видов флоры и фауны. В статье представлены сведения о некоторых крупнейших биобанках и их значимость в решении данной глобальной проблемы. Приводится опыт казахстанских научных центров, и обобщаются результаты Национального центра биотехнологии, в области биобанкирования биоматериалов дикой флоры и фауны, в том числе редких и исчезающих видов.

Ключевые слова: биоразнообразие, сокращение биоразнообразия, сохранение биоразнообразия, флора, фауна, биобанк, биобанкирование.

БИОБАНКТЕР, ЖАБАЙЫ ФЛОРА МЕН ФАУНА ТҮРЛЕРДІҢ ӘРТҮРЛІЛІГІНІҢ ҮЗДІКСІЗ ТӨМЕНДЕУІ ЖАҒДАЙЫНДА БИОӘРТҮРЛІЛІКТІ САҚТАУ ТӘСІЛІ РЕТІНДЕ

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ТҮЙІН

Бүгінгі таңда адамның іс-әрекеті жер бетінің 75%-ын айтарлықтай өзгертті және адамзат тарихында бұрын-соңды болмаған биоалуантүрліліктің жоғалуына әкелді. Халықаралық табиғатты және табиғи қорларды қорғау одағының деректері бойынша соңғы 500 жылда антропогендік фактордың тікелей немесе жанама әсері нәтижесінде жануарлардың 774 түрі және өсімдіктердің 123 түрі жойылып кеткен. Жалғасып жатқан «биоалуантүрлілік дағдарысы» жағдайында, биоалуантүрліліктің одан әрі жоғалуына жол бермеу мақсатында, бүкіл әлемде және оның ішінде Қазақстанда, өсімдіктер мен жануарлардың, ең алдымен сирек кездесетін және жойылып бара жатқан түрлердің генетикалық ресурстарын сенімді сақтау қажеттілігі туындайды. Осы тұрғыда флора мен фаунаның сирек кездесетін және құрып кету қаупі төнген түрлерінің популяцияларын сақтау және қалпына келтіру үшін жануарлар дүниесінің мамандандырылған биобанктерін – тірі биоматериалдардың ұйымдастырылған коллекцияларын пайдаланудың табысты әлемдік тәжірибесін атап өтуге болады. Мақалада кейбір ірі биобанктер туралы мәліметтер және олардың осы жаһандық мәселені шешудегі маңызы келтірілген. Қазақстандық ғылыми орталықтардың тәжірибесі келтіріліп, Ұлттық биотехнология орталығының жабайы флора мен фауна биоматериалдарын, оның ішінде сирек кездесетін және жойылып кету қаупі төнген түрлерді биобанкілеу саласындағы нәтижелері жинақталады.

Түйінді сөздер**:** биоалуантүрлілік, биоалуантүрліліктің азаюы, биоалуантүрлілікті сақтау, флора, фауна, биобанк, биобанкілеу.