ISSN 1563-0218; eISSN 2617-7498

ӘЛ-ФАРАБИ атындағы ҚАЗАҚ ҰЛТТЫҚ УНИВЕРСИТЕТІ

ХАБАРШЫ

Биология сериясы

КАЗАХСКИЙ НАЦИОНАЛЬНЫЙ УНИВЕРСИТЕТ имени АЛЬ-ФАРАБИ

ВЕСТНИК

Серия биологическая

AL-FARABI KAZAKH NATIONAL UNIVERSITY

EXPERIMENTAL BIOLOGY

№3 (96)

Алматы
“Қазақ университеті”
2023

ISSN 1563-0218; eISSN 2617-7498

KazNU Science · ҚазҰУ Ғылымы · Наука КазНУ

ХАБАРШЫ

БИОЛОГИЯ СЕРИЯСЫ №3 (96) қыркүйек

04.05.2017 ж. Қазақстан Республикасының Ақпарат және коммуникация министрлігінде тіркелген

Куәлік № 16494-Ж

Журнал жылына 4 рет жарыққа шығады
(наурыз, маусым, қыркүйек, желтоқсан)

Журнал материалдарында ауқымды биологиялық мәселелері – ғылыми шолу, теориялық және эксперименталдық зерттеулердің нәтижелері қарастырылады.

Мақалалар биологияның келесі бөлімдері бойынша жарияланады: ботаника, биотехнология, биохимия, өсімдіктер физиологиясы, генетика және молекулалық биология, клеткалық биология, биофизика, адам және жануарлар физиологиясы, зоология және ихтиология, цитология және гистология, микробиология және вирусология.

Комитет по обеспечению качества в сфере образования и науки МОН РК

Crossref Content Registration

DIGITAL OBJECT IDENTIFIER

Национальный центр государственной научно-технической экспертизы

РОССИЙСКИЙ ИНДЕКС НАУЧНОГО ЦИТИРОВАНИЯ Science Index

ҚАЗАҚ УНИВЕРСИТЕТІ
БАСПА ҮЙІ

Жоба менеджері
Гульмира Шаккозова
Телефон: +7 701 724 2911
E-mail: Gulmira.Shakkozova@kaznu.kz

Компьютерде беттеген
Айгүл Алдашева

ИБ № 15125

Пішімі 60x84/16. Көлемі 21,0 б.т. Тапсырыс № 7045.
Әл-Фараби атындағы Қазақ ұлттық университетінің
"Қазақ университеті" баспа үйі.
050040, Алматы қаласы, әл-Фараби даңғылы, 71.
"Қазақ университеті" баспа үйінің баспаханасында басылды.

ШОЛУ МАҚАЛАСЫ

REVIEW ARTICLES

ОБЗОРНЫЕ СТАТЬИ

IRSTI 34.25.01 https://doi.org/10.26577/eb.2023.v96.i3.01

S.Zh. Khaydarov[1]*, E.D. Burashev[2]

[1]Al- Farabi Kazakh National University, Kazakhstan, Almaty
[2]«Research Institute for Biological Safety Problems»
of the Ministry of Health of the Republic of Kazakhstan , Kazakhstan, Almaty
*e-mail: logicalmind1984@mail.ru

THE SARS-COV2 EPOCH AND PROPER MANAGING STRATEGIES TO FACE THE CHALLENGES BOTH IN VIRAL RESEARCH AND TREATMENT

SARSCOV2 or COVID-19 caused 2020 the greatest pandemic since the end of WW1 and crippled the global healthcare and economy within a relatively short period of time. This article reveals a wide range of issues like vaccination issues by understanding the innate and adaptive immune responses and how tightly they are interconnected with each other. There are also to grasp the cellular and humoral parts of immunity and receptor binding recognition mechanisms, antibody neutralization, and antibody mediation both in adaptive and innate immunity to be discussed. The defense strategies of immunity are the objects along with clinical cases to discuss and how effective or not effective vaccination could be in a view of antibody role in creating immunity against this virus The problems of the viral genome are studied in an extent of functionality. There is also the thesis on antiviral treatment, strategies, and side-effects that could appear This review article will be interesting to those who are willing to design either antiviral research or develop the strategies for COVID-19 treatment and even vaccination as a drug design.

Key words: SARS-COV2, mRNA-genome, ORFs (open reading frames), structural proteins, non-structural proteins (np), virus classification, immunity, antiviral drugs, antibodies, IgGs, vaccination, and lethal mutagenesis. steroids.

С.Ж. Хайдаров[1]*, Е.Д. Бурашев[2]

[1]Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
[2]Қазақстан Республикасы Денсаулық сақтау министрлігі «Биологиялық қауіпсіздік проблемаларының ғылыми зерттеу институты», Қазақстан, Алматы қ.
*e-mail: logicalmind1984@mail.ru

SARS-CoV2 дәуірі және вирустық зерттеулер мен емдеудегі қиындықтарға қарсы тұру үшін дұрыс басқару стратегиялары

SARSCOV2 немесе COVID-19 2020 жылы 1-ші дүниежүзілік соғыс аяқталғаннан бергі ең үлкен індетті тудырды және салыстырмалы түрде қысқа уақыт ішінде жаһандық денсаулық сақтау мен экономиканы құлдыратты. Бұл мақала туа біткен және бейімделген иммундық жауаптарды және олардың бір-бірімен қаншалықты тығыз байланысты екенін түсіну арқылы вакцинация мәселелері сияқты мәселелердің кең ауқымын ашады. Сондай-ақ иммунитеттің жасушалық және гуморальды бөліктерін және рецепторларды байланыстыруды тану механизмдерін, антиденелерді бейтараптандыруды және адаптивті және туа біткен иммунитетте антидене делдалдықтарын түсіну керек. Иммунитеттің қорғаныс стратегиялары – бұл вирусқа қарсы иммунитетті құрудағы антиденелердің рөлі тұрғысынан вакцинацияның қаншалықты тиімді немесе тиімсіз болуы мүмкін екендігі және клиникалық жағдайлармен бірге талқыланатын объектілер Вирустық геномның мәселелері функционалдық дәрежеде зерттеледі. Сондай-ақ пайда болуы мүмкін вирусқа қарсы емдеу, стратегиялар және жанама әсерлер туралы тезис бар Бұл шолу мақаласы вирусқа қарсы зерттеулерді әзірлеуге немесе COVID-19 емдеу және тіпті дәрілік дизайн ретінде вакцинация стратегияларын әзірлеуге дайын адамдарға қызықты болады.

Түйін сөздер: SARS-COV2, мРНҚ-геномы, ORF (ашық оқу шеңберлері), құрылымдық белоктар, құрылымдық емес ақуыздар (np), вирус классификациясы, иммунитет, вирусқа қарсы препараттар, антиденелер, IgGs, вакцинация және өлімге әкелетін мутагенез. стероидтар.

С.Ж. Хайдаров[1*], Е.Д. Бурашев[2]
[1]Казахский национальный университет имени аль-Фараби, Казахстан, г. Алматы
[2]«Научно-исследовательский институт проблем биологической безопасности»
Министерство Здравоохранения Республики Казахстан, Казахстан, г. Алматы
*e-mail: logicalmind1984@mail.ru

Эпоха SARS-COV2 и правильные стратегии управления для решения проблем как в вирусных исследованиях, так и в лечении

SARS-COV2 или COVID-19 вызвали в 2020 году самую крупную пандемию со времен окончания Первой мировой войны и за относительно короткий период времени нанесли серьезный ущерб мировому здравоохранению и экономике. Эта статья раскрывает широкий спектр вопросов, таких как вопросы вакцинации, путем понимания врожденных и адаптивных иммунных реакций и того, насколько тесно они взаимосвязаны друг с другом. Также необходимо обсудить клеточную и гуморальную части иммунитета и механизмы распознавания связывания рецепторов, нейтрализацию антител и опосредование антителами как в адаптивном, так и врожденном иммунитете. Стратегии защиты иммунитета являются предметом обсуждения наряду с клиническими случаями и того, насколько эффективной или неэффективной может быть вакцинация с точки зрения роли антител в создании иммунитета против этого вируса. Проблемы вирусного генома изучаются в степени функциональности. Существует также тезис о противовирусном лечении, стратегиях и побочных эффектах, которые могут возникнуть. Эта обзорная статья будет интересна тем, кто готов спроектировать противовирусные исследования или разработать стратегии лечения COVID-19 и даже вакцинацию как дизайн лекарства.

Ключевые слова: SARS-COV2, мРНК-геном, ORF (открытые рамки считывания), структурные белки, неструктурные белки (np), классификация вирусов, иммунитет, противовирусные препараты, антитела, IgG, вакцинация и летальный мутагенез. стероиды.

Introduction

Viruses are quasi-organisms that strongly depend on the cell host and on their replication – transcription – translation machinery. Viruses can infect both domains: the eucaryotic as well as procaryotic organisms (phages). It is really difficult to classify them as true parasites or pseudo parasites. Viruses are the smallest organisms with compact genomes enveloped mostly by capsid proteins that can operate not only DNA as a genetic footprint but easily mediate RNAs thanks to various types of transcriptase. named for their corona-shaped appearance in the electron microscope.

Severe acute respiratory syndrome-associated coronavirus 2 (SARS-COV2) is an acute respiratory infection caused by the SARS-CoV-2 virus, which belongs to the coronavirus family and genus Betacoronavirus. Single stranded positive-sense RNA virus (ssRNA$^+$). Variants of the SARS-CoV-2 coronavirus are continually emerging due to the ongoing transmission and evolution of this virus around the world. Since the pandemic was first declared by the World Health Organization (WHO) in March 2020 (1), B.1.17 (alpha), B.1.351 (beta), P.1 (gamma), B.1.617.2 (delta), and B.1.1.529 (omicron) [2–5]. **Kazakhstan had** the first case of human infection with coronavirus COVID-19 **Registered** in March 2020 [6]. According to the Johns Hopkins University database, as of January. In October 2022, the Republic of Kazakhstan had **1,484,400** registered confirmed cases**,** of which **19,052** died [7].

The coronavirus or SARS-COVID2 or COVID-19 belongs to the Coronaviridae family that are enveloped, positive-sense single-stranded RNA viruses [8]. The SARS-COVID2 consists of viral genome: fourteen open reading frames (ORFs), two-thirds of which encode sixteen nonstructural proteins (nsp 1–16) that make up the replicase complex [9,10]. The rest encodes the nine accessory proteins (ORF) and four structural proteins: spike (S), envelope (E), membrane (M), and nucleocapsid (N), of which Spike enables the SARS-CoV entry into cytosol of target cell [11]. As any virus of these type, the Spike protein is the most variable and due to this capacity, the SARS-CoVs are capable to penetrate the various cell membrane types of mammals [9].

There are approximately 30,000 nucleotides in RNA; encoding 11 proteins. Retroviruses have caused a lot of harm over the years, and they're now a major threat to human well-being. These are the viruses that belong to the family retroviridae and typically carry their genetic material in the form of RNA. The genetic material of their hosts is in the form of DNA. Retroviruses are named after an enzyme called reverse transcriptase (RT). RT is responsible

for copying genetic information from one virus particle to another. The most known viruses of that family are Lentivirus (human immunodeficiency virus (HIV) and SARS-COV2 (COVID-19) [12]. It is important to mention that virus infections serve the aim to magnify the viral genome and assemble new viral units to be able to invade other surrounding cells and tissues, mostly such processes are carried out lethally to a cell or even to whole tissue systems like lungs. Thus, it is very difficult to classify any viral 'organism' as a parasite whose middle-term and long-term survival correlates with the host's wellbeing. 'The side effect' of viral infections as inflammatory or less obvious clinically distinguishable signs is the integration into the cell genome due to enzymatic activity of viral RNA of various tissue types; this in term causes various types of critical mutations in renewable tissues having a sometimes the devastating disease like pneumonia, renal failure or other chronic, irreversible diseases. The negative effect on the global healthcare state on the population which was exposed to the COVID-19 pandemic is only about to experience in near future. So, the harm potential of this type of viruses are never to neutralize completely and underestimation of its pandemic capacities is the highest priority to avoid of any authority [13-16].

SARS – stays for severe acute respiratory syndrome. The majority of those diagnosed with SARS were healthy adults between the ages of 25 and 70. Children under the age of 15 have been the victims of a few alleged SARS cases. SARS typically has an incubation period of 2 to 7 days, but it can last as long as 10 days. People who have an illness that meets the current WHO case definition for probable and suspected cases of SARS have a case fatality rate of around 3%. Since COVID-19 infection became the subject of pandemic in 2020, United Nations considers this virus and related diseases to it as a global problem for health care systems worldwide. The consequence of SARS-COVID 2 infection could lead to chronic, long term health issue and sometimes to some extent of medical and mental impairment. In many countries the hospitalization rates reached the critical levels so many infected ones were forced to stay at home and get treated far from inpatient wards. Pneumonia is one of the most widely spread health condition among COVID-19 patients and needed to be separated according to the severity of the illness progress and lung damage surface. The more damage occurred the less oxygenation gained via lung breath, so many patients with acute lung damage were heavily dependent on artificial lung ventilation apparatus in intensive care. It was crucial to monitor whether the pneumonia patients with COVID-19 infection were regularly assessed for bacterial infection and try to detect bacterial co-infection and if a need occurred also the antibiotic treatment strategy would have been implemented to avoid pulmonary collapse [17].

The SARS-CoV-2/human/KAZ/B1.1/2021 strain

Strain SARS-CoV-2/ human/KAZ/Britain/2021 consists of 29,815 nucleotides and belongs to lineage B.1.1.7, according to the Pangolin COVID-19 database [18]. The SARS-CoV-2/ human/KAZ/B1.1/2021 strain was obtained from the Scientific and Practical Center for Sanitary and Epidemiological Expertise and Monitoring branch of the Republican state enterprise on the right of economic use, National Center for Public Health, Ministry of Health, Republic of Kazakhstan. Nucleic acids were extracted from the test sample using a *QIAamp* viral RNA minikit (Qiagen, Germany) according to the manufacturer's protocol. Reverse transcription was performed using the *SuperScript* VILO cDNA synthesis kit (Invitrogen, USA). For amplification to cover the entire genome of the virus, 65 primer pairs were designed using the online Primer-BLAST program (http://www.ncbi.nlm.nih.gov/tools/primer-blast) in order to generate amplicons ranging in size from 600 to 750 bp and tiled to overlap by about 100 bp. These amplicons were generated by PCR and visualized by 1.2% agarose gel electrophoresis (Sigma, USA). PCR amplicons were purified using the Pure Link PCR purification kit (Thermo Fisher Scientific, USA). Purified amplicons were sequenced using the Sanger dideoxy method using an AB3130xl (Hitachi Applied Biosystems) 16-capillary genetic analyzer autosequencer with the Big Dye Terminator 3.1 cycle sequencing kit (ABI, Foster City, CA, USA). Raw chromatograms were collected using *Sequencher* version 5 (Gene Codes Corp.) [18].

SARS-COV2 and its molecular feature

The viral Spike has an S1/S2 polybasic cleavage site that is proteolytically cleaved by cellular cathepsin L and the transmembrane protease serine 2 (**TMPRSS2**), and a receptor-binding domain (RBD) that mediates direct contact with a cellular receptor, angiotensin-converting enzyme 2 (ACE2) [8,19,20]. **ORF1a** and **ORF1b** are translated into viral replicase proteins as soon as the viral genome is inserted into the cytoplasm of the host

and cleaved into individual nsps (via host and viral proteases: PL^{pro}); The RNA-dependent RNA polymerase (nsp12, which is derived from ORF1b) is formed by these [21]. The components of the replicase move the endoplasmic reticulum (ER) into double-membrane vesicles (DMVs) at this location, which makes it easier for the virus to replicate genomic and subgenomic RNAs (sgRNA). The latter is turned into accessory or auxiliary proteins as well as viral structural proteins, which make it easier for the virus to form particles [22,23]. In conclusion, the secondary part of genome encodes the nine accessory proteins (ORF) that ensures viral mRNA genome to be translated, it is worth to mention that the replicase for accessory protein production is significantly bigger than the primary one. In addition, the four structural proteins: spike (S), envelope (E), membrane (M), and nucleocapsid (N), of which Spike enables the SARS-CoV entry into cytosol of target cell [Perlman, S., et al, 2009]. ORF1a and ORF1b are translated into viral replicase proteins as soon as the viral genome is inserted into the cytoplasm of the host and cleaved into individual nsps (via the host and viral proteases: PL^{pro}); The RNA-dependent RNA polymerase (nsp12, which is derived from ORF1b) is formed by these [Perlman, S., et al., 2009]. The latter is turned into an accessory or auxiliary protein as well as viral structural proteins, which make it easier for the virus to form particles [Snijder, E.J. et al., 2006, Wu, H.-Y. et al., 2010]. Unlike the HIV virus, which has a complicated capsid structure with sophisticated (negatively charged $dNTPs^-$ permeable) pores that are permeable for negatively charged dNTPs which serves as building blocks for the formation of RNA-host-DNA-hybrid. The SARS-COVs do not possess such protection from hostile enzymes inside the host cells [24]. So, the secondary part of genome encodes the nine accessory proteins (ORF) that ensures viral mRNA genome to be translated, it is worth to mention that the replicase for accessory protein production is highly important to be integrated into host genome or to let virus to reproduce itself.

The retroviruses (Retroviridae) family and their common features

There are six common characteristics that unite all retroviridae to one

1. Despite having DNA-dependent replication steps, retroviruses contain RNA as their genetic material.

2. Replicates via reverse transcription thanks to the presence of reverse transcriptase enzyme.

3. Due to the presence of the enzyme reverse transcriptase, reproduces via reverse transcription.

4. Integrase moves the viral DNA into the nucleus of the cell, where it is randomly and covalently integrated with the host genome.

5. Gene sequences like viral oncogenes and proto-oncogenes are found in retroviruses that are capable of rapidly transforming host cells into their needs.

6. Immune deficiencies, cancer, and neurological conditions can all be brought on by human retroviruses.

Structure, genome, and proteins

The typical retrovirus structure is **enveloped,** spherical to pleomorphic in shape, and they have diameter of 80–100 nm. The different genuses of retrovirus virions have diverse morphology, but they have their same **virion** component, which includes the outer envelope coat, two copies of the genetic material, and the viral proteins. **Envelope** consists of lipids that are obtained from the host plasma membrane during budding process and the **glycoprotein** such as **gp120** and **gp41** in case of HIV for example [25]. The outer lipid bilayer of the retroviral envelope protects it from the extracellular environment, aids in the entry and exit of host cells through endosomal membrane trafficking, and allows it to simply enter the host cells by fusing with their membranes are the **three distinct functions** of the retroviral envelope. A retrovirus has a **monopartite, linear, dimeric, ss RNA (+) genome** that is between 8 and 10 kilobases long and has a 5'-cap and a 3'-poly-A tail. Between the R regions are flanks for the group-specific gene (gag), pol, pro, and envelope (env) genes. The U3, R primer binding site (PBS), and U5 regions make up the 5'-long terminal repeats (LTRs). A polypurine tract (PPT), U3, and R regions make up the 3' end. During reverse transcription, a brief repeated sequence at each end of the genome is used to guarantee correct end-to-end transfer in the growing chain. On the other hand, U5 is a brief exceptional arrangement that sits between PBS and R [26]. The 18 bases in the PBS correspond to the tRNA primer's 3' end. The untranslated leader region known as the L region indicates how genome RNA is packaged. The gag, **protease**, pol, and env proteins make up the retroviral protein. The gag is the primary **retroviral** structural protein that orchestrates the majority of viral assembly processes. The interactions with the three gag subdomains—matrix (MA), capsid (CA), and nucleocapsid (NC)—effect the **majority of**

these assembly steps. While the gag subdomains are structurally distinct, their functions in the viral assembly process overlap [27,28].

Global COVID-19 spread and clinical consequences

According to the WHO dashboard, more than 6.4 million people worldwide died from COVID-19 by the August 18, 2022. The omicron strain has been diagnosed within over 590 000 000 people worldwide, a brand-new variant that appeared toward the end of November 2021, is now the most common strain worldwide and has contributed to the ongoing rise in several nations. In a number of high-income nations, vaccination is significantly reducing the number of cases and hospitalizations, but a lack of universal access to vaccines leaves many populations vulnerable. Even in people who have been vaccinated, there are still questions about how effective and for how long the current vaccines against Omicron and other new SARS-CoV-2 variants are. There is still a need for more efficient COVID-19 treatments as a whole. The COVID-19 pandemic, as well as the avalanche of research and false information, has shown how important it is to have reliable, easily accessible, and frequently updated living guidelines so that new findings can be understood and clear recommendations for clinical practice can be provided [29].

Apart the severe acute respiratory syndrome and acute respiratory destress syndrome (ARDS) causing serious health impairment, COVID 19 is also capable to cause post COVID 19 health conditions like cognitive impairment states Other neurological and non-neurological deficits, such as **fatigue** and **mental health** symptoms, may overlap or cluster with cognitive deficits. In conditions following COVID-19, fatigue or exhaustion manifests as severely depleted systemic energy levels that are unrelated to activities or exertion and unaffected by usual rest or sleep. The quality of one's life, physical and cognitive function, social participation, and employment are all negatively impacted by fatigue. The core symptoms of depression following COVID-19 include a persistent low mood and sadness for at least two weeks and a markedly diminished interest in enjoyable activities. Depression can also cause problems sleeping, changes in appetite, fatigue, thoughts of self-harm or suicide, and feelings of worthlessness. Anxiety symptoms can include restlessness, racing or uncontrollable thoughts, difficulty concentrating, a sense of dread, difficulty sleeping, a lack of appetite, and irritability [30].

Innate Immunity and SARS-COV2

The issues of the innate immune system are a very complicated matter and deserve detailed view in a distinct paper. However, within this article, it is important to include innate immunity to grasp the real pathogenic nature of COVID-19. Innate immunity in humans is the first defense line that helps our body to clear and distinguish the viral invasion and start to respond to it. Human cell immunity mostly heavily relies on two types of innate immunity: The macrophages that absorb the pathogen and tend to disintegrate viruses inside and neutrophils that are able to initiate the cell death to stop the virus from spreading, because one single by SARS-COV 2 infected cell is capable to produce up to 10.000 viral units until it experiences the cellular burst [31].

Limiting viral entrance, translation, replication, and assembly, assisting in the detection and extermination of infected cells, and coordinating and speeding up the development of adaptive immunity are all functions of innate immune responses. Pathogen-associated molecular patterns (PAMPs) are recognized by cell surface, endosomal, and cytosolic pattern recognition receptors (PRRs), which then cause inflammatory reactions and programmed cell death (neutrophils) to prevent viral infection and encourage clearance [32]. The COVs (coronaviruses) developed innate immune system suppressors thanks to ORFs (ORF3 and 3CL) that are responsible for accessory protein encoding that sustains the viral replication and translation types of machinery and mitigates the antiviral response as an evasion strategy [33]. The cyclic GMP-AMP synthase (cGAS) is a STING (Stimulator of interferon genes) signaling pathway that gets activated by cytoplasmic DNA. cGAS-STING is the protective cascade-driven reaction that significantly limits both DNA and RNA viruses during the active phase of infection [34-37]. The SARS-COV 2 disintegrates the organelles' unity and one of its victims is mitochondria. Mitochondria get seriously damaged and their DNA freely swims in the cytosol by which the cGAS gets activated to fight the invaders' genome [38]. Last but not least, it makes sense to mention the cellular components of innate immunity against viral infections. Macrophages, monocytes, dendritic cells, neutrophils, innate lymphoid cells (ILCs) such as natural killer (NK) cells, are capable to resists virus invasion with a help of PRRs (Pathogen resistance receptors) that recognize PAMPs or damage-associated molecular patterns (DAMPs) to induce inflammatory signaling

pathways and immune responses [39]. To sum up this chapter, SARS-COV-2 or COVID 19 like other COVs and retroviruses has an extremely high potential to invade a cell and replicate itself fast and effectively enough to overcome the innate immunity and sometimes to escape the B-cells antibody formation. Adaptive immunity faces also high challenges due to the high variability of spike – proteins that enable it to form new strains with novel defensive evasion strategies. The virus is capable to cause serious health and life-threatening conditions to almost all groups of people worldwide. It is able to make its survival effective in a host cell thanks to accessory proteins and thanks to rapid integration into replication and translation cell machinery and actively defending the positive RNA-original genome. The virion rate production is well synchronized by the assembly process allowing COVID-19 to produce its copies in an average amount of 10.000 units per single eukaryotic cell, allowing it to achieve high infection rates among human and animal populations. So, we can surely say that COVID 19 is still very dangerous pathogenic organism whose potential is not fully understood.

Adaptive immunity and SARS-COV2

Viruses are in capsid coated relatively small genome carrying (mRNA or DNA) 'nano-living-being' with so called ORFs (open reading frames – the viral genome sequence) when they enter the host cytosol [40].

Many times, in medical history the viral infections showed the high potential of increasing their population in host cells. The virus load speed is extremely important in viral spread before the secondary immune response occurs that definitely will be able to cap any viral threat spreading. The corona viruses can reproduce their copies up to 10.000 viral particle per an infected cell [41].

The occurrence of repetitive, i.e., monotonically repeating, letter sequences is a characteristic that is extremely baffling in many genomes of higher organisms and some viruses, the latter to a very limited extent. The human genome of $3.2x10^9$ hereditary letters utilizes under 2% of those letters to store the data of working qualities, to the extent that we know up until this point. Sequences of letters that are repeated millions of times make up well over 40% to 50% of the genetic letters that are housed in our 46 chromosomes. The purpose and significance of these repetitions are unknown to us [42].

However there some theories that suggest that the human genome is so profound with a purpose, a defensive way to secure the vital genes or group of genes, to keep them relatively stable against mutations or exposures that cause various mutations that interferes or even blocks the essential expressions, and maybe also to withstand many viral genome integrations both in replication and translation processes as well.

The following options were utilized when vaccination options were highly specialized: vaccination with viruses that have been killed (inactivated) and are no longer able to reproduce or with parts of the viruses. Accidents also occurred during the early stages of vaccine development, primarily as a result of incomplete inactivation or contaminated vaccine derived from virus-infected cells. One well-known instance is the contamination of an early preparation for the polio vaccine with the rodent tumor virus SV40, a previously unknown simian virus. Fortunately, this accident did not result in any problems: there is no evidence that receiving the contaminated vaccine increased the risk of tumor development [43].

The safest vaccines available today are the recombinant virus vaccines produced by using genetic engineering technologies. Since the virus genes whose products are responsible for antibody production are isolated from the virus genome. The proteins of these viral genes are then expressed in bacteria or in yeast, the viral proteins synthesized in this way are then purified and used as a vaccine. These vaccines are virus free [44].

Innate immunity – the primary response and cell defense.

The immune system consists of specific as well as unspecific mechanisms that fight viral invasion with various efficiency as well as time reaction. There are unidentified antiviral compounds in the mucous membranes of the inner surfaces. While some defense cells can kill viruses by phagocytosis (eating), this method isn't very effective without supporting mechanisms. Some viruses, like HIV, have the capacity to grow in the macrophages that phagocytize them, allowing them to get past this antiviral defense The generation of interferons, or molecules that stop virus replication and spread, is a very intriguing and common defense mechanism. The formation of these proteins occurs far earlier than the development of antiviral antibodies following viral infection. The interferon α, β, γ are currently the most well-known [45].

Table1 – The interferon types and cells that generate them as unspecified auxiliary virus-fighting agents in humoral immunity.

Interferon	Functions and cells
interferon α	induced mainly in leukocytes by foreign cells, virus-infected cells, tumor cells, or virus envelopes.
interferon β	induced by viruses and foreign nucleic acids in many different cells of the body.
Interferon γ	formed by T lymphocytes when foreign proteins enter the body.

The cellular unspecified immunity consists of macrophages, basophils, and natural killer T-cells.

NKTs and NKs, also known as natural killer T-cells, are a class of leukocytes. White blood cells called leukocytes help the body to fight various infections. Less than 1% of the body's lymphocytes are these uncommon cells. Are T-cells specialized or generalized? The only T-cell subset regarded as non-specific is natural killer T-cells, which facilitate communication between the non-specific immune system and the specific immune system. These cells take direct aim at microbial intruders [43].

Leukocytes called basophils have previously been misinterpreted. Scientists found it difficult to study these cells because of their short lifespans of one or two days. According to recent studies, basophils are the only white blood cells that express histamine and congregate in connective tissues. The com-ponent histamine is what causes allergy symptoms to manifest in the body. Basophils have the ability to eliminate cancer cells in the early stages before they pose a threat to the body [42].

The immune system's warning systems and so-called 'missile defenses' are called macrophages. Macrophages will raise the alarm by releasing cytokines into the circulatory system when they find a pathogen. When a cell surrounds and kills another cell or organism, the process is known as phagocytosis [44].

Neutrophils are also innate immune cells which also have small life span. Neutrophils are the first cell type to be drawn to inflammatory areas. They can then change phenotypic and produce a number of subpopulations with various cell functions. Additionally, neutrophils can interact with other immune cells directly or indirectly through cytokines and chemokines to modify innate and adaptive immune responses. We still don't fully comprehend these neutrophil subpopulations, but the instances that follow make it very evident that they do exist as real inflammatory subsets [44].

To sum up, the innate immunity is comprehensively complicated, and the humoral immunity is tightly interconnected with cellular part. Some leukocytes have multiple functions with in different levels. The innate immunity is capable to face almost any microbial challenge with various molecular induceable arsenal that sustains integrity and healthy state.

Vaccination

The adaptive immunity consists both of cellular and humoral (antibodies) particles that helps to neutralize the pathogen in short as well as long term perspectives due to formation memory cells. The adaptive immunity requires time to select and expand the virus-specific cells from the large variability pools of naïve B cells and T cells for further specification in molecular structures and sequences – priming.

Table 2 – Shows the consistent adaptive immunity with cellular and humoral part with aduaquate functions with high specifity and efficassy when innate immunity get overwhelmed with infectiom

Acute immunity	**Humoral**	**Cell**	**Cell**	**Cell**
	Antibody	$CD4^+$ T-cells	$CD8^+$ T-cells	B-cells
Functions	Identification of epitops of intrest, forms cellular memory	Have Helpers and Effectors activities	Kill the infected cells	Production of Antbodies

When SARS-COV2 infection proceeds, the viral genome rapidly gets integrated into host protein and replication machinery, the race with time starts and the innate immunity has to withstand with viral load till the adaptive immunity get proliferated and properly differentiated to charge already circulating virions and virus seized cells. The innate immunity tries to manage the viral infections by its own by activating the immune response type I and type III interferons that are supposed to delay the intercellular viral infections and till the viral load gets the critical values and starts to alarm dendritic cells to call the adaptive immunity to help [43.].

In average situations of SARS-COV2, a so called 'simple' model appears to cause the temporal

delay in innate immunity response which is enough to launch the asymptomatic infection that occurs roughly in 40% percent of COVID-19 cases and the T-cells with antibodies get formed relatively rapidly to control the occurred viral load and infection rates [44.]. The presence in blood stream of COVID-19 patients the T-cells and antibodies in sufficient amounts is signaling that the positive resolution of COVID-19 took place [45.].

To sum up, the timely and accurately activated the adaptive immunity with humoral as well as cellular response brings the resolution from severe COVID-19 infection and its clinical outcome. Thus, ignoring the importance of innate immunity that charges the first viral invasion with specific delaying responses on viral replication as well as translation can grant a vital time to withstand rapidly increasing viral load. And thankfully, a significant part of COVID-19 infections run in asymptomatic manner with enough T-cells and secreted by B-cells – Antibodies. So, to ensure such scenario the innate and adaptive immunity must balance between magnitude levels and inpatient time. Ideally, the innate immunity holds the primary viral invasion long enough not only to control the viral load increase with the same immune intensity but also to provide time for B-Cell and T-cells to be released in blood stream from the lymph nodes. However, the clinical practices faced with relatively ineffective innate immunity so the viral load got significantly higher than the primary defense could withstand but then the adaptive immunity was in average capable to clear the COVID-19 infection. In severe cases the viral load was not even opposed by innate immunity response or the reaction was so excessive (The cytokinin shock – overreaction of macrophages and neutrophiles) that it only harmed and benefited the further viral invasion. In bad situations, the time line of innate immunity overlaps with adaptive and does not stop the exponential growth of virus production and viral load seriously dominates over the number of antibodies and the T-cells magnitude levels so their amount is critically low to fight effectively both the intercellular circulation of virions and infected cells as well causing serious health damage or even death.

Immunoglobulins (IgGs, IgA and IgM)

The vaccination is a process in which it is tried to cause the immune response as save as it only possible and as antigen – the response causing particle could be applied in our case alive but weakened viruses, viral structural proteins like spike protein or even based on mRNA (viral genome) vector vaccines and etc. There are always risks to face during the vaccination despite the multiple clinical approval procedures and trials.

Table 3 – Shows five main immunoglobulin or antibodies (Ab) classes properties and importance. GI*- gastrointestinal Secretions, GU*- glucagon secretion.

Class	Percentage in total	Features and purposes
IgG	~75%	Found in blood and lymph, active against Bacteria and their metabolites (toxic agents), viruses, increases **phagocytosis,** cross placenta and **active in second response**
IgA	~15%	Saliva, tears, bronchial, GI, prostatic, and vaginal secretions. Provides the local protection on surfaces, has anti-viral potential Prevents the absorption of antigens from food and protects against the **respiratory infections** as well as against GI and GU infections
IgM	~10%	Found in blood and lymph, levels go down during stress, the first antibody produced during t**he primary response, high** concentration in initial stage of infection. The level of IgM reduces within one week.
IgE	~less than 1%	Found in mast cells and neutrophils, involved instant hypersensitive response.
IgD	~less 0.1%	Found in blood and lymph, unknown functions

The B-cells and antibodies are the major players of adaptive immunity in antigen of interest triggered immune response – called seroconversion in a hope to get vaccination or so-called memory cells. The primary response or seroconversion leads within 5 days the increased amount of IgM – titter, and IgG-titters appears first only after 14 days, so the increased amount IgG demonstrates either the past infection or the vaccination active event [42].

The brightest correlations of seroconversion on IgG illustrated the Spike and Nucleocapsid viral structure protein. The clear tendency was

shown SARS-COV2 was neutralized by receptor binding domain (RBD) with over 90% frequency in COVID-19 cases antibodies [46]. Spike IgG, IgA and IgM start to develop simultaneously during the viral infection [47]. Receptor binding domain (RBD) of Spike protein of SARS-COV2 is the mile stone of virus neutralizing dogma both in vaccine or medicine design, to deny such important aspect of viral defense is not productive, however the virus neutralization follows also outside the cells thanks to antibodies, the infected cells can be also killed directly by antibodies [48].

Almost complete COVID-19 neutralizing antibodies run the seroconversion in Spike range [49]. In this extent it makes sense to claim that almost all neutralizing antibodies come from naïve or virgin B-cells, not from pre-existing cross-reactive memory B-cells [50]. As a result, the epitopes which are capable to neutralize the SARS-COVID-2 on RBD domain, especially those who corresponds highly likely to the ACE2 receptor binding footprint (or ACE2 – like repertoire which mostly found in the lung tissue) strives about to be effectively immunogenic and easily detected by antibodies. At the same time, it would be fair to state that the substantial fraction among recovered patients from COVID-19 of antibody titter is considerably low [51]. It means that most effective period of immunogenic response lasts relatively short and secondary response takes time to be activated. Thus, the most active period of viral fighting is timely limited and so-called memory cells are built to stand against repeated infection and viral load exposure and of course till the next B-cell proliferation takes place.

Fc-receptor-associated protective immunity against SARS – COV2 (lung tissue)

Many studies showed that humoral responses and neutralizing antibodies alone were not enough to overcome successfully the COVID-19 viral infection, especially, in severe cases or even among deceased patients [52]. Despite the fact that there is still no direct evidence that Fc-mediated (dependent) effector activity is responsible for effective protective immunity against SARS-COV-2, some studies showed that deceased patients had very reduced Fc-dependent antibody effector activity [53].

A variable fragment (Fab) that mediates antigen binding and a constant fragment (Fc) that mediates downstream effector functions by interacting with Fc-receptors on (innate) immune cells or with C1q, the recognition molecule of the complement system, are the two structural regions that make up an antibody. Through a number of immune effector mechanisms, such as **antibody-dependent cell-mediated cytotoxicity (ADCC)** and antibody-dependent cellular phagocytosis, the contact with Fc-receptors can cause the death of virus-infected cells (ADCP). Complement-dependent cytotoxicity may result from complement-mediated antibody activation (CDC). Complement activation and Fc-receptor interactions can both have a variety of immunomodulatory effects [54].

The Fc domain of antibodies that are linked to viral proteins on the surface of virus-infected cells activates Fc gamma receptors (*FcRs*) on innate effector cells, inducing ADCC. Infected cells are killed as a result of this interaction, which causes the release of cytotoxic granules that contains perforins and granzymes [55]. Natural killer (NK) cells, neutrophils, monocytes, and macrophages are just a few of the innate effector cells that can engage in ADCC in a lab setting. However, NK cells, which solely express *FcRIIIA*, are believed to be the most significant in vivo contributors to ADCC. ADCC has been acknowledged as a crucial mode of action for therapeutic monoclonal antibodies (mAbs) that target tumor cells in the field of tumor immunology [56].

The assimilation of virus-antibody complexes or virus-infected cells that are coated with antibodies by phagocytic cells is known as ADCP or opsonophagocytosis. Phagocytic cells such as monocytes, macrophages, neutrophils, eosinophils, and dendritic cells (DCs) express *FcRI, FcRII*, and *FcRI*, which are all capable of mediating immune complex absorption. The type of cell, stage of development, and degree of FcR expression all affect how effectively effector leukocytes can phagocytose. As a result of ADCP, immune complexes are eliminated from the infected host by being transported to lysosomes where they are processed for antigen presentation on Major Histocompatibility Complex (MHC) molecules on the cell surface. It's interesting to note that certain viruses have taken use of this method to infect phagocytes by evading lysosomal breakdown. However, this mechanism is mostly induced during the bacterial infection, in the matters of viral infections, the ADCP needs to be clarified [57].

The complement system has several parts and uses various paths to activate its effector functions. Complement plays a crucial role in antibody-mediated defense against viral infection, according to studies in complement-deficient mice. There

have been numerous proposed methods for this complement-enhanced defense. So, first of all, the steric hindrance of bound antibodies may increase when complement components are fixed to virus-antibody complexes to directly enhance the neutralization capacity of antibodies [58]. Another potential mechanism is complement-dependent opsonization of virus-infected cells, which results in phagocyte uptake later on. In an in vivo mouse model, complement has additionally been demonstrated to enhance the CD4(+) T cell response in the presence of respiratory syncytial virus (RSV) immune serum [59-64].

To sum up, complement activation and Fc-receptor interactions can have a variety of immunomodulatory effects on different levels. The Fc domain of antibodies that are linked to viral proteins on the surface of virus-infected cells activates Fc gamma receptors (FcRs) on innate effector cells, inducing ADCC. Natural killer (NK) cells, neutrophils, monocytes, and macrophages are just a few of the innate effector cells that can engage in ADCC in a lab setting. Phagocytic cells such as monocytes, macrophages, neutrophils, eosinophils, and dendritic cells (DCs) express *FcRI, FcRII*, and *FcRI*, which are all capable of mediating immune complex absorption. As a result of ADCP, immune complexes are eliminated from the infected host by being transported to lysosomes where they are processed for antigen presentation on major histocompatibility complex (MHC) molecules on the cell surface. There have been numerous proposed methods for this complement-enhanced defense. Another potential mechanism is complement-dependent opsonization of virus-infected cells, which results in phagocyte uptake later on.

Modern methods to produce immune modulators and SARS-COV2

Viruses are special ‘microorganisms’ that need to be treated specially, not like Bacteria or Protista or even various parasite worms. Virus infections are usually swift, aggressive and extremely virulent. The successful infection proceeds successfully if the virus concentration alternatively viral load is high enough to cause the infection that is why HIV for example can be pestilent if the infection runs through blood or in utero from mother to child. In other ways HIV-positive person does not demonstrate the social threat, because the virus load in his fluids like salvia or sweat is not sufficient to trigger HIV-infection. SARS-COV2 in striking contrast can infect airborne in the person-person way relatively easy. Alone this difference demonstrates clearly how complicated is the pathology and biological nature of viral infection and in order to prevent viruses to succeed the modern scientific idea should offer new methods to modulate, reinforce or improve the protective immunity against viral invasion. In this article we consider two sides of the viral nature, one how effectively fight them and how to use them as drug delivery system. The polyclonal technologies in antibody production have some weighty advantages. First and foremost, it is price, with reasonable and rational immunization with properly prepared antigen can produce enough number of antibodies from blood serum by protein purification methods that were proven by time. The physical methods mostly based on **photometrical methods such as ELISA or flow cytometry and electrochemical, optical or piezoelectric immunosensors (biosensors).** However, despite the solid advantage, polyclonal antibodies have low level of sensitivity on particular antibodies and lower specialization on particular reaction or antigen of interest, instead it can react on various reactions and epitopes in some extent it could be considered as a reasonable upper hand in methodology. The monoclonal antibodies are powerful tool both in research and in clinical approach as reliable agent, nonetheless, is very expensive method to produce highly specified antibodies, as laboratory animals mostly used rabbits for advantageous reasons for instance, still an animal must be killed to get plasma cells or lymph nodes. Thus, recombination technologies became the main headliner with a help which there is no need to kill the lab animal, by collecting blood samples and get from the blood centrifugation **the PBMC** (peripheral blood of mononuclear cells) to isolate the B-cells and their m-RNA. This technology allows us to magnify the production rates of monoclonal antibodies through recombination for yeast, phage etc. essays. The hybridoma technology offers the immortality potential of adenoma cell to produce almost unlimited rates of monoclonal antibodies in HAT-media.

Corona virus belongs to IV-group of viruses of Baltimore classification. Corona virus infection can be easily neutralized by conventional IgG produced by B-cells as secondary immunity response or by eventually by monoclonal heavy chain nano antibody (VHH) derived from the blood of camelids or sharks, still the role of virus neutralization agent must be confirmed clinically.

Polyclonal antibodies

Polyclonal antibodies or immunoglobulins refer to a mixture of IgG-molecules which are secreted against particular; each antibody or IgG (IgG_2-IgG_4) recognizes different epitopes that brings the further polyclonal properties for IgGs:

- They are produced by multiple clones of B-white blood cells
- Heterogeneous antibody population
- Interaction with various epitopes on the same antigen of interest
- Increased likelihood for cross reactivity for similar antigens
- *'Lot to lot'* or side by side variability
- The expense of production is relatively reasonable.

In laboratory allowed condition work with living organisms, polyclonal antibody production represents the simplest way in comparison to other more sophisticated ways like monoclonal approach [65]. Since our work bases and will be based in the future in SARS-COV2 pathogens derived antigen, there will be no need to worry about to add adjuvants to avoid hypersensitive reaction or response or development of tolerability.

The most important part of polyclonal antibodies production is the animal choice, mostly rabbits are the most convenient polyclonal antibody producer in terms of maintenance and produced number of antibodies [66]. Polyclonal antibodies can be arranged also against whole microorganisms; their planning has also been detailed utilizing rabbits immunized by peptides such as two parts – bacteriocin and pediocin PA-1 from *Pediococcus acidilactici* conjugated to the carrier protein keyhole limpet hemocyanin [67] and parts of human chaperonin 10 bound to ovalbumin [68]. Small molecules like organophosphates could be also applied with several additional modifications, however it could be used only as a fact of appearance ignoring the cross-linking reaction and minimal specification and in general the polyclonal assay could easily run either false positive or false negative reaction due to its nature – poly epitope reaction, still animals in polyclonal antibodies production could be used as specialized inbreeds. For instance, particular specificity of polyclonal antibodies can be improved when specific pathogen-free (SPF) animals are utilized. The safe framework of SPF creatures is *"tabula rasa"*. On the other hand, SPF creatures may be inclined to tall mortality due to the naivety of their immune framework. Antibodies can be recognized concurring to the number of B-lymphocyte lines that create them. Polyclonal antibodies are created from distinctive B-lymphocyte lines as a blend of immunoglobulins. Numerous decontamination strategies have been created for the generation of crude antibodies (it means it is needed to be humanized in order to be used in clinical trials or experiments) over the past decades. Since the structures of immunoglobulins are normal proteins, current strategies for protein decontamination are reasonable too for the refinement of immunoglobulins. For case, gel chromatography is one helpful strategy for isolating IgG from the IgM display in polyclonal counter acting agent tests. Precipitation by ammonium sulfate is able to separate the isotypes of immunoglobulins [69]. Proteins A, G and L are exceptionally common and commercially provided either free or bound to underpins such as agarose. Antibodies can be essentially filtered by strong stage extraction utilizing as it were a framework with the capturing protein A, G, or L [70]. Another appropriate bio-ligand is a counter acting agent particular against either an entire Ig gather or to one course or subclass of immunoglobulins. Compounds arranged by natural blend such as mercaptoethyl pyridine are effective options to naturally determined ligands. To sum up, the polyclonal antibodies mostly produced *in vivo*, production time is relatively short (2-3 months), have large variability if we use batch to batch approach – detect easy and fast some substances with lower specify but robust. Last but not least, the cross reactivity is possible and this probability level depends on purification level.

Monoclonal antibodies

Monoclonal antibodies are homogeneous population of antibodies which are produced by a single clone of plasma B-cells. This fact brings a lot of advantages like predictable reaction response, high specificity both on particular epitope and antigen of interest which is why monoclonal antibodies are so highly valued in oncological and recombination technology studies. Nothing is so precise as monoclonal IgG for instance in detection and in further neutralization of viruses or viral particles in adaptive immunity that also enables to build up firm long-term protection via consolidation of so-called immune memory cells. The monoclonal antibody is a product of a clone of B lymphocytes. A specific problem is a preparation of recombinant antibodies [70.] true genetic manipulation and the producer cell is applied could have different origins.

The monoclonal antibodies in general have further characteristics that seriously distinguish them from polyclonal ones:

- The genetical clone of one B-cells
- The primary Nucleotide (**mRNA**) should and could be isolated either from blood (PBMC), lymph nodes or spleen from animals.
- Antibody population represents a high value of appliance – like identical lots in laboratory working flow
- Low cross reactivity
- Clear interaction with particular epitope on antigen
- High price of studies

So, monoclonal antibodies are produced by a same clone plasma B-cell or isolated intact plasma cells from spleen or lymph node tissue. Population of the antibodies (IgG for instance) is homogeneous. Monoclonal antibodies interact solely with specified epitope on antigen that allow them to have very low cross reactivity and have identical lots, nevertheless this approach is much more expensive and more sophisticated than polyclonal methodology. However, in case of hybridoma, the production life span is significantly higher than *in vivo* way and modified (fused) cells and they are capable to produce pricy monoclonal antibodies for six and more moths [71].

Hybridoma

Monoclonal antibodies are identical antibodies produced by hybridized cloning of immortalized B cells derived from a parent cell. Hybridoma technology was used by Kohler and Milstein in 1975 to produce monoclonal antibodies [72]. Hybridoma technology is effective mostly to produce precisely to treat cancer and produce the antidots, such as anti-snake venom. The antigen is a key factor for production. The small mammals like mice, rats and rabbits are the main model organisms. The blood streams immunization enables to produce monoclonal B-cells (antibody secreting cells) and spleen is the main organ to extract for synthesis/ cultivation plasma cells/B-cells.

The main problem of plasma cells/spleenocytes/ isolated B-cells. Hybridoma innovation produces monoclonal antibodies particular to antigens. These cell lines can moreover be cryopreserved for a long period of time. Hybridoma innovation has brought about the generation of an assortment of diverse monoclonal antibodies with specificity for a particular antigen.

Antigen particles incorporate chemicals, hormones, inner and outside structures of microbes, infections, and eukaryotic cells. Monoclonal antibodies created by this strategy are exceedingly particular antibodies, which are determined from a single parental B cell clone [73]. Analysts for the most part favor hybridoma innovation, for monoclonal counter acting agent generation over other strategies to preserve a helpful, cost-effective, and boundless generation of monoclonal antibodies [74]. Out of the several techniques developed over years to produce monoclonal antibodies (single lymph cell amplification or by culturing strategies), hybridoma technology is one of the most important and most commonly used [75].

Main steps of Hybridoma technology

To begin with, **immunization** includes infusing the research facility animals like rabbits or mice with a chosen antigen against which the antibodies are raised through an arrangement of infusions over a period of a few weeks to invigorate B cell separation into plasma B cells and memory B cells. Once an adequate number of antibodies are made within the animal serum taking after many weeks of immunization, the alive subject is died [76].

Isolation of B- cells is tightened strongly with a biomaterial like the spleen which is evacuated in aseptic conditions to confine the enacted B-cells. This strategy is performed utilizing ***density gradient centrifugation***. The nearness of antibodies within the Serum is recognized utilizing strategies like ELISA or ***flow cytometry***. The serum contains the actuated B lymphocytes (that create a counteracting agent). The enacted B lymphocytes are at that point combined with myeloma cells.

To prepare myeloma cells a few weeks before the ***cell fusion*** takes place, metastatic tumor cells are incubated in 8-azaguanine to urge non-functional hypoxanthine-guanine phosphoribosyltransferase (HGPRT) qualities within the myeloma cells. Non-functional HGPRT can halt the get-together of nucleotides from the rescue pathway and makes the metastatic tumor cells touchy to HAT media as the favoured strategy in hybridoma innovation [76].

Cell fusion is that the method within which the activated B lymphocytes area unit consolidated with HAT-sensitive malignant tumour cells. This step is performed by natural action of freshly obtained activated B-cells with HAT-sensitive malignant tumour cells in a very fusion-promoting media. synthetic resin glycol (PEG) is employed during this procedure PEG helps within the fusion of cells by promoting the fusion of the cell wall of

the malignant tumour cells with the cell wall of the antibody-producing cells, so giving rise to a cell with over one nucleus, forming heterokaryon. Another technique used for fusion is electrofusion, within which cells area unit consolidated beneath the result of an electrical field. This technique is additional deficient than the previous technique [76,77].

Hybridoma **selection** starts in the PEG-containing media, cells area unit amalgamated to create somatic cell cells however even foremost economical fusion methodology can permit the formation of solely concerning one to twenty of amalgamated somatic cells. Therefore, there are a unit variety of unfused cells inside the media [72]. This step permits the choice of the amalgamated cells from all the unfused cells. this is often achieved by incubating the cell mixture followed by culturing for 10–14 days in HAT media (a choice media). HAT medium contains hypoxanthine-aminopterin-thymidine. Aminopterin gift in HAT media blocks the ability of cells to synthesize nucleotides by the Delaware novo synthesis pathway. Hypoxanthine and nucleoside permit cells with purposeful hypoxanthine-guanine phosphoribosyltransferase (HGPRT) genes to survive through salvage pathways. thanks to a restricted lifetime, unfused B cells decease inside some days. Unfused malignant growth cells die as a result of the shortage of the hypoxanthine-guanine phosphoribosyltransferase (HGPRT) cistron. The presence of aminopterin blocks their ability to synthesize nucleotides through the Delaware novo pathway [78]. Therefore, the remaining viable cells left within the media area unit the hybrid cells; these hybrid cells have the power to grow and divide on HAT media as a result of they need purposeful HGPRT cistron from the B lymphocytes, that makes them HGPRT positive, and thus, they will grow in unlimited concentration on HAT media [76].

The further screening needs HAT- somatic cells selection that are transferred to enzyme-linked-immunosorbent serologic assay plates, wherever every well home one somatic cell this is often achieved victimization the limiting dilution methodology [76]. The genes of the lymph cell lineage gift within the somatic cell cells turn out a selected protein with a selected epitope; this protein is thought as a "monoclonal protein." There is also alternative hybridomas gift in alternative wells manufacturing antibodies specific to a different epitope for identical matter. once the separation and isolation of various hybridomas, screening is performed for choosing hybridomas that turn out the required associate degree antibodies targeting specific epitopes for a matter [79].

Functional genome

The SARS-COVID2 consists of viral genome: fourteen open reading frames (ORFs), two-thirds of which encode **sixteen nonstructural proteins (nsp 1–16)** that make up the **replicase complex** [80,81]. The rest encodes the nine accessory proteins (ORF) and four structural proteins: spike (**S**), envelope (**E**), membrane (**M**), and nucleocapsid (**N**), of which Spike enables the SARS-CoV entry into cytosol of target cell [81]. As any virus of these type, the Spike protein is the most variable and due to this capacity, the SARS-COVs are capable to penetrate the various cell membrane types of mammals [80-81].

A s viral genome of *beta* strain containing about 31,3kB in total. The polyprotein regions (pp) or so-called opened reading frames (ORFs) are mostly represented in the viral genome for replicase genes serving, the fragments of which are defined as non-structural proteins or NSPs. The most appealing regions to impact on are **nsp5** and **nsp12** which are crucial for viral replication. The structural genes encode for further purposes: spike (**S**), envelope (**E**), membrane (**M**), and nucleocapsid (**N**), and with auxiliary or accessory proteins among them [82].

Drug antiviral activity

The COVID19 pandemic caused the huge problems to national health care (NHC) worldwide. The first response on such epidemical spread was how to treat the infected patients, in order to ensure the clinical effect and people around the globe stormed the pharmacies to get paracetamol which is effective against fever, others were claiming anti flu drugs, hoping to get the therapeutical effects and some even bought out the antibiotics, considering that it would help too. Covid 19 is single stranded positive RNA ((+) ssRNA) corona virus that attaches to host cell receptor (ACE2) receptor via spike glycoprotein in a combination of surface protease (TMPRSS2). This virus relies heavily on **replicase targets** such as: RNA – dependent RNA polymerase (RdRp), Helicase, Exonuclease and Endoribonuclease. None of above mentioned claimed drugs could not handle the fast-increasing viral load and could bring neither therapeutic nor prophylactic (preventive) effect. Since then, the scientist worldwide launched the rally to find the best drug against anti-viral activity with replication-inhibiting feature that could ease the patients' infection spread.

The viral infections are hard to fight without harming the host cells, because viral genome uses the cell host machinery to replicate and assembly themselves into the new copies. The viral load is fully dependent on the assembly rates take a COVID19, one infected host cell can produce over 10 thousand of new corona viruses till the cell burst.

To understand how effectively to fight and to treat the viral infection, we need to embrace the viral life cycle that consist of further stages: Attachment to the host (animal) cell receptor. The most animal specific viruses have the additional lipid membrane called **envelope** with protein **spikes** that serves to attach a target cell, in SARS-COV2 genome by the way they belong to the structural protein's cohort. Viral entry (endocytosis, fusion). Release of genome (uncoating). Replication of viral genome. Proteins synthesis or processing, assembly. Release of new viruses.

Antiviral drugs

Represents almost 60 years development of antiviral drugs in USA since early 60s in 20th century. Unfortunately, only with virus discoveries, the research studies on antiviral drugs took place allowing viral infection either to spread or adapt to human immunity and genome, causing pharmacology industry many problems in strategy establishment to fight the viral invasion. Thus, only few drugs were approved to fight them effectively. To make things worse, the pharmacology and science were being aimed only against persistent viral diseases that require long and expensive therapy just to drag down the viral load in host cells, furthermore viruses are difficult to treat without serious side effects. During many decades the antiviral medicine production has created four main groups. They are 1) Anti-influenza, 2) Anti-HIV drugs, 3) Anti-hepatitis and 4) Anti-herpes.

Favipiravir is pyrazine analog T-705 and capable inhibitor of influenza viral RNA polymerase [83]. Favipiravir's metabolite (Favipiravir RTP (ribofuranosyl 5'-triposhpate interacts with viral RNA dependent polymerase (RdRp). It is assumed that the antiviral effect can be downgraded in the appearance of purine nucleotides ATP and GTP. In addition, this metabolite can be identified as a 'false' purine by the viral RdRp [84]. The previous *in-vitro* studies showed that SARS-COV2 Vero E6 infected cells tolerable cytotoxic response, namely half-cytotoxic concentration (CC_{50}) was at the level of 400μM and above [85]. Thus, it became clear that Favipiravir could be used at high concentrations to serve as safe and effective medicine against COVID19 infection.

Ribavirin is well-known antiviral drug with clear RNA and DNA replication interfering guanosine analog. The RNA-polymerase is no single target, but also thanks to it structure it prevents RNA caping during the RNA strand maturing that is heavily dependent on natural guanosine that keeps RNA from degradation [86]. According to some studies, no significant cytotoxicity was detected at ribavirin concentrations of 31.3 μg/mL in Vero cells model [87]**.** The clinical experience during the pandemic showed that the patients in worsening cases were given 400mg every 8hours in addition methylprednisolone administration to decrease the progressive viral load activity [88]. High specialization of ribavirin drug made doctors to pair with either IFN-α2a or IFN-α2b (interferon) to cover the therapeutic threshold to stop viral replication [89]. In 2003, in Canada, the ribavirin therapy with a dose of 500mg every 8 hours for 4-6days long was also combined with a corticosteroid in 40% of SARS patients [90]. So, Ribavirin is universal antiviral agent that could be taken solely or in a combination with either antiviral compound like interferon or excessive immune suppressors like corticosteroid in a worsening clinical dynamic.

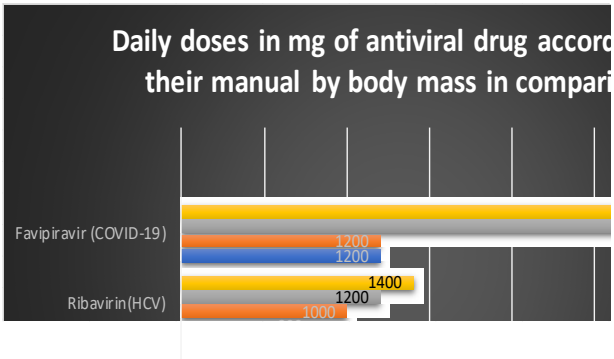
Tenofovir belongs both for anti-HIV drugs and Antihepatitic drug according to the producer's manual. Tenofovir represents the reverse transcriptase inhibitors or nucleoside reverse transcriptase inhibitors (NRTIs) are structural analogues of nucleic acids which competitively inhibit the reverse transcription by causing the chain termination after they got involved into viral DNA. This viral DNA-incorporation causes so-called 'lethal mutagenesis'. Tenofovir is also used as antiviral drug against chronic hepatitis B as nucleotide analogue. Tenofovir inhibits the HBV (hepatitis B virus) polymerase by competing with natural substrate for in cooperation with growing viral DNA-strand causing as in HIV (human immune deficit virus) chain termination, subsequently stalls the reverse transcription and synthesis of viral DNA. Tenofovir is yet another nucleotide analogue that was initially designed to inhibit the HIV (human immunogenicity virus) reverse transcriptase by interfering the ATP-Polymerization in the growing nucleic acid chain [9,10]. Tenofovir was also assumed to be effective against COVID-19 as it showed the tendency to dock the RNA- dependent RNA-polymerase and silence its activity in replication as well as in transcription and translation

of structural and accessory proteins making virions assembly almost impossible [91]. Tenofovir that is used in our study is for oral administration medicine in a form of disoproxil furmate (TDF) has many side effects if it is used in high dosage, such as renal toxicity, bone density degradation etc. [92]. *In-vitro* studies suggest that at concentrations under 100μM, tenofovir does not inhibit the viral replication in VeroE6 cells at the multiple infections in a so-called preventive way, when tenofovir was administered 1h prior to infection and up to 48h post infection. In the discussion of results, researchers came to idea that tenofovir in ATP-forms require the activation by host kinase and any cell type has probably the proper kinase activity to launch the tenofovir antiviral features and was suggested to try a study on human airway epithelial cells [93.95].

Dexamethasone according to **medicine producer's manual** dexamethasone is synthetic glucocorticoid (GCS), a methylated derivative of fluoroprednisolone. Provision of anti-inflammatory, anti-allergic, immunosuppressive action, increased sensitivity of beta-adrenergic receptors to endogenous catecholamines. The anti-inflammatory effect is linked to decreased capillary permeability, stabilization of cell membranes (especially lysosomal) and organelle membranes, inhibition of eosinophil and mast cell release of inflammatory mediators, induction of lipocortin formation, and reduction in the number of mast cells that produce hyaluronic acid.It acts on all stages of the inflammatory process: it inhibits the synthesis of prostaglandins (Pg) at the level of arachidonic acid (lipocortin inhibits phospholipase A2, inhibits the liberation of arachidonic acid and inhibits the biosynthesis of endoperoxides, leukotrienes, which contribute to inflammation, allergies, etc.), the synthesis of "pro-inflammatory cytokines" (interleukin 1, tumor necrosis factor alpha, etc.); increases the resistance of the cell membrane to the action of various damaging factors. The immunosuppressive effect is brought on by lymphoid tissue involution, inhibition of lymphocyte proliferation (especially T-lymphocyte proliferation), suppression of B-cell migration and interaction between T- and B-lymphocytes, inhibition of cytokine release from lymphocytes and macrophages (interleukin-1, 2; interferon gamma) [94]. And decreased antibody production. The antiallergic effect develops as a result of a decrease in the synthesis and secretion of allergy mediators, inhibition of the release of histamine and other biologically active substances from sensitized mast cells and basophils, a decrease in the number of circulating basophils, T- and B-lymphocytes, mast cells; suppression of the development of lymphoid and connective tissue, reducing the sensitivity of effector cells to allergy mediators, inhibition of antibody formation, changes in the body's immune response. It is worth to mention that 0.5 mg of dexamethasone is equivalent to roughly 3.5 mg of prednisone (or prednisolone), 15 mg of hydrocortisone, or 17.5 mg of cortisone, depending on the degree of glucocorticoid action. According to WHO data, dexamethasone should be used in severe cases of COVID-19 cases, especially, if a patient is dependent on live supporting systems.

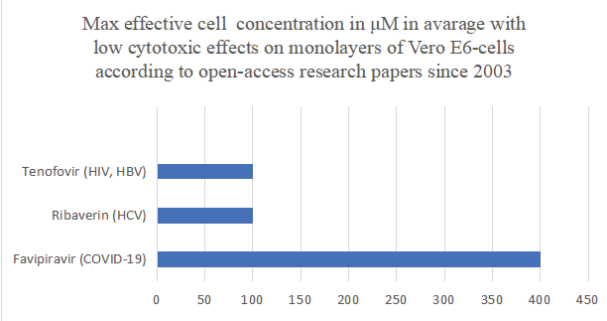
Effective doses of antiviral effect of Favipiravir, Ribavirin and Tenofovir for humans (in vivo) for Vero E6 cells (in vitro)

Toxicity has a definition as the amount or degree of a substance required to be poisonous. Toxicity depends on the amount and concentration involved, frequency of use, interactions of the person receiving the substance of interest, and individual reaction of the person [96].



Graph 1 – Since only Favipiravir or also known in the market as Fabiflu is specialized medicine against SARS-COV2 infection, its dose is so high and is designed to administer within 10 days for minor or moderate stages of COVID19 infection. Unlike Fabiflu, Ribavirin for instance was designed to slow down the hepatitis C replication up to 72 weeks, taking a drug twice a day at least. Tenofovir is suggested by its manual to take once a day one tablet that contains 300mg of tenofovir also for a long period of time under strict physician prescription and control according to manufacturers' manual and according to publications [83-95].

Effective doses of antiviral effect of Favipiravir, Ribavirin and Tenofovir for humans (invitro) Vero E6 cells



Graph 2 – Vero E6 -model also shows the toxicity edge for monolayers cells tenofovir and ribavirin could be and dose control plays a significant role not only to gain absolute viral RNA/DNA-replication silencing but also to minimize the negative side effect impact on contacting cells and tissues

Effective concentrations (EC_{10}, EC_{50}, EC_{90}), concertation efficacy of three drugs (Inhibition activity)

Half maximal viable concentration (**EC_{50}**) may be a degree of the concentration of a medicate, counter-acting agent (*e.g.,* antibodies), or toxicant which actuates a reaction *midway* (halfway) between the pattern and *the greatest value* after an indicated introduction time, saying it differently, EC_{50} can be specified as the concentration needed to obtain a 50% drug, antibody or toxicant effect.

$$\mathbf{pEC_{50}} = -\log_{10}(\mathbf{EC_{50}}) \quad (1)$$

There is a wide run of EC_{50} (1) values of drugs; they are regularly at any value from *nM to mM*. Thus, it is frequently more common sense to allude to the logarithmically transformed **pEC_{50}** values rather than EC_{50}. The term "potency" refers to the EC_{50} value. The lower the EC_{50} value, **the lower** the drug concentration required to achieve 50% of the maximal effect and **the higher** the potency. The EC_{10} and EC_{90} concentrations to induce 10% and 90% maximal responses respectively.

However, viral replication is needed to be stopped utterly, even 90% of replication silencing or 'breaking' is not enough to achieve the therapeutic effect of antiviral medication. Thus, so called old drugs like **ribavirin** and **tenofovir** are designed to be administrated for a long period of time and in relatively moderate concentration to inhibit the viral replication activity in host cells. **Ribavirin** and **tenofovir** are the antivirals for a long run drug therapy for primary purposes, but the increased concentration for 10 days prescribed therapy like **favipiravir** can be either reasonable risk for a cheap and effective alternative or 'side-effect disaster' for a chance to fight COVID-19 for instance or influenzas. To make things worse, the effective concentrations (EC_{10}, EC_{50}, EC_{90}) measure was heavily criticized already in 2003 due its 'vagueness' [97].

To support the idea of the vagueness of this measure methodology, A study for antivirals as individual run and as a drug combination effectiveness were made in Japan to show how E_{50} values span *in vitro* studies, the difference between minimum and maximum values are in average 40 times [98]. Thus, the values of E_{10} and E_{90} also demonstrated the wide range of 'runaway' values with data infirmity in its veracity.

To sum up, to fight the viral replicase of fast developing SARS-COV2 (i.e., its intercellular spread), 100% silencing is required and to gain this, physicians prescribe either high drug doses withing 10days in average with a particular drug like T-705 (favipiravir) or a combination of drugs like ribavirin with corticosteroids (such as: dexamethasone), or even 300mg tenofovir daily up to one week period, yet not at critical phase of COVID-19 infection.

Lethal mutagenesis as a purpose

The lethal mutagenesis characterization for virus existence and since any virus after entrance into the host cytosol consists of genetical information (mRNA), the lethal error rates in replicating itself plays critical role, so that the threshold line between extinction and survival is very thin and as proof-reading-important for viral survival as for pharmacology to target viral replicating machinery in a host cell. **[104].**As mRNA -Virus, COVID-19 has basically two ways to fight against, namely vaccination and drug intervention. The drug intervention of these antivirals is mostly bound with **RdR-** inhibition to reach lethal mutagenesis of viral infection. When the viral genomic RNA (gRNA) ingests itself in the host cell it has relatively unstable single stranded positive genomic RNA that requires to be replicated as soon as possible to be able to replicate new genomic RNA for structural proteins synthesis and assembly, furthermore, after replicating itself the **'original'** genomic RNA craves to build the sub-genomic RNAs (sgRNA) via transcription, these sg-RNAs (with caped mRNA, as in eucaryotic cells) are essential for translation in expressing the structural proteins that go to viral

assembly as well as **newly** replicated gRNA. As a result, inhibiting or interfering the viral replicase represents a serious arsenal in antiviral therapy that allows us to insert mutated gRNA or damaged gRNA into assembly process, providing so called extinction by fatal error in viral genome during and after replication [99,100,105].

The lethal mutagenesis of Ribavirin

As it was already mentioned ribavirin was invented roughly 40yeras ago and showed antiviral efficacy not only in human but also in animal lines. As guanosine analog it goes to host kinase as ribavirin triphosphate and pairs either with **cytidine** or **uridine-**triphosphate and mimics the purine nucleobase, causing the serious mutations during replicase and causes the lethal mutagenesis as anti-viral therapy reducing the viral load rates [99-101, 103]. In 2019 a new drug against influenzas was developed-**molnupirovir** having the same RdR-inhibiting properties as ribavirin has, and it showed the promising results during Covid-19 pandemic. Both drugs are **nucleoside-inhibitors**. Unlike ribavirin, molnupirovir is **pyrimidine analog**. It is worth to mention that ribavirin is much cheaper and more carefully observed drug than *molnupirovir* demonstrating the similar effectiveness. Nevertheless, during pandemic crisis in 2003 and 2019 the treatment was combined either with other drugs or so-called adjuvants like interferons and corticosteroids to achieve maximum outcome from treatment, and ribavirin was a classic example for these combination lines with acceptable survival as well as recovery rates among mild and moderate patients with SARS and SARS-COV2 infection [105].

The lethal mutagenesis of Favipiravir

Favipiravir is yet another effective nucleoside -inhibitor with proven wide-spectrum viruses that strongly rely on RdR. In countries like India and Japan, favipiravir showed the high rates of clinical effectiveness and relatively low cytotocity as well as side-effect potential. Along with ribavirin it was mainly prescribed for mild or moderate patient with 9-14days inpatient background. [102,105]. ***Favipiravir*** has also a good response on host RNA dependent replicase kinase that enables favipiravir as effective lethal mutagenesis causer not only in SARS-CoV2 populations but also against deadly Ebola, commonly known influenza and terrifying rabies which makes it valuable asset as antiviral medicine [99-105].

The lethal mutagenesis of Tenofovir

The most cytotoxic drug among our antiviral drug list (only 300mg oral administration is allowed daily). Tenofovir belongs too to the nucleoside -inhibitor that incorporates with RdR and makes viral DNA synthesis not viable and shouts down the virulence potential. Originally, it was designed against HIV and Hepatitis B viral invasion [103,105].

Steroids save lives in critical and sever cases of SARS-COV2 infection, nevertheless, it has its cost – bone infarct development

As it was already mentioned the immune system in humans is responsible for 'overdefensive' response on viral invasion causing huge tissue damage independently on age group casing severe pneumonia as 'final act' of immunity – so called '*cytokinetic storm'* which probably was the main reason of lethal outcomes during Spanish influenza pandemic after WWI. All three antiviral drugs a clinically prescribed for patients with **mild or moderate** state of viral infection, reducing the viral load through lethal mutagenesis, enabling us to achieve ideally the viral extinction. In severe cases, doctors mostly betake steroids to calm the overreacted immune response that could be lethal if it is not stopped and here comes corticosteroids in combination with antiviral therapies like with ribavirin already in 2003. The antiviral effect was so high and effective that WHO (world health organization) recommends dexamethasone as additional and safe medicine to fight COVID-19 infection in mild and moderate patients care,

Before 2019, the steroids' side-effects were studied among many patients with passivated immunity. The bone infarct mostly caused by chronic appearance of immune passivation as well as during other health destructive patterns like alcohol misusage and chronic smoking The doses risk mostly started from 500mg of **corticosteroids** of daily administration for 1-3months [106]. However, the low doses up to 100mg a day showed the low risk, somewhere between 2-3%. The dexamethasone has 4mg/ml interveinal administration protocol during the COVID-19 treatment and only a physician makes a decision on the effective dose. WHO recommends to use in mild stages of infection 15-20mg a day as auxiliary therapy option. But what happens with severe cases is still not clear and everything is highly individual and intense steroids therapy was inevitable to fight the progressing pneumonia and other signs of acute COVID-19 complications [1.8,14].

Conclusion

All above mentioned aspects of COVID-19 virus and its spread potential are based on its structure like receptor binding capacities and host cell invasion procedures that fully depend on functional genome both of non-structural (***nsps***) or poly-protein regions and of course the structural proteins synthesis which play the most important role in viral assembly. The innate immunity takes the first defense line that allows to withstand the intense viral load growth. The adaptive immunity is the most powerful arsenal against human to human – spreading way, that neutralize viruses or viral particles not only intercellular but also intracellular way. The vaccination against SARS-CoV2 show high rates of resistance and survival rates among hospitalized patients and temporary protection for healthy individuals. Apart vaccination, the biotechnological approaches like poly- and mono-clonal antibody synthesis can offer a big deal of advantages to comprehend the viral infection patterns and set the sophisticated strategy lines to neutralize the viral infection, nevertheless, polyclonal and monoclonal antibodies studies bare upper hand therapy strategies as well as serious drawbacks that cannot be ignored freely. The hybridoma technologies, for example can offer the high rates of monoclonal immunoglobins that could be used in recombination science, yet only in lablotory scales. The pharmacological therapies also give some solutions in antiviral drug development. By comprehending the nature of viral replication, the lethal mutagenesis concept began to be one of the main directions of COVID-19 spreading fighting policy in clinical practice. The combination of drugs like using wide range nucleoside – analogs (Ribavirin, Tenofovir and Favipiravir) with corticosteroids like dexamethasone showed the marvelous effect in mild and moderate stages of COVID-19 – infection severeness. Three discussed drugs form a basis of antiviral therapy for many years because they were primarily used against so called static and long-lasting viral infections like Hepatitis B and C, HIV and even against Ebola-virus. These drugs represent the real antiviral effect on COVID-19 virus replication, causing so called **viral extinction** through lethal mutagenesis. However, as it was already discussed the steroids can have profound negative effect on human health in long term perspectives as side-effect(s) and one of them is the *bone infarct*. Thus, any practicing physician has to weigh the risks of steroids involving in antiviral therapy.

Acknowledgments

This article is a part of doctorate research-scientific work and this laboratory practice was conducted at Republican State Enterprise on the right of economic management «Research Institute for Biological Safety Problems» of the Ministry of Health of the Republic of Kazakhstan.

This work was carried out within the framework of the grant funding project on the topic: AP09058338 “STUDY OF ANTI-VIRAL ACTIVITY OF DRUGS AGAINST SARS-COV-2 VIRUS IN VITRO AND CONDUCTING MOLECULAR-EPIDEMIOLOGICAL ANALYSIS OF CIRCULATING COVID-19 STRAINS “under targeted funding for 2021–2023 with the support of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Reference

1. World Health Organization. 2020. Coronavirus disease (COVID-19) weekly epidemiological update and weekly operational update. https://www.who.int/ emergencies/diseases/novel-coronavirus-2019/situation-reports/. Retrieved 15 October 2022.

2. Jia Y, Shen G, Nguyen S, Zhang Y, Huang K-S, Ho H-Y, Hor W-S, Yang C-H, Bruning JB, Li C, Wang W-L. 2020. Analysis of the mutation dynamics of SARS-CoV-2 reveals the spread history and emergence of RBD mutant with lower ACE2 binding affinity. BioRxiv. https://doi.org/10.1101/2020.04.09.034942.

3. Chiara M, Horner DS, Gissi C, Pesole G. 2020. Comparative genomics suggests limited variability and similar evolutionary patterns between major clades of SARS-CoV-2. BioRxiv. https://doi.org/10.1101/2020.03.30.016790.

4. Ivan Dorp L, Acman M, Richard D, Shaw LP, Ford CE, Ormond L, Owen CJ, Pang J, Tan CCS, Boshier FAT, Ortiz AT, Balloux F. 2020. Emergence of genomic diversity and recurrent mutations in SARS-CoV-2. Infect Genet Evol 83:104351. https://doi.org/10.1016/j.meegid.2020.104351.

5. Walls AC, Park Y-J, Tortorici MA, Wall A, McGuire AT, Veesler D. 2020. Structure, function, and antigenicity of the SARS-CoV-2 spike glycoprotein. Cell 181:281–292.e6. https://doi.org/10.1016/j.cell.2020.02.058.

6. Zhugunissov K, Zakarya K, Khairullin B, Orynbayev M, Abduraimov Y, Kassenov M, Sultankulova K, Kerimbayev A, Nurabayev S, Myrzakhmetova B, Nakhanov A, Nurpeisova A, Chervyakova O, Assanzhanova N, Burashev Y, Mambetaliyev M,

Azanbekova M, Kopeyev S, Kozhabergenov N, Issabek A, Tuyskanova M, Kutumbetov L. 2021. Development of the inactivated QazCovid-in vaccine: protective efficacy of the vaccine in Syrian hamsters. Front Microbiol 12:720437. https://doi.org/10.3389/fmicb.2021 .720437.

7. Johns Hopkins University. 2019. COVID-19 data repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. https://github.com/CSSEGISandData/COVID-19. Retrieved 15 October 2022.)

8. Gorbalenya, A.E. et al. (2020) The species severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2. Nat. Microbiol. 5, 536–544.

9. 2.Lu, R. et al. (2020) Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 395, 565–574.

10. Zhang, Y.Z. and Holmes, E.C. (2020) A genomic perspective on the origin and emergence of SARS-CoV-2. Cell 181, 223–227.

11. Perlman, S. and Netland, J. (2009) Coronaviruses post-SARS: update on replication and pathogenesis. Nat. Rev. Microbiol. 7, 439–450.

12. Zhang W, Cao S, Martin JL, Mueller JD, Mansky LM. Morphology and ultrastructure of retrovirus particles. AIMS Biophys. 2015; 2(3): 343-369.

13. Wyatt R, Sodroski J. The HIV-1 envelope glycoproteins: Fusogens, antigens, and im- munogens. Science. 1998; 280(5371): 1884-1888.

14. Wang, D. et al. (2020) Clinical characteristics of 138 hospitalzed patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 323, 1061–1069.48

15. Li, Q. et al. (2020) Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N. Engl. J. Med. 382, 1199–1207

16. Chan, J.F.W. et al. (2020) A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to person transmission: a study of a family cluster. Lancet 395, 514–523.

17. Clinical management of COVID-19 15th September 2022, WHO p.35- 62.

18. Burashev Y. et al. Coding Complete Genome Sequence of the SARS-CoV-2 Virus Strain, Variant B.1.1, Sampled from Kazakhstan, 2022, *Microbiology Resource Announcements.* doi: https://journals.asm.org/doi/10.1128/mra.01114-22

19. Wu, F. et al. (2020) A new coronavirus associated with human respiratory disease in China. Nature 579, 265–269.

20. Hoffmann, M. et al. (2020) SARS-CoV-2 cell entry depends on ACE2 and **TMPRSS2** and is blocked by a clinically proven protease inhibitor. Cell 181, 271–280.

21. Perlman, S. and Netland, J. (2009) Coronaviruses post-SARS: update on replication and pathogenesis. Nat. Rev. Microbiol. 7, 439–450.

22. Snijder, E.J. et al. (2006) Ultrastructure and origin of membrane vesicles associated with the severe acute respiratory syndrome coronavirus replication complex. J. Virol. 80, 5927–5940.

23. Wu, H.-Y. and Brian, D.A. (2010) Subgenomic messenger RNA amplification in coronaviruses. Proc. Natl. Acad. Sci. U. S. A. 107, 12257–12262.

24. Shailendra K. Saxena and Sai V. Chitti (2016) Molecular Biology and Pathogenesis of Retroviruses. Advances in Molecular Retrovirology, 9-24.

25. Varmus H. Retroviruses. Science. 1988; 240(4858): 1427-1435.

26. Coffin JM. Structure and classification of retroviruses. In: Levy, JA. The Retroviridae (First edition). New York: Plenum; 1992. p. 20. ISBN 0-306-44074-1.

27. Rabson AB, Graves BJ. Synthesis and processing of viral RNA. In: Coffin JM, Hughes SH, Varmus HE, editors. Retroviruses. Cold Spring Harbor (NY): Cold Spring Har- bor Laboratory Press; 1997.

28. Bharat TA, Davey NE, Ulbrich P, Riches JD, de Marco A, Rumlova M, Sachse C, Ruml T, Briggs JA. Structure of the immature retroviral capsid at 8 Å resolution by cryo -electron microscopy. Nature. 2012; 487(7407): 385-389].

29. Clinical management of COVID-19 15th September 2022, WHO p.110

30. Clinical management of COVID-19 15th September 2022, WHO p.113-115

31. Marilyn J. Roossinck, Viren, https://doi.org/10.1007/978-3-662-61684-0, ISBN 978-3-662-61684-0 (eBook), pp.28

32. Kanneganti, T. D. Intracellular innate immune receptors: life inside the cell. Immunol. Rev. 297, 5–12 (2020).

33. Rui, Y. et al. Unique and complementary suppression of cGAS–STING and RNA sensing—triggered innate immune responses by SARS-CoV-2

34. Franz, K. M., Neidermyer, W. J., Tan, Y. J., Whelan, S. P. J. & Kagan, J. C. STING-dependent translation inhibition restricts RNA virus replication. Proc. Natl Acad. Sci. USA 115, E2058–E2067 (2018).

35. Sun, B. et al. Dengue virus activates cGAS through the release of mitochondrial DNA. Sci. Rep. 7, 3594 (2017).

36. Briard, B., Place, D. E. & Kanneganti, T. D. DNA sensing in the innate immune response. Physiology 35, 112–124 (2020).

37. Sun, L., Wu, J., Du, F., Chen, X. & Chen, Z. J. Cyclic GMP–AMP synthase is a cytosolic DNA sensor that activates the type I interferon pathway. Science 339, 786–791 (2013)

38. Singh, K. K., Chaubey, G., Chen, J. Y. & Suravajhala, P. Decoding SARS-CoV-2 hijacking of host mitochondria in COVID-19 pathogenesis. Am. J. Physiol. Cell Physiol. 319, C258–C267 (2020).

39. Kanneganti, T. D. Intracellular innate immune receptors: life inside the cell. Immunol. Rev. 297, 5–12 (2020).

40. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 37-42.

41. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 42-49.

42. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 49-51.

43. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 49-52.
44. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 52-53.
45. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 54-58.
46. Viren, Walter Doerfer (2002), ISBN 3-596-15369-7, pp. 60-61.8.
47. Beyrau, M., Bodkin, J. V., and Nourshargh, S. (2012). Neutrophil heterogeneity in health and disease: a revitalized avenue in inflammation and immunity. Open Biol. 2:120134. doi: 10.1098/rsob.1201349.
48. Blanco-Melo, D., Nilsson-Payant, B.E., Liu, W.-C., Uhl, S., Hoagland, D., Møller, R., Jordan, T.X., Oishi, K., Panis, M., Sachs, D., et al. (2020). Imbalanced Host Response to SARS-CoV-2 Drives Development of COVID-19. Cell 181, 1036–1045.e9.
49. Oran, D.P., and Topol, E.J. (2020). Prevalence of Asymptomatic SARS-CoV-2 Infection: A Narrative Review. Ann. Intern. Med. 173, 362–367.11.
50. Grifoni, A., Weiskopf, D., Ramirez, S.I., Mateus, J., Dan, J.M., Moderbacher, C.R., Rawlings, S.A., Sutherland, A., Premkumar, L., Jadi, R.S., et al. (2020). Targets of T Cell Responses to SARS-CoV-2 Coronavirus in Humans with COVID-19 Disease and Unexposed Individuals. Cell 181, 1489–1501.e15.
51. Piccoli, L., Park, Y.-J., Tortorici, M.A., Czudnochowski, N., Walls, A.C., Beltramello, M., Silacci-Fregni, C., Pinto, D., Rosen, L.E., Bowen, J.E., et al. (2020). Mapping Neutralizing and Immunodominant Sites on the SARS-CoV-2 Spike Receptor-Binding Domain by Structure-Guided High-Resolution Serology. Cell 183, 1024–1042.e21.
52. Isho, B., Abe, K.T., Zuo, M., Jamal, A.J., Rathod, B., Wang, J.H., Li, Z., Chao, G., Rojas, O.L., Bang, Y.M., et al. (2020). Persistence of serum and saliva antibody responses to SARS-CoV-2 spike antigens in COVID-19 patients. Sci. Immunol. 5, eabe5511.
53. Lu, L.L., Suscovich, T.J., Fortune, S.M., and Alter, G. (2018). Beyond binding: antibody effector functions in infectious diseases. Nat. Rev. Immunol. 18, 46–61.15.
54. Gudbjartsson, D.F., Norddahl, G.L., Melsted, P., Gunnarsdottir, K., Holm, H.,Eythorsson, E., Arnthorsson, A.O., Helgason, D., Bjarnadottir, K., Ingvarsson,R.F., et al. (2020). Humoral Immune Response to SARS-CoV-2 in Iceland.N. Engl. J. Med. 383, 1724–1734.
55. Anderson, E.M., Goodwin, E.C., Verma, A., Arevalo, C.P., Bolton, M.J., Weirick, M.E., Gouma, S., McAllister, C.M., Christensen, S.R., Weaver, J., et al. (2020). Seasonal human coronavirus antibodies are boosted upon SARS-CoV-2 infection but not associated with protection. medRxiv.
56. Dan, J.M., Mateus, J., Kato, Y., Hastie, K.M., Faliti, C.E., Ramirez, S.I., Frazier, A., Yu, E.D., Grifoni, A., Rawlings, S.A., et al. (2021). Immunological memory to SARS-CoV-2 assessed for up to eight months after infection. Science, eabf406.
57. Reed Magleby, Lars F Westblade, Alex Trzebucki, Matthew S Simon, Mangala Rajan, Joel Park, Parag Goyal, Monika M Safford, Michael J SatlinImpact of Severe Acute Respiratory Syndrome Coronavirus 2 Viral Load on Risk of Intubation and Mortality Among Hospitalized Patients with Coronavirus Disease 2019 | Clinical Infectious Diseases | Oxford Academic (oup.com)
58. Zohar, T., Loos, C., Fischinger, S., Atyeo, C., Wang, C., Slein, M.D., Burke, J.,Yu, J., Feldman, J., Hauser, B.M., et al. (2020). Compromised humoral functional evolution tracks with SARS-CoV-2 mortality. Cell 183, 1508–1519.e12.
59. Van Erp, E. A., Luytjes, W., Ferwerda, G., & van Kasteren, P. B. (2019). *Fc-Mediated Antibody Effector Functions During Respiratory Syncytial Virus Infection and Disease. Frontiers in Immunology, 10.* doi:10.3389/fimmu.2019.00548 pp. 221.
60. Smyth MJ, Cretney E, Kelly JM, Westwood JA, Street SE, Yagita H, et al. Activation of NK cell cytotoxicity. Mol Immunol. (2005) 42:501–10. doi: 10.1016/j.molimm.2004.07.03422.
61. Van Erp, E. A., Luytjes, W., Ferwerda, G., & van Kasteren, P. B. (2019). *Fc-Mediated Antibody Effector Functions During Respiratory Syncytial Virus Infection and Disease. Frontiers in Immunology, 10.* doi:10.3389/fimmu.2019.00548 pp.2-3.23.
62. Van Erp, E. A., Luytjes, W., Ferwerda, G., & van Kasteren, P. B. (2019). *Fc-Mediated Antibody Effector Functions During Respiratory Syncytial Virus Infection and Disease. Frontiers in Immunology, 10.* doi:10.3389/fimmu.2019.00548 pp 4.
63. Kaul TN, Welliver RC, Ogra PL. Comparison of fluorescent-antibody, neutralizing-antibody, and complement-enhanced neutralizing-antibody assays for detection of serum antibody to respiratory syncytial virus. J Clin Microbiol. (1981) 13:957–62.25.
64. Kruijsen D, Bakkers MJ, van Uden NO, Viveen MC, van der Sluis TC, Kimpen JL, et al. Serum antibodies critically affect virus-specific CD4+/CD8+ T cell balance during respiratory syncytial virus infections. J Immunol. (2010) 185:6489–98. doi: 10.4049/jimmunol.1002645.].
65. Pohanka M, Pavliš O, Kroča M: ELISA detection of Francisella tularensis using polyclonal and monoclonal antibodies. Def Sci J 58:698–702, 2008a.
66. Morris TJ, Stanley EF: A simple method for immunocytochemical staining with multiple rabbit polyclonal antibodies. J Neurosci Methods 127:149–155, 2003.
67. Martínez JM, Martínez MI, Suárez AM, Hezzanz C, Casaus P, Cintas LM, Rodríguez JM, Hernández PE: Generation of polyclonal antibodies of predetermined specificity against pediocin PA-1. Appl Environ Microbiol 64:4536–4545, 1998.
68. Somodevilla-Torres MJ, Hillyard NC, Morton H, Alewood D, Halliday JA, Alewood PF, Vesey DA, Walsh MD, Cavanagh AC: Preparation and characterization of polyclonal antibodies against human chaperonin 10. Cell Stress Chaperones 5:14–20, 2000.
69. Bergmann-Leitner ES, Mease RM, Duncan EH, Khan F, Waitumbi J, Angov E: Evaluation of immunoglobulin purification methods and their impact on quality and yield of antigen-specific antibodies. Malar J 7:129, 2008.
70. Pohanka M: Evaluation of immunoglobulin production during tularemia infection in BALB/c mouse model. Acta Vet Brno 76:579–584, 2007.
71. Emanuel PA, Dang J, Gebhardt JS, Aldrich J, Garber EAE, Henrieta K, Stopa P, Valdes JJ, Schultz AD: Recombinant antibodies: a new reagent for biological agent detection. Biosens Bioelectron 14:761–770, 2000.
72. Köhler G, Milstein C: Continuous cultures of fused cells secreting antibody of predefined specificity. Nature 256:495–497, 1975.

73. Shulman M, Wilde CD, Köhler G (1978) A better cell line for making hybridomas secreting specific antibodies. Nature 276(1978):269–270.

74. Parray HA, Shukla S, Samal S et al (2020) Hybridoma technology a versatile method for isolation of monoclonal antibodies, its applicability across species, limitations, advancement and future perspectives. Int Immunopharmacol. 85:106639. https://doi.org/10.1016/j.intimp.2020.1066.

75. Ghosh S, Wakchaure R (2013) Monoclonal antibodies: a tool in clinical research. J Indian Acad Clin Med 4:9–21. https://doi.org/10.4137/IJCM.S11968.

76. Ganguly S, Wakchaure R (2016) Hybridoma technology: a brief review on its diagnostic and clinical significance. Pharmaceut Biol Eval 3(issue 6):554–555.

77. Buck DW, Larrick JW, Raubitschek A, Truitt KE, Senyk G, Wang J, Dyer B (1984) Production of human monoclonal antibodies. In. Kennett RH, Bechtol KB and McKearn TJ (ed) Monoclonal Antibodies and Functional Cell Lines. Progress and Applications. New York: Plenum Press; pp 275-309.

78. Saeed AFUH, Awan SA (2016) Advances in monoclonal antibodies production and cancer therapy. MOJ Immunol 3(4):00099. https://doi.org/10. 15406/moji.2016.03.00099.

79. Parray HA, Shukla S, Samal S et al (2020) Hybridoma technology a versatile method for isolation of monoclonal antibodies, its applicability across species, limitations, advancement and future perspectives. Int Immunopharmacology. 85:106639. https://doi.org/10.1016/j.intimp.2020.106639.

80. Lu, R. et al. (2020) Genomic characterization and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 395, 565–574.

81. Zhang, Y.Z. and Holmes, E.C. (2020) A genomic perspective on the origin and emergence of SARS-CoV-2. Cell 181, 223–227.) Perlman, S. and Netland, J. (2009) Coronaviruses post-SARS: update on replication and pathogenesis. Nat. Rev. Microbiol. 7, 439–450).

82. Roe et al., Journal of General Virology 2021;102:001558 DOI 10.1099/jgv.0.001558.

83. Joshi S, Parkar J, Ansari A, Vora A, Talwar D and Tiwaskar M: Role of favipiravir in the treatment of COVID-19. Int J Infect Dis 2021; 102: 501-8.

84. Delang L, Abdelnabi R and Neyts J: Favipiravir as a potential countermeasure against neglected and emerging RNA viruses. Antiviral Res 2018; 153: 85-94.

85. Wang M, Cao R, Zhang L, Yang X, Liu J and Xu M: Remdesivir and chloroquine effectively inhibit the recently emerged novel coronavirus (2019-nCoV) in-vitro. Cell Res 2020; 30(3): 269-71.

86. Graci JD, Cameron CE. Mechanisms of action of ribavirin against distinct viruses. Rev Med Virol. 2006;16(1):37-48.

87. Myung J.1., Kye-Hyung Kim. In vitro antiviral activity of ribavirin against severe fever with thrombocytopenia syndrome virus. Korean J Intern Med. 2017 Jul; 32(4): 731–737.

88. Lee N, Hui D, Wu A, et al. A major outbreak of severe acute respiratory syndrome in Hong Kong. N Engl J Med. 2003;348(20):1986-1994.

89. Falzarano D, de Wit E, Martellaro C, Callison J, Munster VJ, Feldmann H. Inhibition of novel beta coronavirus replication by a combination of interferon-alpha2b and ribavirin. Sci Rep. 2013;3: 1686.

90. Koren G, King S, Knowles S, Phillips E. Ribavirin in the treatment of SARS: A new trick for an old drug? CMAJ. 2003;168(10):1289-1292.

91. Balzarini, J.; Holy, A.; Jindrich, J.; Naesens, L.; Snoeck, R.; Schols, D.; De Clercq, E. Differential antiherpesvirus and antiretrovirus effects of the (S) and (R) enantiomers of acyclic nucleoside phosphonates: Potent and selective in vitro and in vivo antiretrovirus activities of (R)-9 (2phosphonomethoxypropyl)-2,6-diaminopurine. Antimicrob. Agents Chemother. 1993, 37, 332–338.

92. Edited Tsai, C.-C.; Follis, K.E.; Sabo, A.; Beck, T.W.; Grant, R.F.; Bischofberger, N.; Benveniste, R.E.; Black, R. Prevention of SIV Infection in Macaques by (R)-9-(2-Phosphonylmethoxypropyl) adenine. Science 1995, 270, 1197–1199.

93. Elfiky, A.A. Ribavirin, Remdesivir, Sofosbuvir, Galidesivir, and Tenofovir against SARS-CoV-2 RNA dependent RNA polymerase (RdRp): A molecular docking study. Life Sci. 2020, 253, 117592.

94. Edited Li, G.; Yue, T.; Zhang, P.; Gu, W.; Gao, L.-J.; Tan, L. Drug Discovery of Nucleos(t)ide Antiviral Agents: Dedicated to Prof. Dr. Erik De Clercq on Occasion of His 80th Birthday. Molecules 2021, 26, 923.

95. Choy, K.-T.;Wong, A.Y.-L.; Kaewpreedee, P.; Sia, S.F.; Chen, D.; Hui, K.P.Y.; Chu, D.K.W.; Chan,M.C.W.; Cheung, P.P.-H.; Huang, X.; et al. Remdesivir, lopinavir, emetine, and homoharringtonine inhibit SARS-CoV-2 replication in vitro. Antivir. Res. 2020, 178, 104786.

96. Rob W. Brooker; Zaal Kikvidze. Importance: an overlooked concept in plant interaction research. Journal of Ecology 2008, 96, 703–708. https://doi.org/10.1111/j.1365-2745.2008.01373.x

97. Neubig, Richard R. (2003). "International Union of Pharmacology Committee on Receptor Nomenclature and Drug Classification. XXXVIII. Update on Terms and Symbols in Quantitative Pharmacology". Pharmacological Reviews. 55 (4): 597–606. doi:10.1124/pr.55.

98. Yousuke. A., et.al. Favipiravir (T-705), a broad-spectrum inhibitor of viral RNA polymerase. Proc. Jpn. Acad., Ser. B 93 (2017).

99. Perales, C., Gallego, I., de Ávila, A. I., Soria, M. E., Gregori, J., Quer, J., & Domingo, E. (2019). *The increasing impact of lethal mutagenesis of viruses. Future Medicinal Chemistry, 11(13), 1645–1657.* doi:10.4155/fmc-2018-0457

100. Perales, C., Martín, V., & Domingo, E. (2011). *Lethal mutagenesis of viruses. Current Opinion in Virology, 1(5), 419–422.* doi:10.1016/j.coviro.2011.09.001

101. Crotty, S., & Andino, R. (2002). *Implications of high RNA virus mutation rates: lethal mutagenesis and the antiviral drug ribavirin. Microbes and Infection, 4(13), 1301–1307.* doi:10.1016/s1286-4579(02)00008-4

102. Espy, N., Nagle, E., Pfeffer, B., Garcia, K., Chitty, A. J., Wiley, M., … Palacios, G. (2019). *T-705 induces lethal mutagenesis in Ebola and Marburg populations in macaques. Antiviral Research.* doi:10.1016.

103. McDaniel, Y. Z., Patterson, S. E., & Mansky, L. M. (2019). *Distinct dual antiviral mechanism that enhances hepatitis B virus mutagenesis and reduces viral DNA synthesis. Antiviral Research, 104540.* doi:10.1016/j.antiviral.2019.1045

104. Bull, J. J., Sanjuan, R., & Wilke, C. O. (2007). Theory of Lethal Mutagenesis for Viruses. Journal of Virology, 81(6), 2930–2939. doi:10.1128/jvi.01624-06. pp. 2937.

105. Xiaoying XuYuheng ChenXinyu LuWanlin ZhangWenxiu FangLuping YuanXiaoyan Wang. An update on inhibitors targeting RNA-dependent RNA polymerase forCOVID-19 treatment: Promises and challenges. Biochemical pharmacology 205 (2022). https://doi.org/10.1016/j.bcp.2022.115279.

106. Christian Powell, Christopher Chang, Stanley M. Naguwa, Gurtej Cheema, M. Eric Gershwin, *Steroid induced osteonecrosis: An analysis of steroid dosing risk.* Autoimmunity Reviews (2010) 724-743.

1-бөлім
БОТАНИКА

Section 1
BOTANY

Раздел 1
БОТАНИКА

IRSTI 62.09.37 https://doi.org/10.26577/eb.2023.v96.i3.02

Zh.E. Aimenova[1]*, A.D. Matchanov[2], S.D. Dzhumanov[3], A.A. Sumbembayev[4], Sh.E. Duisebayev[1]

[1]M.Auezov South Kazakhstan University, Kazakhstan, Shymkent
[2]Institute of Bioorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan named after Academician A.S. Sadykov, Uzbekistan, Tashkent
[3]Aksu-Jabagly Nature Reserve, Kazakhstan, Jabagly village
[4]Altai Botanical Garden, Kazakhstan, Ridder
*e-mail: zhanar.aimenova@auezov.edu.kz

DISTRIBUTION FEATURES AND BIOLOGICAL CHARACTERISTICS OF ENDEMIC PLANT OF WESTERN TIEN-SHAN *ERANTHIS LONGISTIPITATA*

The article provides updated data on the distribution of the endemic species of the Western Tien Shan Eranthis longistipitata Regel on the territory of the Aksu-Jabagly Nature Reserve. The features of the structures of the discovered coenopopulations are described. As a result of route field studies of the Kazakh part of the Western Tien Shan, 3 coenopopulations of Eranthis longistipitata were discovered. The first population is the Taldy-Bulak Gorge (left bank of the stream); the second population is the Zhetimsai Gorge (left bank of the stream); the third population is the Valley of the Irsu River. The discovered populations are marked on the map of the Aksu-Jabagly Nature Reserve. Monitoring sites were created for all coenopopulations, the species density was calculated using the method of A.A.Uranov, the species composition was determined. The average density of Eranthis longistipitata species varied from 14 to 22 pcs/2m^2. The morphometric characteristics of the detected species growing in 3 different sites have been studied. The population of Eranthis longistipitata growing in the valley of the Irsu River was marked by the maximum indicators (stem height, number of leaves and sepals). The plant community of 3 monitoring sites and the predominant soil type were determined. Explanatory graphs and tables have been created and an assessment of the current state of the structural features of the distribution and coenopopulations of Eranthis longistipitata in the Kazakh part of the Western Tien Shan has been given.

Key words: Eranthis longistipitata Regel, Western Tien Shan, Aksu Jabagly Nature Reserve, endemic, population density, morphometric characteristics.

Ж.Е. Айменова[1]*, А.Д. Матчанов[2], С.Д. Джуманов[3], А.А. Сумбембаев[4], Ш.Е. Дуисебаев[1]

[1]М.Әуезов атындағы Оңтүстік Қазақстан университеті, Қазақстан, Шымкент
[2]Академик А.С.Садыков атындағы Өзбекстан Республикасы ғылым академиясының биоорганикалық химия институты, Өзбекстан, Ташкент
[3]Ақсу-Жабағылы мемлекеттік табиғи қорығы, Қазақстан, Жабағылы ауылы
[4]Алтай ботаникалық бағы, Қазақстан, Риддер
*e-mail: zhanar.aimenova@auezov.edu.kz

Батыс Тянь-Шань эндемикалық *Eranthis longistipitata* өсімдігінің таралу ерекшеліктері мен биологиялық сипаттамалары

Мақалада Ақсу-Жабағылы мемлекеттік табиғи қорығының аумағында өсетін Батыс Тянь-Шаньның эндемикалық Eranthis longistipitata Regel өсімдігінің таралуы туралы нақтыланған мәліметтер келтірілген. Анықталған ценопопуляция құрылымдарының ерекшеліктері сипатталған. Батыс Тянь-Шаньның қазақстандық бөлігін маршруттық далалық зерттеу нәтижесінде Eranthis longistipitata өсімдігінің 3 ценопопуляциясы табылды. Бірінші популяция – Талдыбұлақ шатқалы (ағынның сол жағалауы); екінші популяция – Жетімсай шатқалы (ағынның сол жағалауы); үшінші популяция – Ирсу өзенінің аңғары. Табылған популяциялар Ақсу-Жабағылы табиғи қорығының картасында белгіленген. Барлық ценопопуляциялар үшін мониторингтік алаңдар құрылды, түрдің тығыздығы А.А. Уранов әдісімен есептелді, тірі жер жамылғысының түрлік құрамы анықталды. Eranthis longistipitata өсімдігінің орташа тығыздығы 14-тен 22 дана/2м^2-ге дейін анықталды. 3 түрлі аймақта өсетін табылған Eranthis longistipitata өсімдігінің морфометриялық сипаттамалары зерттелді. Табылған популяциялардың арасында максималды көрсеткіштер (сабағының биіктігі, жапырақтары мен сепалдарының саны) Ирсу өзенінің аңғарында туған. 3 бақылау алаңының өсімдіктер қауымдастығы және топырақтың басым түрі анықталды. Түсіндірме графиктер

мен кестелер жасалды және Батыс Тянь-Шаньның Қазақстандық бөлігінде (Ақсу-Жабағылы мемлекеттік табиғи қорығының аумағында) Eranthis longistipitata өсімдігінің таралуы мен ценопопуляцияларының құрылымдық ерекшеліктерінің қазіргі жай-күйіне баға берілді.

Түйін сөздер: Eranthis longistipitata Regel, Батыс Тянь-Шань, Ақсу-Жабағылы мемлекеттік табиғи қорығы, эндемик, популяцияның тығыздығы, морфометриялық сипаттамалары.

Ж.Е. Айменова[1]*, А.Д. Матчанов[2], С.Д. Джуманов[3],
А.А. Сумбембаев[4], Ш.Е. Дуисебаев[1]

[1]Южно-Казахстанский университет имени М. Ауэзова, Казахстан, г. Шымкент
[2]Институт биоорганической химии имени академика А.С. Садыкова
Академии наук Республики Узбекистан, Узбекистан, г. Ташкент
[3]Аксу-Джабаглинский государственный природный заповедник, Казахстан, с. Жабагылы
[4]Алтайский ботанический сад, Казахстан, г. Риддер
*e-mail: zhanar.aimenova@auezov.edu.kz

Особенности распространения и биологические характеристики эндемичного растения Западного Тянь-Шаня *Eranthis Longistipitata*

В статье предоставлены уточненные данные о распространении эндемичного вида Западного Тянь-Шаня Eranthis longistipitata Regel на территории Аксу-Джабаглинского заповедника. Описаны особенности структур обнаруженных ценопопуляций. В результате маршрутных полевых исследований Казахстанской части Западного Тянь-Шаня были обнаружены 3 ценопопуляции Eranthis longistipitata. Первая популяция – Ущелье Талды-булак (левый берег ручья); вторая популяция – Ущелье Жетімсай (левый берег ручья); третья популяция – долина реки Ирсу. Обнаруженные популяции отмечены на карте Аксу-Джабаглинского природного заповедника. Для всех ценопопуляций были созданы мониторинговые площадки, плотность вида рассчитывалась по методу А.А.Уранова, определялся видовой состав живого напочвенного покрова. Средняя плотность вида Eranthis longistipitata варьировала от 14 до 22 шт/2м^2. Исследованы морфометрические характеристики обнаруженного вида, произрастающих в 3 разных участках. Максимальными показателями (высотой стебля, количеством листьев и чашелистиков) отмечена популяция Eranthis longistipitata, произрастающая в долине реки Ирсу. Определено растительное сообщество 3 мониторинговых площадок и преобладающий тип почв. Созданы пояснительные графики и таблицы и дана оценка современного состояния структурных особенностей распространения и ценопопуляций Eranthis longistipitata на Казахстанской части Западного Тянь-Шаня.

Ключевые слова: Eranthis longistipitata Regel, Западный Тянь-Шань, Аксу-Джабаглинский государственный природный заповедник, эндемик, плотность популяций, морфометрические характеристики.

Introduction

The flora of Kazakhstan includes more than 13 thousand species, including more than 5750 species of higher vascular plants, about 5000 – fungi, 485 – lichens, more than 2000 – algae, about 500 – mossy. There are centers of flora endemism in Kazakhstan (Karatau Mountains, Western Tien Shan), a number of unique natural complexes and communities original in floral composition. The country has a full range of subzonal vegetation variants of steppes, deserts and mountain belts characteristic of central Eurasia [1].

The Western Tien Shan is characterized by exceptional diversity, mosaic and beauty of landscapes; outstanding evidence of large-scale geological and evolutionary processes; a unique combination of different types of ecosystems; a rich animal and plant world, a considerable proportion of which are endemic species and communities, as well as a significant number of rare and endangered species [2].

Aksu-JabaglyNature Reserve is the northern part of the Western Tien Shan at the point of convergence of the borders of three states – Kazakhstan, Kyrgyzstan and Uzbekistan. It occupies a mountainous territory stretching 53 km from west to east and 41 km from south to north. Aksu-Jabagly Nature Reserve is unique not only for the duration of the protection regime established in it and the diversity of the flora and fauna represented [3].

The flora of the Reserve is about 50% of the flora of the Western Tien Shan (without Karatau) and almost 25% of the flora of the entire Central Asia. It is characterized by a high degree of endemism – representatives of 20 out of 64 genera endemic to the Mountainous Central Asian province grow here. 72 species of plants – wild relatives of cultivated plants, about 200 species of medicinal plants and 57

species listed in the Red Books of Kazakhstan, Uzbekistan and Kyrgyzstan grow on the territory of the Reserve [4].

One of the endemic species of the Western Tien Shan is *Eranthis longistipitata* Regel (Figure 1).

All *Eranthis* species are distributed in limited areas from southern Europe to central Asia that extend to China, Eastern Russia, Central Asia, Korea and Japan (Fig. 2).

Three species with yellow sepals are *E.hyemalis* (L.) Salisb., which grow in southern Europe including parts of France, Italy, and the Balkans; *E.cilicica* Schott Kotschy, which is considered conspecific with *E.hyemalis* and is found in southwestern Asia including Turkey and Afghanistan; and *E.longistipitata* Regel is native to central Asia from central southern Russia eastward to Uzbekistan and Iran.

Figure 1 – *E.longistipitata* flowering period on the territory of Aksu-Jabagly Nature Reserve

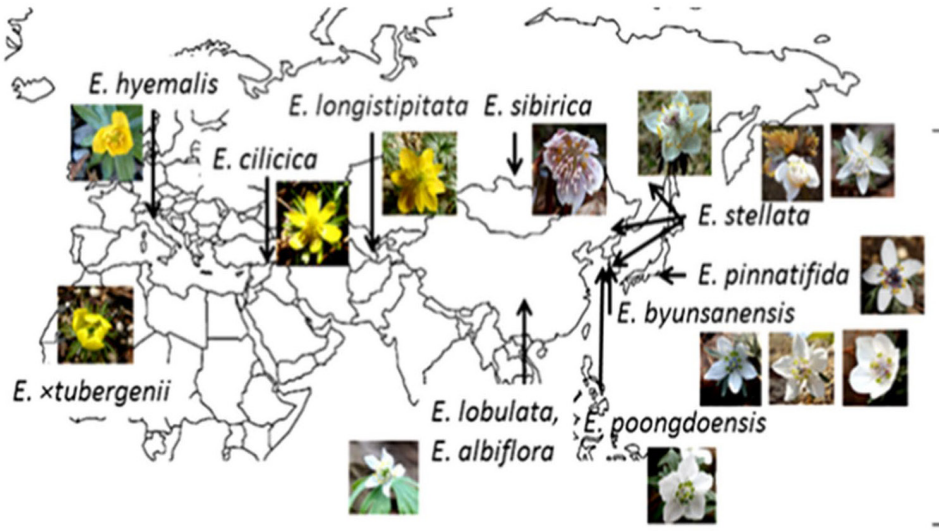


Figure 2 – Distribution of *Eranthis* species [5]

Species with white sepals include *E.sibirica* D.C., native to northern Asia; *E.albifora* Franchet and *E.lobulata* W.T.Wang, native to western China; *E.stellata* Maxim., native to eastern Asia including northern China, Korea, and southeast Russia [6]; *E.byunsanensis* B.Y.Sun, native to the southern part of Korea; *E.pungdoensis* B.U. Oh, native to a very small Pungdo island of the west coast of Korea; and *E.pinnatifda* Maxim., native to Japan. Most species of *Eranthis* have flowers with a single petal.

On the basis of morphology, the genus has been divided into two sections: *E.* sect. *Eranthis* and *E.* sect. *Shibateranthis* (Nakai) Tamura [7]. The type section is characterized by annual tubers, yellow sepals and emarginate or slightly bilobate upper petal margins without swellings (nectaries), whereas the members of section *Shibateranthis* have long-lived tubers, white sepals and bilobate or forked petal margins with swellings [8].

Plants of the *Eranthis* genus are endemic perennial tuberous ephemeroids [9], psychromesophytes (plants growing mainly on cold and moist soils [10], semigeliophytes (this ecological group includes those plants that are adapted to life in places with good sunlight, but resistant to shading [11]. During the growing season, plant stems grow up to 25 cm at flowering and up to 40 cm at fruiting. There is a single basal leaf, which increases in size during fruiting. Stem leaves, depending on the species, may be present or absent and also change their size during the growing season. Some species have trichomes on the peduncle and peduncle. The flowers are white or yellow, depending on the section, most often single, bisexual, stamens in the amount of about 40 pieces. The fruit is a leaflet that contains up to 8 seeds of a rounded shape [12-16].

Plants of the *Eranthis* genus have practical applications. Studies of *E.cilicica* components have led to the isolation of ten chromone derivatives, two of which were previously known. Antioxidant activity was determined in a number of substances [17]. In another study, phytochemical analysis of *E.cilicica* tubers showed the presence of eleven new cycloartan glycosides and one new oleanane glycoside, together with one known oleanane glycoside. Aglycone and its C–23 epimer and ioleanane glycosides have shown cytotoxic activity against HL–60 leukemic cells [18].

The lectin found in *E.hyemalis* tubers (L) is a protein that inactivates Type II ribosomes (Type II RIP). It has shown anti-cancer properties and has great potential as a therapeutic agent [19]. In an earlier study, a modified protocol for the extraction and purification of EHL using affinity chromatography was presented and the cytotoxic effect of lectin against amphid neurons of Caenorhabditis elegans was proved [20].

Since the Western Tien Shan is divided by three Central Asian states: Kazakhstan, Uzbekistan and Kyrgyzstan (figure 3), previously, the endemic species of the Western Tien Shan *E. longistipitata* was also found on the Uzbek and Kyrgyz sides of the Western Tien Shan (table 1).

Figure 3 – Location of Western Tien-Shan [21]

Table 1 – Location of points of the natural growth of *E.longistipitata* in the Western Tien Shan [22]

№	Locality, coordinates	Habitat
1	Kyrgyzstan, Chuya region, Issyk-atinskii district, Niczniaya Serafimovka village; 42°45′02″N, 74°51′37″ E	foot of the mount
2	Kyrgyzstan, Chuya region, Issyk-atinskii district, Karandolot tract; 42°44′22″N, 74°55′50″ E	foot of the mount
3	Uzbekistan, Andijan region, Khojaabad district, east-southeastern part of Fergana valley, Kyrtashtau mountains, near Imamat village; 40°32′27″ N, 72°36′28″ E	mossy stony slope
4	Uzbekistan, Samarkand region, Urgut district, western Pamir-Alai, Gissar-Alai, western part of the Zeravshan ridge, right bank of Amankutansai river, near Amankutan kishlak; 39°18′16″ N, 66°55′45″ E	juniper forest on the slope
5	Uzbekistan, Tashkent region, Bostanlyk district, western Tian Shan, spurs of northwestern part of Chatkal ridge, Galvasay river valley—left tributary Chirchik river, left bank; 41°32′20″ N, 69°53′03″ E	walnut grove on the slope
6	Uzbekistan, Tashkent region, Bostanlyk district, Western Tian Shan, north-western part of Chatkal ridge, foot of Big Chimgan mountain, area between Galvasay and Mramornaya rivers, on road from Uchterek tract to Chimgan tract; 41°31′05″ N, 69°59′15″ E	bushy slope

The research objective is to identify *E. longistipitata* populations on the territory of the Kazakh part of the Western Tien Shan and study their abundance, density and morphological features.

Materials and methods

The subject of the study is a perennial herbaceous endemic species of the Western Tien-Shan belonging to the family *Ranunculaceae* Juss. (figure 1).

The work was carried out according to generally accepted methods for studying coenopopulations [23-25].

The method of research was a route-reconnaissance survey of the territory. To study the general composition of the flora, as well as to monitor the growth points of *E. longistipitata*, field trips were carried out in spring, summer and autumn. The survey was carried out using existing maps of the Aksu-Jabagly State Nature Reserve, as well as a GPS navigator (GPS Map 65, Garmin). All locations were recorded and were identified plants that make up the phytocenosis of the monitoring site. For this purpose geobotanical monitoring plots were established, investigation of which was carried out according to the generally accepted method [26]. To study the floristic composition of the communities, about 80 herbarium specimens were collected and processed. The species were identified using the main reports [27-29].

Taking into account that *E. longistipitata*is endemic plant of the Western Tien-Shan, we have studied its morphological characteristics. For this, measurements of generative and vegetative individuals (50–80) were carried out, and data on the morphological variability of flowers were collected. To verify the distribution range of *E. longistipitata*. in Kazakhstan, all available floristic summaries and other literary sources, as well as the herbarium of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan (TASH), the herbarium of the Altai Botanical Garden (ABG)and materials from the Plantarium website [30] were consulted. Statistical data processing was carried out using the Descriptive Statistics MS Excel 2007 program.

Results and discussion

The studies were carried out on the territory of the Aksu-Jabagly State Nature Reserve (established by the resolutions of the Council of People ‘s Commissars of the Kazakh ASSRdated July 14, 1926), in 2022–2023.

E.longistipitata is a perennial plant with an almost spherical tuber bearing 1-2 basal palmately 3-5-separated leaves and a leafless stem, 3-25 cm long, at the top of which there is a wrapper-cover divided into linear segments (figure 1).

To establish the actual places of growth in Kazakhstan, a review of herbarium funds in Kazakhstan (ABG) and Uzbekistan was carried out (TASH) (table 2).

Based on the database collected before the study, a population map of *E.longistipitata* was created (Table 3, Figure 4).

Table 2 – Synopsis of archival herbarium finds of *E. longistipitata* in Kazakhstan

Location	Date	Collector
Kazakhstan, Novo-Nikolavka village, Aksu-Dzhabagly nature reserve, northern slope, thickets of wild roses	24.04.1969	Collected by: Rusov, Shmarina Determined by: Rusov
Kazakhstan, Karatau mountains, under a snow patch, at the top of the Meshistye Mountains, near Tyulkubas station	22.05.1939	Collected by: N.V. Pavlov Determined by: N.V. Pavlov
Kazakhstan, Karatau mountains, on a rocky slope	2.05.1928	Collected by: N.N. Graz-Guseva Determined by: N.V. Pavlov
Kazakhstan, Turkestan region, Karatau mountains, Bazhibil pass, under a snow patch on a slope	29.04.1930	Collected by: S.Yu. Lipschitz Determined by: S.Yu. Lipschitz
Kazakhstan, Turkestan region, foothills of the ridge Karatau, rocky slopes near the village of Babay Kurgan	2.04.1930	Collected by: S.Yu. Lipschitz Determined by: S.Yu. Lipschitz
Kazakhstan, Karatau ridge, Mount Arkarly Tau. Forb steppe, on a slope near the village of Vasilievka	2.05.1935	Collected by: L. Chilikina, A. Mamirova Determined by: L. Chilikina
Kazakhstan, Shymkent, along the ridges to the west of the city	12.03.1932	Collected by: P. Zhugina Determined by: N.V. Pavlov
Kazakhstan, Turkestan region, Karatau mountains, lawns on the slopes of the mountains in the Ush-Uzen tract	4.04.1930	Collected by: S.Yu. Lipschitz Determined by: S.Yu. Lipschitz
Kazakhstan, Shymkent region, between the villages of Vysokoe and Rappovka	8.05.1973	Collected by: L. Pimenov Determined by: L. Pimenov
Kazakhstan, South Kazakhstan region, gravelly slopes on the tops of the Kuyuk mountains	1.05.1939	Collected by: N.V. Pavlov Determined by: N.V. Pavlov

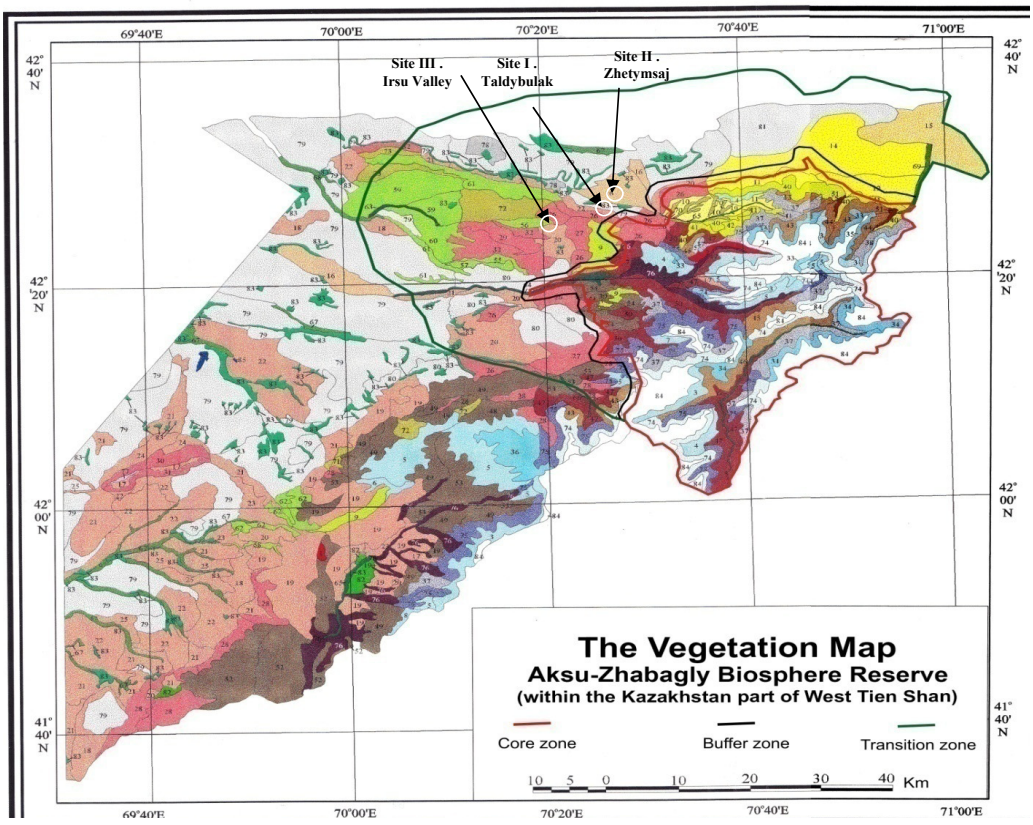


Figure 4 – Map of the distribution areas of *E.longistipitata* populations on the territory of Aksu-Jabagly Nature Reserve [31] (Site I – Taldy-bulak Gorge, Site II – Zhetimsai Gorge, Site III – Irsu Valley)

Table 3 – Geographical location of the studied *E.longistipitata* populations

№	Location	Geographical coordinates
Coenopopulation 1	Taldy-bulak Gorge, left bank of the stream	42º 25'12N 70°28'28E
Coenopopulation 2	Zhetimsai Gorge, left bank of the stream	42º 24'41N 70°32'41E
Coenopopulation 3	Irsu Valley	42º 21'33 N 70°22'28E

The study of coenopopulations began with the study of the geographical location of the studied *E.longistipitata* species and the establishment of a plant community. Phytocenotic and ecological features of the habitat were determined by the main parameters.

As shown in Figure 4 and Table 2 populations of *E.longistipitata* in the Aksu-Jabagly Nature Reserve are represented in 3 growth sites:

1. Site I – Taldy-bulak Gorge. Community: Deciduous-shrubby. Trees and shrubs– *Crataegus turkestanica* Pojark, *Lonicera tianschanica* Pojark., *Spiraea hypericifolia* L., *Rosa kokanica* Regel, *Rosa fedtschenkoana* Regel, *Ephedra equisetina* Bunge. Population contains 14 individuals of *E.longistipitata.*

Herbaceous plants – *Ziziphora bungeana* Juz, *Hypericum perforatum* L., *Eremurus regelii* Vved, *Achillea millefolium* L., *Crocus alatavicus* Regel & Semen., *Gagea lutea* (L.) Ker Gawl, *Arum korolkowii* Regel, *Hypericum perforatum* L.

2. Site II – Zhetimsai Gorge. Comminuty: Deciduous-shrubby. Trees and shrubs – *Crataegus turkestanica* Pojark, *Lonicera tianschanica* Pojark., *Lonicera nummulariifolia* Jaub. & Spach, *Spiraea hypericifolia* L., *Rosa kokanica* Regel ex Juz., *Rosa fedtschenkoana* Regel, *Salix babylonica* L., *Malus sieversii* (Ledeb.) M.Roem.Population contains 15 individuals of *E.longistipitata.*

Herbaceous plants –*Ziziphora bungeana* Juz., *Hypericum perforatum* L., *Eremurus regelii* Vved, *Achillea millefolium* L., *Crocus alatavicus* Regel & Semen., *Gagea lutea* (L.) Ker Gawl., *Hypericum perforatum* L., *Leontice albertii* Regel, *Corydalis ledebouriana* Kar. & Kir., *Verbascum songaricum* Schrenk., *Hordeum bulbosum* L., *Tulipa kaufmanniana* Regel.

3. Site III – Irsu Valley. Comminuty: Savannoid. Trees and shrubs –*Spiraea hypericifolia* L., *Rosa kokanica* Regel ex Juz.Population contains 22 individuals of *E.longistipitata.*

Herbaceous plants –*Ziziphora bungeana* Juz., *Hypericum perforatum* L., *Eremurus regelii* Vved, *Achillea millefolium* L., *Crocus alatavicus* Regel & Semen., *Gagea lutea* (L.) Ker Gawl., *Leontice albertii* Regel, *Corydalis ledebouriana* Kar. & Kir., *Verbascum songaricum* Schrenk., *Hordeum bulbosum* L, *Tulipa kaufmanniana* Regel, *Tulipa greigii* Regel, *Rhinopetalum karelinii* Fisch. ex D. Don, *Sedum alberti* Regel.

In all coenopopulations the number of *E. longistipitata*plants was 150 individuals. The average density of the coenopopulations ranged from 14 – 22 individuals/2m^2 in the 3 populations (Figure 5).

Next step of our researches was investigation of differences in morphometric characteristics of generative individuals of the *E.longistipitata* populations (table 4).

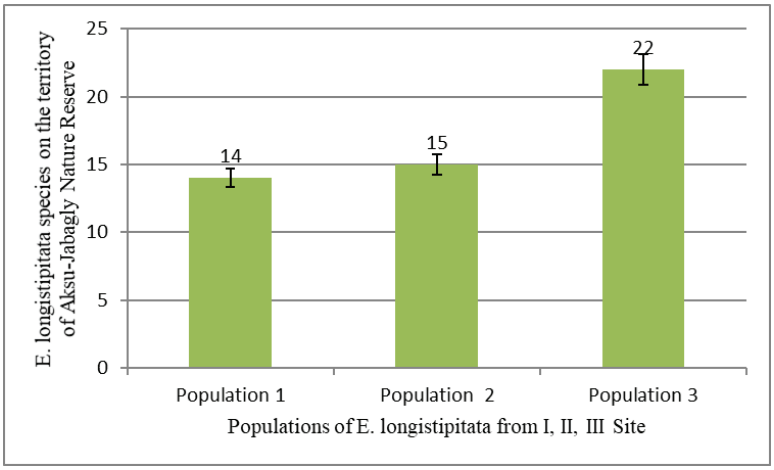


Figure 5 – Average density of the *E.longistipitata* species on the territory of the Aksu-Jabagly Nature Reserve

Table 4 – Morphometric characteristics of *E.longistipitata* generative individuals in 3 coenopopulations.

Indicators	Coenopopulation from the Site I(Taldy-bulak Gorge)	Coenopopulationfrom the Site II (Zhetimsai Gorge)	Coenopopulation from the Site III (Irsu Valley)
	M±m	M±m	M±m
Stem height, см	4.7	4.7	5.9
Number of leaves	2.5	2.6	3.4
Number of sepals	15	18	22

According to the data obtained in Table 4, the main morphometric characteristics of individuals from coenopopulation III are superior to the rest. These individuals have the highest stem length, the maximum number of leaves and the number of sepals. Also, as shown in Figure 5, the maximum number of *E.longistipitata* individuals was also noted in the coenopopulation growing in the Irsu valley.

This fact may be due to the fact that the Irsu Valley is higher than the other two points (1454 m above sea level). Accordingly, the amount of precipitation and the humidity level are higher than in Taldybulak (1198 m above sea level) and Zhetimsai Gorge (1452 m above sea level). It should also be noted that the level of humidity and precipitation is higher there, since populations of *E. longistipitata* grow in the valley of the Irsu River, and in the other two points – Taldy-bulak gorge and Zhetimsai populations of *E. longistipitata* grow along small streams. The soil type in the Irsu River Valley is also different. Stony soil type and savanna vegetation type prevail here, while deciduous shrub vegetation type and gray-brown soils prevail in Taldybulak and Zhetimsai gorges.

Conclusion

As a result of the conducted research, the areas of growth of *E.longistipitata* populations in the Kazakh part of the Western Tien Shan (the territory of the Aksu-Jabagly Reserve) have been established. 3 points are marked: Taldy-bulak Gorge, Zhetimsai Gorge and Irsu Valley. Established growth sites have different levels of altitude above sea level. The highest point of the place where *E.longistipitata* grows is the valley of the Irsu River. At the same time, the average population density of *E.longistipitata* at these three points has been established. The highest density is noted on site No. III (the valley of the Irsu River). The next stage of the research was to determine the morphometric characteristics of the detected populations. The following parameters were selected as indicators: the height of the stem, the number of leaves and the number of sepals. The maximum values are marked by the coenopopulations of *E.longistipitata* growing in the valley of the Irsu River. The data obtained indicate the presence of factors influencing the favorable growth of coenopopulations in the natural habitats of *E.longistipitata*: humidity, the presence of rocky soil and a savanoid plants community.

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflict of interest.

Funding

The work was carried out within the framework of the grant funding program for young scientists under the project “Zhas Galym” for 2022-2024, carried out by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, on theme AP15473152 “Conservation of biodiversity and research of biologically active compounds of *Eranthis longistipitata*”.

References

1 Materials of the Fifth National Report of the Republic of Kazakhstan on biological diversity. – Astana, 2014.

2 Akzhigitova N.I. Diversity of plant communities of the main formations of the subalpine belt of the Western Tien Shan // Biodiversity of the Western Tien Shan: protection and rational use. – Tashkent, 2002. – P. 32–35.

3 Kovshar’ A.F. Aksu-Jabagly Nature Reserve is 90 years old // Nature Conservation Research. Reserved science. 2016. №1 (1). C.111-118

4 Karmysheva N.K. 1973. Flora and vegetation of AksuDzhabagly nature reserve. Alma-Ata. 176 p.

5 Park, S.Y., Jeon, M.J., Ma, S.H. *et al.* Phylogeny and genetic variation in the genus *Eranthis* using nrITS and cpIS single nucleotide polymorphisms. *Hortic. Environ. Biotechnol.* **60**, 239–252 (2019). https://doi.org/10.1007/s13580-018-0113-0

6 Li L, Tamura M (2001) Etranthis Salisbury, Trans. Linn. Soc. London 8:303. 1807, nom. cons. Flora China 6:148–149

7 Tamura M (1987) *Eranthis* and *Shibateranthis*. Acta Phytotaxonomica et Geobotanica 38: 96–97.

8 Tamura M (1995) *Eranthis*. In: Hiepko P (Ed.), Die Natürlichen Pflanzenfamilien, vol. 17(4). Duncker und Humblot, Berlin, 253–255.

9 Sokolova T. G. Diagnoses and keys of age-related conditions of forest plants. Ephemeroids. / T.G.Sokolova. – M.: Lenin Moscow State Pedagogical Institute, 1987. – 80 p.

10 Bykov B.A. Geobotanical Dictionary./ B.A.Bykov. –2nd ed., reworked. and add.– Alma–Ata.: Science, 1973. – 216 p.

11 Garkusha L.Ya. Intra-landscape structure and ecological features of hornbeam forests of the Mountainous Crimea // Scientific notes of the V. I. Vernadsky Crimean Federal University. Geography. Geology. – 2008. –Vol.21. – № 60. – P. 102–118.

12 Krasnopevtseva V.M. Biology of *Eranthis sibirica* DC. on Hamar–Daban / V.M.Krasnopevtseva, A.S. Krasnopevtseva // Proceedings of the Samara Scientific Center of the Russian Academy of Sciences. – 2013. – Vol.15. – № 3/2. – P. 845–848.

13 Erst A. S. An integrative taxonomic approach reveals a new species of *Eranthis* (*Ranunculaceae*) in North Asia / A.S. Erst [et al.] // PhytoKeys. – 2020. – № 140. – P. 75–100.

14 Jung Wo–Ch. Comparative seed morphology of Korean Eranthis (Ranunculaceae) / Wo–Ch. Jung, D.–Yo. Shin, K. Heo // Korean Journal of Plant Taxonomy. – 2010. – Vol. 40. – № 2. – P. 105–107.

15 Oh B.–Un. Comparative seed morphology of Korean Eranthis (Ranunculaceae) / B.–Un Oh, S.–J. JI // Korean Journal of Plant Taxonomy. – 2009. – Vol. 39. – № 2. – P. 86–88.

16 Sun B. Yu. A New species of Eranthis (Ranunculaceae) from Korea: E. byunsanensis / B. Yu. Sun, Ch. H. Kim, T. Ji. Kim // Korean Journal of Plant Taxonomy. – 1993. – Vol. 23. – № 1. – P. 21–26.

17 Kuroda M. Chromones from the tubers of Eranthis cilicica and their antioxidant activity / M. Kuroda [et al.] // Phytochemistry. – 2009. – № 70. – P. 288–293.

18 Watanabe K. Cycloartane and Oleanane Glycosides from the Tubers of Eranthis cilicica / K. Watanabe [et al.] // Molecules. – 2018. – Vol. 24. – № 1. – 69 p.

19 Djafari Ja. Synthesis of Gold Functionalised Nanoparticles with the Eranthis hyemalis Lectin and Preliminary Toxicological Studies on Caenorhabditis elegans / Ja. Djafari [et al.] // Materials. – 2018. – Vol. 11. – № 8. – 1363 P.

20 McConnell. Winter Aconite (Eranthis hyemalis) Lectin as a cytotoxic effector in the lifecycle of Caenorhabditis elegans / McConnell [et al.] // PeerJ – Life and Environment Journal. – 2015. – Vol. 20. – № 3. – 1206 p.

21 https://www.naturalworldheritagesites.org/sites/western-tien-shan/

22 Kostikova, V.A.; Chernonosov, A.A.; Kuznetsov, A.A.; Petrova, N.V.; Krivenko, D.A.; Chernysheva, O.A.; Wang, W.; Erst, A.S. Identification of Flavonoids in the Leaves of Eranthis longistipitata (Ranunculaceae) by Liquid Chromatography with High-Resolution Mass Spectrometry (LC-HRMS). Plants 2021, 10, 2146. https://doi.org/10.3390/ plants10102146

23 Rabotnov T. A. Methods for determining the age and duration of life in herbaceous plants. Field geobotany. – Vol. 2. M.- L. – 1960. – P. 240-262.

24 Zlobin Y.A. Principles and methods of studying cenotic plant populations. – Kazan: Publishing of KSU. – 1989. – P. 147-196.

25 Uranov A.A. Age spectrum of cenopopulations as a function of time and energy wave processes // Scientific report of the higher school. Biol.science. – 1975. – Vol. 2. – P. 7-34.

26 Field geobotany. – M.-L.: Publishing House of the USSR Academy of Sciences. 1964-1971.

27 Flora of the USSR. Vv. 1-30. M. – L.– 1934-1964.

28 Flora of Kazakhstan. Vv. 1-9. Alma-Ata, – 1956-1966.

29 The determinant of Central Asia. Critical Synopsis of flora. Vv. 1-10. – Tashkent. – 1968-1993.

30 https://www.plantarium.ru/

31 https://www.kazmab.kz/index.php/biosfernye-rezervaty1/natsionalnaya-set/aksu-zhabagly/opisanie

References

1 Akzhigitova N.I. Raznoobrazie rastitel'nyh soobshhestv osnovnyh formacij subal'pijskogo pojasa Zapadnogo Tjan'-Shanja [Diversity of plant communities of the main formations of the subalpine belt of the Western Tien Shan] // Bioraznoobrazie Zapadnogo Tjan'-Shanja: ohrana i racional'noe ispol'zovanie. – Tashkent, 2002. – P. 32–35.

2 Bykov B.A. Geobotanicheskij slovar' [Geobotanical Dictionary]. / B.A.Bykov. – 2-e izdanie, pererabotannoe i dopolnennoe – Alma–Ata. : Nauka, 1973. – 216 p.

3 Djafari Ja. Synthesis of Gold Functionalised Nanoparticles with the Eranthis hyemalis Lectin and Preliminary Toxicological Studies on Caenorhabditis elegans / Ja. Djafari [et al.] // Materials. – 2018. – Vol. 11. – № 8. – 1363 P.

4 Erst A. S. An integrative taxonomic approach reveals a new species of Eranthis (Ranunculaceae) in North Asia / A.S. Erst [et al.] // PhytoKeys. – 2020. – № 140. – P. 75–100.

5 Field geobotany. – M.-L.: Publishing House of the USSR Academy of Sciences. 1964-1971.

6 Flora of Kazakhstan. Vv. 1-9. Alma-Ata, – 1956-1966.

7 Flora of the USSR. Vv. 1-30. M. – L.– 1934-1964.

8 Garkusha L.Ya. Vnutrilandshaftnaja struktura i jekologicheskie osobennosti grabovyh lesov Gornogo Kryma [Intra-landscape structure and ecological features of hornbeam forests of the Mountainous Crimea] // Uchenye zapiski Krymskogo federal'nogo universiteta imeni V.I.Vernadskogo. Geografija. Geologija. – 2008. – Vol.21. – № 60. – P. 102–118.

9 https://www.kazmab.kz/index.php/biosfernye-rezervaty1/natsionalnaya-set/aksu-zhabagly/opisanie

10 https://www.naturalworldheritagesites.org/sites/western-tien-shan/

11 https://www.plantarium.ru/

12 Jung Wo–Ch. Comparative seed morphology of Korean Eranthis (Ranunculaceae) / Wo–Ch. Jung, D.–Yo. Shin, K. Heo // Korean Journal of Plant Taxonomy. – 2010. – Vol. 40. – № 2. – P. 105–107.

13 Karmysheva N.K. 1973. Flora i rastitel'nost' Aksu-Dzhabaglinskogo zapovednika [Flora and vegetation of AksuDzhabagly nature reserve]. Alma-Ata. 176 p.

14 Kostikova, V.A.; Chernonosov, A.A.; Kuznetsov, A.A.; Petrova, N.V.; Krivenko, D.A.; Chernysheva, O.A.; Wang, W.; Erst, A.S. Identification of Flavonoids in the Leaves of Eranthis longistipitata (Ranunculaceae) by Liquid Chromatography with High-Resolution Mass Spectrometry (LC-HRMS). Plants 2021, 10, 2146. https://doi.org/10.3390/ plants10102146

15 Kovshar' A.F. Aksu-zhabaglinskomu zapovedniku 90 let [Aksu-Jabagly Nature Reserve is 90 years old] // Nature Conservation Research. Zapovednaja nauka. 2016. №1 (1). P.111-118

16 Krasnopevtseva V.M. Biologija *Eranthis sibirica* DC. na Hamar–Dabane [Biology of *Eranthis sibirica* DC. on Hamar–Daban] / V.M.Krasnopevtseva, A.S. Krasnopevtseva // Izvestija Samarskogo nauchnogo centra Rossijskoj akademii nauk. – 2013. – Vol. 15. – № 3/2. – P. 845–848

17 Kuroda M. Chromones from the tubers of Eranthis cilicica and their antioxidant activity / M. Kuroda [et al.] // Phytochemistry. – 2009. – № 70. – P. 288–293.

18 Li L, Tamura M (2001) Etranthis Salisbury, Trans. Linn. Soc. London 8:303. 1807, nom. cons. Flora China 6:148–149

19 Materialy Pjatogo nacional'nogo doklada Respubliki Kazahstan o biologicheskom raznoobrazii [Materials of the Fifth National Report of the Republic of Kazakhstan on biological diversity]. – Astana, 2014.

20 McConnell. Winter Aconite (Eranthis hyemalis) Lectin as a cytotoxic effector in the lifecycle of Caenorhabditis elegans / McConnell [et al.] // PeerJ – Life and Environment Journal. – 2015. – Vol. 20. – № 3. – 1206 p.

21 Oh B.–Un. Comparative seed morphology of Korean Eranthis (Ranunculaceae) / B.–Un Oh, S.–J. JI // Korean Journal of Plant Taxonomy. – 2009. – Vol. 39. – № 2. – P. 86–88.

22 Park, S.Y., Jeon, M.J., Ma, S.H. *et al.* Phylogeny and genetic variation in the genus *Eranthis* using nrITS and cpIS single nucleotide polymorphisms. *Hortic. Environ. Biotechnol.* **60**, 239–252 (2019). https://doi.org/10.1007/s13580-018-0113-0

23 Rabotnov T. A. Methods for determining the age and duration of life in herbaceous plants. Field geobotany. – Vol. 2. M.- L. – 1960. – P. 240-262.

24 Sokolova T. G. Diagnozy i kljuchi vozrastnyh sostojanij lesnyh rastenij. Efemeroidy [Diagnoses and keys of age-related conditions of forest plants. Ephemeroids] / T. G.Sokolova. – M.: Moskovskij gosudarstvennyj pedagogicheskij institut im. V. I. Lenina, 1987. – 80 c.

25 Sun B. Yu. A New species of Eranthis (Ranunculaceae) from Korea: E. byunsanensis / B. Yu. Sun, Ch. H. Kim, T. Ji. Kim // Korean Journal of Plant Taxonomy. – 1993. – Vol. 23. – № 1. – P. 21–26.

26 Tamura M (1987) *Eranthis* and *Shibateranthis*. Acta Phytotaxonomica et Geobotanica 38: 96–97.

27 Tamura M (1995) *Eranthis*. In: Hiepko P (Ed.), Die Natürlichen Pflanzenfamilien, vol. 17(4). Duncker und Humblot, Berlin, 253–255.

28 The determinant of Central Asia. Critical Synopsis of flora. Vv. 1-10. – Tashkent. – 1968-1993.

29 Uranov A.A. Age spectrum of cenopopulations as a function of time and energy wave processes // Scientific report of the higher school. Biol.science. – 1975. – Vol. 2. – P. 7-34.

30 Watanabe K. Cycloartane and Oleanane Glycosides from the Tubers of Eranthis cilicica / K. Watanabe [et al.] // Molecules. – 2018. – Vol. 24. – № 1. – 69 p.

31 Zlobin Y.A. Principles and methods of studying cenotic plant populations. – Kazan: Publishing of KSU. – 1989. – P. 147-196.

МРНТИ 87.15.02 https://doi.org/10.26577/eb.2023.v96.i3.03

З.А. Инелова[1] *, Д. Едилхан[2] , А.Е. Ермеков[2] , Д.К. Бисенгалиева[2]

[1]Казахский национальный университет имени аль-Фараби, Казахстан, г. Алматы
[2]Astana IT University, Казахстан, г. Алматы
*e-mail: zarina.inelova@kaznu.edu.kz

ЭФФЕКТИВНОСТЬ ОЧИСТКИ ВОЗДУХА БИОТЕХНОЛОГИЧЕСКИМ ФИЛЬТРОМ НА ОСНОВЕ ЕСТЕСТВЕННОЙ РАСТИТЕЛЬНОЙ КУЛЬТУРЫ

Увеличение антропогенной деятельности является главным фактором, вызывающим изменения в климате, атмосфере, биосфере и криосфере Земли, которые непосредственно или косвенно влияют на экосистемы на локальном, региональном и глобальном уровнях. Основными газовыми загрязнителями антропогенного происхождения являются углекислый газ (CO_2), оксид углерода (CO), диоксид серы (SO_2), оксиды азота (NO_x), тяжелые металлы, а также твердые частицы $PM_{2.5}$, PM_{10}. Проблему по очистке воздуха от загрязняющих факторов можно решить биологическим путем, используя мох Сфагнум. Моховые культуры являются практичными, так как легко поглощают вещества из атмосферы своей поверхностью, не прихотливы в уходе, а также культивирование мха не требует длительного периода. Целью данной работы является определение эффективности растительной культуры мха, используемой в биотехнологическом фильтре, в качестве очистителя воздуха от загрязняющих веществ. Для проведения исследований выбран вид мха Sphagnum, который обладает высокой поглощающей способностью и способностью улавливать вредные вещества из окружающей среды, а также создан биотехнологический фильтр, который расположен на территории EXPO в городе Астана. Согласно полученным результатам, t не имеет значительных изменений со временем и имеет уровень в пределах от 26 до 37 °C. Уровень частиц $PM_{2,5}$ и PM_{10} ($\mu g/m^3$) на входе и на выходе анализируемого объекта показывает, что в целом уровень этих частиц на выходе ниже, чем на входе. Уровень углекислого газа (CO_2) остается стабильным на уровне 0,01% на входе в биофильтр. Это может указывать на эффективную работу системы фильтрации или очистки воздуха, а также отсутствие серьезных источников выбросов CO_2.Экспериментальные данные подтвердили эффективность моховых культур в поглощении углекислого газа и выделении кислорода в дневной период. Это подчеркивает потенциал моховых растений, используемых в биотехнологическом фильтре, в качестве инструмента для смягчения проблемы изменения климата. Мхи представляют собой перспективный ресурс для улучшения качества воздуха и смягчения воздействия антропогенных факторов на окружающую среду.

Ключевые слова: мох Sphagnum, биотехнологический фильтр, тяжелые металлы, Smart City, очистка воздуха.

Z.A. Inelova[1*], D. Yedilkhan[2,] A.Ye. Yermekov[2], D.K. Bissengaliyeva[2]

[1]Al-Farabi Kazakh National University, Kazakhstan, Almaty
[2]Astana IT University, Kazakhstan, Astana
*e-mail: zarina.inelova@kaznu.edu.kz

Efficiency of air cleaning with a biotechnological filter based on natural plant culture

The increase in anthropogenic activity is the main factor causing changes in the climate, atmosphere, biosphere and cryosphere of the Earth. The main gas pollutants of anthropogenic origin are CO_2, CO, SO_2, NO_x, heavy metals, as well as solid particles PM2.5, PM10. The problem of air purification from pollutants can be solved biologically using Sphagnum moss. Moss crops are practical, as they easily absorb substances from the atmosphere with their surface, are not whimsical in care, and moss cultivation does not require a long period. The purpose of this work is to determine the effectiveness of a moss plant culture used in a biotechnological filter as an air purifier from pollutants. A species of Sphagnum moss has been selected for research, which has a high absorption capacity and the ability to capture harmful substances from the environment, and a biotechnological filter has been created, which is located on the territory of EXPO, Astana. According to the results obtained, t has no significant changes over time and has a level ranging from 26 to 37°C. The level of particles PM2.5 and PM10 (μg/m3) at the input

lower than at the input. The level of carbon dioxide remains stable at 0.01% at the entrance to the biofilter. This may indicate the efficient operation of the purification system, as well as the absence of serious sources of CO_2 emissions. Experimental data have confirmed the effectiveness of moss in absorbing CO_2 and releasing oxygen during the daytime. This highlights the potential of moss plants used in the biotechnological filter as a tool to mitigate climate change. Mosses are a promising resource for improving air quality and mitigating the impact of anthropogenic factors on the environment.

Key words: moss Sphagnum, biotechnological filter, heavy metals, Smart City, air purification.

З.А. Инелова[1*], Д. Едилхан,[2] А.Е. Ермеков[2], Д.К. Бисенгалиева[2]
[1]Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
[2]Astana IT University, Қазақстан, Астана қ.
*e-mail: zarina.inelova@kaznu.edu.kz

Табиғи өсімдік мәдениеті негізіндегі биотехнологиялық фильтрмен ауаны тазалаудың тиімділігі

Антропогендік белсенділіктің артуы жергілікті, аймақтық және жаһандық деңгейде экожүйелерге тікелей немесе жанама әсер ететін климаттың, атмосфераның, биосфераның және жердің криосферасының өзгеруін тудыратын негізгі фактор болып табылады. Антропогендік факторлар негізіндегі басты газды ластаушы заттар – көмірқышқыл газы (CO_2), көміртегі оксиді (CO), күкірт диоксиді (SO_2), азот оксидтері (NO_x), ауыр металдар, сондай-ақ PM2.5, PM10 қатты бөлшектер болып табылады. Ауаны ластаушы факторлардан тазарту мәселесін Sphagnum мүгінің көмегімен биологиялық жолмен шешуге болады. Мүк дақылдары практикалық болып табылады, өйткені олар атмосферадан заттарды өз денесімен оңай сіңіреді, күтімді талғамайды, сонымен қатар мүк өсіру ұзақ уақытты қажет етпейді. Бұл жұмыстың мақсаты биотехнологиялық фильтрде ауаны ластаушы заттардан тазартқыш ретінде қолданылатын мүк өсімдік дақылының тиімділігін анықтау болып табылады. Зерттеу жүргізу үшін қоршаған ортадан зиянды заттарды сіңіру қабілеті мен ұстау қабілеті жоғары Sphagnum мүгінің түрі таңдалды, сондай-ақ Астана қаласындағы EXPO аумағында орналасқан биотехнологиялық фильтрі жасалды. Алынған нәтижелерге сәйкес, t уақыт өте келе айтарлықтай өзгермейді және 26-дан 37°C-қа дейінгі деңгейге ие. Талданатын объектінің кірісі мен шығысындағы PM2,5 және PM10 (μg/m3) бөлшектерінің деңгейі тұтастай алғанда бұл бөлшектердің шығысы кіріске қарағанда төмен екенін көрсетеді. Көмірқышқыл газының деңгейі (CO_2) биофильтрге кіре берісте 0,01% тұрақты болып қалады. Бұл ауаны тазарту жүйесінің тиімді жұмысын және CO_2 шығарындыларының маңызды көздерінің жоқтығын көрсетуі мүмкін. Эксперименттік дәлелдер мүк дақылдарының көмірқышқыл газын сіңірудегі және күндізгі оттегін шығарудағы тиімділігін растады. Бұл климаттың өзгеруін азайту құралы ретінде биотехнологиялық фильтрде қолданылатын мүк өсімдіктерінің потенциалы бар екенін көрсетеді. Мүктер ауа сапасын жақсарту және антропогендік факторлардың қоршаған ортаға әсерін азайту үшін перспективті ресурс болып табылады.

Түйін сөздер: Sphagnum мүгі, биотехнологиялық фильтр, ауыр металдар, Smart City, ауа тазалау.

Сокращения и обозначения:

CO_2 – углекислый газ; CO – оксид углерода; SO_2 – диоксид серы; NO_x – оксиды азота; ПДК – предельно допустимая концентрация; NH_2OH – гидроксиламин; CH_4 – метан; нм – нанометр; μg/m^3 – микрограмм на кубический метр

Введение

Увеличение антропогенной деятельности является главным фактором, вызывающим изменения в климате, атмосфере, биосфере и криосфере Земли, которые непосредственно или косвенно влияют на экосистемы на локальном, региональном и глобальном уровнях. До промышленной революции загрязняющий фактор был связан с природными причинами, но с наступлением промышленной революции в 19 веке наша экосистема начала подвергаться загрязнению в разы больше. Увеличение загрязнения приводит к таким последствиям как засуха, увеличение пустыни, глобальное потепление, таяние ледников и др. [1-6] Развивающиеся страны стали более уязвимыми из-за демографического роста, быстрой индустриализации и развития мегаполисов. В результате, качество воздуха, воды и почвы ухудшается, а земли подвергаются деградации. Эти неблагоприятные последствия приводят к увеличению заболеваний дыхательной системы, желудочно-кишечного тракта и сердечно-сосудистой системы [7-9].

Основными газовыми загрязнителями антропогенного происхождения являются углекислый газ (CO_2), оксид углерода (CO), диоксид серы (SO_2), оксиды азота (NO_x). Кроме того, к загрязняющим агентам можно отнести тяжелые металлы, а также твердые частицы $PM_{2.5}$, PM_{10}. Нужно отметить, что частицы размером меньше 2,5 микрон пагубно влияют на дыхательную систему человека, проникая в глубь легких [10-11].

Согласно ежедневным данным бюллетени состояния воздушного бассейна №335 состояние атмосферного воздуха в г. Алматы на 1 декабря 2022 года было следующим. Концентрация частиц PM-2,5 превышало ПДК в 3,3 кратности, PM-10 – 1,8, оксид углерода – 1,7, диоксид азота – 2,4, оксид азота – 1,3. [12].

Полученные показатели как пример демонстрируют высокий уровень превышения ПДК, что в последствии провоцирует болезни дыхательных путей или может привести к летальному исходу. В Казахстане в год около 16 тысяч смертей случаются из-за заболеваний, вызванных низким качеством воздуха. Такие данные привел представитель Программы развития ООН в Казахстане Якуп Бериш. В исследованиях CORE по выявлению степени заболеваемости болезнями верхних дыхательных путей, диагностирование с помощью спирометрии показало, что в Казахстане 6,7% населения страдают от хронической обструктивной болезни легких [13].

В целом если обратиться к статистическим показателям от Бюро национальной статистики Агентства по стратегическому планированию и реформам РК, они действительно подтверждают прогрессивную динамику совокупных выбросов парниковых газов в эквиваленте CO_2 – с 216,19 млн.т/год до 342,87 млн.т/год в период 1990-2020 гг., где пик выбросов с показателем 392,75 млн.т был в 2018 году [14] электроэнергетики с использованием угольных теплоэлектростанций является главным источником выбросов парниковых газов, достигнув показателя 940 тыс. тонн. в 2018 году. Например, в 2022 году электрическая энергия, вырабатываемая на тепловых электростанциях, сжигающий уголь, составляет 78,1% [15]. Далее, горно-металлургический сектор имеет второе место с объемом выбросов 760 тыс. тонн в год, за которым следуют нефтедобыча (520 тыс. тонн в год) и секторы транспорта и сельского хозяйства с объемами выбросов 320 тыс. тонн в год [16].

В большинстве городов Казахстана частные дома, использующие печи со сжиганием угля, являются источниками загрязнения воздуха мелкой пылью, образующий смог. Практически одна половина сжигаемого угля остается в виде золы, так как зольность колеблется в пределах 40-50% [17-18]. Зола, в виде мелкодисперсной пыли PM2.5, образуют смог над городом. В столице страны согласно данным Бюро национальной статистики насчитывается 24 393 частных домов [19-20].

Глобальный средний показатель CO_2 в 2015 году приблизился к порогу 400 на уровне 399,4 частей на миллион [21]. Содержание углекислого газа в воздухе в 2021 году составлял примерно 419 частей, что является равным показателю 4 млн лет тому назад. Стоит отметить, что в тот период средняя температура была больше на 13,9°C, уровень моря выше на 24 м. Ученые утверждают, что содержание CO_2 в атмосфере Земли на данный момент является рекордным. Каждый год в атмосферу прибавляется около 40 миллиардов тонн углекислого газа [22-23].

В исследованиях [24] приведена информация об источниках выбросов и их влияния на здоровье человека (таблица 1).

Закись азота (N_2O) является одним из главных газов, которые уменьшают концентрацию озона (O_3) в стратосфере, что может привести к увеличению солнечной радиации, достигающей поверхности Земли, и увеличению температуры [25]. Согласно отчету Межправительственной группы экспертов по изменению климата (IPCC) за 2021 год, N_2O является третьим по важности парниковым газом после углекислого газа (CO_2) и метана (CH_4). Он отличается от других парниковых газов тем, что его концентрация в атмосфере намного меньше, но его потенциал воздействия на глобальное потепление на единицу массы выше, чем у CO_2 или CH_4 [26-27].

Общепризнано, что окисление NH_2OH, нитрифицирующая денитрификация и гетеротрофная денитрифицирующая денитрификация были тремя основными путями образования N_2O в процессе биологической конверсии азота [28-29]. Это означает, что N_2O может выделяться из болотистых мест в результате биотрансформации с любым видом неорганических соединений азота в сточных водах [30].

Таблица 1 – Источники выбросов, пути проникновения, воздействие на здоровье

Загрязнитель воздуха	Источник	Токсикокинетика	Влияние на здоровье
PM	Автомобильные выхлопные газы, производство электроэнергии, мелкая пыль, жилые камины, грунтовые дороги и промышленные объекты	Нижняя дыхательная система (ингаляция)	Астма, бронхит, снижение функции легких, рак и отравление тяжелыми металлами
Pb	Бензин, плавка, аккумуляторы, производство стали	Органы и мягкие ткани (проглатывание и вдыхание)	Анемия, высокое кровяное давление, рак, неврологические расстройства и интеллектуальная дисфункция
SO_2	Сжигание S-содержащего ископаемого топлива, нефтепереработка, производство серной кислоты, плавка	Дыхательная система (ингаляция)	Раздражение и воспаление тканей, хрипы, стеснение в груди или одышка, астма, бронхит и эмфизема
CO	Неполное сгорание топлива (60% от автотранспортных средств)	Система кровообращения (ингаляция)	Отравление NO2, астма и снижение иммунитета организма
NO_2	Высокотемпературные процессы горения (например, моторные двигатели)	Дыхательная система (ингаляция)	Отравление CO, стенокардия, неврологическая дисфункция, повреждение мозга, аномалии плода и удушье
O_3	Фотохимические реакции между VOCs, NO_2 и O_2	Дыхательная система (ингаляция)	Экстремальное раздражение, воспаление легких, боль в груди, снижение эластичности легких, тошнота и временный кашель

Кроме того, болота могут быть подвержены антропогенному загрязнению оксидами азота, которые выделяются в результате промышленной деятельности, автомобильного транспорта и других источников [31-32]. Однако, если болота находятся в отдаленных местах от источников антропогенного загрязнения, то выделение оксидов азота может быть связано с естественными процессами, такими как нитрификация и денитрификация [33-35].

Некоторые исследования также показывают, что болота могут иметь роль в улавливании оксидов азота и других загрязнителей из атмосферы [36-37]. Таким образом, болота могут как выделять оксид азота, так и улавливать его из атмосферы в зависимости от многих факторов, включая условия окружающей среды и источники загрязнения [38].

Исследование [30] показывает, что на выбросы N_2O из построенных водно-болотных угодий влияют водный азот и растительная биомасса. Кроме того, исследование указывает на важность правильного выбора типа растений для поглощения соответствующих форм азота в водной среде в целях контроля выбросов N_2O из сооруженных водно-болотных угодий при очистке азотистых сточных вод.

В исследованиях по изучению влияния потепления на поток N_2O в регионе Вечной мерзлоты Северо-Восточного Китая ученый Qian Ciu и другие [39] в ходе экспериментов по измерению оксида азота на минероторфных торфяниках, где доминируют моховые культуры как Sphagnum пришли к выводу, что пики N_2O приходились на середину августа и начала сентября из-за завершения вегетационного периода. В активной фазе роста мха, то есть июнь и июль, снижения уровня N_2O, вероятно, связано с поглощением минерального азота растительными культурами [40].

В лесах фотосинтез мхов составляет 10-50% общего поглощения углекислого газа [41].

Наземные растения играют важную роль в поглощении углекислого газа, азота из воздуха [42]. Из-за медленного роста мха сфагнума в летний период, в процессе дыхания он поглощает небольшое количество углекислого газа. В переувлажненной среде мох образуя торф замедляется в дыхании, то есть поглощении углекислого газа уменьшается в разы. Но образуемые обширные торфяные болота способны погло-

щать большое количество углекислого газа из воздуха [43-44].

Результаты работ ученых Bhagawan Bharali1 и Jeffrey W. Bates показывают, что добавление побегов моховых культур позволяет ускорить процесс трансформации SO_2 до безвредных сульфат-ионов или сульфидов. Потеря бисульфита происходит за счет процессов окисления с помощью метаболической энергии, клеточной абсорбции и детоксикации SO_2 в метаболизме [45].

Мхи значительно отличаются по морфологии и анатомии от сосудистых растений, так как не имеют такие ткани как ксилема и флоэма. Мхи являются катионообменником, за счет способности абсорбировать вещества из воздуха. Бактериальная пленка, образованная на поверхности мха, позволяет им трансформировать неорганические вещества, в том числе твердые частицы (PM 2,5 и 10) в доступную органическую форму [46].

В городской атмосфере содержится множество токсичных тяжелых металлов, таких как цинк (Zn), кадмий (Cd), медь (Cu) и свинец (Pb), которые могут накапливаться в организме человека при контакте через кожу, попадании внутрь организма, например, через абсорбцию, проглатывание или вдыхание [47]. Когда тяжелые металлы попадают в систему питания человека через водоснабжение или пищу, они могут вызвать серьезные проблемы со здоровьем. Эти металлы имеют высокую токсичность и стойкость в окружающей среде, что означает, что они могут накапливаться в теле человека и вызывать различные заболевания и нарушения функций органов [48]. Поступление тяжелых металлов, таких как Cd, Zn, Cu и Pb, в организм человека через пищеварение или вдыхание может вызывать различные заболевания и нарушения функций органов, такие как сердечно-сосудистые заболевания, дисфункция легких, повреждение нервной системы и инфекции печени. Учитывая высокую токсичность тяжелых металлов и их вредное воздействие на здоровье человека, необходимо принимать меры по снижению концентрации этих металлов в окружающей среде, особенно в воздухе и почве.

Моховые культуры в течение многих лет широко используются для проведения мониторинга тяжелых металлов [49-51] и полициклических ароматических углеводородов [52-53]. Мхи вида Sphagnum наряду с видами Hypnum, ввиду своих морфологических и физико-химических свойств применяются в методе мешки с мхами [54-56]. Главным механизмом биоаккумуляции тяжелых металлов в мхах является ионный обмен, который позволяет металлам накапливаться внутри клеточных структур мхов. Этот процесс подтверждается участием гидроксильных, аминовых и карбонильных групп в процессе биосорбции катионов металлов [57].

Впервые для мониторинга радиоцезий в воздухе после аварии на атомной электростанции Фукусима Дайити в 2011 г. ученые из Японии использовали мешки со мхом [58]. Для мониторинга радиокезия были выбраны три вида мха: Sphagnum palustre, Hypnum cupressiforme и Hypnum plumaeforme. В ходе экспериментов было выявлено, что все три вида мхов смогли определить наличие радиоцезий в воздухе спустя 8 лет после аварии на атомной электростанции. Мох S. palustre оказался наилучшим биосенсором для накопления радиоказия, при этом он демонстрировал высокую чувствительность к различению мест воздействия на основе их уровня загрязнения.

В годовом отчете за 2022 г. по научному проекту BR10965311 «Разработка интеллектуальных информационно-телекоммуникационных систем для городской инфраструктуры: транспорт, экология, энергетика и аналитика данных в концепте Smart City» были опубликованы результаты экспериментов по наличию тяжелых металлов (Pb, Cd, Zn, Cu, Fe, Ni, Co, Mn, Cr) в воздухе г. Астана с помощью мешочков со мхом Сфагнум. В целом, все показатели не превышали значения ПДК, за исключением свинца, который находился на уровне предельно допустимой концентрации.

Президентом Республики Казахстан 2 февраля 2023 года издан №121 указ об утверждении Стратегии достижения углеродной нейтральности Казахстаном до 2060 года [59]. В разработанной Доктрине по достижению углеродной нейтральности в 2060 году Министерством экологии, геологии и природных ресурсов упоминаются два крупных эмиттеров парниковых газов: интенсификация животноводства и развитие промышленности в отросли металлургии, нефтегаза, производства цемента и др. Для сведения выбросов к нулю запланировано увеличение лесных насаждений, а также разработка технологий по улавливанию и хранению углерода.

Проблему по очистке воздуха от загрязняющих факторов, которым подвергается каждый житель мегаполисов, можно решить биологическим путем, используя мох Сфагнум. Моховые культуры являются практичными, так как

легко поглощают вещества из атмосферы своей поверхностью, не прихотливы в уходе, а также культивирование мха не требует длительного периода. Культуры криптогамических покровов, в том числе мхи, согласно исследованиям [60] поглощают столько же CO_2, сколько выделяются в результате сжигания лесов ежегодно. Также они отличаются высокой способностью ассимилировать углекислый газ при наличии грунтовых вод или осадков [61].

Целью данной работы является определение эффективности растительной культуры мха, используемой в биотехнологическом фильтре, в качестве очистителя воздуха от загрязняющих веществ.

Материалы и методы исследования

Для проведения исследований выбран вид мха Sphagnum, который обладает высокой поглощающей способностью и способностью улавливать вредные вещества из окружающей среды. Создан биотехнологический фильтр (ферма) в условиях закрытой системы, который содержит выбранный мох и обеспечивает поток воздуха через него (Рисунок 1). Мхи размещены на стеллажах на поверхности почвенном субстрате, для обеспечения оптимальной контактной поверхности. Установка состоит из восьми вертикальных лотков по двум противоположным сторонам, по четыре на каждой. Размер вертикального лотка составляет 95х90 см. Между вертикальными лотками установлены шесть горизонтальных лотков. Размер горизонтального лотка – 80х80 см. Лотки изготовлены из нержавеющего материала и покрашены полимерной краской. Общая высота фермы – 270 см, занимаемая площадь 3,24 м^2. Культура укладывается в лотки поверх выбранного субстрата. Субстраты: сухой мох сфагнум, коксовый субстрат, почва. Для фиксации мха и субстрата при вертикальном выращивании применяется сетка.

Биотехнологический фильтр расположен на территории EXPO в городе Астана. Фильтр находится вне тени зданий, в проветриваемом месте.

Рисунок 1 – Биотехнологический фильтр

Для орошения культуры имеется резервуар установленный под горизонтальными лотками. Объем резервуара составляет 0,32 м^3. Над каждым горизонтальным лотком установлен опрыскиватель воды. По периметру лотка монтированы оцинкованные листы для изоляции от брызг воды. При вертикальном выращивании мха над каждым лотком предусмотрены отверстия для орошения культур. Вода поддается в опрыскиватели с помощью насоса для воды. Лотки, как вертикальные, так и горизонтальные, выдвигаются для удобной эксплуатации. Все условия (норма воды, влажность, температура, освещение) для выращивания культуры контролируются с помощью автоматизированного контроллера.

Температура

В ходе исследования был выявлен температурный режим для сфагнумов 3-22°C in vivo или 10-20°C in vitro [62]. Днем оптимальная температура воздуха для выращивания сфагнума в закрытой системе является 22±1°C, ночью 16±1°C, световой период 16 часов, относительная влажность 85±15%. Так как сфагнум является многолетним растением, он способен уходить в зимний покой [63]. Экономически невыгодно вводить культуру в покой в зимний период, так как постоянное охлаждение воздуха требует дополнительных затрат. Кроме того, эффективность мха в очищении воздуха снижается до минимального уровня в период покоя.

Полив

В вертикальном и горизонтальном методах выращивания мха увлажнение субстрата обеспечивается с помощью автоматического орошения. В вертикальной системе выращивания мха орошение установлено в верхней части лотка. В связи с вертикальным расположением излишки воды будут стекать под влиянием силы тяжести сверху вниз в накопительную емкость. При горизонтальном выращивании мха в лотках предусмотрены отверстия для стекания излишек воды с одного уровня на другой, в целях недопущения переувлажнения. Подача воды в лотки происходит в течение одной минуты. Тем самым, культура и субстрат насыщаются влагой в достаточной мере.

Влажность

За счет логических систем контроллеров влажность воздуха поддерживается на уровне 80%. Испарение влаги от системы полива обеспечивает в достаточной мере уровень увлажнения воздуха в биотехнологическом фильтре. В случае недостаточного уровня, увлажнения воздуха компенсируется за счет встроенного увлажнителя. Увлажнитель воздуха контролируется с помощью логических контроллеров.

Освещение

Освещение мха в вертикальных лотках обеспечивается естественным путем. У мха, выращиваемый в горизонтальном положении, нет доступа к естественным источникам света. И поэтому он освещается искусственно, специальными лампами в течение 16 часов в летний период. С середины осени до начала весны можно уменьшить период освещения с 16 часов в день до 10-12 часов. Освещение осуществляется с помощью светодиодного фитосветильника FitoLED 20 модели ДСП 02-20-003. Длина волны hyper red составляет 660 нм, deep blue – 451 нм. Фитолампы размещены на высоте 35 см от мха. Каждый лоток освещается двумя фитолампами.

Субстрат

В качестве субстрата для выращивания мха в горизонтальном положении с учетом экономической эффективности выбрана почва типа чернозем. Также можно использовать почвы с торфяными остатками. Для вертикального выращивания почвенный субстрат не будет подходить из-за сыпучего агрегатного состояния. В данном методе целесообразно использовать сфагнум высушенный с помощью закрепления его на сетку.

Согласно исследованиям [64] высота субстрата должна составлять не более 1 см. Так как мох способен абсорбировать тяжелые металлы в больших концентрациях, его следует заменять каждые 5-6 месяцев [65-66].

Загрязненный воздух, поступивший в биотехнологический фильтр измеряются начальные концентрации загрязнителей и устанавливается поток воздуха через биотехнологический фильтр. Замер показателей уровня углекислого газа проводится на входе и выходе с помощью газоанализатора многокомпонентного МАГ-6. После прохождения через биотехнологический фильтр в течение определенного периода времени измеряются концентрации газа на выходе. Сравниваются начальные и конечные концентрации для определения эффективности очищения воздуха мхами. PM2,5 и PM10 частицы измерялись с помощью пылемеров PM 2,5-10

Результаты исследования и их обсуждение

В таблицах 2, 3 представлены данные об уровне загрязнения воздуха на протяжении 2 недель в июле 2023 года.

Таблица 2 – Уровень загрязнения воздуха мелкодисперсной пылью PM2,5 и PM10 на входе и выходе биотехнологического фильтра за две недели

Дата	сред. t дня, С	PM2,5, µg/m3			PM10, µg/m3		
		на входе	на выходе	разница	на входе µg/m3	на выходе	разница
17.07.2023	36	11	10,56	0,44	10	9,6	0,4
18.07.2023	37	8	7,84	0,16	12	11,76	0,24
19.07.2023	30	9	8,55	0,45	11	10,67	0,33
20.07.2023	28	10	9,4	0,6	16,2	14,74	1,46
21.07.2023	29	15	13,5	1,5	18	17,1	0,9
22.07.2023	28	8,7	7,83	0,87	14,5	13,195	1,305
23.07.2023	29	6	5,46	0,54	11	9,9	1,1
24.07.2023	28	9	8,1	0,9	12	11,4	0,6
25.07.2023	28	5,3	5,04	0,27	9	8,64	0,36
26.07.2023	26	5,6	4,98	0,62	8,9	8,01	0,89
27.07.2023	27	3,4	3,26	0,14	12	10,8	1,2
28.07.2023	29	9	8,82	0,18	14,1	13,82	0,28
29.07.2023	32	8,7	8,15	0,55	8,9	7,9	1
30.07.2023	32	8	7,76	0,24	10	9,4	0,6

Таблица 3 – Уровень углекислого газа на входе и выходе биотехнологического фильтра за две недели (% объемной доли CO_2 – 0,01 равняется 184,84 мг/м^3)

CO2, % об.д.				
дата	сред.Т дня, С	на входе	на выходе	разница
17.07.2023	36	0,01	0,01	0
18.07.2023	37	0,02	0,01	0,01
19.07.2023	30	0,02	0,01	0,01
20.07.2023	28	0,03	0,02	0,01
21.07.2023	29	0,01	0,01	0
22.07.2023	28	0,02	0,01	0,01
23.07.2023	29	0,02	0,01	0,01
24.07.2023	28	0,01	0,01	0
25.07.2023	28	0,02	0,01	0,01
26.07.2023	26	0,01	0	0,01
27.07.2023	27	0,01	0,01	0
28.07.2023	29	0,03	0,01	0,02
29.07.2023	32	0,01	0,01	0
30.07.2023	32	0,01	0	0,01

Из таблицы 2 видно, что среднесуточная температура (сред. t дня, С) остается на уровне от 26 до 37 градусов Цельсия в течение двух недель. Температура не имеет значительных изменений со временем. Уровень частиц PM2,5 и PM10 (µg/m3) на входе и на выходе анализируемого объек-

та показывает, что в целом уровень этих частиц на выходе ниже, чем на входе. Разница между входом и выходом колеблется в пределах от 0,16 до 1,46 μg/m3 для PM2,5 и от 0,24 до 1,46 μg/m3 для PM10.

Уровень углекислого газа (CO_2) в воздухе также мониторится, и процент его объемной доли остается стабильным на уровне 0,01% на входе в биофильтр. Разница углекислого газа на входе и выходе биотехнологического фильтра колеблется в пределах 0-0,02 %об.д. Можно отметить, что разница между показаниями на входе и на выходе для всех параметров (PM2,5, PM10 и CO_2) довольно небольшая и в большинстве случаев не превышает 0,1 единицы. Это может указывать на эффективную работу системы фильтрации или очистки воздуха, а также отсутствие серьезных источников выбросов CO_2.

Важно также отметить, что уровень углекислого газа (CO_2) в пределах 0,01-0,03% объемных долей (184,84-554,52 мг/м3) находится в пределах допустимой нормы для воздуха на открытом воздухе. Этот низкий уровень загрязнения воздуха в области, охватываемой биотехнологическим фильтром, объясняется его удаленностью от источников загрязнения.

Заключение

Экспериментальные данные подтвердили эффективность моховых культур в поглощении углекислого газа и выделении кислорода в дневной период. Это подтверждает ранее опубликованные литературные источники и подчеркивает потенциал моховых растений, используемых в биотехнологическом фильтре, в качестве инструмента для смягчения проблемы изменения климата. Кроме того, мхи, используемые в качестве растительных агентов, выполняют важную функцию в поглощении мелкодисперсной пыли и преобразовании ее в органические остатки. Этот процесс способствует улучшению качества воздуха в близлежащей территории и может иметь положительное воздействие на здоровье человека и экосистемы.

В целом, результаты исследования подтверждают важность дальнейших исследований и разработки методов улучшения эффективности биотехнологического фильтра в экологических и климатических программах. Мхи представляют собой перспективный ресурс для улучшения качества воздуха и смягчения воздействия антропогенных факторов на окружающую среду.

Источник финансирования

Данное исследование выполнено при финансовой поддержке Комитета науки МОН РК, договор №365 от 07.09.2021 г. на программно-целевого финансирования на 2021–2023 годы: научный проект №BR10965311 «Разработка интеллектуальных информационно-телекоммуникационных систем для городской инфраструктуры: транспорт, экология, энергетика и аналитика данных в концепции Smart City».

Литература

1. Raghuvanshi S. P., Chandra A., Raghav A. K. Carbon dioxide emissions from coal based power generation in India // Energy Conversion and Management. – 2006. – Vol.47. – No. 4. – C. 427-441.
2. Wittig R. et al. A study of climate change and anthropogenic impacts in West Africa //Environmental Science and Pollution Research-International. – 2007. – Vol.14. – P. 182-189.
3. Bradshaw R. H. W. Past anthropogenic influence on European forests and some possible genetic consequences //Forest Ecology and Management. – 2004. – Vol.197. – No. 1-3. – P. 203-212.
4. Prasad A. K., Singh R. P. Changes in Himalayan snow and glacier cover between 1972 and 2000 //Eos, Transactions American Geophysical Union. – 2007. – Vol.88. – No. 33. – P. 326-326.
5. Gautam R. et al. Enhanced pre-monsoon warming over the Himalayan-Gangetic region from 1979 to 2007 //Geophysical Research Letters. – 2009. – Vol. 36. – No. 7.
6. Douville H. et al. Anthropogenic influence on multidecadal changes in reconstructed global evapotranspiration //Nature Climate Change. – 2013. – Vol. 3. – No. 1. – P. 59-62.
7. Balakrishnan K. et al. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017 //The Lancet Planetary Health. – 2019. – Vol. 3. – No. 1. – P. e26-e39.
8. Sarkodie S. A., Owusu P. A. Impact of meteorological factors on COVID-19 pandemic: Evidence from top 20 countries with confirmed cases //Environmental Research. – 2020. – Vol. 191. – P. 110101.)
9. Somani M. et al. Indirect implications of COVID-19 towards sustainable environment: an investigation in Indian context //Bioresource Technology Reports. – 2020. – Vol. 11. – P. 100491.
10. Verdin A. et al. An in vitro model to evaluate the impact of environmental fine particles (PM0. 3-2.5) on skin damage // Toxicology Letters. – 2019. – Vol. 305. – P. 94-102.

11. Liu Y. et al. Health impact assessment of PM2. 5 attributable mortality from the September 2020 Washington State Wildfire Smoke Episode //medRxiv. – 2020.

12. Ежедневный бюллетень состояния воздушного бассейна (НМУ) – URL: https://www.kazhydromet.kz/ru/ecology/ezhednevnyy-byulleten-sostoyaniya-vozdushnogo-basseyna-nmu/2022 (дата обращения: 31.08.2023)

13. Nugmanova D. et al. The prevalence, burden and risk factors associated with chronic obstructive pulmonary disease in Commonwealth of Independent States (Ukraine, Kazakhstan and Azerbaijan): Results of the CORE study //BMC Pulmonary Medicine. – 2018. – Vol. 18. – No. 1. – P. 1-14.

14. Выбросы загрязняющих веществ в атмосферный воздух – URL: https://old.stat.gov.kz/for_users/ecologic_indicators/ecologic_indicator/air_pollutant_emissions (дата обращения: 31.08.2023)

15. Как уменьшить выбросы парниковых газов и снизить угольную зависимость энергетики РК?- URL: https://ranking.kz/reviews/industries/kak-umenshit-vybrosy-parnikovyh-gazov-i-snizit-ugolnuyu-zavisimost-energetiki-rk.html (дата обращения: 31.08.2023)

16. Казахстан превысил лимит выбросов парниковых газов: какие регионы "дымят" больше всех – URL: https://ru.sputnik.kz/20191224/kazakhstan-parnikovye-gazy-12359282.html. (дата обращения: 31.08.2023)

17. Казахстанскому углю прописали обогащение – URL: https://kz.kursiv.media/2020-03-09/kazakhstanskomu-uglyu-propisali-obogaschenie/ (дата обращения: 31.08.2023)

18. Askarova A. et al. Computational modeling of pollutants in furnaces of pulverized coal boilers of the republic of Kazakhstan //Energy. – 2022. – Vol. 258. – P. 124826.

19. Статистика жилищного фонда (2022 г.) – URL: https://new.stat.gov.kz/ru/industries/business-statistics/stat-inno-build/publications/14121/?sphrase_id=53829 (дата обращения: 31.08.2023)

20. Токаев провел совещание по развитию Астаны – URL: https://www.zakon.kz/6383032-tokaev-provel-soveshchanie-po-razvitiyu-astany.html (дата обращения: 31.08.2023)

21. Blunden J., Arndt D. S. State of the climate in 2015 //Bulletin of the American Meteorological Society. – 2016. – VOL. 97. – No. 8. – P. Si-S275.

22. Carbon dioxide peaks near 420 parts per million at Mauna Loa observatory – URL: https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide (дата обращения: 31.08.2023)

23. European Commission, 2020. Global CO2 emissions continue to rise but EU bucks global trend. Brussels. Available – URL: https://ec.europa.eu/newsroom/eusciencehubnews/redirection/item/688753//169. (дата обращения: 31.08.2023)

24. Kim K. H. et al. Toward a better understanding of the impact of mass transit air pollutants on human health //Chemosphere. – 2017. – Vol. 174. – P. 268-279.

25. Ravishankara A. R., Daniel J. S., Portmann R. W. Nitrous oxide (N2O): the dominant ozone-depleting substance emitted in the 21st century //science. – 2009. – Vol. 326. – No. 5949. – P. 123-125.

26. Изменение климата, 2021 год – URL: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WG1_SPM_Russian.pdf (дата обращения: 31.08.2023)

27. Myhre G., Shindell D., Pongratz J. Anthropogenic and natural radiative forcing. – 2014.

28. Blum, J.M., Su, Q., Ma, Y., Valverde-P´erez, B., Domingo-F´elez, C., Jensen, M.M., Smets, B.F., 2018. The pH dependency of N-converting enzymatic processes, pathways and microbes: effect on net N2O production. Environ. Microbiol. 20 (5), 1623–1640.

29. Park, S., P´erez, T., Boering, K., Trumbore, S.E., Gil, J., Marquina, S., Tyler, S., 2011. Can N2O stable isotopes and isotopomers be useful tools to characterize sources and microbial pathways of N2O production and consumption in tropical soils? Global Biogeochem. Cycles 25 (1).

30. Cai Z. X. et al. Interactive effects of aquatic nitrogen and plant biomass on nitrous oxide emission from constructed wetlands //Environmental Research. – 2022. – Vol. 213. – P. 113716.

31. Newland M. J. et al. Low-NO atmospheric oxidation pathways in a polluted megacity //Atmospheric Chemistry and Physics. – 2021. – Vol. 21. – No. 3. – P. 1613-1625.

32. Melamed M. L. et al. Detection of pollution transport events southeast of Mexico City using ground-based visible spectroscopy measurements of nitrogen dioxide //Atmospheric Chemistry and Physics. – 2009. – Vol. 9. – No. 14. – P. 4827-4840.

33. Caranto J. D., Lancaster K. M. Nitric oxide is an obligate bacterial nitrification intermediate produced by hydroxylamine oxidoreductase //Proceedings of the National Academy of Sciences. – 2017. – Vol. 114. – No. 31. – P. 8217-8222.

34. Kampschreur M. J. et al. Unraveling the source of nitric oxide emission during nitrification //Water Environment Research. – 2007. – Vol. 79. – No. 13. – P. 2499-2509.

35. Shen J., Zerkle A. L., Claire M. W. Nitrogen cycling and biosignatures in a hyperarid mars analog environment // Astrobiology. – 2022. – Vol. 22. – No. 2. – P. 127-142.

36. Hoffmann C. C., Kronvang B., Audet J. Evaluation of nutrient retention in four restored Danish riparian wetlands // Hydrobiologia. – 2011. – Vol. 674. – P. 5-24.

37. Ji G. et al. Constructed subsurface flow wetland for treating heavy oil-produced water of the Liaohe Oilfield in China // Ecological Engineering. – 2002. – Vol. 18. – No. 4. – P. 459-465.

38. Song L. et al. The interaction between vegetation types and intensities of freeze-thaw cycles during the autumn freezing affected in-situ soil N2O emissions in the permafrost peatlands of the Great Hinggan Mountains, Northeastern China //Atmospheric Environment: X. – 2022. – Vol. 14. – P. 100175.

39. Cui Q. et al. Effects of warming on N2O fluxes in a boreal peatland of Permafrost region, Northeast China //Science of the Total Environment. – 2018. – Vol. 616. – P. 427-434.

40. Jiang C. et al. Short-term effect of increasing nitrogen deposition on CO2, CH4 and N2O fluxes in an alpine meadow on the Qinghai-Tibetan Plateau, China //Atmospheric Environment. – 2010. – Vol. 44. – No. 24. – P. 2920-2926.

41. Goulden M. L., Crill P. M. Automated measurements of CO2 exchange at the moss surface of a black spruce forest //Tree physiology. – 1997. – Vol. 17. – No. 8-9. – P. 537-542.)

42. Köster K. et al. Contrasting effects of reindeer grazing on CO2, CH4, and N2O fluxes originating from the northern boreal forest floor //Land Degradation & Development. – 2018. – Vol. 29. – No. 2. – P. 374-381.

43. Bonn A. et al. (ed.). Peatland restoration and ecosystem services: science, policy and practice. – Cambridge University Press, 2016.

44. Niemi R. et al. Elevated UV-B radiation alters fluxes of methane and carbon dioxide in peatland microcosms //Global Change Biology. – 2002. – Vol. 8. – No. 4. – P. 361-371.

45. Bharali B., Bates J. W. Detoxification of dissolved SO2 (bisulfite) by terricolous mosses //Annals of Botany. – 2006. – Vol. 97. – No. 2. – P. 257-263.

46. Frahm J., Sabovljevic M. Feinstaubreduzierung durch Moose //IMMISSIONSSCHUTZ-BERLIN-. – 2007. – Vol. 12. – No. 4. – P. 152.

47. Hu Y. et al. Bioaccumulation of heavy metals in plant leaves from Yan′ an city of the Loess Plateau, China //Ecotoxicology and environmental safety. – 2014. – Vol. 110. – P. 82-88.

48. Micó C. et al. Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis //Chemosphere. – 2006. – Vol. 65. – No. 5. – P. 863-872.

49. Capozzi F. et al. Sphagnum palustre clone vs native Pseudoscleropodium purum: A first trial in the field to validate the future of the moss bag technique //Environmental Pollution. – 2017. – VOL. 225. – P. 323-328.

50. Di Palma A. et al. Atmospheric particulate matter intercepted by moss-bags: Relations to moss trace element uptake and land use //Chemosphere. – 2017. – VOL. 176. – P. 361-368.

51. Ștefănuț S. et al. National environmental quality assessment and monitoring of atmospheric heavy metal pollution-a moss bag approach //Journal of environmental management. – 2019. – VOL. 248. – P. 109224.

52. Aboal J. R. et al. Testing a novel biotechnological passive sampler for monitoring atmospheric PAH pollution //Journal of hazardous materials. – 2020. – VOL. 381. – P. 120949.

53. Capozzi F. et al. Implication of vitality, seasonality and specific leaf area on PAH uptake in moss and lichen transplanted in bags //Ecological Indicators. – 2020. – VOL. 108. – P. 105727.

54. Ares A. et al. Moss bag biomonitoring: a methodological review //Science of the Total Environment. – 2012. – VOL. 432. – P. 143-158.

55. Beike A. K. et al. Clonal in vitro propagation of peat mosses (Sphagnum L.) as novel green resources for basic and applied research //Plant Cell, Tissue and Organ Culture (PCTOC). – 2015. – VOL. 120. – P. 1037-1049.

56. González A. G., Pokrovsky O. S. Metal adsorption on mosses: toward a universal adsorption model //Journal of colloid and interface science. – 2014. – VOL. 415. – P. 169-178.

57. Świsłowski P. et al. Bioaccumulation of Trace Elements from Aqueous Solutions by Selected Terrestrial Moss Species // Biology. – 2022. – VOL. 11. – No. 12. – P. 1692.

58. Di Palma A. et al. Testing mosses exposed in bags as biointerceptors of airborne radiocaesium after the Fukushima Dai-ichi Nuclear Power Station accident //Chemosphere. – 2022. – VOL. 308. – P. 136179.

59. Указ Президента Республики Казахстан от 2 февраля 2023 года № 121 «Об утверждении Стратегии достижения углеродной нейтральности Казахстаном до 2060 года». – 2023.

60. Elbert W. et al. Contribution of cryptogamic covers to the global cycles of carbon and nitrogen //Nature Geoscience. – 2012. – VOL. 5. – No. 7. – P. 459-462.

61. Robroek B. J. M. et al. Interactive effects of water table and precipitation on net CO2 assimilation of three co-occurring Sphagnum mosses differing in distribution above the water table //Global Change Biology. – 2009. – VOL. 15. – No. 3. – P. 680-691.

62. Антропова VOL. А. Изучение температурной адаптации на клетки некоторых видов мхов //Цитология. – 1974. – VOL. 16. – P. 38-42.

63. Zhao W. et al. Development of a method for protonema proliferation of peat moss (Sphagnum squarrosum) through regeneration analysis //New Phytologist. – 2019. – VOL. 221. – No. 2. – P. 1160-1171.

64. Stenøien H., Bakken S., Flatberg K. I. Phenotypic variation in the Sphagnum recurvum complex: a cultivation experiment //Journal of Bryology. – 1997. – VOL. 19. – No. 4. – P. 731-750.

65. Limo J., Paturi P., Mäkinen J. Magnetic biomonitoring with moss bags to assess stop-and-go traffic induced particulate matter and heavy metal concentrations //Atmospheric Environment. – 2018. – VOL. 195. – P. 187-195.

66. Beike A. K. et al. Clonal in vitro propagation of peat mosses (Sphagnum L.) as novel green resources for basic and applied research //Plant Cell, Tissue and Organ Culture (PCTOC). – 2015. – VOL. 120. – No. 3. – P. 1037-1049.

References

1. “06/01932 Carbon Dioxide Emissions from Coal Based Power Generation in India.” Fuel and Energy Abstracts, vol. 47, no. 4 (2006): pp. 427-441. https://doi.org/10.1016/s0140-6701(06)81938-7.

2. Aboal, J.R., E. Concha-Graña, F. De Nicola, S. Muniategui-Lorenzo, P. López-Mahía, S. Giordano, F. Capozzi, et al. “Testing a Novel Biotechnological Passive Sampler for Monitoring Atmospheric PAH Pollution.” Journal of Hazardous Materials, vol. 381 (2020): P. 120949. https://doi.org/10.1016/j.jhazmat.2019.120949.

3. “Anthropogenic and Natural Radiative Forcing.” Climate Change 2013 – The Physical Science Basis, 2014, pp. 659–740. https://doi.org/10.1017/cbo9781107415324.018.

4. Antropova, A. “Izucheniye Temperaturnoy Adaptatsii Na Kletki Nekotorykh Vidov Mkhov [Study of Temperature Adaptation to the Cells of Some Moss Species].” Cytology, vol. 16 (1974): pp. 38–42.

5. Ares, A., J.R. Aboal, A. Carballeira, S. Giordano, P. Adamo, and J.A. Fernández. “Moss Bag Biomonitoring: A Methodological Review.” Science of The Total Environment, vol. 432 (2012): pp. 143–58. https://doi.org/10.1016/j.scitotenv.2012.05.087.

6. Askarova, Aliya, Aleksandar Georgiev, Saltanat Bolegenova, Meruyert Beketayeva, Valeriyu Maximov, and Symbat Bolegenova. “Computational Modeling of Pollutants in Furnaces of Pulverized Coal Boilers of the Republic of Kazakhstan.” Energy, vol. 258 (2022): P. 124826. https://doi.org/10.1016/j.energy.2022.124826.

7. Beike, Anna K., Valeria Spagnuolo, Volker Lüth, Feray Steinhart, Julia Ramos-Gómez, Matthias Krebs, Paola Adamo, et al. “Clonal in Vitro Propagation of Peat Mosses (Sphagnum L.) as Novel Green Resources for Basic and Applied Research.” Plant Cell, Tissue and Organ Culture (PCTOC), vol. 120, no. 3 (2015): pp. 1037–49. https://doi.org/10.1007/s11240-014-0658-2.

8. Beike, Anna K., Valeria Spagnuolo, Volker Lüth, Feray Steinhart, Julia Ramos-Gómez, Matthias Krebs, Paola Adamo, et al. “Clonal in Vitro Propagation of Peat Mosses (Sphagnum L.) as Novel Green Resources for Basic and Applied Research.” Plant Cell, Tissue and Organ Culture (PCTOC), vol. 120, no. 3 (2015): pp. 1037–49. https://doi.org/10.1007/s11240-014-0658-2.

9. BHARALI, BHAGAWAN, and JEFFREY W. BATES. “Detoxification of Dissolved SO2 (Bisulfite) by Terricolous Mosses.” Annals of Botany, vol. 97, no. 2 (2006): pp. 257–63. https://doi.org/10.1093/aob/mcj026.

10. Blum, Jan-Michael, Qingxian Su, Yunjie Ma, Borja Valverde-Pérez, Carlos Domingo-Félez, Marlene Mark Jensen, and Barth F. Smets. “The Ph Dependency of N-Converting Enzymatic Processes, Pathways and Microbes: Effect on NET N2O Production.” Environmental Microbiology, vol. 20, no. 5 (2018): pp. 1623–40. https://doi.org/10.1111/1462-2920.14063.

11. Bonn, Aletta, Tim Allott, Martin Evans, Hans Joosten, and Rob Stoneman. “Peatland Restoration and Ecosystem Services: An Introduction.” Peatland Restoration and Ecosystem Services, 2016, pp. 1–16. https://doi.org/10.1017/cbo9781139177788.002.

12. Bradshaw, Richard H.W. “Past Anthropogenic Influence on European Forests and Some Possible Genetic Consequences.” Forest Ecology and Management, vol. 197, no. 1–3 (2004): pp. 203–12. https://doi.org/10.1016/j.foreco.2004.05.025.

13. Cai, Ze-Xiang, Qu-Sheng Li, Heng Bai, Cong-Yun Zhu, Guan-Hui Tang, Huan-Zhan Zhou, Jia-Wei Huang, Xinshan Song, and Jun-Feng Wang. “Interactive Effects of Aquatic Nitrogen and Plant Biomass on Nitrous Oxide Emission from Constructed Wetlands.” SSRN Electronic Journal, 2022. https://doi.org/10.2139/ssrn.4118346.

14. Capozzi, F., M.C. Sorrentino, A. Di Palma, F. Mele, C. Arena, P. Adamo, V. Spagnuolo, and S. Giordano. “Implication of Vitality, Seasonality and Specific Leaf Area on PAH Uptake in Moss and Lichen Transplanted in Bags.” Ecological Indicators, vol. 108 (2020): P. 105727. https://doi.org/10.1016/j.ecolind.2019.105727.

15. Capozzi, F., P. Adamo, A. Di Palma, J.R. Aboal, R. Bargagli, J.A. Fernandez, P. Lopez Mahia, et al. “Sphagnum Palustre Clone vs Native Pseudoscleropodium Purum : A First Trial in the Field to Validate the Future of the Moss Bag Technique.” Environmental Pollution, vol. 225 (2017): pp. 323–28. https://doi.org/10.1016/j.envpol.2017.02.057.

16. Caranto, Jonathan D., and Kyle M. Lancaster. “Nitric Oxide Is an Obligate Bacterial Nitrification Intermediate Produced by Hydroxylamine Oxidoreductase.” Proceedings of the National Academy of Sciences, vol. 114, no. 31 (2017): pp. 8217–22. https://doi.org/10.1073/pnas.1704504114.

17. “Climate Change 2021: The Physical Science Basis.” The Intergovernmental Panel on Climate Change (IPCC). Accessed August 31. https://www.ipcc.ch/report/ar6/wg1/.

18. Cui, Qian, Changchun Song, Xianwei Wang, Fuxi Shi, Xueyang Yu, and Wenwen Tan. “Effects of Warming on N2O Fluxes in a Boreal Peatland of Permafrost Region, Northeast China.” Science of The Total Environment, vol. 616–617 (2018): pp. 427–34. https://doi.org/10.1016/j.scitotenv.2017.10.246.

19. Di Palma, A., P. Adamo, T. Dohi, K. Fujiwara, H. Hagiwara, A. Kitamura, A. Sakoda, K. Sato, and K. Iijima. “Testing Mosses Exposed in Bags as Biointerceptors of Airborne Radiocaesium after the Fukushima Dai-Ichi Nuclear Power Station Accident.” Chemosphere, vol. 308 (2022): P. 136179. https://doi.org/10.1016/j.chemosphere.2022.136179.

20. Di Palma, Anna, Fiore Capozzi, Valeria Spagnuolo, Simonetta Giordano, and Paola Adamo. “Atmospheric Particulate Matter Intercepted by Moss-Bags: Relations to Moss Trace Element Uptake and Land Use.” Chemosphere, vol. 176 (2017): pp. 361–68. https://doi.org/10.1016/j.chemosphere.2017.02.120.

21. Douville, H., A. Ribes, B. Decharme, R. Alkama, and J. Sheffield. “Anthropogenic Influence on Multidecadal Changes in Reconstructed Global Evapotranspiration.” Nature Climate Change vol. 3, no. 1 (2012): pp. 59–62. https://doi.org/10.1038/nclimate1632.

22. Elbert, Wolfgang, Bettina Weber, Susannah Burrows, Jörg Steinkamp, Burkhard Büdel, Meinrat O. Andreae, and Ulrich Pöschl. “Contribution of Cryptogamic Covers to the Global Cycles of Carbon and Nitrogen.” Nature Geoscience, vol. 5, no. 7 (2012): pp. 459–62. https://doi.org/10.1038/ngeo1486.

23. "Ezhednevnyj Byulleten' Sostoyaniya Vozdushnogo Bassejna (NMU).” Ezhednevnyj byulleten' sostoyaniya vozdushnogo bassejna (NMU) – Kazgidromet [“Daily Air Basin Status Bulletin (NMU).” Daily Air Basin Status Bulletin (NMU) – Kazhydromet]. Accessed August 31, 2023. https://www.kazhydromet.kz/ru/ecology/ezhednevnyy-byulleten-sostoyaniya-vozdushnogo-basseyna-nmu/2022.

24. “European Commission, 2020. Global CO2 Emissions Continue to Rise but EU Bucks Global Trend. Brussels.” EUSCIENCEHUBNEWS – launch of the EU Award for Gender Equality Champions. Accessed August 31, 2023. https://ec.europa.eu/newsroom/eusciencehubnews/redirection/item/754442/default/169.

25. Frahm, Jan-Peter, and Marko Sabovljevic. “Feinstaubreduzierung Durch Moose.” Immissionsschutz, no. 4 (2007). https://doi.org/10.37307/j.1868-7776.2007.04.03.

26. Gautam, R., N. C. Hsu, K.-M. Lau, S.-C. Tsay, and M. Kafatos. “Enhanced Pre-Monsoon Warming over the Himalayan-Gangetic Region from 1979 to 2007.” Geophysical Research Letters, vol. 36, no. 7 (2009). https://doi.org/10.1029/2009gl037641.

27. González, A.G., and O.S. Pokrovsky. “Metal Adsorption on Mosses: Toward a Universal Adsorption Model.” Journal of Colloid and Interface Science, vol. 415 (2014): pp. 169–78. https://doi.org/10.1016/j.jcis.2013.10.028.

28. Goulden, M. L., and P. M. Crill. “Automated Measurements of CO2 Exchange at the Moss Surface of a Black Spruce Forest.” Tree Physiology, vol. 17, no. 8–9 (1997): pp. 537–42. https://doi.org/10.1093/treephys/17.8-9.537.

29. Hoffmann, Carl Chr., Brian Kronvang, and Joachim Audet. “Evaluation of Nutrient Retention in Four Restored Danish Riparian Wetlands.” Hydrobiologia, vol. 674, no. 1 (2011): pp. 5–24. https://doi.org/10.1007/s10750-011-0734-0.

30. Hu, Youning, Dexiang Wang, Lijing Wei, Xinping Zhang, and Bin Song. “Bioaccumulation of Heavy Metals in Plant Leaves from Yan′an City of the Loess Plateau, China.” Ecotoxicology and Environmental Safety, vol. 110 (2014): pp. 82–88. https://doi.org/10.1016/j.ecoenv.2014.08.021.

31. Ji, Guodong, Tieheng Sun, Qixing Zhou, Xin Sui, Shijun Chang, and Peijun Li. “Constructed Subsurface Flow Wetland for Treating Heavy Oil-Produced Water of the Liaohe Oilfield in China.” Ecological Engineering, vol. 18, no. 4 (2002): pp. 459–65. https://doi.org/10.1016/s0925-8574(01)00106-9.

32. Jiang, Chunming, Guirui Yu, Huajun Fang, Guangmin Cao, and Yingnian Li. “Short-Term Effect of Increasing Nitrogen Deposition on CO2, CH4 and N2o Fluxes in an Alpine Meadow on the Qinghai-Tibetan Plateau, China.” Atmospheric Environment, vol. 44, no. 24 (2010): pp. 2920–26. https://doi.org/10.1016/j.atmosenv.2010.03.030.

33. Kampschreur, Marlies J., Cristian Picioreanu, Nico Tan, Robbert Kleerebezem, Mike S.M. Jetten, and Mark C.M. van Loosdrecht. “Unraveling the Source of Nitric Oxide Emission during Nitrification.” Water Environment Research, vol. 79, no. 13 (2007): pp. 2499–2509. https://doi.org/10.2175/106143007x220815.

34. “Kak Umen'shit' Vybrosy Parnikovykh Gazov i Snizit' Ugol'nuyu Zavisimost' Energetiki RK [How to Reduce Greenhouse Gas Emissions and Reduce Coal Dependence of the Energy Industry of the Republic of Kazakhstan]?” Ranking.kz, December 28, 2022. https://ranking.kz/reviews/industries/kak-umenshit-vybrosy-parnikovyh-gazov-i-snizit-ugolnuyu-zavisimost-energetiki-rk.html.

35. “Kazakhstanskomu Uglyu Propisali Obogashcheniye [Kazakhstan Coal Prescribed Enrichment].”Kursiv Media Kazakhstan, August 31, 2023. https://kz.kursiv.media/2020-03-09/kazakhstanskomu-uglyu-propisali-obogaschenie/ .

36. Kiest, Kristina. “Carbon Dioxide Peaks near 420 Parts per Million at Mauna Loa Observatory.” NOAA Research, February 21, 2023. https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide.

37. Kim, Ki-Hyun, Pawan Kumar, Jan E. Szulejko, Adedeji A. Adelodun, Muhammad Faisal Junaid, Minori Uchimiya, and Scott Chambers. “Toward a Better Understanding of the Impact of Mass Transit Air Pollutants on Human Health.” Chemosphere, vol. 174 (2017): pp. 268–79. https://doi.org/10.1016/j.chemosphere.2017.01.113.

38. Köster, Kajar, Egle Köster, Frank Berninger, Jussi Heinonsalo, and Jukka Pumpanen. “Contrasting Effects of Reindeer Grazing on Co2, CH4, and n2O Fluxes Originating from the Northern Boreal Forest Floor.” Land Degradation & Development, vol. 29, no. 2 (2018): pp. 374–81. https://doi.org/10.1002/ldr.2868.

39. Limo, Jukka, Petriina Paturi, and Joni Mäkinen. “Magnetic Biomonitoring with Moss Bags to Assess Stop-and-Go Traffic Induced Particulate Matter and Heavy Metal Concentrations.” Atmospheric Environment, vol. 195 (2018): pp. 187–95. https://doi.org/10.1016/j.atmosenv.2018.09.062.

40. Liu, Yisi, Elena Austin, Jianbang Xiang, Tim Gould, Tim Larson, and Edmund Seto. Health Impact Assessment of PM2.5attributable mortality from the September 2020 Washington state wildfire smoke episode, 2020. https://doi.org/10.1101/2020.09.19.20197921.

41. Melamed, M. L., R. Basaldud, R. Steinbrecher, S. Emeis, L. G. Ruíz-Suárez, and M. Grutter. “Detection of Pollution Transport Events Southeast of Mexico City Using Ground-Based Visible Spectroscopy Measurements of Nitrogen Dioxide.” Atmospheric Chemistry and Physics, vol. 9, no. 14 (2009): pp. 4827–40. https://doi.org/10.5194/acp-9-4827-2009.

42. Micó, C., L. Recatalá, M. Peris, and J. Sánchez. “Assessing Heavy Metal Sources in Agricultural Soils of an European Mediterranean Area by Multivariate Analysis.” Chemosphere, vol. 65, no. 5 (2006): pp. 863–72. https://doi.org/10.1016/j.chemosphere.2006.03.016.

43. Newland, Mike J., Daniel J. Bryant, Rachel E. Dunmore, Thomas J. Bannan, W. Joe Acton, Ben Langford, James R. Hopkins, et al. “Low-No Atmospheric Oxidation Pathways in a Polluted Megacity.” Atmospheric Chemistry and Physics, vol. 21, no. 3 (2021): pp. 1613–25. https://doi.org/10.5194/acp-21-1613-2021.

44. Niemi, Riikka, Pertti J. Martikainen, Jouko Silvola, Anu Wulff, Satu Turtola, and Toini Holopainen. “Elevated UV-B Radiation Alters Fluxes of Methane and Carbon Dioxide in Peatland Microcosms.” Global Change Biology, vol. 8, no. 4 (2002): pp. 361–71. https://doi.org/10.1046/j.1354-1013.2002.00478.x.

45. Nugmanova, Damilya, Yuriy Feshchenko, Liudmyla Iashyna, Olga Gyrina, Kateryna Malynovska, Eljan Mammadbayov, Irada Akhundova, et al. “The Prevalence, Burden and Risk Factors Associated with Chronic Obstructive Pulmonary Disease in Commonwealth of Independent States (Ukraine, Kazakhstan and Azerbaijan): Results of the Core Study.” BMC Pulmonary Medicine, vol. 18, no. 1 (2018). https://doi.org/10.1186/s12890-018-0589-5.

46. Park, S., T. Pérez, K. A. Boering, S. E. Trumbore, J. Gil, S. Marquina, and S. C. Tyler. “Can N2O Stable Isotopes and Isotopomers Be Useful Tools to Characterize Sources and Microbial Pathways of N2O Production and Consumption in Tropical Soils?” Global Biogeochemical Cycles, vol. 25, no. 1 (2011). https://doi.org/10.1029/2009gb003615.

47. Prasad, Anup K., and Ramesh P. Singh. “Changes in Himalayan Snow and Glacier Cover between 1972 and 2000.” Eos, Transactions American Geophysical Union, vol. 88, no. 33 (2007): pp. 326–326. https://doi.org/10.1029/2007eo330002.

48. (PDF) surface winds [in “State of the climate in 2015”] – researchgate. Accessed August 31, 2023. https://www.researchgate.net/publication/306263103_Surface_winds_in_State_of_the_Climate_in_2015.

49. Ravishankara, A. R., John S. Daniel, and Robert W. Portmann. “Nitrous Oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century.” Science, vol. 326, no. 5949 (2009): pp. 123–25. https://doi.org/10.1126/science.1176985.

50. ROBROEK, BJORN J., MATTHIJS G. SCHOUTEN, JUUL LIMPENS, FRANK BERENDSE, and HENDRIK POORTER. “Interactive Effects of Water Table and Precipitation on Net Co2Assimilation of Three Co-Occurring Sphagnum Mosses Differing in Distribution above the Water Table.” Global Change Biology, vol. 15, no. 3 (2009): pp. 680–91. https://doi.org/10.1111/j.1365-2486.2008.01724.x.

51. Sarkodie, Samuel Asumadu, and Phebe Asantewaa Owusu. “Impact of Meteorological Factors on Covid-19 Pandemic: Evidence from Top 20 Countries with Confirmed Cases.” Environmental Research, vol. 191 (2020): 110101. https://doi.org/10.1016/j.envres.2020.110101.

52. Shen, Jianxun, Aubrey L. Zerkle, and Mark W. Claire. “Nitrogen Cycling and Biosignatures in a Hyperarid Mars Analog Environment.” Astrobiology, vol. 22, no. 2 (2022): pp. 127–42. https://doi.org/10.1089/ast.2021.0012.

53. Somani, Mohit, Abhishek N. Srivastava, Shiva Kumar Gummadivalli, and Aparna Sharma. “Indirect Implications of COVID-19 towards Sustainable Environment: An Investigation in Indian Context.” Bioresource Technology Reports, vol. 11 (2020): 100491. https://doi.org/10.1016/j.biteb.2020.100491.

54. Song, Liquan, Shuying Zang, Lin Lin, Boquan Lu, Yaqing Jiao, Chaofeng Sun, and Hanxi Wang. “The Interaction between Vegetation Types and Intensities of Freeze-Thaw Cycles during the Autumn Freezing Affected in-Situ Soil N2O Emissions in the Permafrost Peatlands of the Great Hinggan Mountains, Northeastern China.” Atmospheric Environment: X, vol. 14 (2022): P. 100175. https://doi.org/10.1016/j.aeaoa.2022.100175.

55. Sputnik Kazakhstan. “Kazakhstan Prevysil Limit Vybrosov Parnikovykh Gazov: Kakiye Regiony ‘Dymyat’ Bol'she Vsekh [Kazakhstan Exceeded Greenhouse Gas Emission Limit: Which Regions ‘Smoke’ The Most.” Sputnik Kazakhstan].” February 1, 2022. https://ru.sputnik.kz/20191224/kazakhstan-parnikovye-gazy-12359282.html.

56. “Statïstïka Jïlïşçnogo Fonda (2022g.).” Qazaqstan Respwblïkası Strategïyalıq josparlaw jäne reformalar agenttigi Ulttıq statïstïka byurosı – Bastı bet. [Statistics on Housing Fund (2022). Agency for Strategic Planning and Reforms of the Republic of Kazakhstan National Bureau of Statistics – Home page.] Accessed August 31, 2023. https://new.stat.gov.kz/ru/industries/business-statistics/stat-inno-build/publications/14121/?sphrase_id=53829.

57. Ștefănuț, Sorin, Kinga Öllerer, Anca Manole, Mihaela C. Ion, Marian Constantin, Cristian Banciu, Gabriel M. Maria, and Larisa I. Florescu. “National Environmental Quality Assessment and Monitoring of Atmospheric Heavy Metal Pollution – a Moss Bag Approach.” Journal of Environmental Management, vol. 248 (2019): P. 109224. https://doi.org/10.1016/j.jenvman.2019.06.125.

58. Stenøien, Hans, Solveig Bakken, and Kjell Ivar Flatberg. “Phenotypic Variation in the Sphagnum Recurvum Complex: A Cultivation Experiment.” Journal of Bryology, vol. 19, no. 4 (1997): pp. 731–50. https://doi.org/10.1179/jbr.1997.19.4.731.

59. Świsłowski, Paweł, Arkadiusz Nowak, Stanisław Wacławek, Daniele Silvestri, and Małgorzata Rajfur. “Bioaccumulation of Trace Elements from Aqueous Solutions by Selected Terrestrial Moss Species.” Biology, vol. 11, no. 12 (2022): P. 1692. https://doi.org/10.3390/biology11121692.

60. “Tokayev “Provel Soveshchaniye Po Razvitiyu Astany [Tokayev held a meeting on the development of Astana].” zakon.kz, January 31, 2023. https://www.zakon.kz/6383032-tokaev-provel-soveshchanie-po-razvitiyu-astany.html.

61. “Ukaz Prezidenta Respubliki Kazakhstan Ot 2 Fevralya 2023 Goda № 121 ‘Ob Utverzhdenii Strategii Dostizheniya Uglerodnoy Neytral'nosti Respubliki Kazakhstan Do 2060 Goda.’” Informatsionnaya sistema PARAGRAF [“Decree of the President of the Republic of Kazakhstan dated February 2, 2023 No. 121 ‘On Approval of the Strategy for Achieving Carbon Neutrality of the Republic of Kazakhstan Until 2060.’” Information system PARAGRAPH], April 11, 2023. https://online.zakon.kz/Document/?doc_id=32669610.

62. “Vybrosy Zagryaznyayushchikh Veshchestv v Atmosfernyy Vozdukh [Emissions of Pollutants into Atmospheric Air] .” Old.stat.gov.kz. Accessed August 31, 2023. https://old.stat.gov.kz/for_users/ecologic_indicators/ecologic_indicator/air_pollutant_emissions.

63. Verdin, Anthony, Fabrice Cazier, Richard Fitoussi, Natacha Blanchet, Katell Vié, Dominique Courcot, Isabelle Momas, Nathalie Seta, and Sophie Achard. “An in Vitro Model to Evaluate the Impact of Environmental Fine Particles (PM0.3-2.5) on Skin Damage.” Toxicology Letters, vol. 305 (2019): pp. 94–102 https://doi.org/10.1016/j.toxlet.2019.01.016.

64. Wittig, Rüdiger, Konstantin König, Marco Schmidt, and Jörg Szarzynski. “A Study of Climate Change and Anthropogenic Impacts in West Africa.” Environmental Science and Pollution Research – International, vol. 14, no. 3 (2007): pp. 182–89. https://doi.org/10.1065/espr2007.02.388.

65. Yin, Peng, Michael Brauer, Aaron J Cohen, Haidong Wang, Jie Li, Richard T Burnett, Jeffrey D Stanaway, et al. “The Effect of Air Pollution on Deaths, Disease Burden, and Life Expectancy across China and Its Provinces, 1990–2017: An Analysis for the Global Burden of Disease Study 2017.” The Lancet Planetary Health, vol. 1, no. 3 (2019). https://doi.org/10.1016/s2542-5196(20)30161-3.

66. Zhao, Wenqian, Zeling Li, Yongyue Hu, Min Wang, Shirui Zheng, Qiuping Li, Youfang Wang, et al. “Development of a Method for Protonema Proliferation of Peat Moss (Sphagnum Squarrosum) through Regeneration Analysis.” New Phytologist, vol. 221, no. 2 (2019): pp. 1160–71. https://doi.org/10.1111/nph.15394.

МРНТИ 34.29.15 https://doi.org/10.26577/eb.2023.v96.i3.04

Е.В. Рахимова[1], Г. Сыпабеккызы[1,2*], Л.А. Кызметова[1], А.М. Асылбек[1]

[1]РГП «Институт ботаники и фитоинтродукции, Казахстан, г. Алматы
[2]Казахский национальный университет им. аль-Фараби, Казахстан, г. Алматы
*e-mail: gulnaz_92_21@mail.ru

РОД *CYTOSPORA* EHRENB. НА ЮГО-ВОСТОКЕ КАЗАХСТАНА

Сведения о пикнидиальных грибах юго-востока Казахстана не достаточны и значительно устарели (особенно таксономия видов) несмотря на то, что некоторые из них имеют большое экономическое значение, как паразиты древесных растений. Поэтому целью нашей работы было выявить виды рода Cytospora Ehrenb. на территории юго-востока Казахстана и провести анализ данных по их распространению и кругу растений-хозяев. Научная и практическая значимость работы заключается в получении данных о новых местонахождениях видов рода Cytospora, имеющих большое значение как возбудители раковых заболеваний и язвенной болезни древесных растений-хозяев, приводящих к отмиранию ветвей деревьев. Материалом для статьи послужили собственные сборы авторов, проведенные в различные годы, гербарные образцы, хранящиеся в гербарии Института ботаники и фитоинтродукции, а также литературные данные. Приготовление препаратов грибов, их изучение и идентификация осуществлялись по стандартной методике. Образцы изучались и фотографировались с помощью фотомикроскопа Polyvar с интерференционной оптикой Номарского. Приводится аннотированный алфавитный список видов с указанием растений-хозяев и координат сбора. Из рода Cytospora на территории юго-востока Казахстана обнаружены 43 вида. Максимальное количество видов (26) обнаружено в предгорьях Заилийского Алатау, в Заилийском Алатау отмечено 20 видов Cytospora, для горных хребтов Джунгарский Алатау, Кунгей Алатау и Алтын-Эмель характерны 10, 9 и 7 представителей рода, соответственно. В пустынных территориях юго-востока Казахстана обнаружено 8 видов. Виды рода Cytospora встречаются на представителях сосудистых растений из 29 семейств. Наибольшее число видов отмечено на семействе Rosaceae Juss. (11 видов), Salicaceae Mirb. (7), Betulaceae Gray (4), Fabaceae Lindl. (3 вида). Ценность проведенного исследования и практическое значение заключаются в получении данных о местонахождении, распространении и приуроченности к хозяину видов Cytospora.

Ключевые слова: Пикнидиальный гриб, раковое заболевание растений, распространение, растение-хозяин, род Cytospora, цитоспороз, юго-восток Казахстана.

E.V. Rakhimova[1], G. Sypabekkyzy[1,2*], L.A. Kyzmetova[1], A.M. Asylbek[1]

[1]Institute of Botany and Phytointroduction", Kazakhstan, Almaty
[2]Kazakh National University. Al-Farabi, Kazakhstan, Almaty
*e-mail: gulnaz_92_21@mail.ru

Genus Cytospora Ehrenb. In the south-east of Kazakhstan

Information about pycnidial fungi of southeast of Kazakhstan is significantly outdated, despite the fact that some of them are of great economic importance as parasites of woody plants. The work aim was to identify species of the genus Cytospora Ehrenb. on south-east of Kazakhstan and to analyze data on their distribution and range of host plants. The scientific and practical significance of the work lies in obtaining data on new localities of species of the genus Cytospora, which are of great importance as causative agents of cancer and peptic ulcer disease of woody host plants, leading to the death of tree branches. The material for the article was the authors' own collections carried out in different years, herbarium specimens stored in the herbarium of Institute of Botany and Phytointroduction and literary data. The preparation of fungi specimens, their study and identification were carried out according to the standard methods. The samples were studied and photographed using Polyvar photomicroscope with Nomarsky optics. An annotated alphabetical list of species is provided with host plants and collection coordinates. Of Cytospora, 43 species were found in the south-east of Kazakhstan. The maximum number (26) was found in the foothills of the Zailiysky Alatau, 20 species were noted in the Zailiysky Alatau, 10, 9 and 7 representatives of the genus, respectively, are typical for the mountain ranges of the Dzhungarsky Alatau,

Kungei Alatau and Altyn-Emel. In the desert territories of the southeast of Kazakhstan, 8 species were found. Species of Cytospora are found on vascular plants from 29 families. The largest number of species was recorded on the family Rosaceae Juss. (11), Salicaceae Mirb. (7), Betulaceae Gray (4), Fabaceae Lindl. (3). The value of the study and its practical significance lies in obtaining data on the location, distribution, and association with the host of Cytospora.

Key words. Pycnidial fungus, Cytosporosis, genus Cytospora, host plant, location, plant cancer, southeast of Kazakhstan.

Е.В. Рахимова[1], Г. Сыпабеккызы[1,2*], Л.А. Кызметова[1], А.М. Асылбек[1]
[1]РМК «Ботаника және фитоинтродукция институты», Қазақстан, Алматы қ.
[2]Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
*e-mail: gulnaz_92_21@mail.ru

Оңтүстік-шығыс Қазақстандағы *Cytospora* Ehrenb туысы

Қазақстанның оңтүстік-шығысында кездесетін пикнидиалы саңырауқұлақтар туралы, олардың кейбір түрлері ағаш өсімдіктерінің паразиттері ретінде экономикалық үлкен маңыздылығына қарамастан мәліметтер жеткіліксіз және едәуір ескірген (әсіресе түрлердің таксономиясы). Сондықтан жұмысымыздың мақсаты Қазақстанның оңтүстік – шығыс аумағында Cytospora Ehrenb туысының түрлерін анықтау және олардың таралуы мен иелік – өсімдіктері бойынша мәліметтерге талдау жүргізу. Жұмыстың ғылыми және практикалық маңыздылығы ағаш өсімдіктерінің бұтақтарын қуратып, ағаштың қатерлі ісігі мен ойық жара ауруларын тудыратын қоздырғыштар ретінде үлкен маңызы бар Cytospora туысы түрлерінің жаңа нүктелерін табу, таралуы туралы мәліметтерге негізделмек. Мақаланың материалы: авторлармен әр жылдары жүргізілген зерттеулер барысында жиналған және Ботаника және фитоинтродукция институтының гербарий қорында сақталған гербарий үлгілері, сонымен қатар, әдеби деректер. Саңырауқұлақтар препараттарын дайындау, оларды зерттеу және анықтау стандартты әдіс бойынша жүзеге асырылды. Үлгілер Номарскийдің интерференциялық оптикасы бар Polyvar фотомикроскобының көмегімен зерттелді және суретке түсірілді. Түрлердің иелік өсімдіктері мен жиналған жерінің координаттары көрсетіле отырып, аннотацияланған алфавиттік тізімі келтірілді. Қазақстанның оңтүстік-шығысында Cytospora туысының 43 түрі анықталды. Түрлердің ең көп саны Іле Алатауының бөктерінде (26 түр) табылды, Іле Алатауында Cytospora туысының 20 түрі анықталса, Жоңғар Алатауы, Күнгей Алатауы және Алтын – Эмель тау жоталары үшін сәйкесінше 10, 9 және 7 туыс өкілдері сипатталған. Қазақстанның оңтүстік-шығысындағы шөлді аймақтардан 8 түр анықталды. Cytospora туысының түрлері түтікті өсімдіктердің 29 тұқымдасында кездеседі. Түрлердің ең көп саны Rosaceae Juss тұқымдасында (11 түр) анықталды, ал Salicaceae Mirb. (7), Betulaceae Gray (4), Fabaceae Lindl. (3) түрден. Жүргізілген зерттеудің құндылығы және практикалық маңыздылығы Cytospora туысы түрлерінің анықталған жері, таралуы және иелік – өсімдігіне бейімделуі туралы мәліметтерді алуға негізделген.

Түйін сөздер: пикнидиалы саңырауқұлақ, өсімдіктердің қатерлі ісік ауруы, таралуы, иелік-өсімдік, Cytospora туысы, цитоспороз, Қазақстанның оңтүстік-шығысы.

Введение

Представители рода *Cytospora* Ehrenb. являются эндофитами, сапробами или экономически значимыми патогенами, которые распространены по всему миру, имеют широкий круг хозяев и обычно связаны с раковыми заболеваниями и язвенной болезнью древесных растений-хозяев, приводящих к отмиранию ветвей деревьев. Цитоспороз (рак или некроз) является одной из самых серьезных грибных болезней плодовых и декоративных деревьев и кустарников. Болезнь часто приводит к гибели большого количества растений [1, 2]. Так, например, в настоящее время цитоспороз начал создавать проблемы для культивирования вишни в Румынии. Если ранее это заболевание было характерно для старых деревьев, то сейчас болезнь чаще регистрируется на молодых вишнях. Заболевают молодые сады 5-8 лет, некоторые из них находятся в тяжелом состоянии, когда спасти растения уже невозможно, что характерно для возделывания чувствительных сортов. Цитоспороз лучше всего развивается при высоких температурах от 32°C (июль-сентябрь), когда рост деревьев низкий. Из видов *Cytospora*, зарегистрированных в Румынии, наиболее частым является *Cytospora leucostoma* (Pers.) Sacc. [3].

Идентификация видов *Cytospora* затруднительна до сих пор, поскольку имеющихся в настоящее время данных о последовательностях ДНК недостаточно. Отсутствие культур экс-типа

или невозможность связать данные о последовательностях ДНК нескольких генов в GenBank с филогенетическими анализами осложняет классификацию таксонов *Cytospora* на уровне видов. Предварительное изучение 34 образцов *Cytospora* из небольшого региона (Европейская часть России), представляющее начальный вклад в понимание рода, показало, что всего три вида являются известными таксонами, 14 видов были описаны, как новые [4].

В настоящее время в соответствии с базой данных Index Fungorum [5] род *Cytospora* насчитывает в мире 387 представителей.

Целью нашей работы было выявить виды рода *Cytospora* на территории юго-востока Казахстана и провести анализ данных по их распространению и кругу растений-хозяев.

Материалы и методы исследования

Микологические обследования проводились маршрутным методом на территории юго-востока Казахстана в течение ряда лет (2013-2015, 2018-2021). Во время обследований собирались веточки древесных растений с типичными симптомами поражения цитоспорой. Приготовление препаратов осуществлялось по стандартной методике [6]. Образцы изучались и фотографировались с помощью фотомикроскопа Polyvar (Reichert-Jung, Австрия) с интерференционной оптикой Номарского. Виды были идентифицированы с помощью соответствующих определителей [7, 8].

Названия видов грибов и авторы приведены в соответствии с базой данных Index Fungorum [5], названия питающих растений – согласно Catalogue of Life [9]. Материалом для статьи послужили собственные сборы авторов, гербарные образцы, хранящиеся в гербарии Института Ботаники и фитоинтродукции, а также литературные данные [10]. Для всех видов, собранных авторами, приведены точки конкретных местонахождений (с указанием координат, высоты над уровнем моря, даты сбора и фамилии коллектора).

Результаты исследования и обсуждение

Из рода *Cytospora*, относящегося к классу Sordariomycetes O.E. Erikss. & Winka, порядку Phomatosporales Senan., Maharachch & K.D. Hyde, семейству Valsaceae Tul. & C. Tul., на территории юго-востока Казахстана обнаружены 43 вида. На территории центрального и северного Казахстана обнаружено 4 вида рода *Cytospora*: *Cytospora leucosperma* (Pers.) Fr. на *Betula pendula* Roth.; *C. microspora* Rabenh. на *Crataegus sanguinea* Pall.; *C. salicis* (Corda) Rabenh. на *Salix fragilis* L. и *Populus nigra* L.; *C. pseudoplatani* Sacc. на *Acer negundo* L. [11].

Алфавитный список видов с указанием растений-хозяев и координат сбора приведен ниже.

Cytospora acaciae Oudem. – на *Amorpha fruticosa* L. и *Robinia pseudoacacia* L., предгорья Заилийского Алатау, 23.06.1964, Н.Ф. Писарева.

Cytospora atra (Bonord.) Sacc. – на *Morus alba* L., предгорья Заилийского Алатау, 23.06.1964, Н.Ф. Писарева.

Cytospora atronitens Chevall. – на *Salix caprea* L. и *S. cinerea* L., хр. Заилийский Алатау, Малое Алматинское ущ., 20.06.1956, А.Г. Семкина; там же, 13.10.1948, С.Р. Шварцман; на *Salix* sp., хр. Алтын-Эмель, ущ. Узын-Булак, т. 498, 1577 м н. у. м., N44°20′10.5″, EO78°50′29.8″, 27.05.2014, Е.В. Рахимова; горы Хантау, к юго-западу от ст. Хантау, сухое ущ., перевал, 704 м н. у. м., N44°15′24.4″, EO73°49′33.9″, 25.06.2014, А.К. Джиенбеков.

Cytospora aurora Mont. & Fr. (Рисунок 1) – на *Salix alba* L., горы Киндиктас, объездная трасса на г. Чу, боковое ущ. с речкой, 900 м н. у. м., N43°25′50.4″, EO74°59′03.7″, 08.03.2016, Е.В. Рахимова; горы Айтау, ущ. напротив ст. Кулакшын, 1004 м н. у. м., N43º47′49.0″, EO74º36′13.8″, 04.06.2016, Е.В. Рахимова; на *S. capusii* Franch., хр. Заилийский Алатау, Малое Алматинское ущ., 11.06.1957, С.Р. Шварцман; горы Киндиктас, ущ., у ручья, 30.05.1958, З.М. Бызова; на *S. fragilis* L., предгорья Заилийского Алатау, 26.02.1937, Г.С. Неводовский; на *S. songarica* Andersson, пойма р. Чарын, 11.05.1943, Б.И. Кравцев; на *Salix* sp., хр. Заилийский Алатау, ущ. Большое Алматинское, т. 262, 1926 м н. у. м., N43º06′27.1″, EO76º56′15.9″, 27.04.2018, У.К. Джетигенова; хр. Алтын-Эмель, 1150 м н. у. м., N44º14′33.1″, EO79º28′39.1″, 09.05.2012, Е.В. Рахимова; нижнее течение р. Или, район Кунаевского моста, 375 м н. у. м., N44º57′56.4″, EO75º47′32.3″, 23.03.2012, Е.В.Рахимова.

Cytospora berberidis C.M. Tian, X.L. Fan & K.D. Hyde – на *Berberis sphaerocarpa* Kar. & Kir., хр. Кунгей Алатау, ущ. Талды, лиственный лес, т. 305, 1677 м н. у. м., N43°01′56.7″, EO78°15′19.2″, 26.07.2020, А.М. Асылбек.

Cytospora capitata Fuckel (Рисунок 2) – на *Malus domestica* Borkh., 19 км в сторону Каскелена, дачи, т 476, 767 м н. у. м., N43º14′40.0″, EO75º42′47.9″, 25.10.2014, Е.В. Рахимова; на

M. floribunda Koidz., предгорья Заилийского Алатау, 05.09.1967, Н.М. Филимонова; на *M.sieversii* (Lebd.) M. Roem., хр. Джунгарский Алатау, правый берег р. Средний Тентек, смешанный лес, т. 453, 1044 м н. у. м., N45°46′49.4″, EO81°06′27.1″, 24.08.2021, Г.А. Урманов; там же, ущ. пос. Сапак, пойменный лес, т. 462, 995 м н. у. м., N45°45′26.2″, EO80°53′21.1″, 26.08.2021, А.А. Иманалинова; там же, ущ. Коксу, пойменный лес, т. 408, 1308 м н. у. м., N44°40′58.0″, EO78°56′20.7″, 18.06.2021, А.М. Асылбек; хр. Заилийский Алатау, Малое Алматинское ущ., 14.07.1964, Н.Ф. Писарева; там же, Глубокая щель, 24.07.1964, Н.Ф. Писарева; там же, хребет между р. Малой Алматинкой и Бутаковкой, западный склон, небольшое ущ., лиственный лес, т. 391, 1496 м н. у. м., N43º10′19.6″, EO77º02′20.0″, 28.07.2020, Е.В. Рахимова; хр. Алтын-Эмель, горы Орикты, безымянное ущ. с речкой, т. 5, 1457 м н. у. м., N44º11′27.9″, EO78º32′24.1″, 29.05.2014, А.М. Асылбек; на *Malus* sp., хр. Джунгарский Алатау, дорога от ст. Коктума до с. Кабанбай, ущ. притока р. Жаманты, возле заброшенного сада, т. 485, 1262 м н. у. м., N45°45′53.5″, E81°21′10.1″, 19.07.2022, Е.В. Рахимова; там же, правый берег р. Коктал, пойменный лиственный лес, т. 409, 1305 м н. у. м., N44°35′50.4″, EO78°58′45.2″, 18.06.2021, А.М. Асылбек; 6 км на северо-запад от с. Балпык Би, правый берег р. Коксу, пойменный лес, т. 1, 535 м н. у. м., N44°54′58.6″, EO78°14′42.5″, 03.10.2021, А.М. Асылбек; горы Сюгаты, южный отщелок ущ. Кокпек, в кустарниках вдоль ручья, т. 1, 1003 м н. у. м., N43°29′57.3″, E78°37′44.9″, 02.05.2021, Е.В. Рахимова; хр. Заилийский Алатау, Большое Алматинское ущ., т. 267, 1926 м н. у. м., N43º06′27.1″, EO76º56′15.9″, 27.04.2018, Е.В. Рахимова; хр. Кунгей Алатау, дорога от ущ. Кудурга к ущ. Курметы, т. 324, 1571 м н. у. м., N43°02′46.6″, EO78°18′34.5″, 21.08.2020, Б.Е. Джунусканова; хр. Жетыжол, ущ. юго-западнее пос. Актерек, т. 19, 1069 м н. у. м., N43°15′14.2″, EO75°24′19.6″, 27.06.2014, У.К. Джетигенова.

Cytospora carphosperma Fr. – на *Malus domestica* Borkh., предгорья Заилийского Алатау, 12.03, 1.04.1936, Г.С. Неводовский; на *M.sieversii* (Ledeb.) M. Roem., хр. Заилийский Алатау, Малое Алматинское ущ., 15.08.1948, С.Р. Шварцман; на *Malus* sp., хр. Джунгарский Алатау, ущ. Саркандское, еловый лес, т. 421, 1838 м н. у. м., N45°10′31.9″, EO80°01′23.8″, 20.08.2021, А.А. Иманалинова; на *Tilia cordata* Mill., предгорья Заилийского Алатау, 26.05.1964, Н.Ф. Писарева.

Cytospora ceratosperma (Tode) G.C. Adams & Rossman – на *Rosa alberti* Regel., хр. Заилийский Алатау, Малое Алматинское ущ., 20.06.1956, А.Г. Семкина; на *Rosa* sp., хр. Турайгыр, 23.07.1956, Б.К. Калымбетов; хр. Алтын-Эмель, ущ. Узынбулак, т. 11, 1612 м н. у. м., N44°20′29.2″, E78°50′37.1″, 17.06.2022, Л.А. Кызметова; горы Жельдикара, влажное понижение, т. 482, 923 м н. у. м., N43°31′42.8″, E77°54′19.7″, 16.07.2022, Е.В. Рахимова.

Cytospora chrysosperma (Pers.) Fr. – на *Populus talassica* Kom., хр. Джунгарский Алатау, правый берег р. Средний Тентек, смешанный лес, т. 452, 844 м н. у. м., N45°47′15.7″, EO80°59′30.7″, 24.08.2021, Ж. Айтымбет; на *P. tremula* L., хр. Заилийский Алатау, Большое Алматинское ущ., гребень хребта по правому берегу реки, 2194 м н. у. м., N43º06′60.7″, EO76º56′65.8″, 12.01.2012, Е.В. Рахимова; на *Populus* sp., предгорья Заилийского Алатау, 1937, Г.С. Неводовский; там же, 23.05.1955, З.М. Бызова. Этот вид характерен для представителей рода *Malus*, и образует многолокульные конидиоматы [12].

Cytospora corni Westend. – на *Cornus foemina* Mill., *Swida alternifolia* (L. f.) Small., *S. australis* (C.A. Mey.) Pojark. ex Grossh., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева.

Cytospora dubyi Sacc – на *Juniperus turkestanica* Kom. и *J. virginiana* L., предгорья Заилийского Алатау, 19.06.1957, Б.К. Калымбетов; там же, 9.06.1947, А.И. Власенко.

Cytospora elaeagni Allesch. – на *Elaeagnus oxycarpa* Schltdl., р. Чарын, 25.05.1943, Б.И. Кравцев; окр. с. Колди, берег пруда Есдаулет-Сай, 15.06.2004, Л.А. Кызметова. В то же время, штаммы, выделенные из ветви *Elaeagnus angustifolia* с симптомами цитоспроза в Синьцзян-Уйгурском автономном районе Китая, на основании морфологического наблюдения и мультилокусного филогенетического анализа (ITS, LSU, ACT и RPB2) отнесены к отдельному новому виду *Cytospora elaeagnicola,* характеризующемуся дисковидными, почти плоскими, пикнидиальными конидиомами с гиалиновыми, аллантоидными конидиями [13].

Cytospora euonymi Cooke – на *Euonymus bungeanus* Maxim. и *E. maackii* Rupr., предгорья Заилийского Алатау, 6.09.1967, С.М. Лопухова.

Cytospora eurotiae Kravtzev – на *Krascheninnikovia ceratoides* (L.) Gueldenst., территория г. Капчагай, р. Или, 12.06.1965, С.Р.Шварцман, М.Н. Кузнецова.

Cytospora greschikii Bres. – на *Myricaria bracteata* Royle., хр. Заилийский Алатау, Тур-

генское ущ., 13.09.1964, С.Р. Шварцман; хр. Терскей Алатау, к юго-востоку от пос. Каркара, правый берег р. Сарытасу, пойменный лес, т. 305, 1935 м н. у. м., N42°47′57.2″, EO79°12′54.6″, 12.09.2021, Г. Сыпабеккызы.

Cytospora grossulariae Laubert – на *Grossularia acicularis* (Sm.) Spach., предгорья Заилийского Алатау, 18.06.1954, Б.К. Калымбетов.

Cytospora halimodendri Kravtzev – на сухой ветке *Halimodendron halodendron* (Pall.) Voss, берег р. Чарын, ясеневая роща, 15.03.1943, Б.И. Кравцев.

Cytospora horrida Sacc. – на *Betula pendula* Roth, хр. Заилийский Алатау, Малое Алматинское ущ., березовая роща, 14.07.1964, Н.Ф. Писарева; хр. Кунгей Алатау, ущ. Кайынды, березовый лес, т. 252, 1734 м н. у. м., N43°00′04.6″, E78°27′07.3″, 23.09.2020, Э.С. Саметова; хр. Джунгарский Алатау, долина р. Коксу, т. 35, 1423 м н. у. м., N44°43′04.1″, E79°03′11.0″, 10.07.2014, У.К. Джетигенова; там же, ущ. Кора, правый берег р. Кора, пойменный березовый лес, т. 396, 1465 м н. у. м., N44°56′22.7″, EO78°53′44.6″, 16.06.2021, А.М. Асылбек.

Cytospora hulthemia Kravtzev – на *Hulthemia berberifolia* (Pall.) Dumort., горки Жамбыл, у пос. Бирлик, 20.06.1945, Б.И. Кравцев.

Cytospora intermedia Sacc. (*Valsa intermedia* Nitschke) – на *Quercus robur* L., хр. Заилийский Алатау, Малое Алматинское ущ., посадки, 12.07.1948, С.Р. Шварцман; там же, агролесхоз, 3.08.1954, С.Р. Шварцман; на *Q. rubra* L., предгорья Заилийского Алатау, 1.09.1967, С.М. Лопухова.

Cytospora juglandina Sacc. – на *Juglans fallax* Dode, хр. Заилийский Алатау, Малое Алматинское ущ., 13.10.1954, С.Р. Шварцман; на *J. mandshurica* Maxim., предгорья Заилийского Алатау, 9.06.1947, С.Р. Шварцман; на *J.ailanthifolia* var. *cordiformis* (Makino) Rehder, предгорья Заилийского Алатау, 1.09.1967, Н.М.Филимонова.

Cytospora leucosperma (Pers.) Fr. – на *Acer campestre* L., хребет между р. Малой Алматинкой и Бутаковкой, небольшое ущ., т. 372, 1360 м н. у. м., N43°10′40.4″, EO77°01′04.5″, 23.06.2020, Г. Сыпабеккызы; на *Carpinus betulus* L. и *C.cordata* Blume, предгорья Заилийского Алатау, 5.09.1967, С.М. Лопухова; там же, 9.06.1947, З.Шухова.

Cytospora leucostoma (Pers.) Sacc. (Рисунок 3) – на *Sorbus tianschanica* Rupr., хр. Заилийский Алатау, Малое Алматинское ущ., 20.10.1946, М.Н. Кузнецова; на *Spiraea hypericifolia* L., горы Сюгаты, ущ. Кокпек, северное каньонообразное ответвление, т. 276, 1047 м н. у. м., N43°29′23.1″, EO78°38′08.6″, 23.05.2018, Е.В. Рахимова; на *Rosa iliensis* Chrshan., пойма р. Или, нижнее течение (ниже Баканаса), 377 м н. у. м., N44°53′08.6″, EO75°58′08.7″,01.07.2012, Е.В. Рахимова. Этот вид обычно ассоциируется с раковой болезнью на подсемействе Prunoideae семества Rosaceae в Китае [14].

Cytospora lonicerae Grove – на *Lonicera altmannii* Regel & Schmalh., южный макросклон хр. Кетмень, за пер. Кеген, верхняя часть ущ. Акбет, у родника, т. 065, 1613 м н. у. м., N43°10′74.9″, EO79°13′71.9″, 24.08.2016, У.К.Джетигенова.

Cytospora microspora Rabenh. – на *Crataegus korolkowii* L. Henry, хр. Заилийский Алатау, Малое Алматинское ущ., 28.08.1956, А.Г. Семкина; на *C. pentagyna* Waldst. & Kit. ex Willd., предгорья Заилийского Алатау, 12.09.1967, Н.М.Филимонова; на *Crataegus* sp., хр. Кетмень, ущ. Дардамты, по левому притоку, пойменный лес, т. 437, 1443 м н. у. м., N43°24′50.5″, E80°03′43.6″, 26.08.2021, Е.В. Рахимова; на *Sorbus tianschanica* Rupr., хр. Заилийский Алатау, Тургенское ущ., западный склон, пойменный лес, т. 323, 1287 м н. у. м., N43°16′17.1″, E77°44′18.9″, 20.05.2019, Е.В. Рахимова; там же, Малое Алматинское ущ., по дороге к Воротам Туюксу, 3.09.1967, М.П.Васягина; там же, ущ. Аюсай, смешанный лес, т. 307, 1877 м н. у. м., N43°05′26.0″, E76°56′51.9″, 28.08.2018, Л.А. Кызметова; там же, ущ. Кимасар, т. 413, 2015 м н. у. м., N43°09′44.7″, E77°05′19.7″, 10.09.2020, А.М. Асылбек; хр. Терскей Алатау, к югу от пос. Каркара, ущ. Мынжилки, пойменный смешанный лес, т. 302, 2169 м н. у. м., N42°44′15.8″, EO79°16′53.7″, 11.09.2021, А.М.Асылбек; хр. Алтын-Эмель, ущ. Узын-Булак, т. 504, 1724 м н. у. м., N44°21′13.5″, EO78°49′39.2″, 27.05.2014, А.М. Асылбек; хр. Джунгарский Алатау, р. Теректы, 30.05.1944, Б.И. Кравцев; Кастекский хр., ущ. Кастек, 1854 м н. у. м., N42°59′70.7″, EO75°53′30.3″, 29.06.2012, Е.В. Рахимова. Вид характеризуется многолокульными (более 10) конидиоматами с неокрашенными, изогнутыми конидиями, размером 6,5 × 1.2 мкм [4].

Cytospora nivea Fuckel (*Valsa nivea* (Hoffm.) Fr.) – на *Betula tianschanica* Rupr., хр. Кунгей Алатау, ущ. Талды, т. 306, осинник, 1677 м н. у. м., N43°01′42.8″, EO78°15′29.8″, 26.07.2020, Г.Сыпабеккызы; на *Populus koreana* Rehder., предгорья Заилийского Алатау, 5.09.1967, С.М.Лопухова. Вид характеризуется многоло-

кульными конидиоматами с индивидуальными остиолами и неокрашенными, изогнутыми конидиями, размером 7,6 × 1.9 мкм [4].

Cytospora oxyacanthae Rabenh. – на *Crataegus almaatensis* Pojark., хр. Заилийский Алатау, Малое Алматинское ущ., 14.07.1964, Н.Ф. Писарева; на *C. pinnatifida* Bunge, предгорья Заилийского Алатау, 5.09.1967, С.М. Лопухова; на *C.songarica* K. Koch., хр. Заилийский Алатау, Малое Алматинское ущ., 27.04.1937, М.Н. Кузнецова; там же, Бутаковская щель, 15.08.1948, С.Р. Шварцман.

Cytospora personata (Fr.) Sacc. (Рисунок 4, 5) – на *Betula pendula* Roth., хр. Заилийский Алатау, Большое Алматинское ущ., граница елового леса, т. 330, 1579 м н. у. м., N43°06′00.5″, E76°56′52.0″, 23.05.2019, Е.В. Рахимова; на *Malus sieversii* (Ledeb.) M. Roem., хребет между р. Малой Алматинкой и Бутаковкой, небольшое ущ., т. 370, 1388 м н. у. м., N43º10′44.6″, EO77º01′10.3″, 26.05.2020, А.М. Асылбек; хр. Джунгарский Алатау, ущ. Большой Усек, смешанный лес, т. 310, 960 м н. у. м., N44°21′10.1″, EO79°53′23.9″, 14.09.2021, А.М. Асылбек; на *Malus* sp., хр. Джунгарский Алатау, ущ. Кора, пойменный березовый лес, т. 397, 1456 м н. у. м., N44°56′11.0″, EO78°53′21.9″, 16.06.2021, А.М.Асылбек; на *Salix* sp., хр. Джунгарский Алатау, ущ. Чажа, пойменный лиственный лес, т. 401, 1249 м н. у. м., N44°51′41.1″, EO78°56′07.4″, 17.06.2021, А.М. Асылбек; на *Rhamnus cathartica* L., хр. Жетыжол, ущ. юго-западнее пос. Актерек, т. 18, 1033 м н. у. м., N43º15′43.7″, EO75º25′26.8″, 26.06.2014, Е.В. Рахимова.

Рисунок 1 – *Cytospora aurora* на *Salix* sp.

Рисунок 2 – *Cytospora capitata* на *Malus* sp.

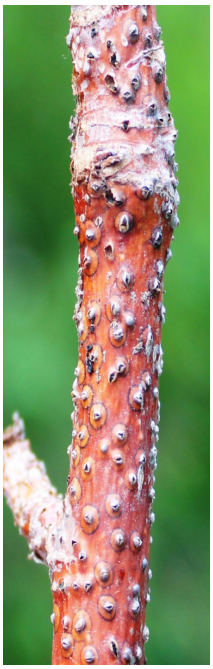


Рисунок 3 – *Cytospora leucostoma* на *Sorbus tianschanica*

Рисунок 4 – *Cytospora personata* на *Betula pendula*

Рисунок 5 – *Cytospora personata* на *Malus sieversii*

Cytospora phellodendri Gucevič – на *Phellodendron amurense* Rupr., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева.

Cytospora philadelphi Pisareva – на *Philadelphus caucasicus* Koehne., предгорья Заилийского Алатау, 23.06.1964, Н.Ф. Писарева.

Cytospora pinastri Fr. (*Valsa abietis* (Fr.) Fr.) – на *Larix sibirica* Ledeb., предгорья Заилийского Алатау, 6.09.1967, С.М. Лопухова.

Cytospora populina (Pers.) Rabenh. – на *Amelanchier ovalis* Medikus, предгорья Заилийского Алатау, 23.06.1964, Н.Ф. Писарева; на *Celtis caucasica* Willd., хр. Жетыжол, ущ. юго-западнее пос. Актерек, т. 24, 1129 м н. у. м., N43º15′14.2″, EO75º24′19.6″, 27.06.2014, У.К. Джетигенова; на *Cotoneaster melanocarpus* Lodd., G. Lodd. & W. Lodd., хр. Заилийский Алатау, Малое Алматинское ущ., 03.10.1965, В.А.

Костин; там же, ущ. Правый Талгар, 21.06.1979, З.М. Бызова; хр. Кунгей Алатау, ущ. Кольсай, берег оз. Кольсай, смешанный лес, т. 309, 1853 м н. у. м., N42°59′27.6″, EO78°19′31.1″, 27.07.2020, А.М.Асылбек; на *Crataegus korolkowii* L. Henry, хр. Заилийский Алатау, Малое Алматинское ущ., 28.06.1956, А.Г. Семкина; на *Rosa* sp., хр. Кунгей Алатау, ущ. Талды, т. 306, осинник, 1677 м н. у. м., N43°01′42.8″, EO78°15′29.8″, 26.07.2020, Г. Сыпабеккызы; на *Ulmus laevis* Pall., предгорья Заилийского Алатау, 26.05.1964, С.Р. Шварцман.

Cytospora pruinosa (Fr.) Sacc. – на *Fraxinus sogdiana* Bunge, р. Чарын, 15.05.1943, Б.И. Кравцев. Вид характеризуется наличием единственной локулы и мелких конидий размером 2–4 × 1 мкм [15].

Cytospora prunorum Sacc. – на *Cerasus besseyi* (L.H. Bailey) Smyth., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева; на *C. tianschanica* Pojark. горы Чулак, юго-западная часть, т. 94, 686 м н. у. м., N43°54′34.1″, EO77°46′08.2″, 21.12.2014, Е.В. Рахимова; на *C. vulgaris* Mill., предгорья Заилийского Алатау, 16.03.1937, Г.С.Неводовский; на *Padellus mahaleb* (L.) Vassilcz., предгорья Заилийского Алатау, 26.05.1964, Н.Ф.Писарева; на *Padus avium* Mill.*,* хребет между р. Малой Алматинкой и Бутаковкой, небольшое ущ., т. 370, 1388 м н. у. м., N43º10′44.6″, EO77º01′10.3″, 26.05.2020, А.М. Асылбек.

Cytospora pseudoplatani Sacc. – на *Acer negundo* L., хребет между р. Малой Алматинкой и Бутаковкой, небольшое ущ., т. 369, 1319 м н. у. м., N43°10′41.2″, EO77°00′59.0″, 26.05.2020, Е.В.Рахимова; на *A. rubrum* L., хр. Заилийский Алатау, Малое Алматинское ущ., 12.08.1948, С.Р. Шварцман; там же, предгорья, 5.06.1964; Н.Ф. Писарева.

Cytospora pyricola Westend. – на *Chaenomeles japonica* (Thunb.) Spach., предгорья Заилийского Алатау, 6.09.1967, Н.М. Филимонова, Н.Кажиева.

Cytospora ribis Ehrenb. – на *Ribes americanum* Mill., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева; на *R. heterotrichum* С.А. Меу., хр. Алтын-Эмель, горы Орикты, безымянное ущ. с речкой, т. 4, 1445 м н. у. м., N44°11′27.9″, EO78°32′32.5″, 29.05.2014, Ж.М. Такиева; на *R. meyeri* Maxim., хр. Заилийский Алатау, Проходное ущ., еловый лес, т. 346, 2240 м н. у. м., N43°03′51.2″, E76°54′28.6″, 16.07.2019, Е.В. Рахимова; там же, ущ. юго-западнее пос. Казстрой, смешанный лес, т. 462, 1636 м н. у. м., N43°15′52.3″, E77°21′15.6″, 28.09.2021, Е.В. Рахимова; хр. Терской Алатау, ущ. Шокпарбай, еловый лес, т. 295, 2277 м н. у. м., N42°35′51.9″, EO79°59′02.5″, 09.09.2021, А.М. Асылбек; на *Ribes* sp., хр. Кунгей Алатау, ущ. Курметы, еловый лес, т. 300, 1810 м н. у. м., N43°00′25.2″, EO78°17′05.4″, 25.07.2020, А.М. Асылбек.

Cytospora ruthenica Petr. – на *Caragana balchaschensis* (Kom.) Pojark., горки Жамбыл, 04.06.1960, З.М. Бызова; на *C. camilli-schneideri* Kom., горы Сюгаты, ущ. Кокпек, боковое северное каньонообразное ответление, т. 276, 1047 м н. у. м., N43º29′23.1″, EO78º38′08.6″, 23.05.2018, Е.В. Рахимова.

Cytospora salicis (Corda) Rabenh. (Рисунок 6-8) – на *Salix capusii* Franch., хр. Заилийский Алатау, Малое Алматинское ущ., 22.09.1954, С.Р. Шварцман; на *S. lucida* Muhl., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева; на *S.tenuijulis* Ledeb., хр. Заилийский Алатау, Чиликская лесная дача, юго-западный склон, 12.07.1948, С.Р. Шварцман; на *S. triandra* L., хр. Кунгей Алатау, ущ. Талды, т. 306, осинник, 1677 м н. у. м., N43°01′42.8″, EO78°15′29.8″, 26.07.2020, Г.Сыпабеккызы; на *S. viminalis* L., хр. Заилийский Алатау, Малое Алматинское ущ., 28.06.1956, А.Г. Семкина; на *S. wilhelmsiana* M. Bieb., р. Чарын, 5.10.1941, Б.И. Кравцев; на *Salix* sp., горы Сюгаты, ущ. юго-восточнее пос. Нура, 908 м н. у. м., N43°31′48.4″, EO78°32′32.9″, 04.05.2017, Е.В. Рахимова; окрестности с. Бактыбай, правый берег р. Коксу, огороды, т. 2, 537 м н. у. м., N44°55′44.1″, EO78°15′25.0″, 03.10.2021, А.М.Асылбек; хр. Джунгарский Алатау, ущ. Чажа, пойменный лиственный лес, т. 401, 1249 м н. у. м., N44°51′41.1″, EO78°56′07.4″, 17.06.2021, А.М. Асылбек; там же, ущ. Саркандское, еловый лес, т. 421, 1838 м н. у. м., N45°10′31.9″, EO80°01′23.8″, 20.08.2021, А.А. Иманалинова; западнее ст. Лепсы, тугайный лес р. Лепсы, т. 494, 392 м н. у. м., N46°13′16.4″, E78°54′49.3″, 9.08.2022, Е.В. Рахимова; хр. Алтын-Эмель, северный макросклон, ущ. южнее пос. Талдыбулак, т. 478, 1397 м н. у. м., N44°29′53.1″, EO78°53′22.1″, 21.06.2022, Е.В. Рахимова; предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева; хр. Кунгей Алатау, ущ. Курметы, вдоль р. Курметы, пойменный лиственный лес, т. 302, 1835 м н. у. м., N43°00′10.2″, EO78°17′16.0″, 25.07.2020, Г. Сыпабеккызы; там же, ущ. Талды, лиственный лес, т. 305, 1677 м н. у. м., N43°01′56.7″, EO78°15′19.2″, 26.07.2020, А.М.Асылбек; там же, ущ. Кольсай, еловый лес, т. 334, 2530 м н. у. м., N42°55′04.7″, EO78°20′37.2″, 23.08.2020, Б.Е. Джунусканова; там же, берег оз. Кольсай, смешанный лес, т.309, 1853 м н. у. м., N42°59′27.6″,

EO78°19′,31.1″, 27.07.2020, А.М. Асылбек; каньон р. Тимерлик, 1132 м н. у. м., N43°15′34.1″, EO79°13′04.0″, 06.07.2017, Е.В. Рахимова; хр. Терской Алатау, к юго-востоку от пос. Каркара, правый берег р.Сарытасу, пойменный лес, т. 305, 1935 м н. у. м., N42°47′57.2″, EO79°12′54.6″, 12.09.2021, Г. Сыпабеккызы; там же, ущ. Большой Какпак, пойменный лес, т. 300, 1798 м н. у. м., N42°48′03.5″, EO79°56′34.6″, 10.09.2021, У.К. Джетигенова; там же, к югу от пос. Каркара, ущ. Мынжилки, пойменный смешанный лес, т. 301, 2122 м н. у. м., N42°44′56.1″, EO79°16′35.9″, 11.09.2021, Г.Сыпабеккызы; там же, пойма р. Каркара, пойменный лиственный лес, т. 443, 1936 м н. у. м., N42°50′29.9″, E79°13′49.8″, 08.09.2021, Е.В. Рахимова; там же, к юго-западу от пос. Кайнар, пойма р. Текес, пойменный лиственный лес, т.447, 1978 м н. у. м., N42°46′34.9″, E79°40′00.1″, 11.09.2021, Е.В. Рахимова; там же, т. 445, 1941 м н. у. м., N42°50′29.9″, E79°13′49.8″, 10.09.2021, Е.В. Рахимова; хр. Кетмень, ущ. Сумбе, т. 224, 1385 м н. у. м., N43°17′00.6″, EO79°27′06.0″, 27.08.2016, Е.В. Рахимова; хр. Жетыжол, юго-западнее пос. Актерек, т. 24, 1129 м н. у. м., N43º15′14.2″, EO75º24′19.6″, 27.06.2014, У.К. Джетигенова.

Рисунок 6 – *Cytospora salicis* на *Salix* sp.

Рисунок 7 – *Cytospora salicis* на *Salix* sp.

Рисунок 8 – Конидии *Cytospora salicis,* шкала – 15 мкм.

Cytospora sambuci Died. – на *Sambucus nigra* L., предгорья Заилийского Алатау, 5.06.1964, Н.Ф. Писарева.

Cytospora tamaricella Syd. & P. Syd. – на *Tamarix hohenackeri* Bunge, Сюгатинская долина, ур. Бартогай, тугаи вдоль р. Чилик, 13.05.1967, Н.М. Филимонова.

Cytospora translucens Sacc. (Рисунки 9, 10) – на *Salix alba* L., хр. Джунгарский Алатау, ущ. Текели, березовый лес, т. 389, 1756 м н. у. м., N44°47′35.2″, EO78°59′22.7″, 15.06.2021, Л.А.Кызметова; хр. Заилийский Алатау, Талгарское ущ., 19.10.1954, С.Р. Шварцман; на *S. depressa* L., хр. Заилийский Алатау, Малое Алматинское ущ., 15.08.1948, С.Р. Шварцман; там же, ущ. Кимасар, подъем на Фурмановскую сопку по хребту, т. 411, 1942 м н. у. м., N43°09′48.6″, E77°04′38.1″, 10.09.2020, Г.А. Урманов; на *S. triandra* L., хр. Кунгей Алатау, р. Шелек, тугайный лес, т. 264, 1475 м н. у. м., N43°04′19.3″, E78°22′04.6″, 25.09.2020, Г. Сыпабеккызы; на *Salix* sp., хр. Малайсары, горы Архарлы, перевал, восточное боковое ущ., т. 189-1, 1061 м н. у. м., N44°14′17.1″, EO77°42′47.7″, 19.12.2021, Е.В. Рахимова; хр. Джунгарский Алатау, ущ. Крутое, пойменный лиственный лес, т. 442, 981 м н. у. м., N45°32′25.9″, EO80°37′11.4″, 22.08.2021, Ж. Айтымбет. Вид характеризуется

однолокульными конидиоматами с неокрашенными, изогнутыми конидиями, размером 4,6 × 1,2 мкм [4].

Cytospora spiraeae X.L. Fan (Рисунок 11)– на *Spiraea hypericifolia* L., горы Сюгаты, южнее ущ. Кокпек, плоскогорье, т. 273, 1197 м н. у. м., N43º27′30.1″, EO78º35′28.6″, 16.05.2018, Е.В. Рахимова; хр. Джунгарский Алатау, ущ. Текели, боковое ущ. Солдатсай, пойменный лес, т. 392, 1754 м н. у. м., N44°47′50.1″, EO78°52′39.8″, 15.06.2021, Ж. Айтымбет; Чу-Илийские горы, Кулжабасы, ущелье с родниками западнее г. Отар, т. 160, 1006 м н. у. м., N43º37′02.2″, EO75º06′43.3″, 15.05.2016, Е.В. Рахимова. Вид отличается от *Cytospora spiraeicola*, вызывающей раковый некроз *Spiraea salicifolia* в Китае, более крупными перитециями и более короткими аскоспорами [16].

Рисунок 9 – *Cytospora translucens* на *Salix alba* L.

Рисунок 10 – Конидии *Cytospora translucens,* шкала – 15 мкм. Окрашивание сафранином О.

Рисунок 11 – *C. spiraeae* на *Spiraea hypericifolia*

Максимальное количество видов рода *Cytospora* (26 видов) обнаружены в предгорьях Заилийского Алатау (Рисунок 12), в настоящее время эта территория внесена в границы города Алматы. В Заилийском Алатау отмечено 20 видов *Cytospora*. Для горных хребтов Джунгарский Алатау, Кунгей Алатау и Алтын-Эмель характерны 10, 9, 7 представителей рода, соответственно. Необходимо отметить, что в пустынных территориях юго-востока Казахстана обнаружено 8 видов *Cytospora* (Рисунок 12). В других локациях количество отмеченных видов невелико.

Виды рода *Cytospora* встречаются на представителях сосудистых растений из 29 семейств. Наибольшее число видов отмечено на семействе Rosaceae (11 видов), Salicaceae (7), Betulaceae (4), Fabaceae (3 вида) (Рисунок 13). Для остальных семейств характерны 1-2 вида *Cytospora.* С момента своего открытия более 110 лет назад рак, вызываемый грибами *Cytospora/Valsa,* превратился в разрушительную болезнь яблони в Восточной Азии. В настоящее время насчитывается 21 вид *Cytospora*, связанный с яблоней, как хозяином, по всему миру, 12 из них идентифицированы с помощью последовательностей рДНК-ITS [17]. Главной угрозой для производства яблок в Иране, включая провинции Западный Азербайджан, Исфахан и Тегеран, считается *Cytospora cincta*. Поэтому этот возбудитель рака яблони должен тщательно контролироваться [18].

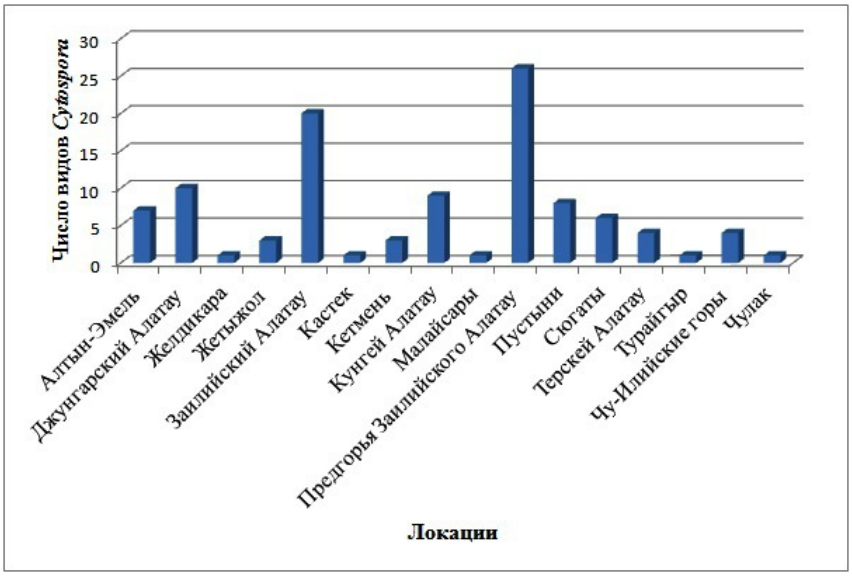


Рисунок 12 – Распределение видов рода *Cytospora* по территории юго-востока Казахстана

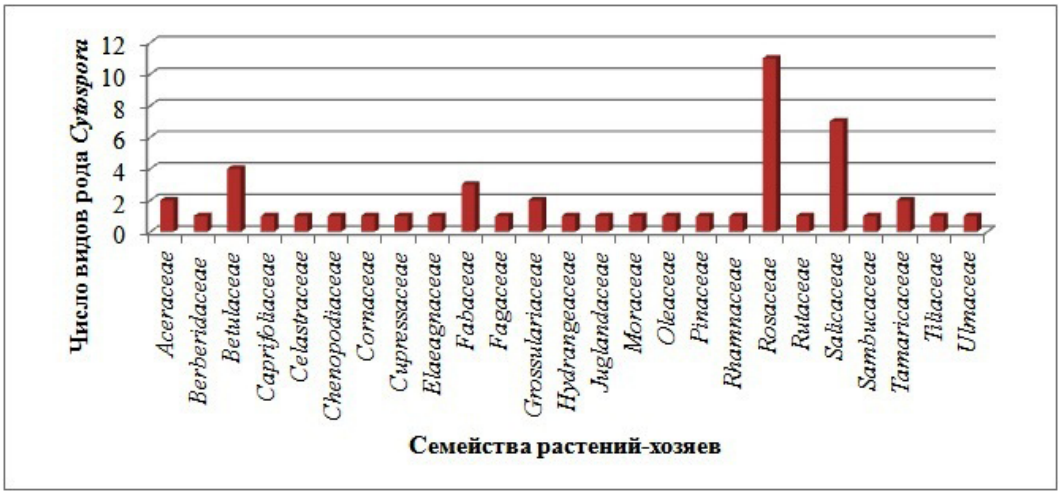


Рисунок 13 – Распределение видов рода *Cytospora* по семействам растений-хозяев

Значительное число видов *Cytospora* на представителях семейств Salicaceae характерно не только для Казахстана, но и по всему миру [1, 2]. Достоверно их можно различить на основе филогенетического анализа, благодаря которому были представлены еще десять новых видов, выделенных из *Salix*, а именно *Cytospora curvata, C. donetzica, C. erumpens, C. longiostiolata, C. rusanovii, C. salicacearum, C. salicina, C. salicacearum, C. salicicola и C. salicina.* [4]. В Китае на широко культивируемых видах ивы обнаружено восемь представителей рода *Cytospora.* Из них два вида (*C. alba* и *C. paracinnamomea*) были описаны как новые на основе морфологии и анализа последовательностей генов ITS, act, rpb2, tef1-a и tub2 [19]. В посадках ивы и тополя в Китае отмечено пять известных видов (*Cytospora chrysosperma*, *C. translucens, C. fugax*, *C. atrocirrhata, C. kantschavelii*) и один новый – *C. davidiana* на тополе [20].

На основе филогенетического анализа последовательностей ДНК (ITS, LSU, ACT и RPB2) десять образцов, собранные из мертвой древесины в Китае, Италии и Таиланде, были отнесены к роду *Cytospora.* На основании их морфологии и филогенетической характеристики описаны че-

тыре новых вида (*C. diopuiensis, C. galegicola, C. pingbianensis* и *C. pubescentis*) и четыре образца отнесены к известным видам (*C. cedri, C. cotini, C. predappioensis* и *C. prunicola*) [21].

Изоляты грибов рода *Cytospora,* собранные с больных и здоровых деревьев в Южной Африке, были идентифицированы на основе морфологии и гомологии последовательностей рибосомальной ДНК. Несколько видов являются новыми находками для Южной Африки, что вдвое превышает предыдущие сообщения об этих грибах. В то же время, виды из *Pinus, Populus, Prunus* и *Salix* на основе сходства между южноафриканскими изолятами и изолятами из Австралии, Европы или Америки, являются чужеродными видами, причем патогены были завезены с хозяевами в виде эндофитов [1]. Произрастающий в Южной Африке карпобротус съедобный, используемый местным населением в пищу, очень сильно поражается цитоспорозом в районах недалеко от Кейптауна. Симптомы включают увядание листьев, связанное с отмиранием одревесневших стеблей. Анализ данных о последовательности ДНК из rDNA-ITS показал, что гриб является новым видом *Cytospora carpobroti*. Его происхождение неизвестно, и есть опасения, что это может быть занесенный патоген, угрожающий состоянию этого важного местного растения [22].

Молекулярно-генетические исследования 150 изолятов выявили 15 видов *Cytospora*, связанных с язвами ветвей и отмиранием миндальных, абрикосовых, вишневых, оливковых, персиковых, фисташковых, сливовых, гранатовых и ореховых деревьев в Калифорнии [23]. Два вида, *Cytospora vinacea* и *C. viticola*, вызывающие отмирание и язвы виноградной лозы, были описаны в США сравнительно недавно [24]. Изолят из язв виноградной лозы в Венгрии, похожий на *C.viticola,* обнаружен в Европе впервые [25].

На территории Украины обнаружено 57 видов рода *Cytospora* [26], в то время как на территории Армении всего 8 видов (*Cytospora annulata* Ellis & Everh., *C. fertilis* Sacc., *C.flavovirens* Sacc., *C. germanica* Sacc., *C. gleditsiae* Ellis & Barthol., *C.hippophaes* Thüm., *C. pruinosa* Defago, *C.sacculus* (Schwein.) Gvrit. [27].

Произведена оценка 52 *Cytospora* spp. в Китае, представленных 88 изолятами из 28 родов хозяев. На основе комбинации морфологии и шестилокусной филогении (ITS, LSU, act1, rpb2, tef1-α и tub2), введены 13 новых видов и одна новая комбинация. Большинство исследованных видов, по-видимому, специфичны для хозяина [14]. При исследовании территории гор Дунглинг (Китай) были получены семь изолятов из шести деревьев-хозяев семейств Betulaceae, Juglandaceae, Rosaceae, Tiliaceae и Ulmaceae. На основании морфологического сравнения и филогенетического анализа с использованием частичного ITS, LSU, act, rpb2, tef1-α и tub2, идентифицированы два известных вида (*Cytospora leucostoma* и *C. pruinopsis*) и два новых вида (*C.coryli* и *C. spiraeicola*) [16]. На лещине (*Corylus heterophylla*) отмечены два известных вида *Cytospora* и один новый [28].

Три вида грибов из рода *Cytospora* (*Cytospora populina* (Pers.) Rabenh. (*C. ambiens* (Pers.) Sacc.), *C. grossularia* Laubert и *C. ribis* Ehrenb.) обнаружены на усыхающих ветвях смородины черной, смородины красной, смородины золотистой и крыжовнике в четырех регионах средней полосы России [29]. 9 видов отмечены на деревьях в долине реки Уссури (с Китайской и Российской сторон): *Cytospora caprea* Fuckel на *Salix* spp.; *C. chrysosperma* (Pers.) Fr. на *Populus* spp., *Salix* spp.; *C. leucosperma* (Pers.) Fr. на *Ulmus japonica* (Rehd.) Sarg., *Acer mono* Maxim.; *C. leucostoma* (Pers.) Sacc. на *Populus* spp., *Schisandra chinensis* (Turz.) Baill.; *C. personata* Fr. на *Betula mandshurica* (Regel) Nakai; *C. pruinosa* Defago на *Fraxinus mandshurica* Rupr.; *C. rubescens* Fr. на *Padus avium* Mill.; *C. sacculus* (Schwein.) Gvrit. на *Pinus koraiensis* Siebold et Zucc.; *C. vitis* Mont. на *Vitis amurensis* Rupr. [30].

При исследовании биоты аскомицетов природного заповедника Нуратау (Узбекистан), было зарегистрировано 6 видов рода *Cytospora* (*Cytospora capitata* Sacc. et Schulzer on *Pyrus regelii* Rehder; *C. carphosperma* Fr. on *Malus* sp.; *C.juglandina* Sacc. on *Juglans regia* L.; *C.microspora* (Desm.) Rabenh. on *Sorbus persica* Hedl.; *C. rubescens* Fr. on *Sorbus persica* Hedl.; *C.salicis* (Corda) Rabenh. on *Salix alba* L.), два образца (*Cytospora* sp. 1 on *Pistacia vera* L.; *Cytospora sp*. 2 on *Crataegus pontica* C. Koch) идентифицированы только до рода, причем оба найдены в Узбекистане впервые [31].

Заключение

Целью нашей работы было выявление видов рода *Cytospora* Ehrenb. на территории юго-востока Казахстана и проведение анализа данных по их распространению и кругу растений-хозяев. В результате проведенных исследований на территории юго-востока Казахстана обнаружены 43 вида рода *Cytospora* на 29 семействах представителях сосудистых растений. Ана-

лизируя распределение представителей рода *Cytospora* на территории исследований, необходимо отметить, что большее число видов (26) отмечено в предгорьях Заилийского Алатау. 20 видов характерны только для территории Заилийского Алатау, 10 видов – для горных хребтов Джунгарского Алатау, 9 видов – Кунгей Алатау и 7 видов – Алтын-Эмеля. В пустынных территориях обнаружено 8 видов. Наибольшее число видов *Cytospora* отмечено на представителях семейств Rosaceae Juss. (11 видов), Salicaceae Mirb. (7), Betulaceae Gray (4), Fabaceae Lindl. (3 вида). Ценность проведенного исследования и практическое значение заключаются в получении данных о местонахождении, распространении и приуроченности к хозяину видов *Cytospora*.

Финансирование

Работа была выполнена при финансовой поддержке научно-целевой программы BR10264557 «Кадастровая оценка современного экологического состояния флоры и растительных ресурсов Алматинской области как научная основа для эффективного управления ресурсным потенциалом».

Конфликт интересов

Авторы статьи подтверждают отсутствие финансовой или какой-либо иной поддержки исследования, или конфликта интересов.

Литература

1. Adams G.C., Roux J., Wingfield M.J. Cytospora species (Ascomycota, Diaporthales, Valsaceae): introduced and native pathogen of tree in South Africa // Australian Plant Pathology. – 2006. – Vol. 35. – P. 521-548. doi: 10.1071/AP06058.

2. Adams G.C., Wingfield M.J., Common R. and Roux J. *Phylogenetic relationships and morphology of Cytospora species and related teleomorphs (Ascomycota, Diaporthales, Valsaceae) from Eucalyptus*. Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands, 2005.

3. Cotuna O., Paraschivu M., Sărăţeanu V., Durău C. Identification of the phyto-pathogenic fungus Cytospora leucostoma (Pers.) Sacc. in cherry trees from western Romania (case study) // Research Journal of Agricultural Science. – 2020. – Vol. 52 (2). – P. 125-131.

4. Norphanphoun C., Doilom M., Daranagama D.A., Phookamsak R., Wen T.C., Bulgakov T.S., Hyde K.D.– Revisiting the genus Cytospora and allied species // Mycosphere. – 2017. – Vol. 8(1). – P. 51–97. doi: 10.5943/mycosphere/8/1/7.

5. Index Fungorum Database URL: http://www.indexfungorum.org/ (дата обращения – 23 января 2023).

6. В.Д. Поликсенова, А.К. Храмцов, С.Г. Пискун. Методические указания к занятиям спецпрактикума по разделу «*Микология. Методы экспериментального изучения микроскопических грибов*» для студентов 4 курса дневного отделения // Минск: БГУ, 2004.

7. Sutton B. C. 1980. *The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stomata*. Commonwealth Mycological Institute, 1980.

8. Головин С. Е., Романченко Т. И. *Диагностика возбудителей микозного усыхания, корневых и прикорневых гнилей плодовых культур и система защитных мероприятий* (монография) // ГНУ ВСТИСП. – Изд. ООО «Издательство Агрорус». – Москва, 2013.

9. Catalogue of Life URL: https://www.catalogueoflife.org/ (дата обращения – 23 января 2023).

10. Рахимова Е.В., Нам Г.А., Ермекова Б.Д., Джетигенова У.К., Кызметова Л.А., Есенгулова Б.Ж. *Разнообразие грибов пустынных низкогорий юго-востока Казахстана и хребта Кетмень.* – Алматы: Luxe Media, 2017.

11. Ospanova A., Anuarova L., Spanbayev A., Tulegenova Z., Yechshzhanov T., Shapalov S., Gabdulkhayeva B., Zhumabekova B., Kabieva S., Baidalinova B. Cytospora Cankers on Tree Plants in Urban Areas (Karaganda, Astana, Pavlodar) of Central and Northern Kazakhstan // Ekoloji. – 2018. – Vol. 27(106). – P. 63-69.

12. Mehrabi M., Mohammadi Goltapeh E., Fotouhifar K.B. Studies on Cytospora canker disease of apple trees in Semirom region of Iran // Journal of Agricultural Technology. – 2011. – Vol. 7(4). – P. 967-982.

13. Zhanga L., Alvarezb L.V., Bonthondc G., Tiana C. and Fana X. Cytospora elaeagnicola sp. nov. Associated with Narrow-leaved Oleaster Canker Disease in China // Mycobiology. – 2019. – Vol. 47 (3). – P. 319–328. doi: 10.1080/12298093.2019.1633902.

14. Fan X.L., Bezerra J.D.P., Tian C.M., Crous P.W. Cytospora (Diaporthales) in China // Persoonia. – 2020. – Vol. 45. – P. 1–45. doi: 10.3767/persoonia.2020.45.01

15. Yang Q., Fan X.L., Crous P.W., Liang Y.M., Tian C.M. *Cytospora* from *Ulmus pumila* in Northern China // Mycological Progress. – 2015. – Vol. 14. – P. 1–12. doi: 10.1007/s11557-015-1096-1.

16. Zhu H., Pan M., Bezerra J.D.P., Tian C., Fan X. Discovery of Cytospora species associated with canker disease of tree hosts from Mount Dongling of China // MycoKeys. – 2020. – Vol. 62. – P. 97–121. doi: 10.3897/mycokeys.62.47854.

17. Wang X., Shi C.-M., Gleason M. L. and Huang L. Fungal species associated with apple Valsa canker in East Asia // Phytopathology Research. – 2020. – Vol. 2. – P. 35-49. doi: 10.1186/s42483-020-00076-5

18. Nourian A., Salehi M., Safaie N., Khelghatibana F. & Abdollahzadeh J. Fungal canker agents in apple production hubs of Iran // Scientific Reports. – 2021. – Vol. 11. – P. 1-16. doi: 10.1038/s41598-021-02245-8.

19. Lin L., Pan M., Tian C., Fan X. Fungal Richness of Cytospora Species Associated with Willow Canker Disease in China // Journal of Fungi. – 2022. – Vol. 8. – P. 377-394. doi: 10.3390/jof8040377.

20. Wang Y.-L., Lu Q., Decock C., Li Y.-X., Zhang X.-Y. Cytospora species from Populus and Salix in China with C. davidiana sp. Nov // Fungal Biology. – 2015. – Vol. 119(5). – P. 420-432. doi: 10.1016/j.funbio.2015.01.005.

21. Shang Q.J., Hyde K.D., Camporesi E., Maharachchikumbura S.S.N., Norphanphoun C., Brooks S., Liu J.K. Additions to the genus Cytospora with sexual morph in Cytosporaceae // Mycosphere. 2020. – Vol. – 11(1). – P. 189-224. doi: 10.5943/mycosphere/11/1/2.

22. Jami F., Marincowitz S., CrousP.W., Jacobsohn A., Wingfield M.J. A new Cytospora species pathogenic on *Carpobrotus edulis* in its native habitat // Fungal Systematics and Evolution. – 2018. – Vol. 2. – P. 37-43. doi: 10.3114/fuse.2018.02.03.

23. Lawrence D.P., Holland L.A., Nouri M.T., Travadon R., Abramians A., Michailides T.J., Trouillas F.P. Molecular phylogeny of Cytospora species associated with canker diseases of fruit and nut crops in California, with the descriptions of ten new species and one new combination // IMA FUNGUS. – 2018. – Vol. 9(2). – P. 333–370. doi: 10.5598/imafungus.2018.09.02.07

24. Lawrence D.P., Travadon R., Pouzoulet J., et al. Characterization of Cytospora isolates from wood cankers of declining grapevine in North America, with the descriptions of two new Cytospora species // Plant Pathology. – 2017. – Vol. 66. – P. 713–725.

25. Crous P.W., Schumacher R.K., Wingfield M.J., Akulov A., Denman S., Roux J., Braun U., Burgess T.I., Carnegie A.J., Váczy K.Z., Guatimosim E., Schwartsburd P.B., Barreto R.W., Hernández-Restrepo M., Lombard L., Groenewald J.Z. New and Interesting Fungi 1 // Fungal Systematics and Evolution. – 2018. – Vol. 1. – P. 169–215. doi: 10.3114/fuse.2018.01.08.

26. Fungi of Ukraine. A preliminary checklist (Eds. D.W. Minter and I.O. Dudka). CAB International, 1996.

27. Осипян Л.Л. Микобиота Армении. Том VIII: ч. 1 – Головневые грибы; ч. 2 – Дополнение к томам Микофлоры Арм. ССР – Ер.: Изд-во ЕГУ, 2013.

28. Gao H., Pan M., Tian C., Fan X. Cytospora and Diaporthe Species Associated with Hazelnut Canker and Dieback in Beijing, China // Front. Cell. Infect. Microbiol. – 2021. – Vol. 11. – P. 1–22. doi:10.3389/fcimb.2021.664366

29. Головин С.Е. Усыхание ветвей смородины и крыжовника, вызываемое грибами из рода *Cytospora*, в средней полосе России. Плодоводство и ягодоводство России. – 2021. – Vol. 66(1). – P. 73-81. doi: 10.31676/2073-4948-2021-66-73-81.

30. Li Y., Azbukina Z. M. Fungi of Ussuri river valley – Beijing. Science Press. China. 2010.

31. Mustafaev I. M., Beshko N. Yu., Iminova M. M. Checklist of ascomycetous microfungi of the Nuratau Nature Reserve (Uzbekistan) // Новости систематики низших растений. – 2019. – Vol. 53(2). – P. 315–332. doi: 10.31111/nsnr/2019.53.2.315

References

1. Adams G.C., Roux J., Wingfield M.J. «Cytospora species (Ascomycota, Diaporthales, Valsaceae): introduced and native pathogen of tree in South Africa». *Australian Plant Pathology* 35, (2006): 521-548. doi:10.1071/AP06058.

2. Adams G.C., Wingfield M.J., Common R. and Roux J. *Phylogenetic relationships and morphology of Cytospora species and related teleomorphs (Ascomycota, Diaporthales, Valsaceae) from Eucalyptus*. Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands, 2005.

3. Cotuna O., Paraschivu M., Sărăţeanu V., Durău C. «Identification of the phyto-pathogenic fungus Cytospora leucostoma (Pers.) Sacc. in cherry trees from western Romania (case study).». *Research Journal of Agricultural Science* 52, no 2 (2020): 125-131.

4. Norphanphoun C., Doilom M., Daranagama D.A., Phookamsak R., Wen T.C., Bulgakov T.S., Hyde K.D. «Revisiting the genus Cytospora and allied species». *Mycosphere* 8, no 1 (2017): 51–97. doi:10.5943/mycosphere/8/1/7.

5. Index Fungorum Database URL: http://www.indexfungorum.org/ (accessed – 23 January 2023).

6. V.D. Poliksenova, A.K. Hramcov, and S.G. Piskun. "Metodicheskie ukazaniya k zanyatiyam specpraktikuma po razdelu «*Mikologiya. Metody eksperimental'nogo izucheniya mikroskopicheskih gribov*» dlya studentov 4 kursa dnevnogo otdeleniya [Guidelines for the special workshop on the section "Mycology. Methods of experimental study of microscopic fungi" for 4th year full-time students]." Minsk: BGU, 2004. (In Russian)

7. Sutton B. C. 1980. *The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stomata*. Commonwealth Mycological Institute, 1980.

8. Golovin S. E., Romanchenko T. I. "Diagnostika vozbuditelej mikoznogo usyhaniya, kornevyh i prikornevyh gnilej plodovyh kul'tur i sistema zashchitnyh meropriyatij (monografiya) [Diagnosis of causative agents of fungal desiccation, root and root rot of fruit crops and a system of protective measures (monograph)]." GNU VSTISP. – Izd. OOO «Izdatel'stvo Agrorus». – Moskva, 2013. (In Russian)

9. Catalogue of Life URL: https://www.catalogueoflife.org/ (accessed – 23 January 2023).

10. Rakhimova Y.V., Nam G.A., Yermekova B.D., Jetigenova U.K., Kyzmetova L.A., and Yessengulova B.Zh. "Raznoobrazie gribov pustynnyh nizkogorij yugo-vostoka Kazahstana i hrebta Ketmen [Diversity of fungi in the desert low mountains of southeastern Kazakhstan and the Ketmen ridge]." Almaty: Luxe Media, 2017. (In Russian)

11. Ospanova A., Anuarova L., Spanbayev A., Tulegenova Z., Yechshzhanov T., Shapalov S., Gabdulkhayeva B., Zhumabekova B., Kabieva S., Baidalinova B. «Cytospora Cankers on Tree Plants in Urban Areas (Karaganda, Astana, Pavlodar) of Central and Northern Kazakhstan». *Ekoloji* 27, no 106 (2018): 63-69.

12. Mehrabi M., Mohammadi Goltapeh E., Fotouhifar K.B. «Studies on *Cytospora* canker disease of apple trees in Semirom region of Iran». *Journal of Agricultural Technology* 7, no 4 (2011): 967-982.

13. Zhanga L., Alvarezb L.V., Bonthondc G., Tiana C. and Fana X. «Cytospora elaeagnicola sp. nov. Associated with Narrow-leaved Oleaster Canker Disease in China». *Mycobiology* 47, no 3 (2019): 319–328. doi: 10.1080/12298093.2019.1633902.

14. Fan X.L., Bezerra J.D.P., Tian C.M., Crous P.W. «Cytospora (Diaporthales) in China». *Persoonia* 45, (2020): 1–45 doi:10.3767/persoonia.2020.45.01.

15. Yang Q., Fan X.L., Crous P.W., Liang Y.M., Tian C.M. «*Cytospora* from *Ulmus pumila* in Northern China». *Mycological Progress* 14, (2015): 1–12. doi: 10.1007/s11557-015-1096-1

16. Zhu H., Pan M., Bezerra J.D.P., Tian C., Fan X. «Discovery of Cytospora species associated with canker disease of tree hosts from Mount Dongling of China». *MycoKeys* 62, (2020): 97–121. doi: 10.3897/mycokeys.62.47854.

17. Wang X., Shi C. M., Gleason M. L. and Huang L. «Fungal species associated with apple Valsa canker in East Asia». *Phytopathology Research* 2, (2020): 35-49. doi: 10.1186/s42483-020-00076-5

18. Nourian A., Salehi M., Safaie N., Khelghatibana F. & Abdollahzadeh J. «Fungal canker agents in apple production hubs of Iran». *Scientific Reports* 11, (2021): 1-16. doi: 10.1038/s41598-021-02245-8.

19. Lin L., Pan M., Tian C., Fan X. «Fungal Richness of Cytospora Species Associated with Willow Canker Disease in China». *Journal of Fungi* 8, (2022): 377-394. doi: 10.3390/jof8040377.

20. Wang Y.-L., Lu Q., Decock C., Li Y.-X., Zhang X.-Y. «Cytospora species from Populus and Salix in China with C. davidiana sp. Nov» *Fungal Biology* 119, no 5 (2015): 420-32. doi: 10.1016/j.funbio.2015.01.005.

21. Shang Q.J., Hyde K.D., Camporesi E., Maharachchikumbura S.S.N., Norphanphoun C., Brooks S., Liu J.K. «Additions to the genus Cytospora with sexual morph in Cytosporaceae». *Mycosphere* 11, no 1, (2020): 189-224, doi: 10.5943/mycosphere/11/1/2.

22. Jami F., Marincowitz S., CrousP.W., Jacobsohn A., Wingfield M.J. «A new Cytospora species pathogenic on *Carpobrotus edulis* in its native habitat». *Fungal Systematics and Evolution* 2, (2018): 37-43. doi: 10.3114/fuse.2018.02.03.

23. Lawrence D.P., Holland L.A., Nouri M.T., Travadon R., Abramians A., Michailides T.J., Trouillas F.P. «Molecular phylogeny of Cytospora species associated with canker diseases of fruit and nut crops in California, with the descriptions of ten new species and one new combination». *Ima Fungus* 9, no 2 (2018.): 333–370. doi: 10.5598/imafungus.2018.09.02.07

24. Lawrence D.P., Travadon R., Pouzoulet J., et al. «Characterization of Cytospora isolates from wood cankers of declining grapevine in North America, with the descriptions of two new Cytospora species». *Plant Pathology* 66, (2017): 713–725.

25. Crous P.W., Schumacher R.K., Wingfield M.J., Akulov A., Denman S., Roux J., Braun U., Burgess T.I., Carnegie A.J., Váczy K.Z., Guatimosim E., Schwartsburd P.B., Barreto R.W., Hernández-Restrepo M., Lombard L., Groenewald J.Z. «New and Interesting Fungi». *Fungal Systematics and Evolution* 1, (2018): 169-215. doi: 10.3114/fuse.2018.01.08

26. Fungi of Ukraine. A preliminary checklist (Eds. D.W. Minter and I.O. Dudka). CAB International, 1996.

27. Osipyan L.L. 2013. “Mikobiota Armenii. Tom VIII: ch. 1 – Golovnevye griby; ch. 2 – Dopolnenie k tomam Mikoflory Arm. SSR [Mycobiota of Armenia. Volume VIII: part 1 – Smut mushrooms; Part 2 – Supplement to the volumes of Mycoflora Arm. SSR].” *Er.: Izd-vo EGU*, 2013. (In Russian)

28. Gao H., Pan M., Tian C. and Fan X. 2021. «Cytospora and Diaporthe Species Associated with Hazelnut Canker and Dieback in Beijing, China». *Front. Cell. Infect. Microbiology* 11, (2021): 1–22. doi:10.3389/fcimb.2021.664366.

29. Golovin S.E. “Usyhaniye vetvey smorodiny i kryzhovnika, vyzyvayemoye gribami iz roda Cytospora, v sredney polose Rossii [Drying of currant and gooseberry branches caused by fungi of the genus Cytospora in central Russia].” *Plodovodstvo i yagodovodstvo Rossii* 66, no 1 (2021): 73-81. doi: 10.31676/2073-4948-2021-66-73-81. (In Russian)

30. Li Y., Azbukina Z. M. *Fungi of Ussuri river valley – Beijing.* Science Press. China, 2010.

31. Mustafaev I. M., Beshko N. Yu., Iminova M. M. «Checklist of ascomycetous microfungi of the Nuratau Nature Reserve (Uzbekistan)». Novosti sistematiki nizshikh rasteniy 53, no 2 (2019): 315–332. doi: 10.31111/nsnr/2019.53.2.315

IRSTI 34.29.35; 34.35.51 https://doi.org/10.26577/eb.2023.v96.i3.05

Ye.A Simanchuk[1*], A.N. Kuprijanov[2], G.J. Sultangazina[1]

[1]A. Baitursynov Kostanay Regional University, Kazakhstan, Kostanay
[2]Kuzbass botanical garden Federal Research Center of Coal and Coal Chemistry SB RAS, Russia, Kemerovo
*e-mail: simyeandr.ksu@mail.ru

ANALYSIS OF COMPLEX PHYTOCENOSES OF IRON ORE COMPANIES DUMPS OF THE KOSTANAY REGION

Restoring the biodiversity of technogenic landscapes, including quarry dump areas, is an acute global problem. The study of the patterns of spontaneous formation of vegetation cover will make it possible to determine the composition of the flora that is most suitable for potential reclamation work.

This article presents the results of a study of the degree of self-overgrowing of dump sites of Sokolovsko-Sarbai Mining and Processing Production Association (SSGPO) JSC and Kachary Ruda JSC at the stage of a complex phytocenosis, which is characterized by the presence of a closed vegetation cover; with a capacity of phytocenoses of 20-40 species; and dominance of zonal flora species. In total, in the course of our study, 63 geobotanical descriptions were compiled, 22 of which describe complex phytocenoses, 26 – group-thicket communities, 15 – pioneer groups.

It was found that the rate of change in the stages of syngenesis and the general patterns of development of the vegetation cover, including at the stage of a complex phytocenosis, differ on saline and non-saline soils. The age of dumping has a lesser effect on the processes of flora restoration than edaphic factors. On non-saline soils, a parazonal meadow-steppe community is formed, birch-aspen plantations are formed with a small admixture of pine. On saline soils, communities form species with a wide ecological amplitude.

Key words: complex phytocenosis, technogenic landscape, self-overgrowing of dumps, iron ore companies dumps, syngenesis

Е.А. Симанчук[1*], А.Н. Куприянов[2], Г.Ж. Сұлтанғазина[1]

[1]А. Байтұрсынов атындағы Қостанай өнірлік университеті, Қазақстан, Қостанай қ.
[2]Кузбас ботаникалық бағы, РҒА СБ көмір және көмір химиясы
Федеральді зерттеу орталығы, Ресей, Кемерово қ.
*e-mail: simyeandr.ksu@mail.ru

Қостанай облысының темір рудасы кәсіпорындарының күрделі фитоценоздарын талдау

Техногендік ландшафттардың, оның ішінде карьер үйінділерін биоәртүрлілігін қалпына келтіру өткір жаһандық проблема болып табылады. Өсімдік жамылғысының өздігінен қалыптасу заңдылықтарын зерттеу потенциалды рекультивациялық жұмыстарға қолайлы флора құрамын анықтауға мүмкіндік береді.

Бұл мақалада «Соколов-Сарыбай тау-кен байыту өндірістік бірлестігі» (ССКӨБ) АҚ және «Қашары руда» АҚ үйінділерінің күрделі фитоценоз сатысында өздігінен өсу дәрежесін зерттеу нәтижелері келтірілген. Бұл кезең сипатталады: жабық өсімдік жамылғысының болуы; 20-40 түрдегі фитоценоздардың сыйымдылығы; және аймақтық флора түрлерінің басымдылығы. Біздің зерттеу барысында барлығы 63 геоботаникалық сипаттама жасалды, олардың 22 – сі күрделі фитоценоздарды, 26-сы топтасын өскен өсімдіктер жиынтығы, 15-і Пионер топтарын сипаттады.

Сингенез кезеңдерінің өзгеру жылдамдығы және өсімдік жамылғысының дамуының жалпы заңдылықтары, соның ішінде күрделі фитоценоз кезеңінде, тұзданған және тұзданбаған топырақтарда ерекшеленетіні анықталды. Үйінді төгу жасы эдафиялық факторларға қарағанда флораны қалпына келтіру процестеріне аз әсер етеді. Тұзданбаған топырақтарда паразональды шалғынды дала қауымы қалыптасады, қарағайдың аздаған қоспасы бар қайың көктерек екпелер түзіледі. Тұзданған топырақтарда қауымдастықтар кең экологиялық амплитудасы бар түрлер құрайды.

Түйін сөздер: күрделі фитоценоз, техногендік ландшафт, үйінділердің өздігінен өсіп кетуі, темір кені өнеркәсібінің үйінділері, сингенез.

Е.А. Симанчук[1*], А.Н. Куприянов[2], Г.Ж. Султангазина[1]
[1]Костанайский региональный университет имени А. Байтурсынова, Казахстан, г. Костанай
[2]Кузбасский ботанический сад, Федеральный исследовательский центр
угля и углехимии СО РАН, Россия, г. Кемерово
*e-mail: simyeandr.ksu@mail.ru

Анализ сложных фитоценозов на отвалах железорудных предприятий Костанайской области

Восстановление биоразнообразия техногенных ландшафтов, в том числе карьерно-отвальных территорий, является острой глобальной проблемой. Изучение закономерностей самопроизвольного формирования растительного покрова позволит определить состав флоры, наиболее подходящий для потенциальных рекультивационных работ.

В данной статье приведены результаты исследования степени самозарастания отвалов АО «Соколовско-Сарбайское горно-обогатительное производственное объединение» (ССГПО) и АО «Качары руда» на стадии сложного фитоценоза, которая характеризуется наличием сомкнутого растительного покрова; емкостью фитоценозов в 20-40 видов; и доминированием видов зональной флоры. Всего в ходе нашего исследования было составлено 63 геоботанических описания, в 22 из которых описаны сложные фитоценозы, 26 – группово-зарослевые сообщества, 15 – пионерные группировки.

Было установлено, что скорость смены стадий сингенеза и общие паттерны развития растительного покрова, в том числе на этапе сложного фитоценоза, отличаются на засоленных и незасоленных почвах. Возраст отсыпки отвала оказывает меньшее влияние на процессы восстановления флоры, чем эдафические факторы. На незасоленных грунтах формируется паразональное лугово-степное сообщество, происходит формирование березово-осиновых насаждений с небольшой примесью сосны. На засоленных грунтах сообщества формируют виды с широкой экологической амплитудой.

Ключевые слова: сложный фитоценоз, техногенный ландшафт, самозарастание отвалов, отвалы железорудной промышленности, сингенез.

Abbreviations

As – aspen, B – birch, CC – class of constancy, CP – cenopopulation, LF – life form, P – pine, PP – projective cover, TMF – Technogenic mineral formations, TPC – total projective cover.

Introduction

The biodiversity of the planet is under constant threat of decline due to human activities. The search, extraction and processing of minerals necessary for mankind to function and develop requires a change in natural landscapes. Technogenic landscapes, formed as a result of these processes, are strikingly different from natural ones: soil and vegetation cover, fauna, hydrological and geochemical regime, meso- and microrelief change up to the complete destruction of individual components and entire systems [1-5].

In addition, there is a clear violation of biogeochemical cycles, resulting in dangerous phenomena: dust emissions, water and wind erosion of soils, subsidence and landslides, endogenous fires [1-5].

To restore even the semblance of systems close in characteristics to natural ones, it is necessary to carry out reclamation after the end of backfilling. However, the high cost and resource consumption, gaps and inaccuracies in the legislation, and more often the lack of scientifically based technologies suitable for a certain type of soil in given natural conditions, lead to the fact that mining and processing industries abandon this idea [3, 6-9].

The mining industry, using open pit methods, turns large areas into a desert, since in addition to the quarry itself, waste sterile rock dumps are formed. Scientists from various countries are studying the impact of industry on the environment. Many works are aimed at finding ways to reduce the anthropogenic impact, preserve biodiversity, and restore disturbed territories [1, 3-14].

Let us dwell on the main ideas common to most of these studies. For example, Feng Yu et al believe that vegetation, which is an efficient biomass generator, is the dominant factor in renewable systems. Jesús D. Peco et al also emphasize the role of vegetation and describe methods for recultivation of open-pit dump areas, including the possibility of phytoremediation, as a cheaper, but effective, method of restoring disturbed areas. Reconstruction of soil and vegetation cover are interrelated and have mutual influence, therefore, when bioremediation, it is necessary to carefully select local zonal species, as indicated by other authors, such as Swab R.M et

al, Fernández-Caliani J.C. et al. They also believe that it is especially important to create favorable edaphic conditions, including the formation of an uncompacted soil environment [5, 8, 12, 14].

According to Pratiwi et al, revegetation of former mining lands not only protects soils from erosion, but also improves the quality of the soil cover itself. Also, as trees and shrubs grow, microclimatic conditions in dump areas improve: lighting intensity decreases, temperature decreases, air humidity increases [13].

Hendrychová M. et al conducted a study of the territories of coal mines and quarries, that completed the mining, of the Czech Republic. The authors, describing the reclamation methods adopted in the country, draw attention to the negative impact of purely technical reclamation, including the annihilation of local species, the destruction of natural ecosystems and the depletion of the habitat in general. Near-natural restoration is a more acceptable alternative. Scientists have identified potential and existing habitats in man-made landscapes after the start of reclamation, and only 9.85% turned out to be unproductive (scree-surface sites, saline soil, orchards, and xerothermic grasslands) out of 6326 identified points, which proves the overall effectiveness of reclamation [6].

All authors, to one degree or another, point to the high cost of reclamation, while there is a watchful waiting policy with a minimum investment of resources. Self-overgrowing of technogenic landscapes is the second, slower, way to restore vegetation. The study of all stages of this process (pioneer group, group-thicket community, and complex phytocenosis) will, first of all, make it possible to determine the composition of the flora that inhabits the disturbed territories and successfully survives under these conditions. Establishing the rate of change of stages on different soils will also make it possible to draw up recommendations for accelerating the processes of partial restoration of landscapes in accordance with the zonality [1, 3-14].

It should also be noted that scientists from neighboring countries showed the greatest interest in the problem of self-overgrowth of open-pit dump territories of various industries. In the course of separate studies, they found that the formation of plant communities on dumps is subject to the general patterns of primary successions. For the emergence of the initial vegetation cover on technogenic landscapes, the proximity of natural vegetation massifs, which are the source of seeds and have a significant impact on the species composition, number and distribution of seedlings, is most important. Settlement on the dumps of plants that are not typical for a certain territory has been repeatedly noted, which indicates the potential possibility of moving plant ovules over considerable distances. In the process of restoration of vegetation cover on technogenic landscapes, zonal and introzonal types of vegetation are formed. Depending on the intensity of environmental factors, this process can continue for tens and hundreds of years [1, 15-22].

The problem of overgrowing of technogenic landscapes formed by industrial facilities is also relevant for the Kostanay region. The growing volumes of open mining of metal ores by enterprises of the region lead to an increase in the formation of waste rock dumps, which in turn leads to a violation of the state of the surrounding natural ecosystem and its significant transformation. According to the "Sixth National Report of the Republic of Kazakhstan on Biological Diversity" (2018), Kostanay region ranks third in terms of the number of disturbed lands in the Republic of Kazakhstan [23].

The purpose of our work is to study the patterns of self-overgrowing of dumps of the iron ore industry in the Kostanay region. This article presents the results of studying the stage of a complex phytocenosis on the dumps of the enterprises of SSGPO JSC and Kachary Ruda JSC.

Materials and methods

There are two large enterprises processing iron ore on the territory of the Kostanay region: SSGPO JSC (Sokolovsky, Sarbaisky and Kurzhunkulsky quarries) and Kachary Ruda JSC (Kacharsky quarry) [24].

The studied dumps belong to deposits of magnetite ores: Sokolov, Sarbay, and Kachar, are located in the northwestern part of Kazakhstan in the Turgai belt. The Turgai deposits are associated with volcanic-sedimentary rocks of the Trans-Ural zone. These deposits, together with other smaller satellite deposits and manifestations, form an extended magnetite-bearing belt extending in the NNE-SSW directions [25, 26].

In the course of this study, the dumps of SSGPO JSC (in the vicinity of the city of Rudny) were studied: South-East of the Sokolovsky deposit, South-West of the Sarbaysky deposit, South-West of the Yuzhno-Sarbaysky site. The railway dump No. 7 of Kachary Ruda JSC within the boundaries

of the village of Kachar was an object of the study along with previously mentioned dump sites.

It is important to note that dumps are the most common type of technogenic massifs in the mining industry, formed as a result of the placement of waste (overburden) rocks or substandard mineral raw materials on the surface. Technogenic mineral formations (TMF) in the form of loose sandy-argillaceous overburden rocks of the platform cover, formed from gaize, sands and clays, were transported to these dumps by road and rail transport. The genetic type of the deposit-source of TMF is contact-metasomatic [27-30].

The study was carried out in the spring and summer period of 2022.

The objects of study are located in the Kostanay region – in the northwestern part of the Republic of Kazakhstan. A sharply continental climate with a wide range of temperatures in winter and summer, day and night, is typical for the entire territory of the region. The northern and central part of the Kostanay region, the territory of the city of Rudny belong to a slightly humidified moderately warm agroclimatic zone, which in general can be considered favorable for plant growth [31].

The studied territories are characterized by the presence of southern, loamy, low-humus, soloniform chernozems. The mechanical composition is dominated by heavy loamy and clayey soils, and a large proportion of soils is sandy loam [27-31].

The route-expeditionary reconnaissance research method was used to study the flora of technogenic ecotopes. Trial areas of 100 m² were determined for the study. A total of 63 geobotanical descriptions were compiled.

Floristic data were processed using the IBIS 7.2 program developed by A.A. Zverev [32].

Qualitative and quantitative accounting of plants was carried out in accordance with accepted general botanical methods; occurrence (%), total and partial projective cover (TPC, %) were noted [1].

Calculation of numerical data: herbage density (pcs/m2), number of species (pcs), occurrence (%), partial projective cover (%) – was carried out according to the previously mentioned indicators. The occurrence rate made it possible to single out classes of constancy (CC) in the descriptions:

I – 0-20%; II – 21-40%; III – 41-60%; IV – 61-80%; V – 81-100% [1].

The geographical structure of the flora of the dumps of the third stage of syngenesis was determined according to the classification adopted in the works of Manakov Yu.A.; life forms – according to Serebryakov I.G. [1].

Results and discussion

As a rule, the stage of a complex phytocenosis (also known as ‘diffuse community’) begins to form 15-30 years after the dumping of the TMF finished. At this stage, well-formed layers appear with the predominant participation of species of zonal phytocenoses.

Criteria for determining this stage:

- the formation of a closed vegetation cover;
- the capacity of phytocenoses is from 20 to 40 species;
- dominance in the vegetation cover of species of zonal flora [1].

At the diffuse community stage, 22 geobotanical descriptions were made during this study: 11 on saline soils and 11 on non-saline soils. During our research we identified a division of edaphic environmental conditions: favorable – non-saline soils, unfavorable – saline soils. This affects number of species, activity, projective cover etc.

The age (end of dumping) of the studied dumps is from 14 to 40 years: CP-58-63 formed on relatively young dump sites (14 years), those on the oldest dump sites include CP-16-26 (40 years).

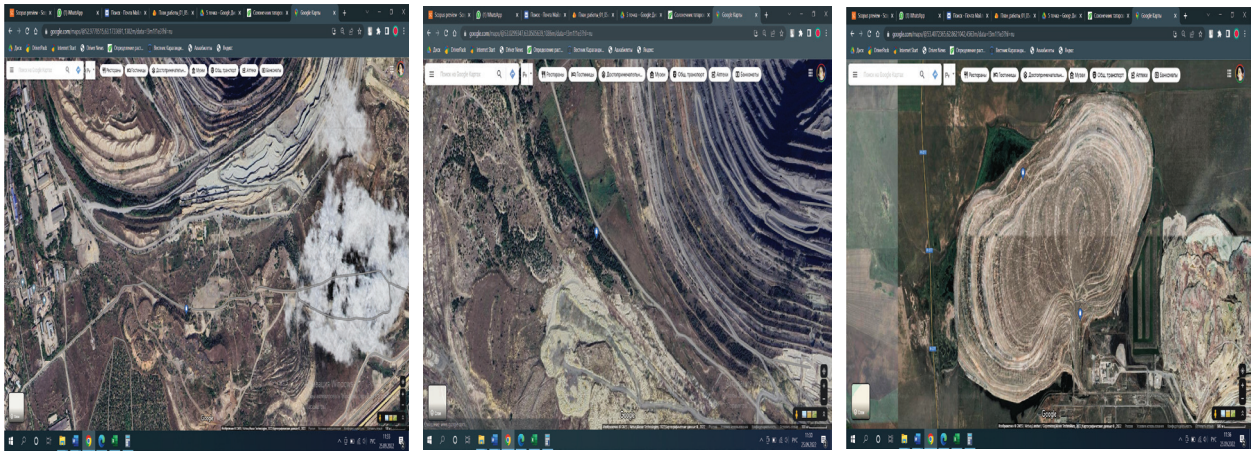
The beginning of the dumping of the oldest dump – 1960 (Table 1, Fig. 1) [24].

In the course of the study of complex phytocenoses on the iron ore dumps, a characteristic of the communities was compiled. Characteristics of cenopopulations of a complex phytocenosis are presented in Tables 2 and 3. The CP numbers are indicated taking into account all 63 geobotanical descriptions made in the course of the whole study of the iron ore dumps of the Kostanay region:

- CP-1-5, CP-43-52 – pioneer groups,
- CP-6-15, CP-27-42 – group-thicket communities,
- CP-16-26, CP-53-63 – complex phytocenosis.

The number of species in a CP at the described stage of syngenesis varies widely from one (CP-60) to nineteen (CP-22), which is associated with differences in edaphic conditions.

The total projective cover on saline soils is 47%, on non-saline soils – 36%. 32 species were found on saline soils, and 58 species on non-saline soils. Most often, *Calamagrostis epigeios, Phragmites australis* and *Festuca valesiaca* are the dominant or co-dominant in the presented CPs (Table 1).



A B C

Figure 1 – Location of the studied plant ecotopes at the stage of complex phytocenosis
A – dump site of the Sokolovsky quarry;
B – dump site of the Sarbaisky quarry;
C – dump site of the Kacharsky quarry

Table 1 – Characteristics of cenopopulations of complex phytocenosis

CP No.	Dominants	Density	Forest stand formula	TPC %	Species quantity
CP-16	*Hieracium umbellatum, Festuca valesiaca*	03	9As+B	40	18
CP-17	*Artemisia austriaca, Bromopsis inermis, Calamagrostis epigeios*	05	10P	20	13
CP-18	*Poa angustifolia, Calamagrostis epigeios*	04	10As+B	30	10
CP-19	*Hieracium umbellatum, Poa angustifolia*	03	10As	30	11
CP-20	*Festuca valesiaca, Artemisia dracunculus*	04	10As	30	14
CP-21	*Artemisia dracunculus, Festuca valesiaca*	04	5B5As	40	15
CP-22	*Tanacetum vulgare, Festuca valesiaca*			30	19
CP-23	*Festuca valesiaca, Galium verum*			30	15
CP-24	*Astragalus buchtormensis, Phragmites australis*			70	13
CP-25	*Hieracium virosum, Calamagrostis epigeios*	04	9B1P	50	12
CP-26	*Festuca valesiaca, Phragmites australis*	04		40	12
CP-53	*Calamagrostis epigeios Phragmites australis*	04	9B1As	25	6
CP-54	*Calamagrostis epigeios Phragmites australis*	03	5B5As	60	7
CP-55	*Calamagrostis epigeios Phragmites australis*	03	5B5As	10	5
CP-56	*Phragmites australis*	03	8B2As	30	3
CP-57	*Phragmites australis*	03	7B3As	50	3
CP-58	*Calamagrostis epigeios, Polygonum salsugineum*			90	14
CP-59	*Artemisia dracunculus, Calamagrostis epigeios*			65	11
CP-60	*Calamagrostis epigeios*			40	1
CP-61	*Calamagrostis epigeios, Polygonum salsugineum*			40	4
CP-62	*Calamagrostis epigeios, Polygonum salsugineum, Artemisia dracunculus*			40	7
CP-63	*Calamagrostis epigeios*	0,3	5B5As	70	6

On the oldest dump sites, the age of which exceeds 40 years, birch-aspen plantations with a density of 05 are formed, the forest stand formula is 8B2As. *Salix caprea* and *Rosa majalis* occur in the undergrowth. On saline soils, mosaic communities are formed with the participation of single pines (*Pinus sylvestris*) and birches (*Betula pendula*) (Table 2).

Since often saline soils are associated with the release of groundwater, numerous self-seeding of birch was noted. In the CP on highly saline soils, mass death of young trees often occurs (Figure 2 A).

Table 2 – Characteristics of communities at the stage of complex phytocenosis on saline soils

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Calamagrostis epigeios (L.) Roth	81.8	24.55	44.82	**V**	*Melilotus albus* Medikus	18.2	0.09	1.28	I
Achillea nobilis L.	54.5	0.27	3.84	**III**	*Pinus sylvestris* L.	18.2	0.09	1.28	I
Betula pendula Roth	54.5	0.16	2.95	**III**	*Conyza canadensis* (L.) Cronqist	9.1	0.05	0.67	I
Phragmites australis (Cav.) Trin. ex Steud.	54.5	10.91	24.39	**III**	*Lactuca serriola* L.	9.1	0.05	0.67	I
Artemisia dracunculus L.	45.5	6.5	17.19	**III**	*Sonchus arvensis* L.	9.1	0.05	0.67	I
Polygonum salsugineum Bieb.	45.5	0.68	5.56	**III**	*Cirsium setosum* (Willd.) Besser	9.1	0.05	0.67	I
Taraxacum officinale F.H.Wigg.	36.4	0.18	2.56	II	*Erigeron acris* L.	9.1	0.05	0.67	I
Chamaenerion angustifolium (L.) Scop.	27.3	0.14	1.95	II	*Senecio jacobaea* L.	9.1	0.05	0.67	I
Populus tremula L.	27.3	0.12	1.81	II	*Lactuca tatarica* (L.) C.A.Mey.	9.1	0.05	0.67	I
Chenopodium album L.	27.3	0.14	1.95	II	*Artemisia sieversiana* Willd.	9.1	0.05	0.67	I
Agropyron cristatum (L.) Gaertn.	18.2	0.09	1.28	I	*Trommsdorffia maculata* (L.) Bernh.	9.1	0.05	0.67	I
Chelidonium majus L.	18.2	0.09	1.28	I	*Elaeagnus oxycarpa* Schltdl.	9.1	0.05	0.67	I
Cichorium intybus L.	18.2	0.09	1.28	I	*Melilotus officinalis* Medikus	9.1	0.05	0.67	I
Crepis tectorum L.	18.2	0.09	1.28	I	*Vicia sepium* L.	9.1	0.05	0.67	I
Hieracium umbellatum L.	18.2	0.09	1.28	I	*Populus × sibirica* G. Kryl. et Grig. ex A. Skvortsov	9.1	0.09	0.9	I
Artemisia nitrosa Weber	18.2	0.09	1.28	I	*Solanum kitagawae* Schonb.-Tem.	9.1	0.05	0.67	I

*V – occurrence, %; PPC – partial projective cover, %; A – activity, points; CC – class of constancy

On saline soils, the only species *Calamagrostis epigeios* has V class of constancy, its activity is 48.8 points. There are 5 species with a high CC – III: *Achillea nobilis, Betula pendula, Phragmites australis, Artemisia dracunculus,* and *Polygonum salsugineum*. Sixty-nine percent of species are characterized by class I constancy.

Due to the high degree of salinity, a complex phytocenosis may have a small number of species; such communities are found on highly saline clays in the Betpak-Dala desert [33].

Despite the significant age of the dump sites studied, the presence of weedy plants remains high at this stage: *Artemisia sieversiana, Chenopodium album, Conyza Canadensis, Lactuca serriola, Melilotus officinalis* etc. On non-saline soils at the stage of a diffuse community, natural birch-aspen plantations are

formed, and on saline soils separate spots of tree plantations are formed.

Tanacetum vulgare, Festuca valesiaca, Artemisia austriaca, Betula pendula have the highest constancy class V – 7%, other species: IV – 3%, III – 9%, II – 19%, I – 62% of all species on non-saline soils.

The taxonomic structure of complex phytocenoses of dumps of SSGPO JSC and Kachary Ruda JSC is presented in Table 4. The total number of families represented in these communities on saline and non-saline soils is 28, genera – 65, species – 79.

A B

Figure 2 – The stage of a complex phytocenosis
A – on saline soils
B – on non-saline soils

Table 3 – Characteristics of communities at the stage of complex phytocenosis on non-saline soils

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Tanacetum vulgare L.	90.9	1.14	10.18	**V**	*Stipa lessingiana* Trin. et Rupr.	18.2	0.32	2.41	I
Festuca valesiaca Gaudin	90.9	6.6	24.49	**V**	*Galium verum* L.	18.2	0.32	2.42	I
Artemisia austriaca Jacq.	81.8	1.73	11.9	**V**	*Veronica spicata* L.	18.2	0.09	1.28	I
Betula pendula Roth	81.8	0.37	5.5	**V**	*Veronica incana* L.	18.2	0.09	1.28	I
Artemisia dracunculus L.	63.6	0.55	5.92	**IV**	*Acer negundo* L.	9.1	0.05	0.67	I
Calamagrostis epigeios (L.) Roth	63.6	3.14	14.13	**IV**	*Eryngium planum* L.	9.1	0.05	0.67	I
Hieracium virosum Pall.	54.5	0.73	6.27	**III**	*Falcaria vulgaris* Bernh.	9.1	0.05	0.67	I
Achillea nobilis L.	54.5	0.5	5.22	**III**	*Artemisia marschalliana* Spreng.	9.1	0.05	0.67	I
Achillea millefolium L.	54.5	0.95	7.2	**III**	*Pilosella echioides* (Lumn.) F. Schulz et Sch. Bip.	9.1	0.05	0.67	I
Chamaenerion angustifolium (L.) Scop.	54.5	0.27	3.84	**III**	*Erigeron acris* L.	9.1	0.05	0.67	I
Medicago falcata L.	45.5	0.23	3.23	**III**	*Helichrysum arenarium* (L.) Moench	9.1	0.05	0.67	I
Phlomis tuberosa L.	36.4	1.55	7.51	II	*Nonea pulla* DC.	9.1	0.05	0.67	I
Hieracium umbellatum L.	36.4	1.55	7.51	II	*Sisymbrium loeselii* L.	9.1	0.05	0.67	I

Table continuation

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Centaurea scabiosa L.	36.4	0.18	2.56	II	*Alyssum turkestanicum var. desertorum* (Stapf) Botsch.	9.1	0.05	0.67	I
Stellaria graminea L.	36.4	0.18	2.56	II	*Gypsophila perfoliata* L.	9.1	0.05	0.67	I
Astragalus buchtormensis Pall.	36.4	1.27	6.8	II	*Euphorbia virgata* Waldst. & Kit.	9.1	0.05	0.67	I
Lonicera tatarica L.	27.3	0.14	1.95	II	*Oxytropis pilosa* (L.) DC.	9.1	0.05	0.67	I
Bromopsis inermis (Leyss.) Holub.	27.3	1	5.22	II	*Ribes aureum* Purch	9.1	0.05	0.67	I
Poa pratensis L.	27.3	0.36	3.13	II	*Plantago media* L.	9.1	0.27	1.57	I
Phragmites australis (Cav.) Trin. ex Steud.	27.3	4.82	11.46	II	*Stipa pennata* L.	9.1	0.05	0.67	I
Polygonum aviculare L.	27.3	0.36	3.13	II	*Elytrigia repens* (L.) Nevski	9.1	0.05	0.67	I
Potentilla chrysantha Trevir.	27.3	0.36	3.13	II	*Poa palustris* L.	9.1	0.27	1.57	I
Asparagus officinalis L.	18.2	0.09	1.28	I	*Agrostis gigantea* Roth	9.1	0.05	0.67	I
Lactuca tatarica (L.) C.A.Mey.	18.2	0.09	1.28	I	*Rosa majalis* Herrm.	9.1	0.91	2.88	I
Taraxacum officinale F.H.Wigg.	18.2	0.09	1.28	I	*Cerasus fruticosa* Pall.	9.1	0.05	0.67	I
Hylotelephium triphyllum (Haw.) Holub	18.2	0.09	1.28	I	*Salix caprea* L.	9.1	0.05	0.67	I
Hippophae rhamnoides L.	18.2	0.09	1.28	I	*Linaria genistifolia* (L.) Mill.	9.1	0.05	0.67	I
Astragalus testiculatus Pall.	18.2	0.09	1.28	I	*Valeriana tuberosa* L.	9.1	0.05	0.67	I
Poa angustifolia L.	18.2	0.95	4.16	I	*Populus tremula* L.	9.1	0.05	0.67	I

*V – occurrence, %; PPC – partial projective cover, %; A – activity, points; CC – class of constancy

The most numerous in terms of the number of species and genera – *Asteraceae* (17 genera, 24 species) – 30% of all species, then *Poaceae* (9 genera, 12 species) – 15%, and *Fabaceae* (5 genera, 7 species) – 9%.

The genus with the largest number of species is *Artemisia* (5), followed by *Poa* (3), then *Achillea, Astragalus, Hieracium, Lactuca, Melilotus, Polygonum, Stipa,* and *Veronica* – 2 species each. Most genera contain only 1 species.

In total, there were 11 species found both on saline and non-saline soils: *Achillea nobilis, Artemisia dracunculus, Betula pendula, Calamagrostis epigeios, Chamaenerion angustifolium, Erigeron acris, Hieracium umbellatum, Lactuca tatarica, Phragmites australis, Populus tremula* and *Taraxacum officinale*.

The dominance of the families *Asteraceae, Poaceae, Fabaceae*, noted by us at the stage of a complex phytocenosis on dumps, is characteristic of the taxonomic structure of the region as a whole [34-37].

Table 4 – Taxonomic structure of complex phytocenoses of dumps of SSGPO JSC and Kachary Ruda JSC

Taxonomic indicators	Values
Total number of species	79
Total number of genera	65
Total number of families	28
Number of single-species genera	55
Number of single-species families	17
Number of homogeneous families	18
Share of species in 5 leading families, %	62
Share of species in 10 leading families, %	72

We also analyzed previous works related to the dumps of SSGPO JSC.

In the previously mentioned 1974 study by Terekhova E.B. et al indicated that already by the beginning of the second decade, complex multi-

species communities were formed on non-saline soils, similar in characteristics to the stage of a complex phytocenosis. *Artemisia marschalliana, Melilotus spp.* predominate here. Significant participation of steppe grasses and forbs was also noted. Contrary, in the communities studied by us, the role of *Artemisia marschalliana* is much lower, this species did not act as a dominant or codominant in any CP, and was noted by us only in non-saline areas. The total number of species at the third stage of syngenesis was 33 [16].

In the study of Konysbayeva D.T. 2003 on a conditionally favorable substrate, the number of species was 67, triad of dominant families: *Asteraceae, Poaceae, Fabaceae*. The author also notes the emergence of new forest, forest-meadow and swamp-meadow species; at the previous stage, steppe, meadow-steppe and steppe-meadow coenotic groups predominated. On an unfavorable substrate, the total number of species was 33; the dominant families remained the same. There was no significant change in the ratio of coenotic and ecological groups in comparison with the previous stages [3].

As can be seen, fluctuations in the floristic composition of the dumps have occurred over half a century. There was a change not only in the dominant species on certain types of soils, but also in entire coenotic groups.

In the course of our study, we analyzed the ecological and coenotic structure of the dump flora at the stage of a complex phytocenosis. We identified 5 ecological-coenotic groups in the dump flora: meadow, forest, steppe, coastal-aquatic, weedy.

As can be seen from Figure 3, there are striking differences in the distribution of species by coenotic groups with respect to soil salinity:

- most types of saline soils are weedy species,
- meadow and steppe species predominate on non-saline soils.

The coastal aquatic group is the least numerous for both types of soils.

In the course of a systematic analysis, the taxonomic structure of the flora, the composition and ratio of the leading families (floristic spectrum) were revealed, characterizing the belonging of the floras to a certain botanical and geographical area. The composition and correlation of geographical elements reveal the features and specifics of the studied flora. Five main groups of geographical areas have been identified:

- *Cosmopolitan* – species that live in different (sometimes all) regions of the globe,
- *Holarctic* – plants growing in most of the Northern Hemisphere, from the high-latitude Arctic to the subtropical zone inclusive,
- *Eurasian* – a group of species distributed in Europe, Western Siberia and the western part of the Ancient Middle-earth (Pan-Eurasian, Mediterranean-Asian, East European-Asian, European-North Asian, Eurosiberian),
- *Asian* – plants of Siberia, Central and North Asia (Asiatic, Central Asian, Siberian),
- *American-Asian* – the group is represented by plants associated with the flora of North America [1].

In the context of geographical elements, the predominance of the pan-Eurasian faction is noticeable (13, 22) – 44% of all species in the dump flora on this stage. Further in descending order for saline soils: Cosmopolitan (6), Holarctic (5); for unsalted – Mediterranean-Asian and Holarctic – 8 each, Cosmopolitan – 4. No species belonging to the American-Asian range has been found.

As a result of studying the patterns of natural overgrowth of dumps of mining enterprises in the Kostanay region of SSGPO JSC and Kachary Ruda JSC at the stage of a complex phytocenosis, it was established:

1) on non-saline soils, a parazonal meadow-steppe community with a high class of constancy is formed: *Tanacetum vulgare*, *Festuca valesiaca, Artemisia austriaca, Betula pendula*. Here, birch-aspen plantations (*Betula pendula* + *Populus tremula*) are formed with a small admixture of *Pinus sylvestris*.

2) on saline soils, communities form species with a wide ecological range: *Calamagrostis epigeios, Phragmites australis, Artemisia dracunculus*, and others.

3) taxonomic analysis showed that the head parts of the flora spectra iron ore dumps and flora of Kostanay region coincide.

4) the flora of the dumps is dominated by species with wide ranges – pan-Eurasian and Holarctic.

5) the representation of geographical groups in the ecological-coenotic spectrum of the flora and life forms distribution of dumps differs depending on the degree of soil salinity.

The study of life forms (LF) makes it possible from an ecological point of view to assess the characteristics of the dump flora, as well as to find some correlative relationships between the LF and confinement to a certain type of community. The classification we used is based on the structure and lifespan of the aboveground skeletal axes of plants.

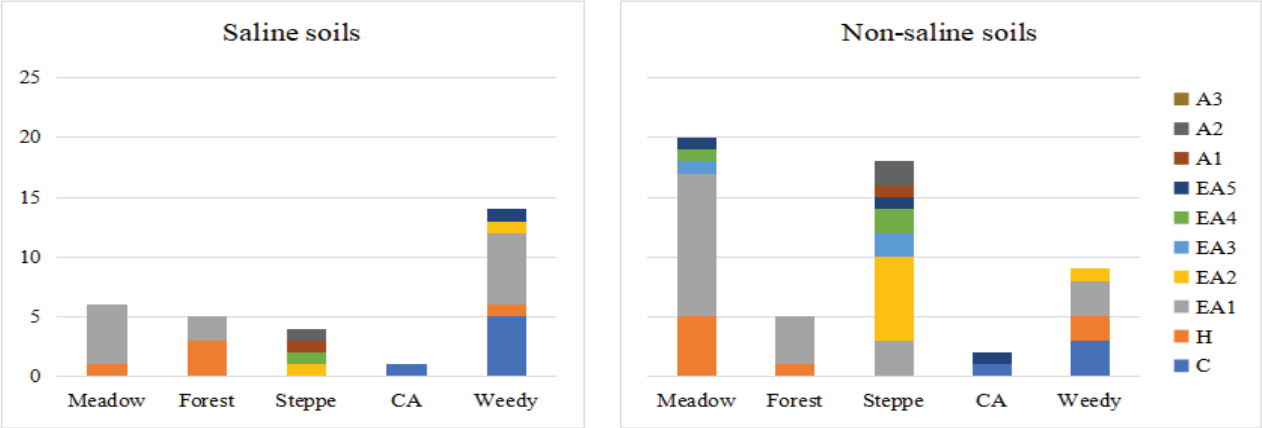


Figure 3 – Characteristics of the flora on different soils

Note: geographical groups: C – Cosmopolitan, H – Holarctic, EA1 – Pan-Eurasian, EA2 – Mediterranean-Asian, EA3 – East European-Asian, EA4 – European-North Asian, EA5 – Eurosiberian, A1 – Asiatic, A2 – Central Asian, A3 – Siberian. CA – coastal aquatic plants

At the third stage of syngenesis, we identified the dominant LFs: for saline soils: long-rhizomatous (8), annuals (6) and taproot (5); for non-saline – short-rhizomatous (15), long-rhizomatous (14), and taproot (12) (Figure 4).

On saline soils in the steppe coenotic groups, long-rhizomatous (50%) prevail; in weedy – annual herbaceous (33%) and taproot (27%) groups; in forest – trees (80%), in coastal aquatic – long-rhizomatous (100%).

Taproot (33%) and short-rhizomatous (28%) dominate on non-saline soils in the steppe groups, long-rhizomatous (30%) dominate in weedy group, and short-rhizomatous (45%) and long-rhizomatous (30%) plants dominate in meadow type.

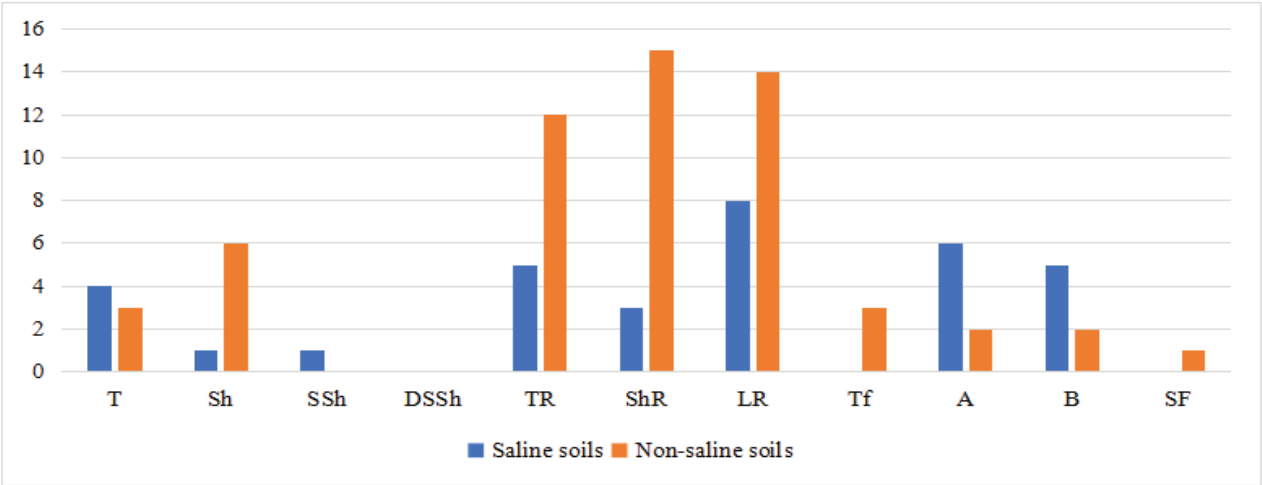


Figure 4 – Characteristics of life forms of plants growing at the stage of CPh

Note: life form according to the classification of I.G. Serebryakov (1962): T – trees, Sh – shrubs, SSh – semishrubs, DSSh – dwarfs semishrubs, TR – taproot, ShR – short-rhizomatous, LR – long-rhizomatous, Tf – turf, A – annuals, B – biennials, SF – stolon-forming.

Conclusion

As a continuation of our study, it is planned to resume work on the dump sites, compiling geobotanical descriptions on the same geo coordinates to compare the results, herbarization of previously unidentified species.

Further, after analyzing the patterns of formation of the vegetation cover of dumps at different stages of syngenesis, recommendations will be drawn up for the restoration of biodiversity by effective scientifically based methods for the mining enterprises of the Kostanay region, on the territory of which the research was carried out.

Acknowledgments

The authors express their gratitude to the management and staff of the department for ecology and subsoil use of SSGPO JSC and Kachary Ruda JSC for their assistance in conducting this study.

Special thanks are expressed to the staff of the Kuzbass Botanical Garden and the Institute of Human Ecology of the Federal Research Center for Coal and Coal Chemistry of the Siberian Branch of the Russian Academy of Sciences; Darkan Dala laboratory.

All authors declare that they have no conflicts of interest.

References

1. Манаков Ю.А. Формирование растительного покрова в техногенных ландшафтах Кузбасса / Ю.А. Манаков, Т.О. Стрельникова, А.Н. Куприянов; Рос. акад. наук, Сиб. отд-ние, Ин-т экологии человека. – Новосибирск: Издательство СО РАН, 2011. – 168 с.

2. Brand U., Wissen M., Danso-Dahmen L., King Z. M., Jungwirth B. The Imperial Mode of Living: Everyday Life and the Ecological Crisis of Capitalism / U. Brand, M. Wissen, L. Danso-Dahmen, Z.M. King, B. Jungwirth, – 2021. – 256 p.

3. Конысбаева Д.Т. Формирование растительного покрова на отвалах предприятий железорудной промышленности в Северном Казахстане: Дис. ... канд. биол. наук: 03.00.05.- Екатеринбург, 2003.- 145 с.: ил. РГБ ОД, 61 03-3/985-4

4. Koščová M., Hellmer M., Anyona S., Gvozdkova T. Geo-Environmental Problems of Open Pit Mining: Classification and Solutions / M. Koščová, M. Hellmer, S.Anyona, T. Gvozdkova // E3S Web of Conferences. – 2018. №41. https://doi.org/10.1051/e3sconf/20184101034

5. Feng Y., Wang J., Bai Zh., Reading L. Effects of surface coal mining and land reclamation on soil properties: A review / Y.Feng, J.Wang, Zh.Bai, L.Reading // Earth-Science Reviews. – 2019. – № 191. – pp. 12-25. https://doi.org/10.1016/j.earscirev.2019.02.015

6. Hendrychová M., Svobodova K., Kabrna M. Mine reclamation planning and management: Integrating natural habitats into post-mining land use, Resources Policy, Volume 69, 2020, 101882, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2020.101882.

7. Peltz, C.D. and Harley, A. (2016). Biochar Application for Abandoned Mine Land Reclamation. In Agricultural and Environmental Applications of Biochar: Advances and Barriers (eds M. Guo, Z. He and S.M. Uchimiya). https://doi.org/10.2136/sssaspecpub63.2014.0047.5

8. Fernández-Caliani J.C., Giráldez M.I., Waken W.H., Del Río Z.M., Córdoba F. Soil quality changes in an Iberian pyrite mine site 15 years after land reclamation, CATENA, Volume 206, 2021, 105538, ISSN 0341-8162, https://doi.org/10.1016/j.catena.2021.105538.

9. Makhnev, A.K., Makhneva, N.E. Landscape-ecological and population aspects of the strategy of restoration of disturbed lands. *Contemp. Probl. Ecol.* 3, 318–322 (2010). [Электронный ресурс]. URL: https://doi.org/10.1134/S1995425510030100

10. Frouz J., Prach K., Pižl V., Háněl L., Starý J., Tajovský K., Materna J., Balík V., Kalčík J., Řehounková K. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites, European Journal of Soil Biology, Volume 44, Issue 1, 2008, Pages 109-121, ISSN 1164-5563, https://doi.org/10.1016/j.ejsobi.2007.09.002.

11. Noviyanto, A; Purwanto, P; Minardi, S; Supriyadi, S. The assessment of soil quality of various age of land reclamation after coal mining: a chronosequence study **Journal of Degraded and Mining Lands Management; Malang** Том 5, Изд. 1, (2017): 1009-1018. DOI:10.15243/jdmlm.2017.051.1009

12. Peco J.D., Higueras P., Campos J.A., Esbrí J.M., Moreno M.M., Battaglia-Brunet F., Sandalio L.M. Abandoned Mine Lands Reclamation by Plant Remediation Technologies. Sustainability 2021, 13, 6555. https://doi.org/10.3390/su13126555

13. Pratiwi Narendra B.H., Siregar C.A., Turjaman M., Hidayat A., Rachmat H.H., Mulyanto B., Suwardi, Iskandar, Maharani R., Rayadin Y., Prayudyaningsih R., Yuwati T.W., Prematuri R., Susilowati A. Managing and Reforesting Degraded Post-Mining Landscape in Indonesia: A Review. Land 2021, 10, 658. https://doi.org/10.3390/land10060658

14. Swab R.M., Lorenz N., Byrd S., Dick R., Native vegetation in reclamation: Improving habitat and ecosystem function through using prairie species in mine land reclamation,Ecological Engineering, Volume 108, Part B, 2017, Pages 525-536, ISSN 0925-8574, https://doi.org/10.1016/j.ecoleng.2017.05.012.

15. Тарчевский, В.В. Закономерности формирования фитоценозов на промышленных отвалах: автореф. дис. . д-ра биол. наук / В.В. Тарчевский.- Том. ун-т Томск: 1967. 36 с.

16. Терехова, З.Б. Естественное зарастание отвалов Соколовского железорудного карьера / З.Б. Терехова, Р.И.Ланина, Л.В.Фоменко // Растительность и промышленная среда. Свердловск: 1974. Вып. 3. – С. 162 — 174.

17. Куприянов А. Н. Биологическая рекультивация отвалов в субаридной зоне. Алма-Ата, 1989. 104 с.

18. Климова О.А., Куприянов А.Н. Влияние экологических условий на занос семян и лесовозобновление на отвалах угольных разрезов Кузбасса // Сибирский лесной журнал. 2018. № 5. С. 45-53.

19. Хархота Т.Г, Дмитриенко П.П. Поширення *Gypsophila paulii* Klok на территориях металургийных заводі в Донбасу. Укр. ботанічій журнал, 1976. Т. 33. С. 391-392.

20. Рева М.Л., Бакланов В.И. Динамика естественного зарастания терриконiков Донбасса // Растения и промышленная среда. Свердловск, 1974. С.109–115.

21. Копцева Е.М. Естественное восстановление растительности на техногенных местообитаниях Крайнего Севера (Ямальский сектор Арктики): Дисс. … канд. биол. наук. Спб, 2005. 237 с.

22. Галченко Ю.П. Исследование условий ревитализации ландшафтов при захоронении твёрдых отходов горного производства в экосистемах естественной биоты Земли // Известия ТулГУ. Науки о Земле. 2020. №2. URL: https://cyberleninka.ru/article/n/issledovanie-usloviy-revitalizatsii-landshaftov-pri-zahoronenii-tvyordyh-othodov-gornogo-proizvodstva-v-ekosistemah-estestvennoy (дата обращения: 07.02.2023).

23. The Sixth National Report on Biological Diversity in The Republic of Kazakhstan. URL: http://www.cawater-info.net/pdf/kz-nr-06-en.pdf (дата обращения: 07.02.2023)

24. SSGPO JSC. URL: https://www.erg.kz/en/content/deyatel-nost/ao-ssgpo (дата обращения: 07.02.2023)

25. Hawkins T., Smith M.P., Herrington R.J., Maslennikov V., Boyce A.J., Jeffries T., Creaser R.A. The geology and genesis of the iron skarns of the Turgai belt, northwestern Kazakhstan / T. Hawkins, M.P. Smith, R.J. Herrington, V. Maslennikov, A.J. Boyce, T. Jeffries, R.A. Creaser // Ore Geology Reviews. – 2017. – №85. – pp. 216–246. https://doi.org/10.1016/j.oregeorev.2015.10.016.

26. Herrington R., Smith M., Maslennikov V., Belogub E., Armstrong R. A Short review of palaezoic hydrothermal magnetite iron-oxide deposits of the South And Central Urals and their geological settings / R.Herrington, M.Smith, V.Maslennikov, E.Belogub, R. Armstrong // Hydrothermal Iron Oxide Copper-Gold & Related deposits A global perspective. – 2002. – №2. – pp. 343–353.

27. Паспорт «О» Техногенные минеральные образования №3/1057. Объект учета Юго-Западный отвал Сарбайского участка. – Рудный: АО «ССГПО», 2022 – 9 с.

28. Паспорт «О» Техногенные минеральные образования №3/1058. Объект учета Юго-Западный отвал Южно-Сарбайского участка. – Рудный: АО «ССГПО», 2022 – 10 с.

29. Паспорт «О» Техногенные минеральные образования №3/1068. Объект учета Юго-Восточный отвал Соколовского месторождения. – Рудный: АО «ССГПО», 2022 – 10 с.

30. Геологические и горнотехнические условия, отрабатываемых на автомобильный транспорт карьера Качарского РУ. – Качары: АО «Качары руда», 2022 – Доступ через внутреннюю систему АО «Качары руда».

31. Агроклиматические ресурсы Костанайской области: научно-прикладной справочник / Ред. С.С. Байшоланов – Астана, 2017. – 139 с.

32. Zverev A.A. Use of equivalence classes and factor sets in the analysis of botanical data // Contemporary Problems of Ecology. – 2012. – No. 2. – pp. 221-230

33. Кубанская З.В. Растительность и кормовые ресурсы пустыни Бетпак-Далы. Алма-Ата: Изд-во АН КазССР. 1956. 264 с.

34. Пережогин Ю.В. Ботанико-географическое районирование и состав флоры Костанайской области (Северный Казахстан) // Вестник ОГУ. – 2008. – Т. 80. – С. 121-125.

35. Tretyakova A., Grudanov N., Petrova Y. Urban flora of Kostanay region (Republic of Kazakhstan). URL: https://www.gbif.org/dataset/1ac5595a-ed78-46d1-9c1f-624197928f38 (date of access: 08.02.2023)

36. Брагина Т.М., Борисова Е.С. Анализ лекарственной флоры памятника природы «Насаждения березовых и сосновых лесов у озера Боровское» // Вестник КГПИ. – 2021. – Т. 3 (63). – С. 62-67.

37. Кобланова С.А., Рогожкина Ю.О. Эколого-таксономический анализ прибрежной флоры Аулиекольского района (Костанайская область) // Вестник КарГУ Серия Биология. Медицина. География. – 2020. – Т. 3 (99). – С. 83–90. https://doi.org/10.31489/2020BMG3/83-90.

References

1. Agroklimaticheskie resursy Kostanajskoj oblasti: scientific and applied reference book / Ed. S.S. Baysholanov – Astana, 2017. – 139 p.

2. Bragina T.M., Borisova E.S. Analiz lekarstvennoj flory pamyatnika prirody «Nasazhdeniya berezovyh i sosnovyh lesov u ozera Borovskoe» // Vestnik KGPI. – 2021. – V. 3 (63). – P. 62-67.

3. Brand U., Wissen M., Danso-Dahmen L., King Z. M., Jungwirth B. The Imperial Mode of Living: Everyday Life and the Ecological Crisis of Capitalism / U. Brand, M. Wissen, L. Danso-Dahmen, Z.M. King, B. Jungwirth, – 2021. – 256 p.

4. Feng Y., Wang J., Bai Zh., Reading L. Effects of surface coal mining and land reclamation on soil properties: A review / Y.Feng, J.Wang, Zh.Bai, L.Reading // Earth-Science Reviews. – 2019. – № 191. – pp. 12-25. https://doi.org/10.1016/j.earscirev.2019.02.015

5. Fernández-Caliani J.C., Giráldez M.I., Waken W.H., Del Río Z.M., Córdoba F. Soil quality changes in an Iberian pyrite mine site 15 years after land reclamation, CATENA, Volume 206, 2021, 105538, ISSN 0341-8162, https://doi.org/10.1016/j.catena.2021.105538.

6. Frouz J., Prach K., Pižl V., Háněl L., Starý J., Tajovský K., Materna J., Balík V., Kalčík J., Řehounková K. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites, European Journal of Soil Biology, Volume 44, Issue 1, 2008, Pages 109-121, ISSN 1164-5563, https://doi.org/10.1016/j.ejsobi.2007.09.002.

7. Galchenko Yu.P. Issledovanie uslovij revitalizacii landshaftov pri zahoronenii tvyordyh othodov gornogo proizvodstva v ekosistemah estestvennoj bioty Zemli // Izvestiya TulGU. Nauki o Zemle. 2020. №2. URL: https://cyberleninka.ru/article/n/issledovanie-usloviy-revitalizatsii-landshaftov-pri-zahoronenii-tvyordyh-othodov-gornogo-proizvodstva-v-ekosistemah-estestvennoy (date of access: 07.02.2023).

8. Geologicheskie i gornotekhnicheskie usloviya, otrabatyvaemyh na avtomobilnyj transport, karera Kacharskogo RU. – Kachary: JSC "Kachary Ruda", 2022 – Access from the internal reference system of JSC "Kachary Ruda"

9. Harhota T.G, Dmitrienko P.P. Poshireniya *Gypsophila paulii* Klok na territoriyah metalurgijnyh zavodi v Donbasu. Ukr. botanichij zhurnal, 1976. V. 33. P. 391-392.

10. Hawkins T., Smith M.P., Herrington R.J., Maslennikov V., Boyce A.J., Jeffries T., Creaser R.A. The geology and genesis of the iron skarns of the Turgai belt, northwestern Kazakhstan / T. Hawkins, M.P. Smith, R.J. Herrington, V. Maslennikov, A.J. Boyce, T. Jeffries, R.A. Creaser // Ore Geology Reviews. – 2017. – Vol. 85. – pp. 216–246. https://doi.org/10.1016/j.oregeorev.2015.10.016.

11. Hendrychová M., Svobodova K., Kabrna M. Mine reclamation planning and management: Integrating natural habitats into post-mining land use, Resources Policy, Volume 69, 2020, 101882, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2020.101882.

12. Herrington R., Smith M., Maslennikov V., Belogub E., Armstrong R. A Short review of palaezoic hydrothermal magnetite iron-oxide deposits of the south and central urals and their geological settings / R.Herrington, M.Smith, V.Maslennikov, E.Belogub, R. Armstrong // Hydrothermal Iron Oxide Copper-Gold & Related deposits A global perspective. – 2002. – Vol. 2. – pp. 343–353.

13. Klimova O.A., Kupriyanov A.N. Vliyanie ekologicheskih uslovij na zanos semyan i lesovozobnovlenie na otvalah ugol'nyh razrezov Kuzbassa // Sibirskij lesnoj zhurnal. 2018. № 5. P. 45-53.

14. Koblanova S.A., Rogozhkina YU.O. Ekologo-taksonomicheskij analiz pribrezhnoj flory Auliekol'skogo rajona (Kostanajskaya oblast') // Vestnik KarGU Seriya Biologiya. Medicina. Geografiya. – 2020. – V. 3 (99). – P. 83–90. https://doi.org/10.31489/2020BMG3/83-90.

15. Konysbaeva D.T. Formirovanie rastitel'nogo pokrova na otvalah predpriyatij zhelezorudnoj promyshlennosti v Severnom Kazahstane: Dis. ... kand. biol. nauk: 03.00.05.- Ekaterinburg, 2003.- 145 s.: il. RGB OD, 61 03-3/985-4

16. Kopceva E.M. Estestvennoe vosstanovlenie rastitel'nosti na tekhnogennyh mestoobitaniyah Krajnego Severa (YAmal'skij sektor Arktiki): Diss. … kand. biol. nauk. Spb, 2005. 237 p.

17. Koščová M., Hellmer M., Anyona S., Gvozdkova T. Geo-Environmental Problems of Open Pit Mining: Classification and Solutions / M. Koščová, M. Hellmer, S.Anyona, T. Gvozdkova // E3S Web of Conferences. – 2018. №41. https://doi.org/10.1051/e3sconf/20184101034

18. Kubanskaya Z.V. Rastitel'nost' i kormovye resursy pustyni Bet-Pak-Daly. Alma-Ata: Izd-vo AN KazSSR. 1956. 264 p.

19. Kupriyanov A. N. Biologicheskaya rekul'tivaciya otvalov v subaridnoj zone. Alma-Ata, 1989. 104 p.

20. Makhnev, A.K., Makhneva, N.E. Landscape-ecological and population aspects of the strategy of restoration of disturbed lands. *Contemp. Probl. Ecol.* 3, 318–322 (2010). https://doi.org/10.1134/S1995425510030100

21. Manakov Yu.A. Formirovanie rastitel'nogo pokrova v tekhnogennyh landshaftah Kuzbassa / YU.A. Manakov, T.O. Strel'nikova, A.N. Kupriyanov; Ros. akad. nauk, Sib. otd-nie, In-t ekologii cheloveka. – Novosibirsk: Izdatel'stvo SO RAN, 2011. – 168 p.

22. Noviyanto, A; Purwanto, P; Minardi, S; Supriyadi, S. The assessment of soil quality of various age of land reclamation after coal mining: a chronosequence study **Journal of Degraded and Mining Lands Management; Malang** V 5(1) (2017): 1009-1018. DOI:10.15243/jdmlm.2017.051.1009

23. Pasport «O» Tekhnogennye mineralnye obrazovaniya №3/1057. Objekt ucheta Yugo-Zapadnyj otval Sarbajskogo uchastka. – Rudny: JSC "SSGPO", 2022 – 9 p.

24. Pasport «O» Tekhnogennye mineralnye obrazovaniya №3/1058. Objekt ucheta Yugo-Zapadnyj otval Yuzhno-Sarbajskogo uchastka. – Rudny: JSC "SSGPO", 2022 – 10 p.

25. Pasport «O» Tekhnogennye mineralnye obrazovaniya №3/1068. Objekt ucheta Yugo-Vostochnyj otval Sokolovskogo mestorozhdeniya. – Rudny: JSC "SSGPO", 2022 – 10 p.

26. Peco J.D., Higueras P., Campos J.A., Esbrí J.M., Moreno M.M., Battaglia-Brunet F., Sandalio L.M. Abandoned Mine Lands Reclamation by Plant Remediation Technologies. Sustainability 2021, 13, 6555. https://doi.org/10.3390/su13126555

27. Peltz C.D. and Harley A. Biochar Application for Abandoned Mine Land Reclamation. In Agricultural and Environmental Applications of Biochar: Advances and Barriers (eds M. Guo, Z. He and S.M. Uchimiya). 2016. https://doi.org/10.2136/sssaspecpub63.2014.0047.5

28. Perezhogin YU.V. Botaniko-geograficheskoe rajonirovanie i sostav flory Kostanajskoj oblasti (Severnyj Kazahstan) // Vestnik OGU. – 2008. – V. 80. – P. 121-125.

29. Pratiwi, Narendra B.H., Siregar C.A., Turjaman M., Hidayat A., Rachmat H.H., Mulyanto B., Suwardi, Iskandar, Maharani R., Rayadin Y., Prayudyaningsih R., Yuwati T.W., Prematuri R., Susilowati A. Managing and Reforesting Degraded Post-Mining Landscape in Indonesia: A Review. Land 2021, 10, 658. https://doi.org/10.3390/land10060658

30. Reva M.L., Baklanov V.I. Dinamika estestvennogo zarastaniya terrikonikov Donbassa // Rasteniya i promyshlennaya sreda. Sverdlovsk, 1974. P.109–115.

31. SSGPO JSC. URL: https://www.erg.kz/en/content/deyatel-nost/ao-ssgpo (date of access: 07.02.2023)

32. Swab R.M., Lorenz N., Byrd S., Dick R. Native vegetation in reclamation: Improving habitat and ecosystem function through using prairie species in mine land reclamation, Ecological Engineering, Volume 108, Part B, 2017, Pages 525-536, ISSN 0925-8574, https://doi.org/10.1016/j.ecoleng.2017.05.012.

33. Tarchevskij, V.V. Zakonomernosti formirovaniya fitocenozov na promyshlennyh otvalah: avtoref. dis. . d-ra biol. nauk / V.V. Tarchevskij.- Tom. un-t Tomsk: 1967. 36 p.

34. Terekhova, Z.B. Estestvennoe zarastanie otvalov Sokolovskogo zhelezorudnogo kar'era / Z.B. Terekhova, R.I.Lanina, L.V.Fomenko // Rastitel'nost' i promyshlennaya sreda. Sverdlovsk: 1974. V 3. – p. 162 — 174.

35. The Sixth National Report on Biological Diversity in The Republic Of Kazakhstan. URL: http://www.cawater-info.net/pdf/kz-nr-06-en.pdf

36. Tretyakova A., Grudanov N., Petrova Y. Urban flora of Kostanay region (Republic of Kazakhstan). URL: https://www.gbif.org/dataset/1ac5595a-ed78-46d1-9c1f-624197928f38 (date of access: 08.02.2023)

37. Zverev A.A. Use of equivalence classes and factor sets in the analysis of botanical data // Contemporary Problems of Ecology. – 2012. – No. 2. – pp. 221-230

2-бөлім

МОЛЕКУЛАЛЫҚ БИОЛОГИЯ ЖӘНЕ ГЕНЕТИКА

Section 2

MOLECULAR BIOLOGY AND GENETICS

Раздел 2

МОЛЕКУЛЯРНАЯ БИОЛОГИЯ И ГЕНЕТИКА

IRSTI 34.35.17, 68.35.03 https://doi.org/10.26577/eb.2023.v96.i3.06

A.Y. Amalova[1], M.A. Yessimbekova[2], A.K. Ortaev[3], M.M. Baimagambetova[1], A.M. Burakhoja[1], S.I. Abugalieva[1], Y.K. Turuspekov[1]*

[1]Institute of Plant Biology and Biotechnology, Kazakhstan, Almaty
[2]Kazakh Research Institute of Agriculture and Plant Industry, Kazakhstan, Almaty
[3]Krasnovodopad Breeding Station, Kazakhstan, Turkestan region
*e-mail: yerlant@yahoo.com

PHENOTYPIC VARIATION OF WINTER WHEAT COLLECTION FROM CENTRAL ASIA HARVESTED IN KAZAKHSTAN

In this work, the ecological testing of 139 accessions of the winter wheat collection from Central Asia was conducted on the field plots of the Kazakh Research Institute of Agriculture and Plant Industry (Almaty region, South-east Kazakhstan) and Krasnovodopad Breeding Station (Turkestan region, South Kazakhstan) during 2020-2021 and 2021-2022 growing seasons. The collection was analyzed using 12 traits: heading date, seed maturation date, vegetation period, plant height, peduncle length, spike length, number of kernels per spike (NKS), number of productive spikes, weight kernel per plant, weight kernel per spike, thousand kernel weight (TKW) and yield per square meter (YM2). The Pearson correlation index showed positive correlations between yield component traits in the two studied regions. The average YM2 value of 107 and 134 accessions exceeded the local check cultivars in Almaty (Zhetisu) and Turkestan (Pamyat 47) regions, respectively. Seven cultivars (Karaspan, Mars 1, Pamyat, Dank, Zhamin, KYIAL, and Talimi) were revealed to be highly productive for three traits (NKS, TKW, and YM2) in two regions. The analysis of variance showed that genotype × environment interaction affected the studied traits of the winter wheat collection from Central Asia under Kazakhstan's conditions. The results of this research will be used for further studies related to the adaptation and productivity of winter wheat in the breeding program for the selection of best candidate lines and genome-wide association study for yield and yield-related traits in winter wheat.

Key words: winter wheat, genotype × environment interaction, yield components.

А.Ы. Амалова [1], М.А. Есимбекова[2], А.К. Ортаев[3], М.М. Баймагамбетова[1], А.М. Бураходжа[1], С.И. Абугалиева[1], Е.К. Туруспеков[1]*

[1]Өсімдіктер биологиясы және биотехнологиясы институты, Қазақстан, Алматы қ.
[2]Қазақ егіншілік және өсімдік шаруашылығы ғылыми-зерттеу институты, Қазақстан, Алматы қ.
[3]Красноводопад ауыл шаруашылығы тәжірибе станциясы, Қазақстан, Түркістан облысы
*e-mail: yerlant@yahoo.com

Қазақстан жағдайында өсірілген ортаазиялық күздік бидай коллекциясының фенотиптік өзгергіштігі

Бұл зерттеу жұмысында 2020-2021 және 2021-2022 жылдардағы вегетациялық кезеңдер ішінде Қазақ егіншілік және өсімдік шаруашылығы ғылыми-зерттеу институтының (Алматы облысы, оңтүстік-шығыс) және Красноводопад ауыл шаруашылығы тәжірибе станциясының (Түркістан облысы, оңтүстік) тәжірибелік алқаптарында өсірілген Орта Азиялық күздік бидай коллекциясының 139 үлгісіне экологиялық тестілеу жүргізілді. Коллекция 12 белгі бойынша талданды: масақтану уақыты, пісу уақыты, вегетациялық кезең, өсімдіктің биіктігі, жоғарғы буын аралығының ұзындығы, масақтың ұзындығы, масақтағы дәндердің саны (МДС), өнімді масақтардың саны, өсімдіктен алынған дәндердің массасы, масақтағы дән массасы, 1000 дәннің массасы (МДМ) және 1 м^2 өнімділігі (М2Ө). Пирсон бойынша корреляция индексі зерттелетін екі аймақта өнімділікке байланысты белгілер арасындағы оң байланысты көрсетті. Коллекция сорттарының ішінде М2Ө орташа мәндер бойынша Алматы облысындағы сорт-стандарт (Жетісу) 107 үлгісі және Түркістан облыстарында Память 47 сортының 134 үлгісі асып түсті. Жеті сорт (Karaspan, Mars 1, Pamyat, Dank, Zhamin, KYIAL және Talimi) екі аймақта өнімділікке байланысты үш белгі (МДС, МДМ, М2Ө) бойынша жоғары көрсеткіштерді көрсетті. Орталық Азиядан келген күздік бидай коллекциясының дисперсиялық талдауы генотип × орта өзара қатынасының Қазақстан жағдайында зерттелген белгілерге әсерін көрсетті. Алынған нәтижелер

күздік бидайдың бейімделгіштігі мен өнімділігіне қатысты қосымша зерттеулер үшін, ең жақсы үміткер-линияларды таңдау үшін селекциялық бағдарламада және өнімділікке байланысты белгілерді толық геномдық ассоциативті талдау үшін пайдаланылуы мүмкін.

Түйін сөздер: күздік жұмсақ бидай, генотип × орта қатынасы, өнімділік компоненттері.

А.Ы. Амалова[1], М. А. Есимбекова[2], А. К. Ортаев[3], М.М. Баймагамбетова[1], А.М. Бураходжа[1], С.И. Абугалиева[1], Е.К. Туруспеков*[1]

[1]Институт биологии и биотехнологии растений, Казахстан, г. Алматы
[2]Казахский научно-исследовательский институт земледелия и растениеводства, Казахстан, Алматинская область
[3]Красноводопадская сельскохозяйственная станция, Казахстан, Туркестанская область
*e-mail: yerlant@yahoo.com

Фенотипическая изменчивость коллекции озимой пшеницы из Средней Азии, выращенной в условиях Казахстана

В данной работе проведено экологическое тестирование 139 образцов коллекции озимой пшеницы из Средней Азии, выращенных на опытных полях Казахского научно-исследовательского института земледелия и растениеводства (Алматинская область, юго-восток) и Красноводопадской сельскохозяйственной опытной станции (Туркестанская область, юг) в течение вегетационных периодов 2020-2021 и 2021-2022 годов. Коллекция была проанализирована по 12 признакам: время колошения, время созревания, вегетационный период, высота растения, длина верхнего междоузлия, длина колоса, количество зерен в колосе (КЗК), количество продуктивных колосьев, масса зерен с растения, масса зерна с колоса, масса 1000 зерен (МТЗ) и урожайность с 1 м^2 (УМ2). Индекс корреляции по Пирсону показал положительную связь между признаками, связанными с урожайностью, в двух исследуемых регионах. Среди сортов коллекции 107 образцов превзошли по средним значениям УМ2 сорт-стандарт в Алматинской (Жетысу) и 134 образца сорт Память 47 в Туркестанской областях. Семь сортов (Karaspan, Mars 1, Pamyat, Dank, Zhamin, KYIAL и Talimi) продемонстрировали высокие показатели по трем признакам (КЗК, МТЗ, УМ2), связанным с урожайностью, в двух регионах. Дисперсионный анализ коллекции озимой пшеницы из Средней Азии показал влияние взаимодействия генотип × среда на изученные признаки в условиях Казахстана. Полученные результаты могут быть использованы для дальнейших исследований, связанных с адаптацией и продуктивностью озимой пшеницы, в программе селекции для отбора лучших линий-кандидатов, а также для полногеномного ассоциативного анализа признаков, связанных с урожайностью.

Ключевые слова: озимая мягкая пшеница, взаимодействие генотип × среда, компоненты урожая.

Introduction

The Central Asia region includes five former Soviet Union Republics, including Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, and Tajikistan, and they collectively grow wheat in an area of over 15 million ha [1]. Kazakhstan is one of the top 10 bread wheat producers and exporters in the world marketplace [2,3]. According to the Foreign Agricultural Service of the US Department of Agriculture (USDA), wheat production in Kazakhstan in 2022-2023 is expected to reach 16.0 million tons [4]. In Uzbekistan, estimated production will increase to 6.6 million tonnes in 2022-2023. Wheat production in 2022-2023 in Kyrgyzstan and Tajikistan is expected to reach 593 thousand tons and 820 thousand tons, respectively [4]. By the year 2050, the wheat yield should increase by 60% to provide the world's population with sufficient protein [5].

Kazakhstan is traditionally a large area of production of high-quality grain of wheat. In Kazakhstan, wheat is mainly grown in the northern part of the country, with a major focus on the spring type of habitat. The main lands under winter wheat are located in the south and south-east regions of Kazakhstan [6]. The yield of winter crops is 25-30% higher than that of spring type because they productively use autumn and spring moisture. Early ripening of winter wheat makes it possible to carry out its harvesting in a warm, dry time, which positively affects the grain's technological qualities [7,8]. The development of new cultivars is the most important factor in increasing yields and improving the quality of agricultural products. It is important to study the agronomic traits to develop high-yielding and high-quality cultivars. Agronomic traits such as heading date, plant height, number of productive tillers, number of kernels per spike, spike length, thousand-kernel weight, har-

vest index, and kernel weight per spike are important factors affecting wheat yield [9,10].

The genotype and the environment dramatically affect the grain yield and its components. Genotypes are stable if they show only slight deviations in the genotype performance across various growing conditions. It has long been recognized that wheat productivity and grain quality vary considerably because of the genotype (G), environment (E), and their interaction (G × E), but there is no consensus about which of these factors is more important [11]. To increase the yield, the study of the effects of yield components provides the basis for its successful breeding program. Hence, yield increase can be improved more effectively because of the performance of yield components. Multiple genes usually control agronomic traits, and a large number of quantitative trait loci (QTL) for them have been reported on A, B, and D genomes in bread wheat [12,13,14].

There is a necessity to pay special attention to the breeding and genetic research of common wheat using the best resources from other countries and regions of the world in a breeding program, as well as to apply modern methods of molecular genetics, including new genomic technologies [14,15]. One of these methods is genome-wide association study (GWAS), which relies on genotypic and phenotypic variation assessment of quantitative traits in large and diverse collections [16,17,18]. As a result of an international workshop between participants of the countries of Central Asia and the UK, conducted by scientists from the UK and the Institute of Plant Biology and Biotechnology, the Central Asian Wheat Breeding Initiative (CAWBIN) was developed, where a special place was given to the breeding of winter wheat [19]. One of the major parts of the CAWBIN collection study is the evaluation of the agronomic traits performance of a winter wheat collection in the conditions of south and south-east Kazakhstan, the main areas for winter wheat growth in the country. The results may help to assess the CAWBIN collection for the selection of best candidate lines for further breeding purposes of winter wheat in these regions and play a vital role in the identification of new QTLs for agronomic traits with the following application of marker-trait association approach in breeding schemes.

Materials and methods

Plant materials. The subject of the study is a winter wheat collection consisting of 139 accessions from Central Asian countries – Kazakhstan (KAZ, 42), Kyrgyzstan (KGZ, 52), Uzbekistan (UZB, 38), and Tajikistan (TJK, 11).

Assessment of the field data. All genotypes were tested in two regions of Kazakhstan – on the field plots of the Kazakh Research Institute of Agriculture and Plant Industry (KRIAPI, Almaty region, Southeast Kazakhstan) and Krasnovodopad Breeding Station (KBS, Turkestan region, South Kazakhstan) during 2020-2021 and 2021-2022 growing seasons. The collection was analyzed using 12 traits: heading date (HD, days), seed maturation date (SMD, days), vegetation period (VP, days), plant height (PH, cm), peduncle length (PL, cm), spike length (SL, cm), number of kernels per spike (NKS, pcs), number of productive spikes (NPS, pcs), weight kernel per plants (WKP, g), weight kernel per spike (WKS, g), thousand kernel weight (TKW, g) and yield per square meter (YM2, g/m^2). Studied accessions were planted in a random design in double rows and two replications per genotype. The distances between rows were 15 cm [20]. The standard cultivars "Zhetisu" and "Pamyat 47" were planted as check cultivars for KRIAPI and KBS, respectively. The meteorological data recorded during the trials are shown in Table 1.

Table 1 – Location, environment, and weather data at two regions in Kazakhstan

Site / Region	Almaty region (South-east of Kazakhstan)		Turkestan region (South Kazakhstan)	
Latitude / Longitude	43°21′ / 76°53′		41° 46′ / 69°45′	
Soil type	Light chestnut (humus 2.0-2.5%)		Light serozem (humus 1.1%)	
Conditions	Rainfed		Rainfed	
Year	2020-2021	2021-2022	2020-2021	2021-2022
Annual rainfall, mm	464.7	568.9	279.4	421.0
Mean temperature, °C	10.5	12.2	17.5	11.7
Max temperature, °C	26.9	26.5	31.6	23.3
Min temperature, °C	1.8	1.1	2.7	4.0

Statistical data analysis. The descriptive statistical analyses of all traits and the yield graph were conducted using MS Excel. Pearson correlation analysis, analysis of variance (ANOVA), variability of key yield traits, and principal component analysis (PCA) have been calculated using the Rstudio software [21].

Results and discussion

Phenotypic variability in yield components of the winter wheat collection in two regions of Kazakhstan

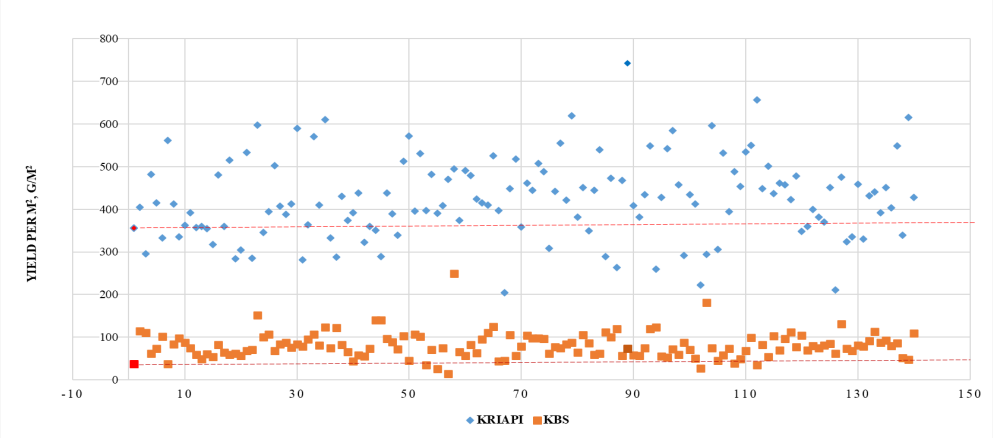
The phenotypic variability of studied traits was assessed in two regions over two years. The average PH was higher in samples grown in the Almaty region than in accessions harvested in the Turkestan region (Table 2). The means of the yield components (SL, NKS, WKS, TKW, and YM2) showed higher values at KRIAPI. However, the average NPS was higher at KBS in comparison to KRIAPI.

The average value of YM2 ranged from 80.9±2.55 g/m^2 (KBS) to 423.5±8.10 g/m^2 (KRIAPI). The analysis of the means for YM2 revealed that 107 and 134 accessions exceeded the local standard cultivar in south-east and south Kazakhstan, respectively (Figure 1).

In addition, the results of YM2 showed that the Central Asia winter wheat collection suits local environmental conditions (Figure 1). Seven cultivars (Karaspan, Mars 1, Pamyat, Dank, Zhamin, KYIAL, and Talimi) were revealed to be highly productive for three traits in two regions (Table 3). They can be successfully used for further breeding studies of winter wheat in Kazakhstan.

Table 2 – Average values of agronomic traits of winter wheat collection growing in two regions of Kazakhstan

Traits	Almaty region (KRIAPI)	Turkestan region (KBS)
Heading date (HD, days)	102.5±0.23	99.3±0.23
Seed maturation date (SMD, days)	35.8±0.18	36.7±0.24
Vegetation period (VP, days)	137.9±0.90	136.1±0.27
Plant height (PH, cm)	73.5±0.95	45.2±0.40
Peduncle length (PL, cm)	24.3±0.44	18.8±0.32
Spike length (SL, cm)	9.7±0.09	8.1±0.06
Number of productive spikes (NPS, pcs)	3.6±0.07	4.4±0.06
Number of kernels per spike (NKS, pcs)	46.7±0.42	39.90±0.40
Weight kernel per spike (WKS, g)	1.8±0.02	1.27±0.02
Weight kernel per plant (WKP, g)	7.9±0.11	5.1±0.12
Thousand kernel weight (TKW, g)	39.2±0.41	32.9±0.30
Yield per square meter (YM2, g/m^2)	423.5±8.10	80.9±2.55



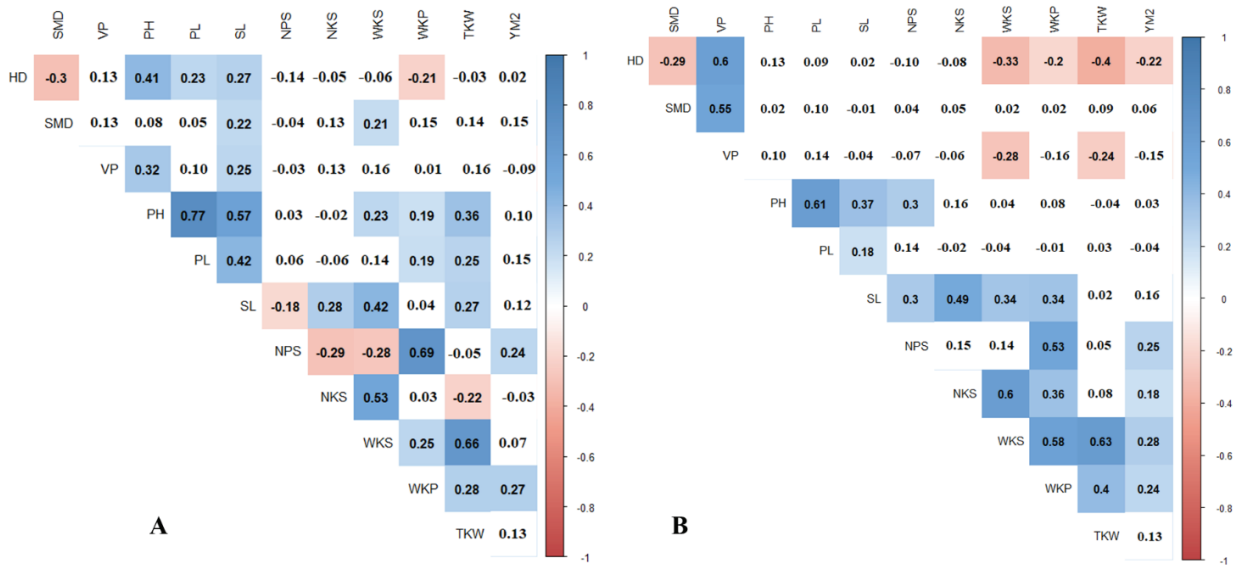
Note: check cultivar "Zhetisu" and "Pamyati 47" – red colour, accessions – blue and orange colour. Over the red line are samples with the highest YM2 values compared to the local check cultivar

Figure 1 – The range of averaged YM2 of winter wheat collection in two regions

Table 3 – The list of accessions of winter wheat collection showed the best average values for three yield components (NKS, TKW, and YM2) in two regions

Cultivars	Origin	KRIAPI			KBS		
		NKS, pcs	TKW, g	YM2, g/m^2	NKS, pcs	TKW, g	YM2, g/m^2
Karaspan	KAZ	51.3	45.5	359.1	41.8	31.0	64.3
Mars 1	UZB	54.4	43.3	479.4	37.3	35.4	82.1
Pamyat	UZB	51.9	43.0	525.3	47.3	35,7	124.4
Dank	KGZ	54.3	43.9	534.5	30.0	31.1	68.0
Zhamin	KGZ	51.6	47.1	549.6	37.8	34.7	99.8
KYIAL	KGZ	52.0	47.5	399.6	38.8	35.5	80.6
Talimi	KGZ	55.8	42.5	458.5	39.4	30.5	81.5
Local check cultivar		50.5	40.7	354.8	18.5	30.3	36.7

Pearson's correlation analysis of studied traits showed a negative correlation between HD with SMD and HD with WKP in both regions (Fig. 2). Also, it was revealed that SMD was favorable for higher yield components (WKS, WKP, and YM2) in KRIAPI. At the time, SMD was not a significant factor in the yield in KBS. The PH and PL positively correlated with yield components (SL, WKS, WKP, TKW) in KRIAPI. In addition, in KRIAPI, there was a predictable negative correlation between TKW and NKS. Expectedly, the PL was noted as highly significantly correlated with PH in both regions (Fig. 2). The correlation analysis at KBS showed the HD's negative influence on WKS, TKW, and YM2 (Fig. 2B) and a positive correlation between yield components (SL, NPS, NKS, WKS, WKP) (Fig. 2B).



Note: Correlations with P < 0.05 are highlighted in color. The color indicates positive (blue) or negative (red) correlation.

Figure 2 – Pearson's correlation index among means of 12 studied traits in winter wheat collection in two Kazakhstan regions in 2020-2022

The analysis of variance (ANOVA) for 12 traits showed a significant difference between three factors (genotype, region, year) for YM2 (6.35). In addition, a highly significant difference was observed for two factors (year and region) in all studied traits (Table 4). The ANOVA showed meaningful genotype-by-environments interaction (GEI) on studied traits of the winter wheat collection.

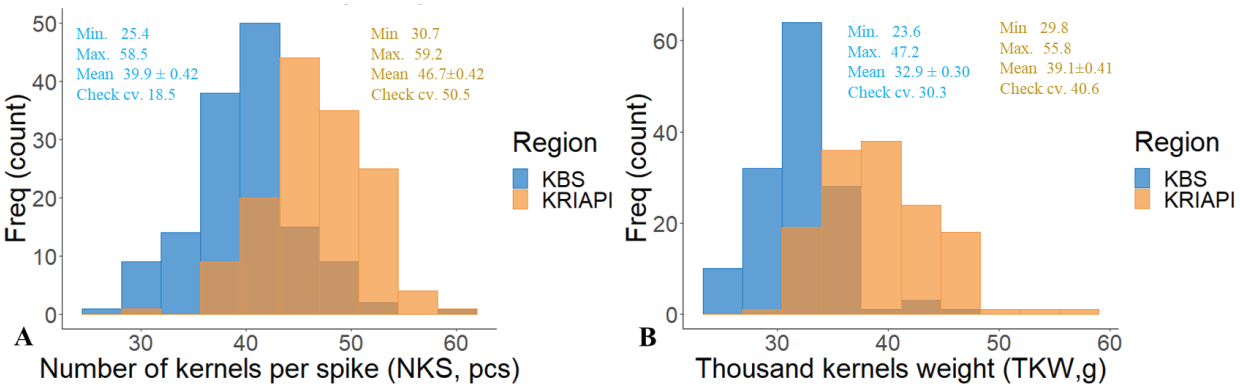
Table 4 – Analysis of variance of studies traits in the south-east of Kazakhstan.

Factor	df	HD	SMD	PH	PL	SL	NPS
		F-value					
Genotype (G)	142	1.649 ***	0.602	4.090***	2.061***	0.673	1.124
Year (Y)	1	9735.907***	637.352***	563.079***	220.863***	5.220*	44.033 ***
Region (R)	1	143.862 ***	6.867**	2040.203***	178.558***	11.602***	84.263***
G:Y	141	2.010 ***	0.542	0.795	0.823	0.560	0.874
G:R	138	1.877***	0.362	2.971***	1.331*	0.316	1.061
Y:R	1	5499.367 ***	12.312***	1292.122***	786.465***	1.131	0.899
G:R:Y	132	0.758	0.400PH	1.088	0.819	0.296	0.812
Factor	**df**	**NKS**	**WKS**	**WKP**	**TKW**	**YM2**	
		F-value					
Genotype (G)	155	0.727	1.199	0.639	2.850***	5.116***	
Year (Y)	1	6.975**	129.654***	58.686 ***	282.944***	3487.223***	
Region (R)	1	42.656***	200.414***	0.048	222.147***	9168.193***	
G:Y	154	0.609	0.609	0.520	0.994	5.046***	
G:R	150	0.784	0.849	0.546	1.372*	6.703***	
Y:R	1	0.434	26.327***	7.821 **	64.386***	2454.963***	
G:R:Y	144	0.585	0.669	0.464	0.723	6.353***	

Note: P – values are provided with a significance level shown by the asterisks; * P < 0.05, ** P < 0.01, *** P < 0.001

Variability in yield components

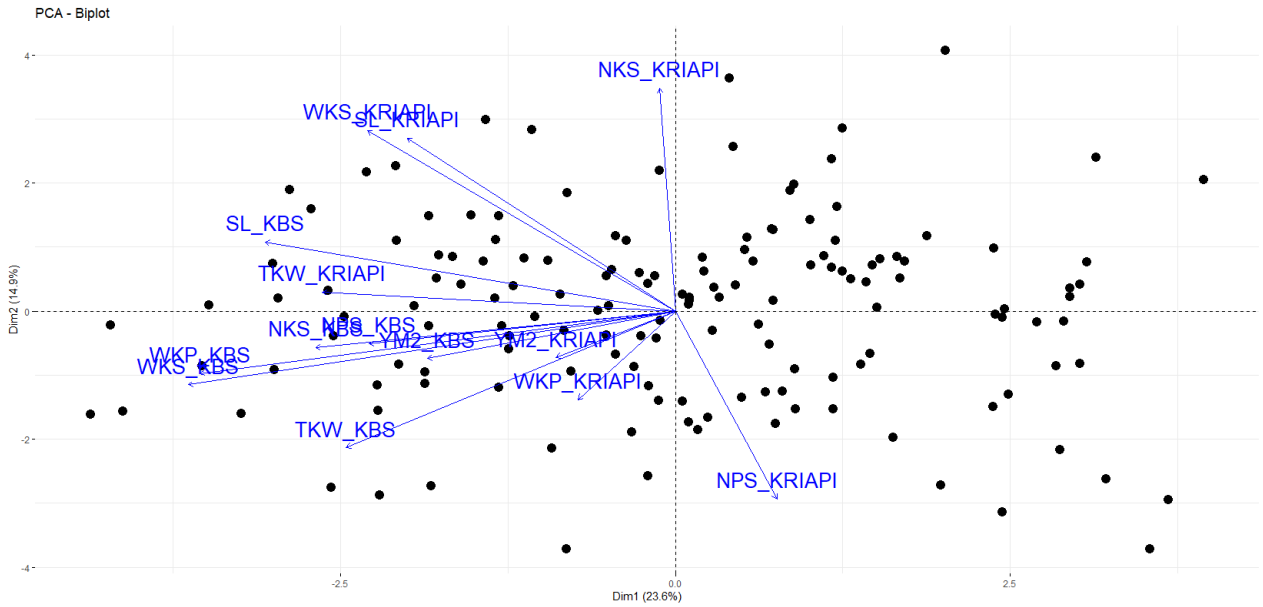
Yield is a complex trait that is associated with main components, such as the number of productive spikes, number of spikelets per spike, SL, NKS, kernel size, and TKW [22]. The correlation analysis showed that PH, SL, NKS, and TKW are the major yield components for the studied regions (Fig. 2), and the phenotypic variability of these four traits was marked by the wide range indicated in Table 2. The mean of NKS ranged from 39.9 pcs (KBS) to 46.7 pcs (KRIAPI). The NKS assessment showed that thirty-three samples of the collection exceeded the check cultivar " Zhetisu" in the Almaty region (Fig. 3A). The values of the TKW, another important yield trait, were varied from 32.9 g (KBS) to 39.1 g (KRIAPI) (Fig. 5B). The evaluation of TKW values suggested that the 50 and 101 accessions exceeded the check cultivar "Zhetisu " and "Pamyat' 47", respectively.



Note: A – number of kernels per spike, B – thousand kernels weight

Figure 3 – The binomial distributions of major yield-related traits of winter wheat collection in two regions.

The principal component analysis (PCA) for the yield components divided the accessions of winter wheat collection into two distinct principal components: PC1 and PC2, which explain 23.6 % and 14.9 % total variation, respectively. Also, there was a similar negative correlation between NKS and TKW at KRIAPI, with arrows pointing in different directions (Fig. 4). The same trend was noted using Pearson correlation analysis at KRIAPI (Fig. 2 A).



Note: accessions – point, directions of traits – blue color.

Figure 4 – Principal component analysis for the yield components in the winter wheat collection from Central Asia

The evaluation of yield components allowed the selection of accessions, which could play an important role in the future wheat breeding program in south and south-east Kazakhstan. In addition, the variation of the field data can be successfully used in further activities related to GWAS for grain yield and yield-related traits in winter wheat. The significant difference in soil and weather conditions of the two regions gave a variance in yield components between South-east and South Kazakhstan.

Conclusion

This study described the field assessments of the winter wheat collection from Central Asia consisting of 139 accessions. The collection was tested over the two years from 2020 to 2022 in the fields of the KRIAPI (south-east Kazakhstan) and KBS (south Kazakhstan). The field assessments showed that the collection is a potentially important genetic resource for winter wheat breeding projects, as it showed a wide range of variation in yield-related traits, including PH, SL, NKS, TKW, and YM2.

The average YM2 value of 107 and 134 accessions exceeded the check cultivars in Almaty (Zhetisu) and Turkestan (Pamyat 47) regions, respectively. The Pearson correlation index showed positive correlations between yield-related traits in the two studied regions. The ANOVA predicted a significant effect of environmental factors on the performance of winter wheat in the south and south-east of Kazakhstan. Obtained results will be used to select promising lines for winter wheat breeding projects in Kazakhstan and for further studies related to GWAS of yield and yield-related traits in bread wheat.

Conflict of interest

All authors are familiar with the article's text and declare that they have no conflict of interest.

Acknowledgments

This study was supported by the grant AP09259168 «Genome-wide association study of yield and grain quality traits for enhancing efficiency in winter wheat breeding in Kazakhstan» by the Ministry of Science and Higher Education (former Ministry of Education and Science) of the Republic of Kazakhstan for 2021-2023.

References

1. Morgounov A., Gómez-Becerra H. F., Abugalieva A., Dzhunusova M., Yessimbekova M., Muminjanov H., Zelenskiy Y., Ozturk L., Cakmak I. Iron and zinc grain density in common wheat grown in Central Asia // Euphytica.. – 2006. – Vol. 155(1-2). – P. 193-203. doi:10.1007/s10681-006-9321-2

2. USDA "Kazakhstan – Republic of Grain and Feed Update Kazakhstan Grain and Feed July Report". – 2019**. –** 11 p.

3. Food and Agriculture Organization of the United Nations. Available online: https://www.fao.org/faostat/en/#home (accessed on 25 February 2022)

4. Foreign Agricultural Service of the US Department of Agriculture (USDA) https://fas.usda.gov/ (accessed on 20 February 2022)

5. Shiferaw B., Smale M., Braun H.J., Duveiller E., Reynolds M., Muricho G. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security // Food Security. – 2013. – Vol. 5(3). – P. 291-317. doi: 10.1007/s12571-013-0263-y

6. Abugalieva A., Peña-Bautista R.J. Grain quality of spring and winter wheat of Kazakhstan // The Asian and Australasian Journal of Plant Science and Biotechnology. – 2010. – Vol. 4. –P. 87-90

7. Вавилов Н.И. Центры происхождения культурных растений // Труды по прикладной ботанике и селекции. – 1926. – Т. 16. № 2. – 248 с.

8. Duggan B.L., Domitruk D.R., Fowler D.B. Yield component variation in winter wheat grown under drought stress // Canadian Journal of Plant Science. – 2000. – Vol. 80(4). – P. 739-745. doi: https://doi.org/10.4141/P00-006

9. Tura H., Edwards J., Gahlaut V., Garcia M., Sznajder B., Baumann U., Shahinnia F., Reynolds M., Langridge P., Balyan H.S., Gupta P.K., Schnurbusch T., Fleury D. QTL analysis and fine mapping of a QTL for yield-related traits in wheat grown in dry and hot environments // Theoretical and Applied Genetics. – 2020. – Vol. 133. – №.1. – P. 239-257.

10. Tshikunde N.M., Mashilo J., Shimelis H., Odindo A. Agronomic and physiological traits, and associated quantitative trait loci (QTL) affecting yield response in wheat (*Triticum aestivum* L.): A review // Frontiers in plant science. – 2019. – Vol. 10. – P. 1428.

11. Rozbicki J., Ceglińska A., Gozdowski D., Jakubczak M., Cacak-Pietrzak G., Mądry W., Golda J., Piechocinski M., Sobczynski G., Studnicki M., Drzazga, T. Influence of the cultivar, environment and management on the grain yield and bread-making quality in winter wheat // Journal of cereal science. – 2015. – Vol. 61. – P. 126-132.

12. Sukumaran S., Dreisigacker S., Lopes M., Chavez P., Reynolds M. P. Genome-wide association study for grain yield and related traits in an elite spring wheat population grown in temperate irrigated environments // Theoretical and applied genetics. – 2015. – Vol. 128. – №. 2.– P. 353-363

13. Xu Y., Li P., Yang Z., Xu C. Genetic mapping of quantitative trait loci in crops // The Crop Journal. – 2017. – Vol. 5. – №. 2. – P. 175-184.

14. Newbury H. J. Plant molecular breeding // CRC Press. – 2003. – 265 p.

15. Collard B.C.; Jahufer M.Z.Z.; Brouwer J.B.; Pang E.C.K. An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: the basic concepts // Euphytica. – 2005. – Vol. 142(1). – P. 169-196. doi: 10.1007/s10681-005-1681-5

16. Pang Y., Liu C., Wang D., Amand P.S., Bernardo A., Li W., Li L., Wang L., Yuan X., Dong L., Su Y., Zhang H., Zhao M., Liang Y., Jia H., Shen X., Lu Y., Hongming J., Wu Y., Li A., Wang H., Kong L., Bai G., Liu S., Liu S. High-resolution genome-wide association study identifies genomic regions and candidate genes for important agronomic traits in wheat // Molecular Plant. – 2020. – Vol. 13(9). – P. 1311-1327. doi: 10.1016/j.molp.2020.07.008

17. Kumar A., Mantovani E.E., Simsek S., Jain S., Elias E.M., Mergoum M. Genome wide genetic dissection of wheat quality and yield related traits and their relationship with grain shape and size traits in an elite non-adapted bread wheat cross // PLoS One. – 2019. – Vol. 14(9). – P. e0221826. doi: 10.1371/journal.pone.0221826.

18. El-Feki W.M.; Byrne P.F.; Reid S.D.; Haley S.D. Mapping quantitative trait loci for agronomic traits in winter wheat under different soil moisture levels // Agronomy. – 2018. – Vol. 8(8). – P. 133. doi: 10.3390/agronomy8080133.

19. Amalova A., Yermekbayev K., Griffiths S., Winfield M.O., Morgounov A., Abugalieva S., Turuspekov Y. Population Structure of Modern Winter Wheat Accessions from Central Asia // Plants. – 2023. – Vol. 12(12). – P. 2233. DOI: 10.3390/plants12122233

20. Доспехов Б. А. Методика полевого опыта. – Москва: Агропромиздат, – 1985. – 350 с.

21. RStudio Team 2023. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/

22. Halder J., Gill H.S., Zhang J., Altameemi R., Olson E., Turnipseed B., Sehgal S. K. Genome-wide association analysis of spike and kernel traits in the US hard winter wheat // The Plant Genome. – 2023. – P. e20300.

References

1. Abugalieva A., Peña-Bautista R.J. (2010) Grain quality of spring and winter wheat of Kazakhstan, The Asian and Australasian Journal of Plant Science and Biotechnology, vol. 4, pp. 87-90

2. Amalova A., Yermekbayev K., Griffiths S., Winfield M.O., Morgounov A., Abugalieva S., Turuspekov Y. (2023) Population Structure of Modern Winter Wheat Accessions from Central Asia. Plants, vol. 12(12), p. 2233. doi: 10.3390/plants12122233

3. Collard B.C., Jahufer M.Z.Z., Brouwer J.B., Pang E.C.K. (2005) An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: the basic concepts. Euphytica, vol. 142(1), pp. 169-196. doi: 10.1007/s10681-005-1681-5

4. Dospekhov B. Methods of field experience [Metodika polevogo opyta.]. Moscow: Kolos 1985, 350 p. [in Russian]

5. Duggan B.L., Domitruk D.R., Fowler D.B. (2000) Yield component variation in winter wheat grown under drought stress. Canadian Journal of Plant Science, vol. 80(4), p. 739-745. doi: https://doi.org/10.4141/P00-006

6. El-Feki W.M., Byrne P.F., Reid S.D., Haley S.D. (2018) Mapping quantitative trait loci for agronomic traits in winter wheat under different soil moisture levels. Agronomy, vol. 8(8), p. 133. doi: 10.3390/agronomy8080133.

7. Food and Agriculture Organization of the United Nations. Available online: https://www.fao.org/faostat/en/#home (accessed on 25 February 2022)

8. Foreign Agricultural Service of the US Department of Agriculture (USDA) https://fas.usda.gov/ (accessed on 20 February 2022)

9. Halder J., Gill H.S., Zhang J., Altameemi R., Olson E., Turnipseed B., Sehgal S. K. Genome-wide association analysis of spike and kernel traits in the US hard winter wheat // The Plant Genome. – 2023. – P. e20300.

10. Kumar A., Mantovani E.E., Simsek S., Jain S., Elias E.M., Mergoum M. (2019) Genome wide genetic dissection of wheat quality and yield related traits and their relationship with grain shape and size traits in an elite non-adapted bread wheat cross. PLoS One, vol. 14(9), p. e0221826. doi: 10.1371/journal.pone.0221826.

11. Morgounov A., Gómez-Becerra H. F., Abugalieva A., Dzhunusova M., Yessimbekova M., Muminjanov H., Zelenskiy Y., Ozturk L., Cakmak I (2006). Iron and zinc grain density in common wheat grown in Central Asia, Euphytica, 2006, vol. 155(1-2), pp. 193-203. doi:10.1007/s10681-006-9321-2

12. Newbury H. J. (2003) Plant molecular breeding. CRC Press., 265 p.

13. Pang Y., Liu C., Wang D., Amand P.S., Bernardo A., Li W., Li L., Wang L., Yuan X., Dong L., Su Y., Zhang H., Zhao M., Liang Y., Jia H., Shen X., Lu Y., Hongming J., Wu Y., Li A., Wang H., Kong L., Bai G., Liu S., Liu S. (2020) High-resolution genome-wide association study identifies genomic regions and candidate genes for important agronomic traits in wheat. Molecular Plant, vol. 13(9), pp. 1311-1327. doi: 10.1016/j.molp.2020.07.008

14. Rozbicki J., Ceglińska A., Gozdowski D., Jakubczak M., Cacak-Pietrzak G., Mądry W., Golda J., Piechocinski M., Sobczynski G., Studnicki M., Drzazga, T. (2015) Influence of the cultivar, environment and management on the grain yield and bread-making quality in winter wheat. Journal of cereal science, vol. 61, pp. 126-132.

15. Shiferaw B., Smale M., Braun H.J., Duveiller E., Reynolds M., Muricho G. (2013) Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security, Food Security, vol. 5(3), p. 291-317. doi: 10.1007/s12571-013-0263-y

16. Studio Team 2023. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/

17. Sukumaran S., Dreisigacker S., Lopes M., Chavez P., Reynolds M. P. (2015) Genome-wide association study for grain yield and related traits in an elite spring wheat population grown in temperate irrigated environments. Theoretical and applied genetics,vol. 128, №. 2, pp. 353-363

18. Tshikunde N.M., Mashilo J., Shimelis H., Odindo A. (2019) Agronomic and physiological traits, and associated quantitative trait loci (QTL) affecting yield response in wheat (*Triticum aestivum* L.): A review. Frontiers in plant science, vol. 10, pp. 14-28.

19. Tura H., Edwards J., Gahlaut V., Garcia M., Sznajder B., Baumann U., Shahinnia F., Reynolds M., Langridge P., Balyan H.S., Gupta P.K., Schnurbusch T., Fleury D. (2020) QTL analysis and fine mapping of a QTL for yield-related traits in wheat grown in dry and hot environments. Theoretical and Applied Genetics, vol. 133, №.1, pp. 239-257.

20. USDA (2019) "Kazakhstan – Republic of Grain and Feed Update Kazakhstan Grain and Feed July Report", p.11.

21. Vavilov N.I. (1926) Centers of origin of cultivated plants [Tsentry proiskhozhdeniya kul'turnykh rasteniy]. Proceedings on Applied Botany and Breeding,vol. 16. № 2., 248 p. [in Russian]

22. Xu Y., Li P., Yang Z., Xu C. (2017) Genetic mapping of quantitative trait loci in crops. The Crop Journal, vol. 5, №. 2, pp. 175-184.

3-бөлім

МИКРОБИОЛОГИЯ

Section 3

MICROBYOLOGY

Раздел 3

МИКРОБИОЛОГИЯ

IRSTI 68.41.53;68.41.41 https://doi.org/10.26577/eb.2023.v96.i3.07

N. Abdolla[1,2]*, A.S. Mashzhan[1], S. Kuatbekova[1], S.A. Kan[1,2], A.V. Lushova[1,2], S.M. Mamadaliyev[1]

[1]Almaty Branch of the National Center for Biotechnology, Kazakhstan, Almaty
[2]M.A. Aitkhozhin Institute of Molecular Biology and Biochemistry, Kazakhstan, Almaty
*e-mail: nurshata@gmail.com

RISK ASSESSMENT OF SHEEP AND GOAT POX SPREAD IN KAZAKHSTAN

Sheep and goat pox (SGP) disease is a highly contagious and dangerous viral infection, characterized by fever, formation of papular-pustular lesions in the epithelium of the skin and respiratory tract of small ruminants. This disease causes enormous damage to sheep breeding due to the death of animals, forced slaughter, loss of productivity, costs for veterinary and sanitary and quarantine measures. The causative agents are two closely related viruses: sheep pox virus and goat pox virus, belonging to the family Poxviridae, the genus Capripoxvirus. SGP is considered an endemic in Kazakhstan and SGP outbreaks have been registered in a number of regions both in our country and bordering states. The uncontrolled spread of this infection can be associated with colossal economic losses and significant damage of the image of our country as an exporter of lamb. Thus, it is important to monitore the epizootological situation of SGP in the country, control outbreaks of infection, and develop veterinary and sanitary measurements to adequately anticipate of the disease spread. Therefore, the purpose of this study is to perform risk analyses of SGP transmission in Kazakhstan. As a result of the research, the SGP risk factors, epizootological characteristics of this infection in Kazakhstan in the last 10 years, and the districts with high risks regarding the possible occurrence of large outbreaks of SGP were identified and the epizootic visualization map was created. This work provides valuable information on the importance of SGP control and prevention programs in Kazakhstan.

Key words: epizootology, sheep pox, goat pox, virus, risk analysis.

Н. Абдолла[1,2]*, А.С. Машжан[1], С. Куатбекова[1],
С.А. Кан[1,2], А.В. Лушова[1,2], С.М. Мамадалиев[1]

[1]«Ұлттық биотехнология орталығы» Алматы қаласындағы филиалы, Қазақстан, Алматы қ.
[2]М.А. Айтхожин атындағы молекулалық биология және биохимия институты, Қазақстан, Алматы қ.
*e-mail: nurshata@gmail.com

Қазақстанда қой мен ешкі шешек ауруының таралу қаупін талдау

Қой мен ешкі шешегі (ҚЕШ) – өте жұқпалы, қауіпті вирустық инфекциялық ауру, ол ұсақ күйіс қайыратындардың жауарлардың дене қызуының көтерілуімен, тері және өкпе эпителийінде папулезді-пустулярлы ошақтардың пайда болуымен сипатталады. Бұл ауру малдың қырылуы, амалсыз сою, төлдеуінің төмендеуі, ветеринариялық-санитариялық және қауіпсіздік пен карантиндік шараларға жұмсалатын шығындар салдарынан қой шаруашылығына орасан зор зиян келтіреді. Қоздырғыштары – Capripoxvirus туысы Poxviridae тұқымдасына жататын бір-бірімен тығыз байланысты екі вирус қой шешек вирусы және ешкі шешек вирусы болып табылады, ҚЕШ Қазақстанда эндемиялық болып саналады және ҚЕШ ошақтары біздің елдің де, шекаралас мемлекеттердің де бірқатар аймақтарында тіркелген. Бұл инфекцияның бақылаусыз таралуы, біздің еліміздің экономикалық әл-ауқатына орасан зор шығындар әкелуімен қатар, елдің қой етін экспорттаушы ретіндегі халқаралық имиджісінің айтарлықтай бұзылуына әсер етеді. Осылайша, елдегі ҚЕШ эпизоотологиялық жағдайын бақылау, инфекция пайда болуы мүмкін ошақтарын қадағылау, аурудың таралу қаупін болжау үшін ветеринариялық-санитариялық өлшемдерді әзірлеу маңызды. Сондықтан, бұл зерттеудің мақсаты – Қазақстандағы ҚЕШ таралу қаупіне талдау жасау. Жүргізілген зерттеулер нәтижесінде ҚЕШ таралуының қауіп факторлары, Қазақстандағы соңғы 10 жылдағы осы инфекцияның эпизоотологиялық сипаттамасы және ҚЕШ ірі ошақтарының пайда болу қаупі жоғары аймақтар анықталды, сонымен бірге эпизоотиялық визуализация картасы жасалды. Бұл аналитикалық зерттеу жұмысы Қазақстандағы ҚЕШ бақылау және алдын алу бағдарламаларының маңыздылығы туралы құнды ақпарат береді.

Түйін сөздер: эпизоотология, қой шешегі, ешкі шешегі, вирус, қауіп талдауы.

Н. Абдолла[1,2]*, А.С. Машжан[1], С. Куатбекова[1],
С.А. Кан[1,2], А.В. Лушова[1,2], С.М. Мамадалиев[1]
[1]Филиал «Национальный центр биотехнологии», Казахстан, г. Алматы
[2]Институт молекулярной биологии и биохимии им. М.А. Айтхожина, Казахстан, г. Алматы
*e-mail: nurshata@gmail.com

Анализ рисков распространения оспы овец и коз в Казахстане

Оспа овец и коз (ООК) – высококонтагиозное, особо опасное вирусное заболевание, характеризующееся лихорадкой, образованием папулезно-пустулезных высыпаний на эпителии кожи и дыхательных путей мелких жвачных животных. Это заболевание наносит колоссальный ущерб овцеводству из-за падежа животных, вынужденного убоя, потери продуктивности, затрат на ветеринарно-санитарные и охранно-карантинные мероприятия. Возбудителями являются два близкородственных вируса: вирус оспы овец и вирус оспы коз, принадлежащие к семейству Poxviridae, роду Capripoxvirus. Вспышки ООК были ранее зарегистрированы в ряде регионов Казахстана, что привело к значительным экономическим потерям. В связи с тем, что эта инфекция является эндемичной в Казахстане, важно следить за эпизоотологической ситуацией в стране, контролировать вспышки инфекции и разрабатывать ветеринарно-санитарные мероприятия, позволяющие адекватно прогнозировать распространение болезни. В связи с этим, целью данного исследования является проведение анализа рисков распространения ООК в Казахстане. В результате исследования нами были выявлены факторы риска ООК, эпизоотологическая характеристика ООК в Казахстане за последние 10 лет, определены районы с высоким риском возникновения крупных вспышек ООК и разработана эпизоотическая карта. Эта работа предоставляет информацию, подчеркивающую важность проведения программ контроля и предотвращения распространения ООК в Казахстане.

Ключевые слова: эпизоотология, оспа овец, оспа коз, вирус, анализ риска.

Introduction

Sheep and goat pox (SGP) is one of the most economically significant diseases of small ruminants (SRs). SGP is a highly contagious viral disease, characterized by fever, the formation of papular-pustular lesions in the epithelium of the skin and mucous membranes, and lung damage [1]. Large outbreaks of this infection usually have a cyclical nature (recurring in the same area in 3-5 years) [1]. Asian and African countries are considered endemic.

SGP are caused by two viruses, the sheep pox virus (SPPV) and the goat pox virus (GTPV), which are combined into a single supraspecific complex, capripox virus of small ruminants. These two viruses are genetically separable, but it is not possible to differentiate them serologically even using a neutralization reaction [2]. Both capripoxviruses can be present in both goat and sheep populations. Like all poxviruses, SPPV and GTPV are large (200–450 nm in diameter) dsDNA viruses surrounded by several layers of lipid–protein envelopes [3]. Like all poxviruses, capripoxviruses encode a variety of proteins that help them evade the host's immune response. Like all poxviruses, they encode analogs of mammalian cytokines, but unlike most other poxviruses, their genome also encodes proteins that inhibit antigen presentation on molecules of the major histocompatibility complex (MHC) [4]. Such adaptive mechanisms allow capripoxviruses to persist in animal organisms for a long time.

The main ways of infection are aerogenic (through the air), contact and alimentary (through food). In addition, blood-sucking stable flies (Stomoxys calcitrans) have been implicated in infections through mechanical transmission of capripoxviruses [5].

Clinical manifestations of the disease: eyelids swell, discharges begin to flow from the eyes and nose (first serous-mucous, then serous-purulent). Breathing in animals becomes difficult and sniffling, hyperthermia is observed (up to 40-41°C). A smallpox rash begins to appear on the head, lips, around the eyes, on the fore and hind limbs, on the scrotum and foreskin in males, as well as on the skin of the udder and the mucous membrane of the shameful lips of females. The disease spreads in the form of epizootics. After 2-4 weeks in the herd, if measures are not taken in a timely manner, most animals in the herd will be infected. Mortality in smallpox outbreaks in regions endemic for the disease from the disease itself is low (up to 2-5%), although it can reach 100% in non-endemic areas, as well as among imported livestock [2]. Mortality among young animals is much higher than adult animals.

The initial stage of SGP must be differentiated from fungal scab, tick-borne scabies and papular non-contagious eczema, as well as contagious pus-

tular dermatitis of sheep (ecthyma). For this, virological, immunological and molecular biological methods are used. serological methods allow assessing the effectiveness of livestock vaccination, as well as assessing the level of antibody prevalence in herds that have not been vaccinated against the virus [6, 7]. For the detection of capripoxviruses in MRS herds, both by classical PCR and by real-time PCR, the following loci are used: GPCR (G-protein-coupled chemokine receptor gene), RPO30 (viral RNA polymerase gene), P32 (P32 envelope protein gene). Real-time PCR methods are an order of magnitude more sensitive than viral DNA detection methods based on regular PCR [8].

The chosen topic of the research is crucial as the SGP is endemic in Kazakhstan, for 186 outbreaks of this infection were recorded in the country during the period from 1961 to 2000 [9]. Over the past 10 years, outbreaks have been recorded in Kyzylorda (2013), Turkistan (2013 and 2015), East Kazakhstan (2015), West Kazakhstan (2015, 2019), Mangystau (2019) and Atyrau (2019) [10]. Previously, the disease was also recorded in other regions, for example, in Pavlodar region (2010). These outbreaks led to large economic losses in the country.

Vaccination is the most promosing method to prevent spreading of SGP. In our country, where more than 80% of the SRs livestock are concentrated in private backyards and small enterprises, the total vaccination of SRs is therefore a rather difficult task, which, moreover, is associated with significant economic costs. At the same time, large-scale monitoring of SGP has not been carried out over the past 10 years, which was one of the reasons for the outbreak of this infection in western Kazakhstan in 2019. Since this infection is endemic in Kazakhstan, it is important to monitore the epizootological situation regularly in the country, control outbreaks of infection, and develop veterinary and sanitary measures to adequately anticipate of the disease spread. Therefore, the purpose of this study is to perform risk analyses of SGP transmission in Kazakhstan.

Methods and materials

Epidemiological methods. All calculations of epidemiological parameters were carried out using the EpiInfo v. 7.2.2.2 (CDC).

Analysis of epizootological aspects. the epizootological description of SGP in the world and in Kazakhstan was studied on the basis of electronic information sources.

Cartographic analysis and GIS. The creation of a GIS database and the determination of the geographical coordinates of farms and collection points was carried out using GPS navigators of Android mobile devices, as well as the database of GeoHack (https://geohack.toolforge.org) and GoogleMaps (https://www.google .com/maps).

Risk Analysis. For risk analysis and forecasting chosen the method of analogy and modeling and we used an additional add-in in Microsoft Excel – Decision Tools Suite 6.0 Professional from Palisade.

Calculation of the sample size for SGP monitoring. The minimum (critical) sample size for conducting an annual monitoring study in relation to common sheep and goats is determined by the formula [11]:

$$\text{Sample size (n)} = N^* [Z^2 * p * (1\text{-}p)/e^2] / [N - 1 + Z^2 * p * (1\text{-}p)/e^2] \quad (1)$$

Where:

N – is the population size;

Z – is the critical value of the normal distribution at the required confidence level;

p – is the expected level of prevalence, %;

e – is the permissible error.

Results and discussion

Analysis of the epizootological process of SGP in the world. SGP is widespread in Africa and Asia [12]. According to the World Organization for Animal Health (WOAH), SGP are notifiable diseases due to the rapid spread of the infection and the significant economic damage it can cause [13]. As for nearby states, outbreaks of sheep and goat pox were detected from 2018 to 2020 on the territory of the Russian Federation, and in 2018 in the Xijiang Uygur Autonomous Region of China, bordering on the Republic of Kazakhstan [14], in 2022 in Tajikistan [15]. Kyrgyzstan officially denies the fact of outbreaks of sheep and goat pox on its territory, but there are clear indications that numerous outbreaks of infection of unclear etiology of SRs that occurred in the republic in 2013 were nothing more than SGP [16]. In general, data on official outbreaks of SGP over the past 10 years are presented in Figure 1.

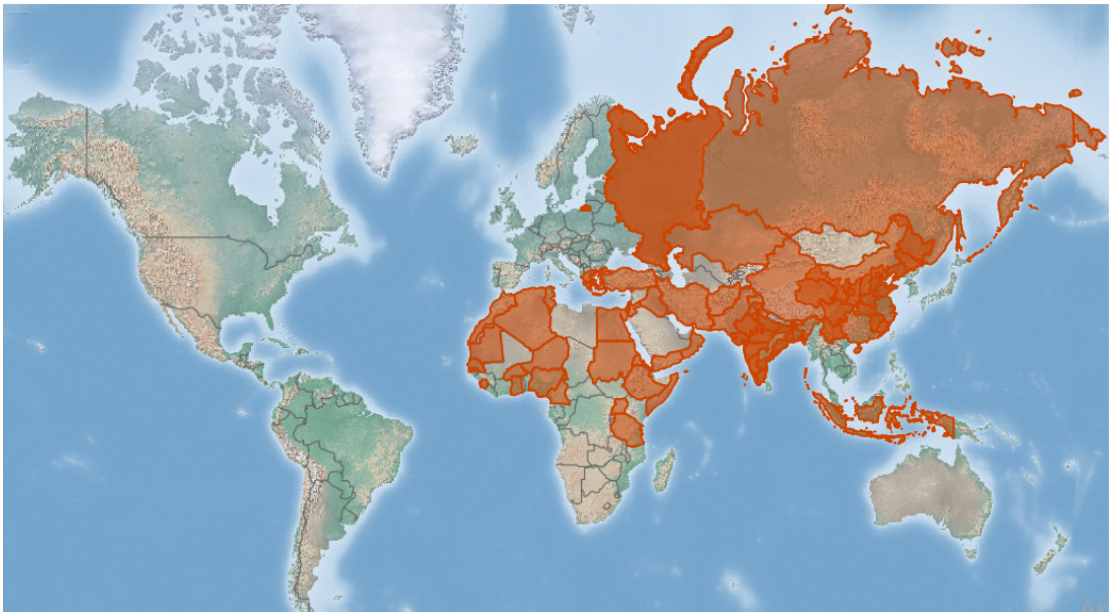


Figure 1 – The spread of SGP for the period 2011 – 2022yy. Red indicates the regions and states in which the disease was detected by the WOAH [17]

Analysis of the epizootological process of SGP in Kazakhstan. Outbreaks of sheep pox have occurred in our country for the past five years. In April 2019, an outbreak of sheep pox occurred in the rural district of Kyzyl Ozen, Tupkaragai district of the Mangystau region (about 50 animals died). A quarantine was declared. On June 14, 2021, by the decision of the administration of the Tupkaragai district, quarantine was lifted from the territory of this district from the rural district of Kyzyl Ozen. The outbreak also took place from July 19 to August 12, 2019 in the village of Suyunduk, Suyunduk rural district, Kurmangazy district, Atyrau region [10]. A quarantine was declared on August 12, 2019, by the decision of the administration of the Suyunduk rural district of the Kurmangazy district of the Atyrau region, in connection with the implementation of a complex of veterinary and quarantine measures to eliminate the sheep pox disease, quarantine was officially lifted from this territory. Before the outbreaks, neither Mangystau nor Atyrau regions vaccinated livestock against SPPV and GTPV, but after 2019, annual immunization of animals against this infection was carried out in both regions. There is also evidence that in the same 2019, an outbreak of sheep pox occurred in the 'Birlik' breeding farm in the Zhangalin district of the West Kazakhstan region [9].

To clarify the reliable epizootic situation of SGP, in 2021, the Kazakh National Agrarian Research University, as part of the program, conducted research in Mangystau, Atyrau, Turkistan, Zhambyl, West Kazakhstan, East Kazakhstan region (since 2022 Abay and East Kazakhstan) and North Kazakhstan region. In seven regins of the Republic of Kazakhstan, 72 epizootic units (EU) were studied. As a result of the study, 7 disadvantaged regions for this infection were identified. These are Mangystau region (Mangistau district, 1 EU., Tupkaragai district, 1 EU., Munailin district, 1 EU), Atyrau region (Kurmangazin district, 2 EU), Turkestan region (Baidibek district, 1EU), Zhambyl region (Shu district, 1 EU), West Kazakhstan region (Akzhaiyk, Koztal district, 2 EU), East Kazakhstan region (Zaisan district, 1 EU), North Kazakhstan region (Akzhar district, 1 EU).

Analysis of the risk of infection spread across the territory of Kazakhstan. The presence or absence of foci of infection in the past (at least within the last ten years) and whether animals are immunized against this infection are extremely important parameters in risk assessment in relation to the prediction of SGP. Table 1 presents data on the total number of SGP-susceptible livestock and on the plan for immunizing animals by region against this infection for 2022. A map showing both of these parameters is shown in Figure 2.

Table 1 – Livestock vaccination plan for SGP in 2022 year.

Oblasts	**total number of SRs** (*thousand*)	**Vaccination plan** *(thousand)*	**Immunized percentage**
Abay	1444,2	0	0,0%
Akmola	751,6	0	0,0%
Aktobe	1 533,5	0	0,0%
Almaty	2981,9	2315,6	(77,7%)
Atyrau	723,6	569,5	(78,7%)
East Kazakhstan	773,6	0	0,0%
Karaganda	992,0	0	0,0%
Kostanay	526,2	0	0,0%
Kyzylorda	895,8	496,7	(55,4%)
Mangystau	357,0	200,9	(56,3%)
North Kazakhstan	624,7	0	0,0%
Pavlodar	818,9	0	0,0%
Turkistan	6044,2	4817,4	(79,7%)
Ulytau	449,0	0	0,0%
West Kazakhstan	1 545,1	1053,2	(68,2%)
Zhambyl	3 917,0	3860,4	(98,6%)
zhetysu	2121,9	1502,3	(70,8%)
Total in Kazakhstan:	**28 023,7**	**14816,0**	

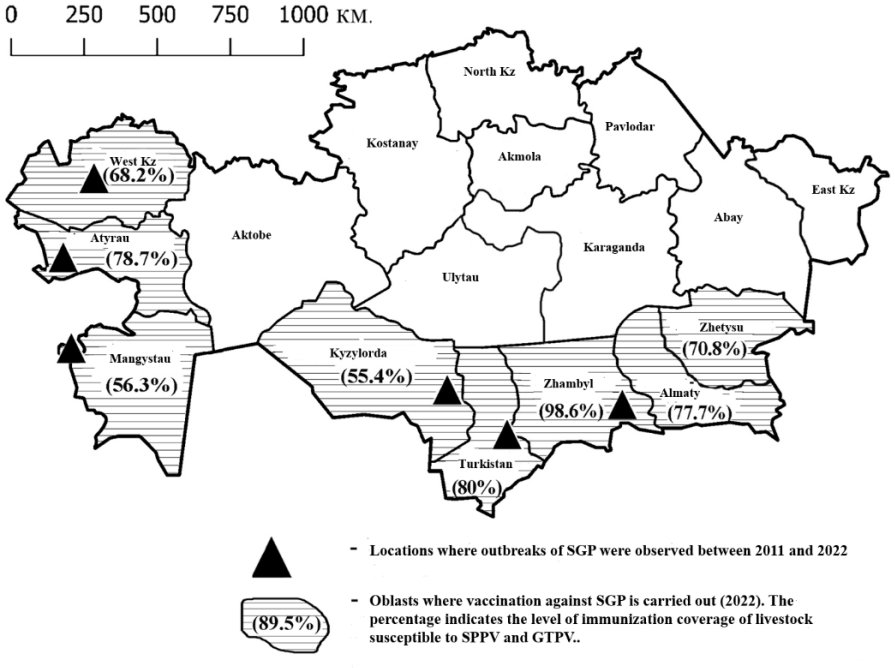


Figure 2 – Locations of outbreaks of SGP in the territory of Kazakhstan over the past 10 years and vaccination data (a plan for 2022)

The greater the density of susceptible SRs in a given area, the greater the risk of SGP epizootics and infection spread. The highest density of sheep and goats is in the south of our country, namely in the Turkistan, Zhambyl, Almaty and Zhetysu oblasts (Figure 3). However, it should be noted that sheep are raised throughout the territory of the Republic of Kazakhstan, and the density of sheep and goats even in the desert and semi-desert regions of the country is quite sufficient for an outbreak of this infection. At the same time, in regions of the country with a low density of SRs, it becomes possible to quickly localize outbreaks and prevent the spread of infection to adjacent territories.

The total number of susceptible livestock is also an important epidemiological indicator, as it can indicate the potential risk of economic loss associated with a given infection. The largest number of sheep and goats in the country is concentrated on the territory of the Turkistan oblast; followed by Zhambyl, Almaty and Zhetysu oblasts, which together account for more than half of the country's total number of SRs (Figure 4).

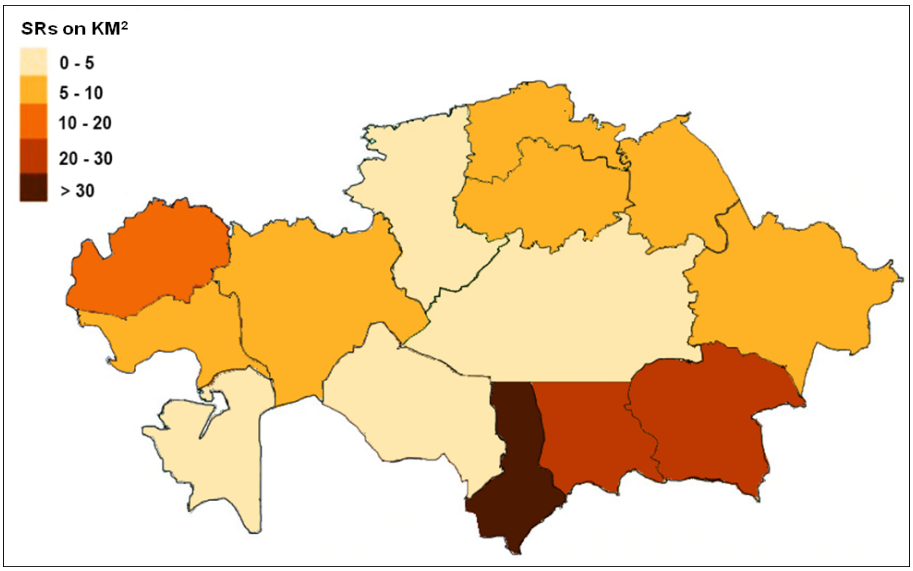


Figure 3 – The density of SRs in the Republic of Kazakhstan by region (data as of 08/01/2022) [18]

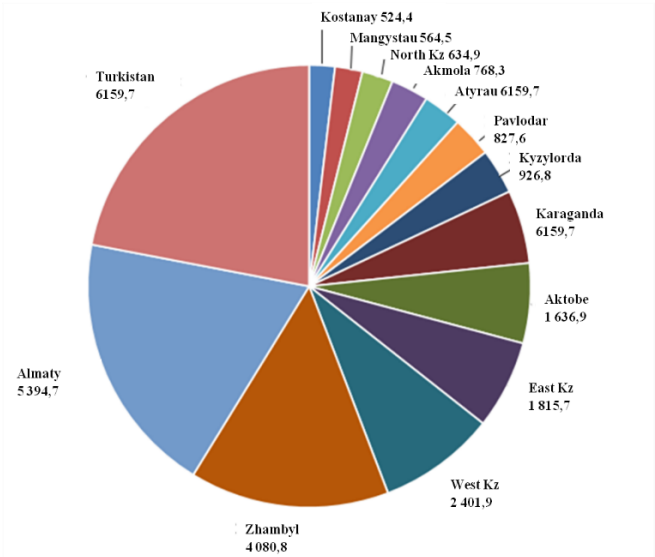


Figure 4 – Number of goats and sheep in the Republic of Kazakhstan (thousand) (01.06.2022) [18]

Thanks to the State Program for supporting domestic animal husbandry, favorable conditions have developed for increasing the number of livestock in the country. Over the past two years, there has been a sharp increase in the number of literally all types of livestock and poultry. Forecasts can be short-term, medium-term and long-term. The medium-term forecast is compiled for a year and serves as the basis for planning veterinary-sanitary and preventive measures.

A parameter that can be tracked over a sufficiently long period is the total number of sheep and goats in the country. Due to the high correlation of this indicator with the frequency of outbreaks of sheep pox and goat pox, it can be used to extrapolate data for risk assessment in the medium term.Goats and sheep are no exception (data on changes in the number of SRs for the entire period of independence of the Republic of Kazakhstan are presented in Figure 5. This circumstance significantly increases the risk of new foci of infection in the country.

Analysis of the risks of importation and predicting outbreaks of SGP. To analyze the risks of introduction and spread of sheep pox, as well as to assess the level of potential economic damage that may be associated with the spread of the causative agent of this disease. The method of analogy and modeling was chosen for this risk analysis. This approach makes it possible, based on the available data concerning the characteristics of the infection process, the main factors of infection spread, and the laboratory analysis data obtained during monitoring, which characterize the current SGP situation in the country, to carry out relatively technically simple risk calculations without resorting the complex multifactorial mathematical models.

In the approach of risk analysis, the following risk factors have been taken into account: 1) the history of outbreaks of SGP in a given area; 2) the density and total number of susceptible animals to virus in the regions; 3) the way of transmission of the pathogen; 4) the availability of preventive methods to minimize the risks associated with the spread of infection (availability of vaccines), the degree of implementation of these in practice (accessibility for households), and the availability of treatment methods; 5) the genotype of the pathogen, mediating the degree of symptomatic manifestations, the level of lethality, and the level of infectivity; 6) the actual state of the sheep pox epizootological process in a given region (country), including the average level of antibody seroprevalence in herds; 7) the risk of introducing infection from regions or states endemic for the disease and assessing the potential rate of infection spread by assessing the geographical features of the regions; 8) opportunities to eradicate the disease from endemic areas; the presence or absence of legislative acts to control or eradicate the infection.

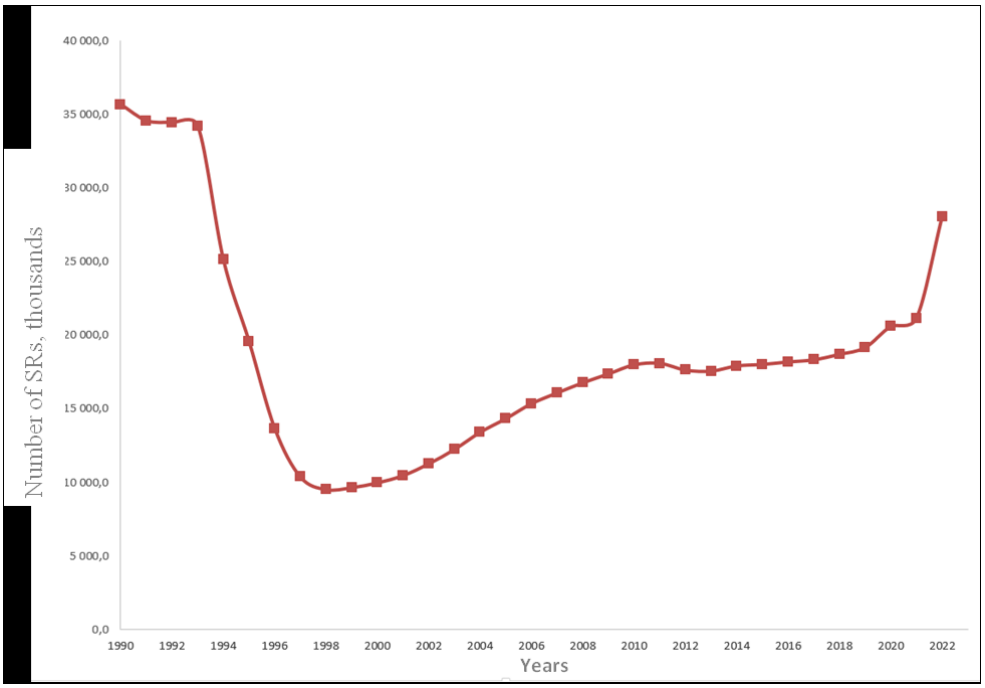


Figure 5 – Change in the number of SRs in Kazakhstan [18]

For each risk factor, the corresponding scores were assigned from 0 to 5, the scoring was carried out by regions of the Republic of Kazakhstan. Conditional scores for each of the main risk factors for outbreaks of SRs and the spread of the infectious agent to non-endemic areas are presented in Table 2. It was decided to consider the "Vaccination" parameter as the most important factor determining the overall risk of outbreaks of infection – whether animals are vaccinated in a given region of the country according to the state program and how effectively this vaccination is carried out (the breadth of coverage of the population of the region by vaccination and the actual effectiveness of vaccination on the ground). The fact is that even in areas with the smallest number of SRs in the country, the number and density of goats and sheep are sufficient for the rapid spread of infection. This confirmed by outbreaks of SGP that occurred in 2019 in Atyrau and Mangystau regions. Thus, it is in the regions of the country where mass vaccination of livestock against SGP is not carried out that the most economically significant outbreaks of infection can be expected in the near future (West Kazahkstan and Aktobe regions are of particular danger). Therefore, vaccination should be considered when planning public events.

Summing up these scores, the regions of the Republic of Kazakhstan were ranked according to the level of risk of new outbreaks of SGP in the country in the medium term:

11 and < points – low risk level;

12-14 points – moderate risk;

15-17 points – medium risk;

18 and > points – high risk.

Based on all processed data, a risk map of the main foci of SGP diseases, which may be present in the territory of Kazakhstan, was created. The map is shown in Figure 6.

Table 2 – Scores for assessing the risks of outbreaks of SGP for certain oblasts of Kazakhstan

Oblasts	Outbreaks	SRs density	Numbers of SRs	Vaccination	Factual data	The risk of infection	Sum
Akmola+.Nur-sultan	0	2	2	5	1	2	12
Aktobe	3	2	3	5	1	5	19
Almaty+ Almaty	1	4	5	1	1	5	17
Atyrau	5	2	2	1	1	5	16
West Kazakhsatn	5	3	3	1	1	5	18
Zhambyl	1	4	4	1	1	4	15
Karaganda	1	1	3	5	1	0	11
Kostanay	0	1	2	5	1	4	13
Kyzylorda	2	1	2	5	1	3	14
Mangystau	4	1	2	3	1	3	14
Pavlodar	1	2	2	5	1	3	14
North Kazakhstan	0	2	2	5	1	4	14
Turkistan+Symkent	2	5	5	1	1	3	17
East Kazakhstan	2	2	3	5	1	4	17

The high risk areas were the West Kazakhstan (due to the extremely high risk of maintaining latent foci of infection) and Aktobe oblasts (mainly because in the region there is no vaccination of SRs against SGP, despite a sufficiently high number of susceptible livestock in the region and the proximity of the regions of Kazakhstan and the Russian Federation, where outbreaks of sheep pox were recorded most recently). Turkistan, Zhambyl, Almaty, and Zhetysu Oblasts require careful attention from regulatory authorities due to the very high density of SRs, optimal conditions for the spread of infection, and the presence of borders with states where the disease considered endemic. Abay and East Kazakhstan oblasts remain at medium risk of outbreaks due to the lack of livestock vaccination programs against sheep pox, the relatively large number of SRs, and the borders with China's Xinjiang Uyghur District. Atyrau and Mangystau oblasts are also at risk, where had

recently been recorded outbreaks of SGP. In the Kyzylorda oblast, the most risky area is the vicinity of Kyzyl-Orda, which is a kind of crossroads for the movement of livestock. At times, the density of livestock susceptible to SGP, which reaches critical values, and the observed rotation of herds contributes to the introduction of infection from regions of the country endemic to the disease. In addition, outbreaks of SGP have previously recorded in the oblast.

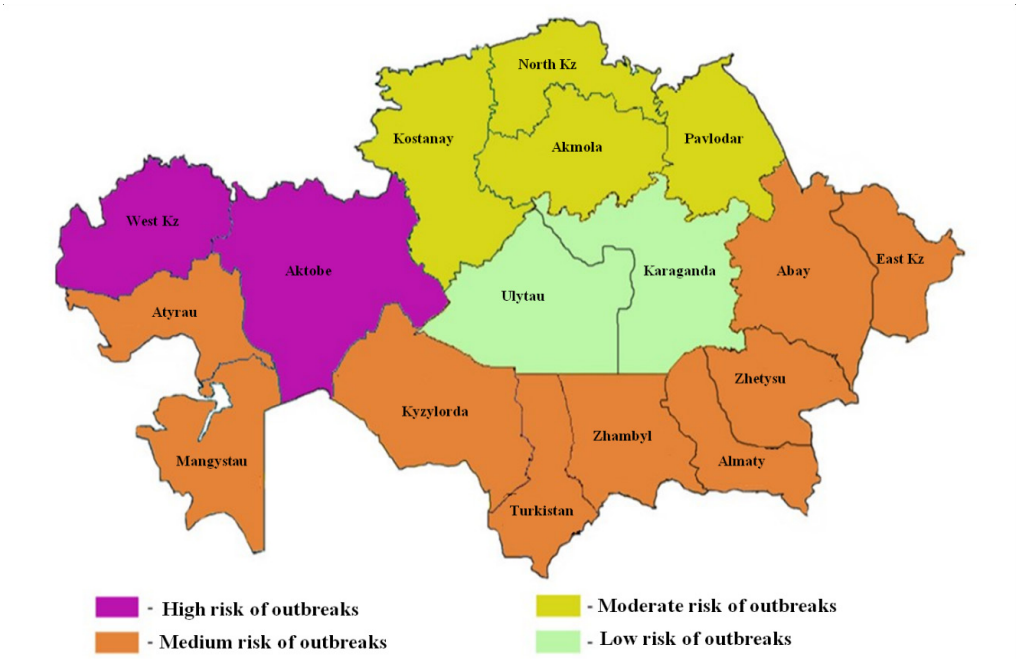


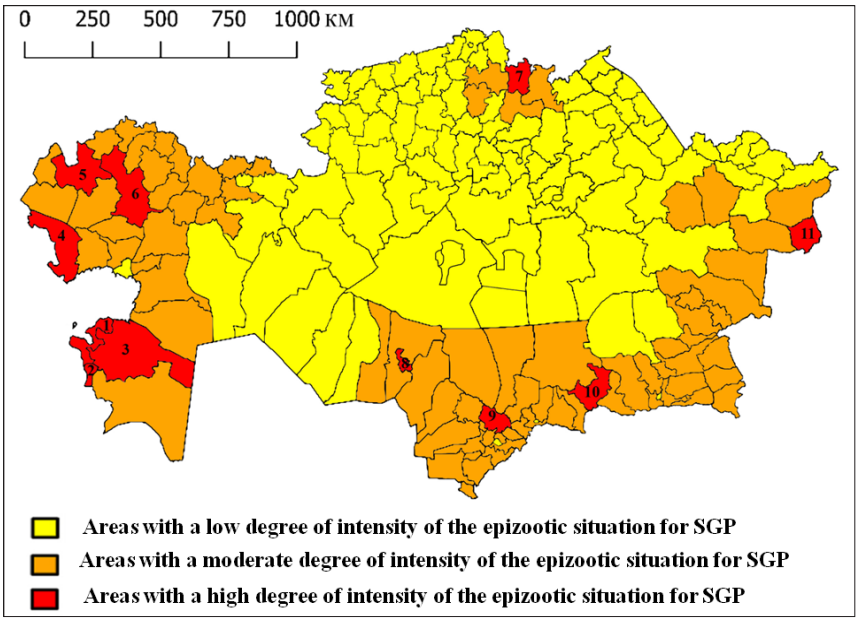
Figure 6 – Map of risks in relation to the occurrence of large outbreaks of SGP in the territory of Kazakhstan (as of 01.09.2022)

Also in the research work, target indicators for the effectiveness of the implementation of veterinary measures have been determined, as it is possible to control the effect of measures to prevent the introduction of SGP into the republic and the spread of infection to non-endemic territories:

- The percentage of vaccinated animals among those selected for monitoring;
- The percentage of SRs covered by the vaccination plan in the regions;
- Level of seroprevalence of antibodies to capripoxviruses in vaccinated animals;
- Level of seroprevalence of antibodies to capripoxviruses in unvaccinated animals;
- The percentage of herds, whose samples were detected by PCR-positive animals, or animals with signs of SGP with confirmation of virus carriage by the method of neutralization reaction or electron microscopy;
- Number of new outbreaks of SGP by region.

Zoning and regionalization of the territory of Kazakhstan. Based on the above information, an epizootic visualization map has developed with indicators of the epizootic process of SGP in the Republic of Kazakhstan for 2019–2022. It included the data from the visual inspection of livestock during monitoring, the data on outbreaks of infection that occurred in given areas, the density of SRs, climatic characteristics, and the presence of borders with regions of other countries where the infection is common. The zoning map of the territory of the Republic of Kazakhstan shown in Figure 7.

The isolates of both SPPV and GTPV were isolated in the country, and their genetic characterization was carried out, including whole genome sequencing of isolates of these viruses [7]. Taking into account the results of the risk analysis, as well as actual evidence of the circulation of SPPV and GTPV throughout the country, a regionalization map of the territory of the Republic of Kazakhstan was developed in relation to the recommended measures for the control of SGP in the country (Figure 8).



Designations: the numbers indicate areas with a high degree of intensity of the epizootic situation for SGP. In the Mangystau oblast: 1 – Tupkaragai district, 2 – Aktau, 3 – Mangystau district; in the Atyrau oblast: 4 – Kurmangazy district; in West Kazakhstan oblast: 5 – Kaztalov district, 6 – Akzhar district; in North Kazakhstan oblast: 7 – Akzhar district; in the Kyzylorda oblast: 8 – Kyzylorda; in the Turkistan oblast: 9 – Baidibek district; in Zhambyl oblast: 10 – Shu district; in East Kazakhstan oblast: 11 – Zaisan district.

Figure 7 – Epizootic visualization map with indicators of SGP epizootic process in Kazakhstan

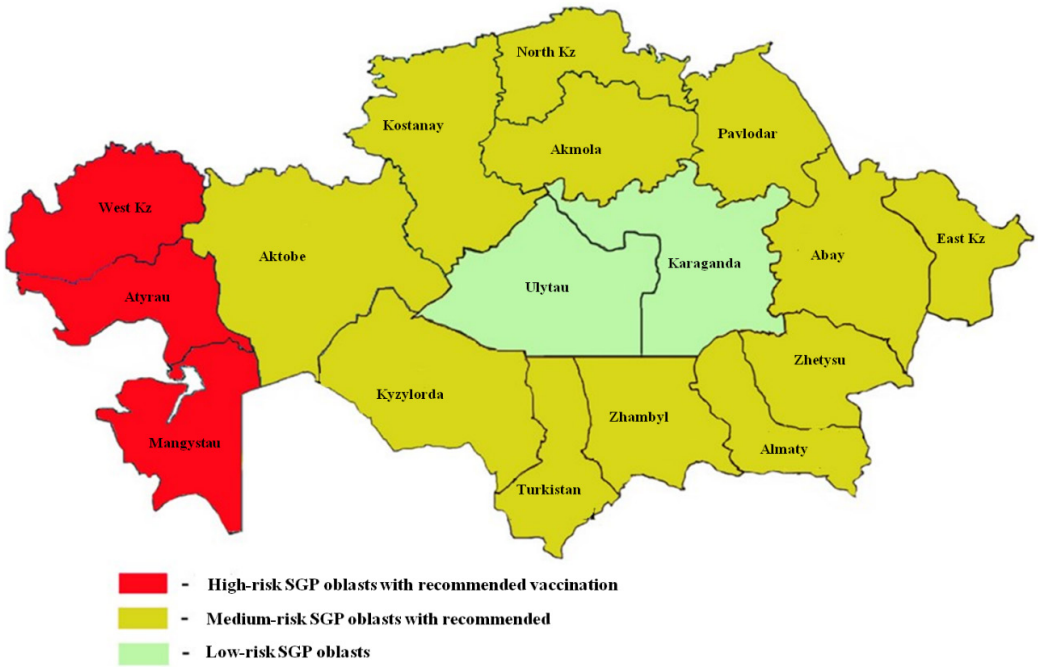


Figure 8 – Regionalization of the territory of Kazakhstan in relation to measures to minimize the risks of outbreaks and the spread of SGP

In order to prevent the occurrence of outbreaks of SGP and ensure the effective implementation of preventive measures, it will be recommaned that the territory of the Republic of Kazakhstan conditionally divided into 3 zones:

- Zone 1 – unfavorable for SGP, where the infection can be spread in a latent form (West Kazakhstan, Mangystau and Atyrau Oblasts);
- Zone 2 – favorable for SGP, with a risk of occurrence and spread of infection (North Kazakhstan, East Kazakhstan, Aktobe, Kyzylorda, Turkestan, Zhambyl, Almaty, Zhetysu, Abay, Akmola, Pavlodar, Kostanay oblasts);
- Zone 3 – favorable for SGP, with a low risk of infection, without vaccination (Ulytau and Karaganda oblast).

In the 1st and 2nd zones, it is recommended to vaccinate SRs against SGP with a wide coverage of livestock (more than 70%), introduce mandatory livestock monitoring and strengthen veterinary and sanitary measures. In these areas, it is also recommended to conduct annual monitoring using both serological and molecular biological methods of analysis to identify the facts of the circulation of viruses that cause SGP in this area. In the 1st zone, it is additionally recommended to strengthen control by veterinary services regarding the identification of animals with signs that can be attributed to manifestations of this infection. In the 3rd zone, it is recommended to carefully check for the presence of clinical symptoms of SGP of animals delivered to this zone from the other two zones or from other states. Total vaccination is optional.

Sample size determination for SGP monitoring. As of 06/01/2022, according to the official data of the Bureau of Statistics in the Republic of Kazakhstan [18], the country contains 28023.699 thousand heads of sheep and goats. Since no large-scale monitoring of SGP has been carried out in the country before, the level of antibody seroprevalence should be taken equal to 50% (according to [11]). For epidemiological studies, the confidence interval in the vast majority of cases is assumed to be 95%, so this value is recommended for calculations; therefore, the Z value for this confidence interval is 1.96 [1, 11]. The allowable error is usually assumed to be 5% in calculations [19]. Thus, for groups of five to thirty animals, the minimum required number of animals is estimated to be 400 per year. As a rule, the number of animals exceeding the critical sample size by at least 10% is involved in monitoring, since some proportion of the samples may not be suitable for analysis (for example, serum may be hemolyzed, and blood clotted).

A specified number of samples taken for monitoring purposes should be distributed among collection points (sampling should be carried out at a minimum of ten different locations, or epidemiological units (EU)). It is desirable that several districts of each of the areas covered by the monitoring program be involved in the monitoring. Within a given location (or EA), the selection of animals for monitoring purposes should be random (unless all animals show symptoms attributable to SGP). It is important that the animals selected for monitoring include animals of both sexes and different age groups. If animals are seen with symptoms similar to those of SGP, they should be additionally selected for laboratory analysis (semi-targeted sampling aimed at detecting signs of virus circulation in herds as efficiently as possible).

Conclusion

According to the conducted research, the epizootological characteristics of the country's territory for the last 10 years on SGP have been determined. Based on the results, an analysis of the epizootic situation and an analysis of the risks of SGP spread, zoning and regionalization of the territory of the Republic of Kazakhstan according to the degree of tension of the epizootic situation of this diseases were carried out, as wells as the sample size for SGP monitoring was determined. These data will help to increase the effectiveness of veterinary-sanitary measurements for the prevention and control of the spread of infection, and fully determine the current situation regarding to SGP, as well as to reduce or prevent the risk of new outbreaks of SGP in Kazakhstan.

Acknowledgments

The work was carried out within the framework of the BR10764899 program "To study the epizootic characteristics of the country's territory for especially dangerous diseases and develop veterinary and sanitary measures to improve their effectiveness", funded by the Ministry of Agriculture of the Republic of Kazakhstan.

Conflict of interest

The authors of the article confirm that there is no financial or any other support for the study, or a conflict of interest.

References

1. Hamdi J., Munyanduki H., Omari Tadlaoui K., El Harrak M., Fassi Fihri O. Capripoxvirus Infections in Ruminants: A Review // Microorganisms. – 2021. – Vol. 9, No.5. – P. 902.

2. Sheep pox and goat pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. Chapter 3.7.12. 2018. – P. 1513-1524.

3. Babiuk S., Bowden T.R., Boyle D.B., Wallace D.B., Kitching R.P. Capripoxviruses: an emerging worldwide threat to sheep, goats and cattle // Transboundary and emerging diseases. – 2008. – Vol.55. – P. 263–272.

4. Yewdell J.W., Hill A.B. Viral interference with antigen presentation // Nature immunology. – 2002. – Vol. 3, No. 11. – P.: 1019–1025.

5. Kitching R.P., Taylor W.P. Transmission of capripoxvirus // Research in Veterinary Science. – 1985. – Vol. 39. – P. 196-199.

6. Tuppurainen E., Venter E.H., Shisler J.L., Gari G., Mekonnen G.A., Juleff N., Lyons N.A., De Clercq K., Upton C., Bowden T.R., Babiuk S., Babiuk L.A. Review: Capripoxvirus Diseases: Current Status and Opportunities for Control. Transbound Emerg Dis. 2017; 64(3): 729–745.

7. Tulman E.R., Afonso C.L., Lu Z., Zsak L., Sur J.H., Sandybaev N.T., Kerembekova U.Z., Zaitsev V.L., Kutish G.F., Rock D.L. The genomes of sheeppox and goatpox viruses // Journal of Virology. – 2002. – Vol. 76. – P. 6054–6061.

8. Lamien Ch.E., Goff Ch.L., Silber R., Wallace D.B., Gulyaz V., Tuppurainen E., Madani H., Caufour P., Adami T., Harrak M.E., Luckins A.G., Albina E., Diallo A. Use of the Capripoxvirus homologue of Vaccinia virus 30 kDa RNA polymerase subunit (RPO30) gene as a novel diagnostic and genotyping target: Development of a classical PCR method to differentiate Goat poxvirus from Sheep poxvirus // Veterinary Microbiology. – 2011. – Vol.149. – P. 30–39.

9. Jepizooticheskaja situacija v Respublike Kazahstan [Epizootic situation in the Republic of Kazakhstan]. https://rel.kz/epizooticheskaya-situatsiya-v-respublike-kazahstan/.

10. Amanova Z., Zhugunissov K., Barakbayev K., Kondybaeva Z., Sametova Z., Shayakhmetov Y., Kaissenov D., Dzhekebekov K., Zhunushov A., Abduraimov Y., Zakarya K., Bulatov Y. Duration of protective immunity in sheep vaccinated with a combined vaccine against peste des petits ruminants and sheep pox // Vaccines (Basel). – 2021. – Vol. 9, No.8. – P. 912.

11. Charan J., Kantharia N.D. How to calculate sample size in animal studies? // Journal of Pharmacology and Pharmacotherapeutics. – 2013. – Vol.4, No.4. – P. 303-306.

12. Zewdie G., Derese G., Getachew B., Belay H., Akalu M. Review of sheep and goat pox disease: Current updates on epidemiology, diagnosis, prevention and control measures in Ethiopia // Animal diseases. – 2021. –Vol. 1, No.1. – P. 28.

13. World Organization for Animal Health. https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/current/chapitre_sheep_pox_goat_pox.pdf.

14. Akimova T.P. Epizooticheskaya situatsiya po ospe ovets i koz v mire [Epizootic situation of sheep pox and goat pox in the world] // Veterinarnaya mikrobiologiya, virusologiya, epizootologiya. – 2019. – Vol. 3. – P. 3-9

15. Atovullozoda R.A. Epizooticheskaya situatsiya po ospe ovets i ospe koz v Tadzhikistane v 2000–2021 gg [Epizootic situation of sheep pox and goat pox in Tajikistan in 2000–2021] // Veterinariya segodnya. – 2022. – Vol. 11, No.1. – P. 61–69.

16. Nurgaziyev R.Z. Genodiagnostika ospy ovets v Kyrgyzskoy Respubliki [Genodiagnostics of sheep pox in the Kyrgyz Republic] // Veterinarnaya meditsina. – 2015. – N.5, Vol.127. – P. 132-135

17. Sheep and goat pox – CABI: https://www.cabi.org/isc/datasheet/81537

18. Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (Kaz.Stat.). https://stat.gov.kz/official/industry/14/statistic/7

19. Sheep pox and goat pox. OIE Terrestrial manual 2018. Ch. 3.7.12. 1513-1524.

4-бөлім
ЗООЛОГИЯ

Section 4
ZOOLOGY

Раздел 4
ЗООЛОГИЯ

IRSTI 34.33.15 https://doi.org/10.26577/eb.2023.v96.i3.08

A.A. Aitzhanova

Institute of Zoology RK, Kazakhstan, Almaty
e-mail: aytzhanovaanel@gmail.com

EXTRAPOLATED DATA-BASED ANALYSIS OF TERRESTRIAL GASTROPOD DISTRIBUTION IN THE NORTHERN TIEN SHAN REGION

A considerable amount of published sources contain incomplete data, as significant knowledge about the diversity of living organisms has been accumulated in museum collections and monographic publications. Nevertheless, the problem of using already published incomplete information remains quite relevant since the monographs covers a significant part of the biological diversity and territories of the planet. In this paper, data on the findings of land mollusks in the Northern Tien Shan were compiled from existing literature. Based on these incomplete data, the distribution of terrestrial mollusks was reconstructed in the whole region. As a result species richness of gastropods in the Northern Tien Shan is not dependent on geographic locality. The study found significant similarities in the fauna of different mountain ridges, with spatial proximity being a significant factor in determining faunal similarity. The difference in the malacofauna between Ile and Kungey Alatau is likely due to the uneven representation of Kungey Alatau in previous studies. The data reconstruction method performed in the study proved to be a simple and quick approach for preliminary estimating faunistic diversity. While this method has some limitations, they can be avoided by incorporating environmental data.

Key words: Northern Tien Shan, gastropods, species distribution, extrapolation.

А.А. Айтжанова

ҚР Зоология институты, Қазақстан, Алматы қ.
e-mail: aytzhanovaanel@gmail.com

Солтүстік Тянь-Шаньдағы жерүсті бауыраяқты моллюскалардың таралуын экстраполяцияланған мәліметтер негізінде талдау

Жарияланған дереккөздердің едәуір бөлігі толық емес мәліметтерді қамтиды, өйткені тірі организмдердің әртүрлілігі туралы білімнің басым көпшілігі мұражай коллекцияларында және монографиялық басылымдарда жинақталған. Осыған қарамастан, жарияланған толық емес ақпаратты пайдалану мәселесі өте өзекті болып қала береді, өйткені олар планетаның биологиялық әртүрлілігі мен аумақтарының едәуір бөлігін сипаттайды. Осы зерттеуде Солтүстік Тянь-Шань тау жүйесінің жер бетіндегі бауыраяқты моллюскалардың табылуы туралы жарияланған әдебиет деректері пайдаланылды. Осы толық емес деректерге сүйене отырып, жер бетіндегі моллюскалардың аймақ бойынша таралуын қайта құру жүргізілді. Нәтижелер Солтүстік Тянь-Шань бауыраяқты моллюскаларының түрлік байлығы географиялық локализацияға байланысты емес екенін көрсетті. Әртүрлі тау жоталарының фаунасында айтарлықтай ұқсастықтар табылды, кеңістіктік жақындық фауна ұқсастығының маңызды анықтаушысы болды. Іле Алатауы мен Күнгей Алатау жоталарының малакофаунасының айырмашылығы бұрынғы зерттеулерде Күнгей Алатауының толық көрсетілмегендігінен болса керек. Зерттеуде фауналық әртүрлілікті алдын ала бағалау кезінде деректердің жетіспеушілігі орын алса қарапайым және жылдам әдісі болып шықты. Қоршаған орта қосымша факторлары туралы деректерді қосу арқылы осы әдістің кейбір шектеулерін болдырмауға болады.

Түйін сөздер: Солтүстік Тянь-Шань, гастроподтар, түрлердің таралуы, экстраполяция.

А.А. Айтжанова
Институт зоологии РК, Казахстан, г. Алматы
e-mail: aytzhanovaanel@gmail.com

Анализ распределения наземных брюхоногих моллюсков в Северном Тянь-Шане на основе экстраполированных данных

Значительное количество знаний о разнообразии живых организмов накоплено в музейных коллекциях и монографиях и представлено неполными, разнородными данными. Тем не менее, проблема использования уже опубликованной неполной информации остается достаточно актуальной, поскольку в них описана значительная часть биологического разнообразия и территорий планеты. В работе были использованы литературные данные о находках наземных моллюсков в Северном Тянь-Шане. На основе этих неполных данных была проведена реконструкция распределения наземных моллюсков во всем регионе. Результаты показали, что видовое богатство брюхоногих моллюсков Северного Тянь-Шаня не зависит от географической локализации. Было выявлено значительное сходство в фауне различных горных хребтов, при этом пространственная близость оказалась важным фактором, определяющим фаунистическое сходство. Разница в малакофауне между хребтами Иле Алатау и Кунгей Алатау, вероятно, связана с неполной репрезентацией Кунгей Алатау в предыдущих исследованиях. Реконструкция данных, использованная в исследовании, показала себя простым и быстрым методом для предварительной оценки фаунистического разнообразия при недостатке данных. Некоторые ограничения метода можно избежать путем включения данных о факторах среды.

Ключевые слова: Северный Тянь-Шань, брюхоногие моллюски, распределение видов, экстраполяция.

Introduction

A significant part of the information about biological diversity has been accumulated in museum collections and faunistic or floristic monographic publications [1, 2]. As a rule, such data are heterogeneous and are represented by numerous series of field collections or single records made by different methods in different seasons and for different purposes. Many of the published sources contain incomplete data on finding localities or circumstances of collection of the studied organisms. This makes it difficult to use these data. As a result, to solve ordinary research or conservation problems, it is necessary to organize new time-consuming and expensive field expeditions. The collection and fixation of new material, especially in the case of rare or protected species, can be associated with harm to the environment.

The need for a detailed description of the preliminary data and depositing them in open depositories has been emphasized many times in the specialized literature [3, 4, 5]. Nevertheless, the problem of using already published incomplete information remains quite relevant since the monographs covers a significant part of the biological diversity and territories of the planet.

In this work, I tried to reconstruct data on the spatial distribution of terrestrial gastropods of the Northern Tien Shan on the basis of incomplete literary descriptions. Based on the obtained dataset, I presented preliminary analysis of malacofaunistic complexes.

The Tien Shan is a mountain range located in Central Asia, spanning across parts of Kazakhstan, Kyrgyzstan, Uzbekistan, and China, between approximately 40° and 45° N latitude and 67° and 95° E longitude [6]. The boundaries between Tien Shan districts can be difficult to define precisely, as they often pass into each other through the valleys. The northern branch of the Tien Shan is located north of Lake Issyk-Kul and is represented by Ile Alatau (Trans-Ili Alatau, Zailiisky Alatau), Kungey Alatau, Terskey Alatau, Ketmen, and Kirghiz ridges [7]. The predominant elevation in this area is between 4000-4600 meters above sea level, making it a high-altitude mountainous region.

Gastropods are one of the most species-rich groups of animals, ubiquitous on land, in fresh and salt waters. Within the Northern Tien Shan, mollusks inhabit various types of habitats from high mountains to river gorges [8]. High interspecific diversity, dwelling in various biotopes, weak ability of mollusks to overcome geographical barriers make them a convenient model object for ecological research. Many gastropod species serve as intermediate hosts for parasitic helminths of humans and domestic animals [9].

Materials and methods

Data on the species composition and geographical distribution of terrestrial mollusks of Ile Alatau, Kungey Alatau and Terskey Alatau ridges were extracted from monograph by Shileyko and Rymzhanov [10]. The monograph reports on 194 species of terrestrial pulmonate mollusks in Kazakhstan and adjacent territories, and is based on extensive data collected by Shileyko and Rymzhanov between 1972 and 2007. However, the monograph does not provide detailed information on the collection localities of the species including geographic coordinates. Therefore, I reconstructed the missing coordinate data.

I extracted a total of 218 species record from the Northern Tien Shan region. Of these, 166 were from Ile Alatau, 37 were from Kungey Alatau, and 15 were from Terskey Alatau (Figure 1).

To conduct my analysis, I reconstructed geographic coordinates (latitude, longitude). Specimen records ranged from 42.5° to 43.7° latitude and 75.5° to 80.2° longitude.

Since each record contains only data of the presence a single species, I divided the study area into cells with a side of 0.2 degrees (in both latitude and longitude). Thus, each cell represented a quasi-habitat with its own species composition and was considered as a separate unit for analysis.

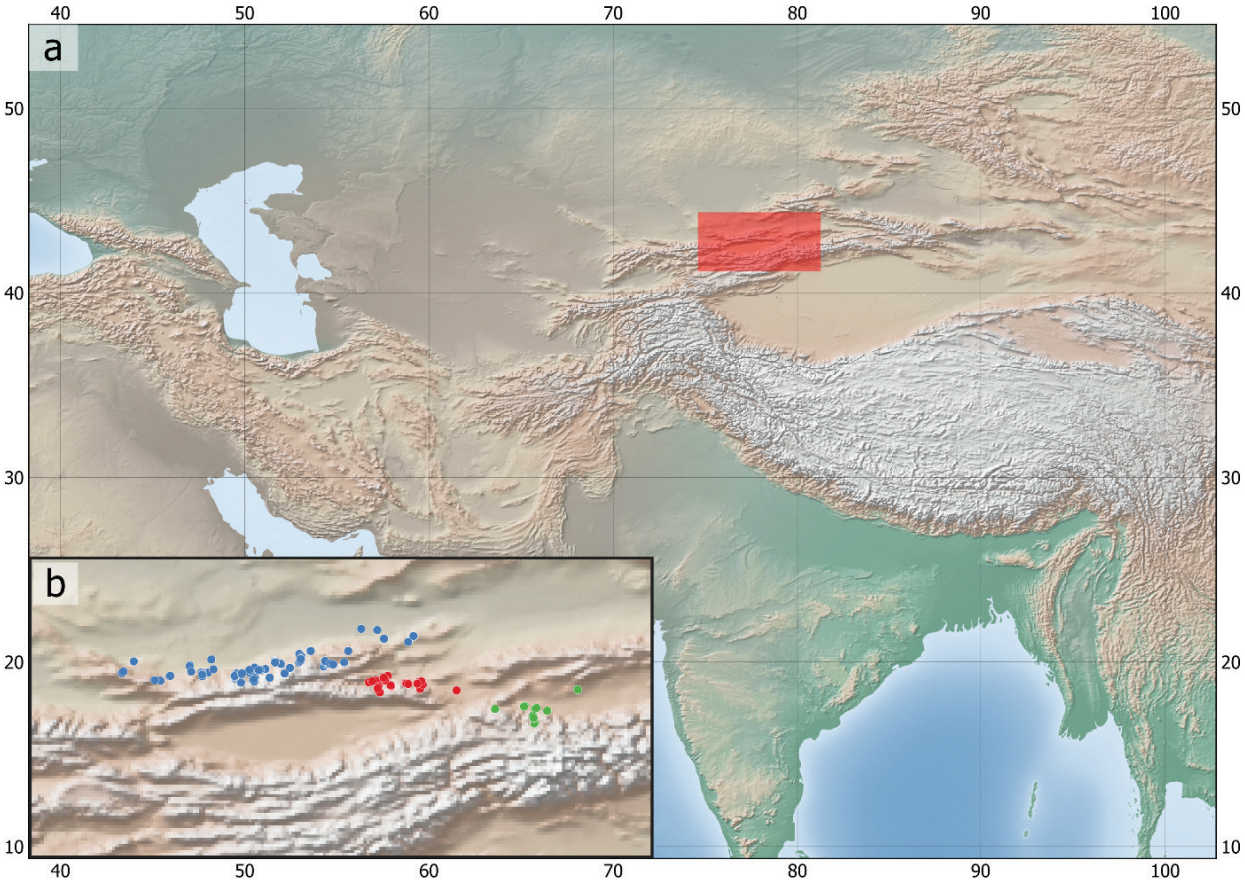


Figure 1 – Localities of reconstructed species records of the Northern Tien Shan. Different ridges are marked by colored dots: blue – Ile Alatau, red – Kungey Alatau, green – Terskey Alatau

To analyze the spatial distribution of mollusks, I used two types of data. First, data on the number of species in each cell; second, data on the species composition in each cell. To reconstruct the species composition, I assumed that the each of the observed species is distributed ubiquitously between the extreme localities. For example, if a species was only collected at 75° and 80° in longitude, I assumed it could be found at any longitude within that range. Similar reconstruction was applied to latitudinal distribution data. The main drawback of this approach is that the middle range may appear to have the rich-

est fauna. To address this, I excluded one row on each side of the overall analysis. Another flaw of the applied method was that the extrapolation zone included the territory of the adjacent Ketmen range, which was not initially included in the analysis.

I conducted a correlation analysis to examine the potential relationship between species richness and geographic longitude and latitude.

In order to evaluate the similarity of the fauna among the ranges, I employed one-way Analysis of Similarities (ANOSIM) with 100,000 bootstrap replications and constructed a dendrogram with bootstrap support of 10,000 replications using the Bray-Curtis similarity index [11]. The contribution of individual species to differences between range faunas was assessed using the Similarity Percentages Analysis (SIMPER) [12, 13].

Routine data processing was conducted using MS Excel. Classical clustering, ANOSIM and SIMPER analyses were performed in Past ver. 4.11 [14]. Maps were constructed in QGIS 3.28.2.

Results and discussion

The Northern Tien Shan was found to possess a total of 81 species and 16 families of terrestrial mollusks. The families Enidae (20 species) and Camaenidae (17 species) were the most abundant in terms of species number, while the family Pyramidulidae was the least numerous, represented only by a single species.

Out of the three ridges studied, Ile Alatau demonstrated the highest species richness with 72 species, out of which 52 are unique, that is, found within the framework of this study only there. Kungey Alatau contained 23 species, with 5 being unique to the area, whereas Terskey Alatau contained 13 species, of which 4 are unique.

The Northern Tien Shan region contains three species (*Turcomilax turkestanus* (Simroth, 1898), *Turcomilax tzvetkovi* Likharev et Wiktor, 1980, *Pseudonapaeus schnitnikovi* (Lindholm, 1922)) and 21 endemic species belonging to 8 genera (*Columella* Westerlund, 1878*, Deroceras* Rafinesque, 1820*, Pupilla* J. Fleming, 1828*, Leucozonella* Lindholm, 1927*, Macrochlamys* J. E. Gray, 1847*, Ponsadenia* Schileyko, 1978*, Pseudonapaeus* Westerlund, 1887*, Turcomilax* Simroth, 1902) [8]. Notably, some of these species are only known from their type locales.

The number of common species for Ile Alatau and Kungey Alatau ridges was 11, while only 2 species were shared between Ile Alatau and Terskey Alatau. There were no common species observed between Kungey Alatau and Terskey Alatau ridges. The total number of species presented on all three ridges was 7.

By extrapolating the data, I obtained a total of 122 cells within the study area, which was reduced to 87 after the exclusion of extreme rows (Figure 2). The number of species observed in the studied cells ranged from 1 to 36, as indicated by the varying sizes of the points on the map. The mid-range region turned out to have the highest species richness.

I found significant differences in the species composition between Kungey Alatau and Ile Alatau (ANOSIM, R=0.0498, p=0.0246), while no significant differences were observed between the Kungey and Terskey Alatau (ANOSIM, R=0.0498, p=0.3466), Ile and Terskey Alatau (ANOSIM, R=0.0498, p=0.1857). Further analysis using SIMPER revealed that the greatest contribution to the difference between Kungey and Ile Alatau ridges was made by *Cochlicopa lubricella* (Porro, 1838) – 6.5%, *Pseudonapaeus dissimilis* (E. von Martens, 1882) – 6.2%, *Truncatellina callicratis* (Scacchi, 1833) – 6.1%, *Columella edentula* (Draparnaud, 1805) – 5.4%.

Correlation analysis revealed no significant dependence of the number of species on geographic latitude (p=0.8444, R=0.1159) and longitude (p=0.6442, R=0.0993).

The dendrogram (Figure 3) of faunal similarity of the studied cells showed the presence of two groups. The Bray-Curtis similarity index between cells depends on their spatial proximity to each other, so the nearby cells in the dendrogram form clusters with a high bootstrap support.

The data reconstruction method used in the work is a simple and quick approach for estimating faunal diversity. This technique is particularly useful where data are limited, serving as a valuable tool for preliminary analyses. However, it has certain disadvantages. Firstly, the Northern Tien Shan is a mountainous region with a complex landscape, so the extrapolation remains an approximate method, and the gastropods will be distributed only in areas suitable for their ecological niches. For precise identification of mollusk distribution, the availability of environmental data such as temperature, humidity, etc. is necessary [15, 16]. Secondly, the middle ranges exhibit the highest richness of fauna.

Correlation analyses showed that gastropod species richness in Northern Tien Shan is not dependent on geographic location. Dendrogram (Fig.3) indicated that spatial proximity was a significant factor in determining faunal similarity between cells, while the distribution of species between the different ranges appeared to be roughly homogeneous.

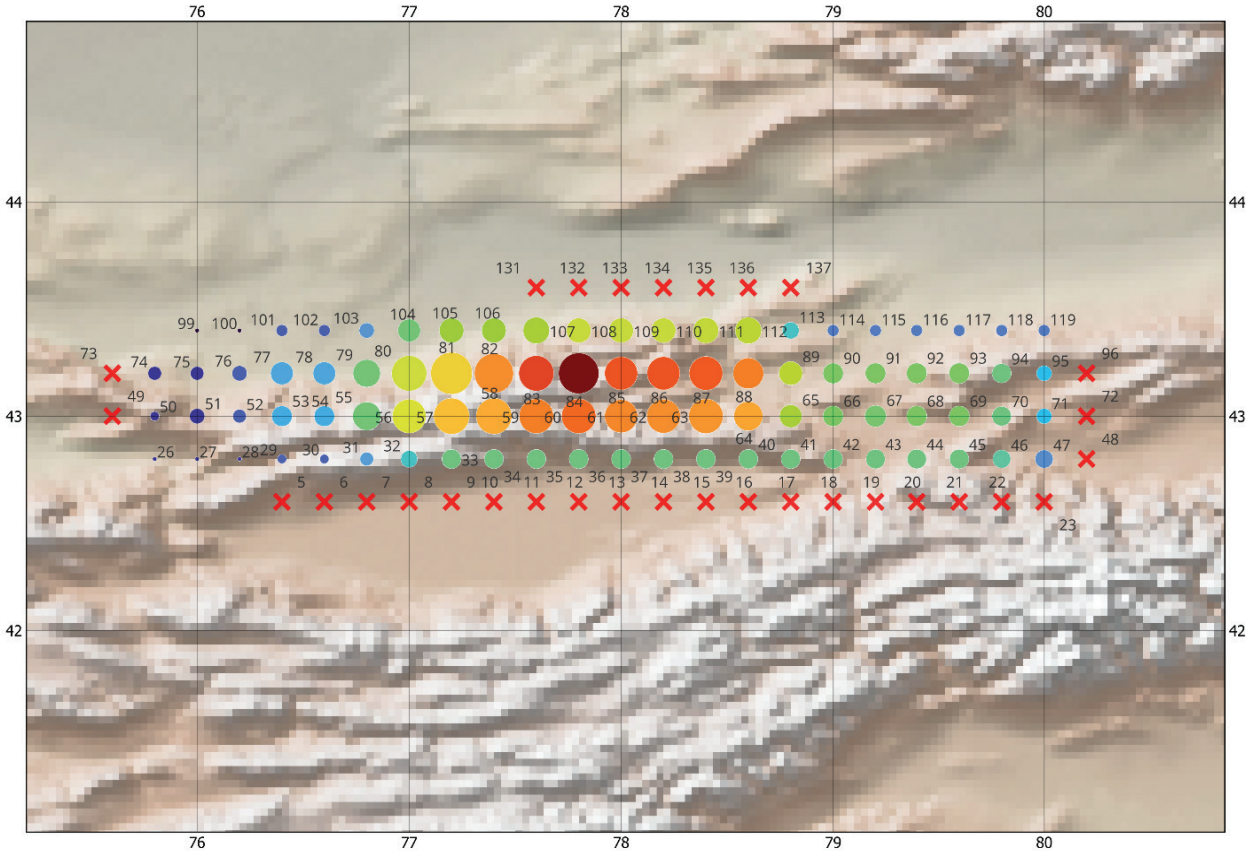


Figure 2 – Reconstructed species composition. The varying sizes of the points on the map indicate the proposed number of species in the studied cells (from 1 to 36). The cell are gradiently colored according to the similarity index to the central cell (brown).

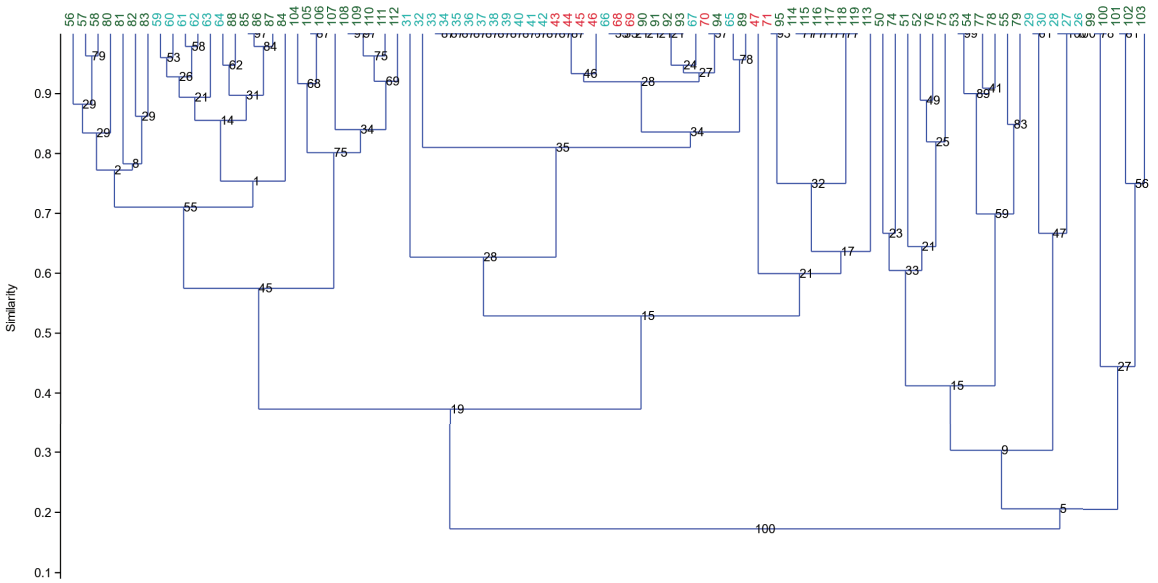


Figure 3 – Cluster dendrogram of faunistic similarity of the studied cells. Colored ordinal number of studied cell signify different ridges: green – Ile Alatau, blue – Kungey Alatau, red – Terskey Alatau. Bootstrap values are located at the nodes.

In the previous works species communities of the ridges was considered as a single entity and was not differentiated between individual ridges [17, 18, 19]. However, Assylbek et al. [20] observed a significant difference in the richness of the species composition of fungi in the Ile and Kungey Alatau. The authors explained this difference by the limited number of studies of the Kungey Alatau. In my study, I also found significant similarities in the fauna of the Kungey and Terskey Alatau, Ile and Terskey Alatau ridges. The difference observed between Ile and Kungey Alatau is likely due to the uneven representation of Kungey Alatau malacofauna in previous studies.

Conclusion

The geographic location does not affect the species richness of gastropods in the Northern Tien Shan. Also, there are significant similarities in the fauna of different mountain ridges. The difference in malacofauna between Ile and Kungey Alatau is likely due to the Kungey Alatau's uneven representation in previous studies. The performed data reconstruction method is a simple and fast approach for preliminary estimating faunistic diversity, although it has some limitations that can be overcome by incorporating environmental data.

Acknowledgements

I would like to extend my sincerest gratitude to Ivan O. Nekhaev for his guidance and editing, which greatly improved the overall quality of this work, as well as to Aidyn B. Yeszhanov for his valuable contribution to the editing process. The study was supported by Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR10965224-OT-22).

References

1. Salvador R.B. & Cunha C.M.. Natural history collections and the future legacy of ecological research. // Oecologia – 2020. – Vol. 192 – No.3 – P. 641-646.
2. Nekhaev, I. O., Merkuliev, A. V. Missing and misidentified museum specimens hinder long-term monitoring: a case study of shell-bearing gastropods from the Kola Meridian transect, Barents Sea. // Polar Research – 2021. – Vol. 40.
3. Holetschek J. et al. The ABCD of primary biodiversity data access // Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology. – 2012. – Vol. 146. – No 4. – P. 771-779.
4. Robertson T., Döring M., Guralnick R., Bloom D., Wieczorek J., Braak K., ... & Desmet, P. The GBIF integrated publishing toolkit: facilitating the efficient publishing of biodiversity data on the internet. // PloS one – 2014. – Vol 9.
5. Nekhaev I. O. Newly arrived or previously overlooked: is there evidence for climate-driven changes in the distribution of molluscs in the Barents Sea? // Biodiversity and conservation. – 2016. – Vol. 25. – P. 807-825.
6. Mazirov M.A., Vasenev I.I., Ilahun A. Agroecological, Soil And Climatic Evaluation Of The Tien Shan Mountain System // Achievements of Science and Technology of AIC. – 2013. – No 2. – P. 32-34.
7. Chupakhin V. M. Physical geography of Tien-Shan // Alma-Ata: Publishing of the Academy of Sciences of the KazSSR. – 1964.
8. Uvalieva K.K. Land Mollusks of Kazakhstan and adjacent territories – Alma-Ata: Publishing of the Academy of Sciences of the KazSSR – 1990.
9. Likharev I. M., Rammelmeier E. S. Terrestrial mollusks of the fauna of the U.S.S.R. – Geology, 1962.
10. Schileyko A.A., Rymzhanov T.S. Fauna of Land Mollusks (Gastropoda, Pulmonata Terrestria) of Kazakhstan and Adjacent Territories – Almaty – KMK Scientific Press – 2013.
11. Bray J.R., Curtis J.T. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs. – 1957. – Vol. 27 – P. 325-349.
12. Clarke, K.R. Non-parametric multivariate analysis of changes in community structure. // Australian Journal of Ecology – 1993. – Vol.18 – P. 117-143.
13. Clarke K. R., Warwick R. M. Change in marine communities // An approach to statistical analysis and interpretation. – 2001. – Vol. 2. – P. 1-68.
14. Hammer D., Harper Ø., D.A.T., and Ryan P. D. PAST: Paleontological Statistics Software Package for Education and Data Analysis // Palaeontologia Electronica – 2001. – Vol.4 – P. 9.
15. Engler R., Guisan A., Rechsteiner L. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data //Journal of applied ecology. – 2004. – Vol. 41. – No 2. – P. 263-274.

16. Guisan A., Edwards Jr T. C., Hastie T. Generalized linear and generalized additive models in studies of species distributions: setting the scene // Ecological modelling. – 2002. – Vol. 157. – No 2-3. – P. 89-100.

17. Korb S.K. A zoogeographical analysis of the vertical structure of the North Tian-Shanian butterfly fauna (Lepidoptera: Rhopalocera) and the questions of the faunagenesis in Central Asia //Caucasian Entomological Bulletin – 2012 – Vol 8 – P 273-286.

18. Otradnykh I.G. Peculiarities of distribution of highland honeysuckles of the Northern Tien Shan. // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. Biological Series. – 2009. – No 2. – P.43-46.

19. Gemejiyeva N. G. Diversity and resource potential of aromatic plants of the northern Tien Shan being promising for elaboration of domestic flavors substituting import ones // Proceedings of the XIV congress of the Russian botanical society and the conference “Botany in the modern world “ – 2018. – Vol. 2. – P. 171.

20. Assylbek A.M., Rakhimova Y.V., Yermekova B.D., Kyzmetova L.A., Jetigenova U.K., Sypabekkyzy G. Distribution of fungi of the genus Septoria in the Northern Tien Shan (Ile Alatau and Kungey Alatau, Kazakhstan) // Problems of Botany of South Siberia and Mongolia. – 2021. – Vol. 20. – No 1. – P. 36-40.

ҒТАМР 34.33.23 https://doi.org/10.26577/eb.2023.v96.i3.09

Б.І. Барбол[1*], Г.К. Сатыбалдиева[2], С.Е. Шарахметов[3, 4], М.О. Аубакирова[5], Ж.Р. Кабдолов[5], Н.М. Джусупбекова[1], А.О. Жанабергенов[2], К.К. Шупшибаев[2], А.Ш. Утарбаева[2], Ж.Б. Бекпергенова[2]

[1]Зоология институты ҒК ҒЖБМ ҚР, Қазақстан, Алматы қ.
[2]С. Сейфуллин атындағы Қазақ агротехникалық зерттеу университеті, Қазақстан, Астана қ.
[3]Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
[4]Экология мәселелері ғылыми-зерттеу институты, Қазақстан, Алматы қ.
[5]Балық шаруашылығы ғылыми-өндірістік орталығы, Қазақстан, Алматы қ.
*e-mail: bekzhan.barbol@gmail.com

СОЛТҮСТІК ҚАЗАҚСТАН СУ ҚОЙМАЛАРЫНЫҢ КӘСІПТІК БАЛЫҚТАРЫНЫҢ ПАРАЗИТОФАУНАСЫ

Паразиттік организмдер табиғи және техногендік түрлендірілген экожүйелердің ажырамас бөлігі бола отырып, физиологиядағы немесе химиялық құрамдағы өзгерістермен тіршілік ету ортасының өзгеруіне жауап беретін, қоршаған ортаға әсерді көрсететін индикаторлық түрлер ретінде қызмет ете алады. Эктопаразиттер қоршаған ортамен әртүрлі тәсілдермен әрекеттесе алатындығына байланысты қоршаған ортаның гидро- және геохимиялық фоны туралы ақпарат бере алады. Эндопаразиттер, өз кезегінде улы заттарға аз ұшырайды және бұл олардың өз ұлпаларының ішіне қоршаған орта токсиканттарын жинақтау қабілетін көрсетеді. Қоршаған ортаның жағдайы паразиттерге айтарлықтай әсер етеді, олардың популяция құрылымының сандық және сапалық көрсеткіштерін анықтайды. Осыған байланысты индикаторлық түр ретінде балық паразиттерін пайдалана отырып, Солтүстік Қазақстанның су айдындарында жоспарлы мониторингтік ихтиопаразитологиялық зерттеулер жүргізу қажеттілігі туындап отыр.

Мақалада паразиттік организмдердің 23 түрі, оның ішінде гельминттердің зоонозды 1 түрі (Raphidascaris acus) және жоғары вирулентті 2 түрі (Gyrodactylus cyprini, Schyzocotyle acheilognathi) анықталған Солтүстік Қазақстанның (Ақмола, Павлодар және Солтүстік Қазақстан облыстары) су айдындарында жүргізілген ихтиопаразитологиялық зерттеулердің нәтижелері келтірілген. Солтүстік Қазақстанның су айдындары үшін алғашқы рет Gyrodactylus cyprini, Gyrodactylus cernuae, Eudiplozoon sp., Diplostomum paraspathaceum, Diplostomum chomatophorum анықталды. Ертіс өзені суалабының Чернояр жығылмасын эргазилез паразитозы бойынша қолайсыз деп санауға болады.

Түйін сөздер: Солтүстік Қазақстан, кәсіптік балықтар, паразиттер, гельминттер, инвазиялық аурулар, паразиттік қауымдастықтар.

B.I. Barbol[1*], G.K. Satybaldiyeva[2], S.E. Sharakhmetov[3,4], M.O. Aubakirova[5], Zh.R. Kabdolov[5], N.M. Jussupbekova[1], A.O. Zhanabergenov[2], K.K. Shupshibayev[2], A.Sh. Utarbayeva[2], Zh.B. Bekpergenova[2]

[1]Institute of Zoology KS MSHE RK, Republic of Kazakhstan, Almaty
[2]S. Seifullin Kazakh Agrotechnical Research University, Kazakhstan, Astana
[3]Al-Farabi Kazakh National University, Kazakhstan, Almaty
[4]Research Institute of Ecological Problems
[5]Fisheries Research and Production Center, Kazakhstan, Almaty
*e-mail: bekzhan.barbol@gmail.com

Parasitic fauna of commercial fishes of reservoirs of Northern Kazakhstan

Parasitic organisms, being an integral part of natural and technogenically transformed ecosystems, can serve as indicator species that reflect the impact on the environment, reacting to changes in the habitat with changes in physiology or chemical composition. Ectoparasites, due to the fact that they can interact with the environment in various ways, they are able to provide information about the hydro- and geochemical background of the environment due to their presence or absence. Endoparasites, in turn, are less susceptible to toxic substances, demonstrating the ability to accumulate environmental toxicants

inside their tissues. The state of the environment has a significant impact on parasites, determining their quantitative and qualitative indicators of the population structure. In this regard, there is a need for systematic monitoring of ichthyoparasitological studies in the reservoirs of Northern Kazakhstan, using fish parasites as indicator species.

The article presents the data of ichthyoparasitological studies conducted in the reservoirs of Northern Kazakhstan (Akmola, Pavlodar and North Kazakhstan regions), as a result of which 23 species of parasitic organisms were identified, including 1 species of zoonotic (Raphidascaris acus) and 2 species of highly virulent (Gyrodactylus cyprini, Schyzocotyle acheilognathi) helminths. Gyrodactylus cyprini, Gyrodactylus cernuae, Eudiplozoon sp., Diplostomum paraspathaceum, Diplostomum chomatophorum were first established for reservoirs of northern Kazakhstan. In the backwater of the Chernoyarsk basin, the Irtysh can be considered unfavorable for ergasileous parasitosis.

Key words: North Kazakhstan, commercial fish, parasites, helminths, invasive diseases, parasitic communities.

Б.І. Барбол[1*], Г.К. Сатыбалдиева[2], С.Е. Шарахметов[3,4], М.О. Аубакирова[5], Ж.Р. Кабдолов[5], Н.М. Джусупбекова[1], А.О. Жанабергенов[2], К.К. Шупшибаев[2], А.Ш. Утарбаева[2], Ж.Б. Бекпергенова[2]

[1]Институт Зоологии КН МН РК, Казахстан, г. Алматы
[2]Казахский агротехнический исследовательский университет им. С. Сейфуллина, Казахстан, г. Астана
[3]Казахский национальный университет им. аль-Фараби, Казахстан, г. Алматы
[4]Научно-исследовательский институт проблем экологии, Казахстан, г. Алматы
[5]Научно-производственный центр рыбного хозяйство, Казахстан, г. Алматы
*e-mail: bekzhan.barbol@gmail.com

Паразитофауна промысловых рыб водоемов Северного Казахстана

Паразитические организмы, являясь неотъемлемой частью природных и техногенно-трансформированных экосистем могут служить в качестве индикаторных видов, которые отражают воздействие на окружающую среду, реагирующие на изменения среды обитания с изменениями в физиологии или химическом составе. Эктопаразиты, в силу того что могут взаимодействовать с окружающей средой различными способами способны предоставлять информацию о гидро- и геохимическом фоне окружающей среды благодаря присутствию или отсутствию. Эндопаразиты, в свою очередь, менее подвержены воздействию токсичных веществ, демонстрируя способность аккумулировать токсикантов окружающей среды внутри своих тканей. Состояние окружающей среды оказывает значительное влияние на паразитов, определяющие их количественные и качественные показатели структуры популяции. В связи с этим создается необходимость проведения планомерных мониторинговых ихтиопаразитологических исследований в водоемах Северного Казахстана, используя паразитов рыб как индикаторных видов.

В статье приведены данные проведенных ихтиопаразитологических исследований в водоемах Северного Казахстана (Акмолинская, Павлодарская и Северо-Казахстанская области), в результате которого установлено 23 видов паразитических организмов, в том числе 1 вид зоонозного (Raphidascaris acus) и 2 вида высоковирулентных (Gyrodactylus cyprini, Schyzocotyle acheilognathi) гельминтов. Для водоемов Северного Казахстана впервые установлены Gyrodactylus cyprini, Gyrodactylus cernuae, Eudiplozoon sp., Diplostomum paraspathaceum, Diplostomum chomatophorum. Затон Черноярский бассейна Иртыш можно считать неблагополучным по эргазилезному паразитозу.

Ключевые слова: Северный Казахстан, промысловые рыбы, паразиты, гельминты, инвазивные болезни, паразитические сообщества.

Кіріспе

Адамзаттың биосферадан техносфераға ауысуы көп факторлы антропогендік және техногендік прессингтің табиғи биоценоздарға, соның ішінде гидробиоценоздарға әсерінің дамуына алып келді [1, 2, 3]. Паразиттік организмдер, сол биоценоздардың жеке құрамдас бөлігі ретінде, өсімдіктер, саңырауқұлақтар мен жануарлар популяциясына басқа факторлармен әсер ететін реттеушілер әрі элиминаторлар болып табылады [4, 5]. Паразиттер, басқа биота өкілдері сияқты, антропогендік және техногендік жүктемелермен тежелуі мүмкін болғандықтан, өз кезегінде табиғи экожүйелердің жағдайын бағалау үшін индикаторлық түр ретінде қызмет ете алады [6-9].

Паразиттік организмдер санының көбеюі су объектілерінің биологиялық ластануына алып келеді. Паразиттік организмдер иелері үшін улы болып табылатын қалдықтарды шығарады, олар

иесінің ағзасына сырттан келетін химиялық токсиканттармен синергетикалық әсер етеді [10, 11, 12]. Табиғи экожүйелердегі фаунистикалық кешендердің барлық құрамдас бөліктері бір-біріне әсер ете отырып, популяциялық құрылымын реттеуші фактор ретінде әрекет етеді. Мысалы, паразиттік организмдер биоценоздың және оның алуан түрлілігінің құрамдас бөлігі ғана емес, сонымен қатар оның әртүрлі деңгейдегі процестерін көрсетеді [13]. Биоәртүрлілікті сақтау мәселелерін паразиттік организмдердің популяциясын есепке алмай шешу мүмкін емес, өйткені зооноздық инвазиялардың қоздырғыштары су және құрлық экожүйелеріндегі жануарлардың санын элиминациялау және реттеуде шешуші рөл атқарады [14-17].

Теориялық тұрғыдан, паразиттік инвазиялардың тұрақты ошақтары сирек кездеседі, өйткені олардың саны көптеген факторларға байланысты. Мысалы, табиғи және техногендік әсер ету факторлары тікелей немесе олардың облигатты аралық иелеріне паразиттердің санын реттеуге ықпал ете алады [18]. Сондықтан паразиттік қауымдастықтардың көптігі мен популяция құрылымы тұрақсыз, осыған байланысты мониторингтік зерттеулерді қажет етеді [19].

Зерттеу материалдары мен әдістері

Далалық зерттеулер гранттық жоба аясында 2022 жылдың шілде айында Ақмола, Павлодар және Солтүстік Қазақстан облыстары аумағында орналасқан кейбір суқоймалардан жиналды. Материалдар жиналған суқоймалар 1-кестеде көрсетілген.

Далалық зерттеулер барысында тұқытектестер (Cyprinidae), тарақбалықтектестер (Leuciscidae) алабұғатектестер (Percidae) және шортантектестер (Esocidae) тұқымдастарына жататын 6 балық түрінің 89 данасына толық паразитологиялық зерттеулер жүргізілді. Жиналған және өңделген материалдардың көлемі 2-кестеде ұсынылған.

1-кесте – Зерттелген суқоймалардың орындары және абиотикалық көрсеткіштері, шілде 2022 жыл

№	Суқоймалар атауы	Координаттар		Ауданы ($км^2$)	O_2 (мг/л)	pH
		ендік	бойлық			
Ақмола облысы						
1	Жалтыркөл көлі	50.995	71.836	1,60	5,6	7,71
2	Майбалық көлі	50.967	71.528	14.60	3.90	7.60
Павлодар облысы						
3	Чернояр жығылмасы	52.523	76.800	-	12,01	7.65
4	Мичурин жығылмасы	52.486	76.810	-	7,6	7.83
5	Пресное көлі	51.881	77.414	0.37	8.7	7.86
Солтүстік Қазақстан облысы						
6	Лебяжье көлі	55.149	69.187	4.80	6.58	8.6

2-кесте – Жиналған және өңделген материалдардың көлемі

№	Балық түрі	Зерттелген күні	Саны
Жалтыркөл көлі (Ақмола облысы)			
1	Сібір тортасы (*Rutilus lacustris*)	12.07.2022	3
2	Бозша мөңке (*Carassius gibelio*)	12.07.2022	10
3	Өзен алабұғасы (*Perca fluviatilis*)	12.07.2022	10
Майбалық көлі (Ақмола облысы)			
1	Сібір тортасы (*Rutilus lacustris*)	13.07.2022	5
2	Шығыс тыраны (*Abramis brama orientalis*)	13.07.2022	3
3	Бозша мөңке (*Carassius gibelio*)	13.07.2022	4

Кестенің жалғасы

№	Балық түрі	Зерттелген күні	Саны
4	Өзен алабұғасы (*Perca fluviatilis*)	13.07.2022	5
Чернояр жығылмасы (Павлодар облысы)			
1	Шортан (*Esox lucius*)	15.07.2022	2
2	Сібір тортасы (*Rutilus lacustris*)	15.07.2022	15
3	Өзен алабұғасы (*Perca fluviatilis*)	15.07.2022	5
4	Кәдімгі көксерке (*Sander lucioperca*)	15.07.2022	2
Мичурин жығылмасы (Павлодар облысы)			
1	Шортан (*Esox lucius*)	16.07.2022	5
2	Сібір тортасы (*Rutilus lacustris*)	16.07.2022	5
Пресное көлі (Павлодар облысы)			
1	Бозша мөңке (*Carassius gibelio*)	17.07.2022	10
Лебяжье көлі (Солтүстік Қазақстан облысы)			
1	Бозша мөңке (*Carassius gibelio*)	18.07.2022	5
Барлығы:			89

Балықтардың паразитологиялық сойып-зерттеу Е.И.Быховская-Павловская модификациясындағы классикалық стандартты әдістер бойынша жүргізілді [20]. Паразитологиялық материалды жинау және бекіту Дж.Л.Джастиннің ұсынған әдістеме көмегімен жасалды [21]. Жиналған паразиттер КСРО тұщы су балықтарының паразиттерінің 3 томдық анықтауышы көмегімен анықталды [22, 23, 24].

Анықталған паразиттердің түрлік құрамының кездесу жиілігі және олардың сәйкестігі бойынша алғашқы өңдеу жұмыстары MS Excel 2016 бағдарламасымен өңделді. Паразитофаунаның түрлік құрамының ұқсастығы және басты компоненттер талдауы Past 4,07 статистикалық бағдарлама қолданбасы көмегімен жүзеге асырылды [25].

Зерттеу нәтижелері мен талқылау

Жалтыркөл көлінің паразиттік гельминттерінің фаунасы тек моногенетикалық және дигенетикалық сорғыштардан тұрады және де түрлер құрамы өте аз. 3-кестеде көріп отырғанымыздай, Жалтыркөл көлінен ауланған сібір тортасының инвазиялану экстенсивтілігі 100%, инвазия қарқындылығы 2-ден 7 данаға дейін, ал қаратеңбіл ауруының қоздырғыштары *Posthodiplostomum cuticola* басым гельминттермен ластанған. Жалтыркөл көліндегі эпизоотиялық жағдайды фондық деп бағалауға болады, өйткені балық ағзасында анықталған гельминттердің қамту индексі жоғары емес.

Майбалық көлінің балықтарының паразиттік гельминттер фаунасы жалпақ құрттардың 3 класына жататын 8 түрден тұрады: моногенетикалық сорғыштар (*Monogenea*), дигенетикалық сорғыштар (*Digenea*) және таспа құрттар (*Cestoda*) (4-кесте).

Ертіс өзенінің Чернояр жығылмасында гельминттерден басқа, балықтарда паразиттік ескекаяқты шаян *Ergasilus sieboldi* анықталды. Жүргізілген ихтиопаразитологиялық нәтижелеріне сүйене отырып эргазилез бойынша эпизоотиялық жағдайын қолайсыз деп санауға болады. Сондай-ақ 5-кестеде көрсетілгендей, шортанның жалғыз данасында зоонозды деп саналатын *Raphidascaris acus* анықталды.

6-кестеде көрсетілгендей, Ертіс өзені суалабы Мичурин жығылмасында паразиттік организмдерінің түрлік алуантүрлілігі өте аз, ал эпизоотиялық жағдай фондық болып саналады.

Пресное көлінде (Павлодар облысы) әртүрлі жастағы 10 дана бозша мөңкеге толық паразитологиялық зеттеулер жүргізіліп, нәтижесінде паразиттік гельминттердің 8 түрі анықталды. Зерттеу барысында зоонозды гельминтоздың қоздырғыштары табылған жоқ. Барлық анықталған гельминттер моногенетикалық және дигенетикалық сорғыштарға жатады, соның ішінде *Gyrodactylus cyprini* жоғары вирулентті, ол тұқытектес балықтардың түрлерінің жас даралары-ның жаппай қырылуына алып келуі мүмкін (7-кесте).

3-кесте – Жалтыркөл көлінің балықтарының паразитофаунасы, шілде 2022 жыл

Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Сібір тортасы						
Diplostomum spathaceum	3	1	33,33%	2 (2)	2	0,67
Tylodelphys clavata	3	1	33,33%	2 (2)	2	0,67
Posthodiplostomum cuticola	3	2	66,66%	3-7 (5)	10	3,33
Барлығы	3	3	100%	2-7 (4,5)	14	4,67
Бозша мөңке						
Dactylogyrus wunderi	10	2	20%	2 (2)	4	0,4
Dactylogyrus zandti	10	2	20%	5 (5)	10	1
Diplostomum paraspathaceum	10	2	20%	4-5 (4,5)	9	0,9
Tylodelphys clavata	10	1	20%	2 (2)	2	0,2
Барлығы	10	4	40%	2-5 (6,25)	25	2,5
Өзен алабұғасы						
Gyrodactylus sp.	10	1	10%	7 (7)	7	0,7
Diplostomum chomatophorum	10	2	20%	2-4 (3)	6	0,6
Барлығы	10	3	30%	2-7 (4,33)	13	1,3
Ескертулер: *ЗБС – зерттелген балық саны, ЗДС – зарарланған даралар саны, ИЭ – инвазиялану экстенсивтілігі, ИҚ – инвазиялану қарқындылығы, ИҚОҚ – инвазиялану қарқындылығының орташа көрсеткіші, ПЖС – паразиттердің жалпы саны, ҚИ – қамту индексі.						

4-кесте – Майбалық көліндегі балықтардың паразитофаунасы, шілде 2022 жыл

Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Шығыс табаны						
Dactylogyrus wunderi	3	2	66,67%	3-5 (4)	8	2,67
Dactylogyrus zandti	3	1	33,33%	5 (5)	5	1,67
Diplostomum spathaceum	3	2	66,67%	4-12 (8)	16	5,33
Барлығы	3	2	66,67%	3-13 (14,5)	29	9,67
Сібір тортасы						
Dactylogyrus rutili	5	1	20%	11 (11)	11	2,2
Gyrodactylus longiradix	5	1	20%	2 (2)	2	0,4
Schyzocotyle acheilognathi	5	1	20%	1 (1)	1	0,2
Tylodelphys clavata	5	1	20%	2 (2)	2	0,4
Барлығы	5	3	60%	1-11 (5,33)	16	3,2
Бозша мөңке						
Dactylogyrus wunderi	4	1	25%	3 (3)	3	0,75
Schyzocotyle acheilognathi	4	1	25%	7 (7)	7	1,75
Diplostomum paraspathaceum	4	1	25%	6 (6)	6	1,5
Tylodelphys clavata	4	1	25%	12 (12)	12	3
Барлығы	4	2	50%	3-12 (14)	28	6
Өзен алабұғасы						
Ancyrocephalus paradoxus	5	1	20%	3	3	0,6
Tylodelphys clavata	5	2	40%	2-14	16	3,2
Барлығы	5	2	40%	2-14	19	3,8

5-кесте – Чернояр жығылмасы балықтарының паразитофаунасы, шілде 2022 жыл

Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Шортан						
Raphidascaris acus	2	1	50%	1 (1)	1	0,5
Ergasilus sieboldi	2	2	100%	7-11 (9)	18	9
Барлығы	2	2	100%	1-11 (9,5)	19	9,5
Сібір тортасы						
Gyrodactylus sp.	15	2	13,33%	7-28 (17,5)	35	2,33
Diplozoon paradoxum	15	1	6,67%	3 (3)	3	0,2
Diplostomum helveticum	15	1	6,67%	14 (14)	14	0,93
Diplostomum spathaceum	15	3	20%	2-10 (4,67)	14	0.93
Diplostomum paraspathaceum	15	2	13,33%	4-18 (11)	22	1,47
Camallanus lacustris	15	4	26,67%	1-11 (4)	16	1,07
Ergasilus sieboldi	15	2	13,33%	1-18 (9,5)	19	1,27
Барлығы	15	8	53,33%	1-28 (15,38)	123	8,2
Өзен алабұғасы						
Diplostomum chomatophorum	5	1	20%	18 (18)	18	3,6
Tylodelphys clavata	5	2	40%	2 (2)	4	0,8
Ergasilus sieboldi	5	1	20%	3 (3)	3	0,6
Барлығы	5	3	60%	2-18 (8,33)	25	5
Кәдімгі көксерке						
Diplostomum chomatophorum	2	2	100%	2-6 (4)	8	4
Ergasilus sieboldi	2	1	50%	2 (2)	2	1
Барлығы	2	2	100%	2-6 (5)	10	5

6-кесте – Мичурин жығылмасы балықтарының паразитофаунасы, шілде 2022 жыл

Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Шортан						
Tetraonchus monenteron	5	1	20%	2	2	0.4
Tylodelphys clavata	5	2	20%	32	32	6,4
Ergasilus sieboldi	5	1	20%	1	1	0,5
Барлығы	5	3	60%	1-32 (11,33)	34	6,8
Сібір тортасы						
Eudiplozoon sp.	5	2	40%	3-5 (4)	8	1,6
Diplozoon paradoxum	5	2	40%	4-5 (4,5)	9	1,8
Tylodelphys clavata	5	2	40%	2 (2)	4	0,8
Camallanus lacustris	5	1	20%	1 (1)	1	0,2
Барлығы	5	5	100%	1-5 (4,4)	22	4,4

7-кесте – Пресное көлінің балықтарының паразитофаунасы, шілде 2022 жыл

Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Бозша мөңке						
Dactylogyrus crucifer	10	1	10%	26 (26)	26	2.6
Gyrodactylus cyprini	10	2	20%	7-16 (12,5)	23	2,3
Gyrodactylus cernuae	10	1	10%	1 (1)	1	0,1
Eudiplozoon sp.	10	1	10%	1 (1)	1	0,1
Diplozoon paradoxum	10	1	10%	6 (6)	6	0,6
Diplostomum spathaceum	10	1	10%	12 (12)	12	1,2
Tylodelphys clavata	10	1	10%	12 (12)	12	1,2
Ichthyocotylurus pileatus	10	1	10%	3 (3)	8	0,8
	10	4	40%	1-27 (8)	32	3,2
Барлығы	10	8	80%	1-27 (15,13)	121	12,1

Лебяжье көлінде толық паразитологиялық зерттеуден өткен барлық 5 бозша мөңкеде паразиттік гельминттердің әртүрлі түрлерімен инвазияланған (8-кесте).

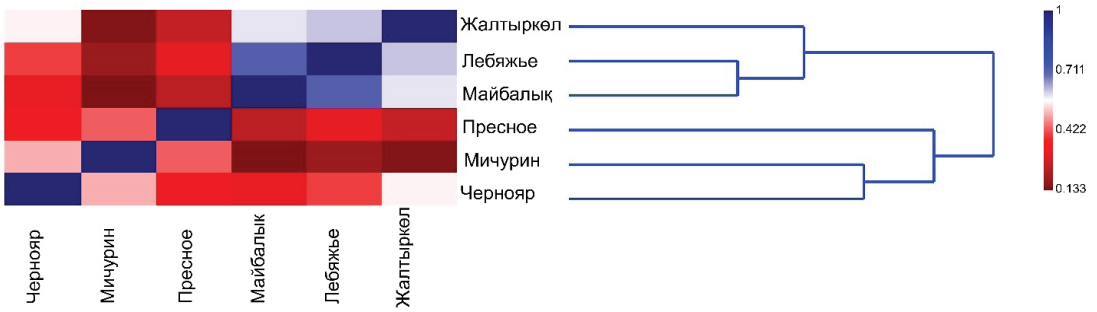
Өзен алабұғасында *Ancyrocephalus paradoxus* анықталды, ол бұрын кәдімгі көксеркенің қатаң спецификалық паразиті болып саналған, алайда қазіргі уақытта оның осы түрге ғана тән екендігіне күмән туындап отыр [26]. Сібір тортасы мен бозша мөңкеден жоғары вирулентті азиялық балық таспасы (*Schyzocotyle acheilognathi*) анықталды, бұл гельминт түрімен Оңтүстік және Оңтүстік-Шығыс Қазақстанның су айдындарындағы эпизоотиялық ушығу жағдай жалғасуда.

8-кесте – Лебяжье көлінің балықтарының паразитофаунасы, шілде 2022 жыл

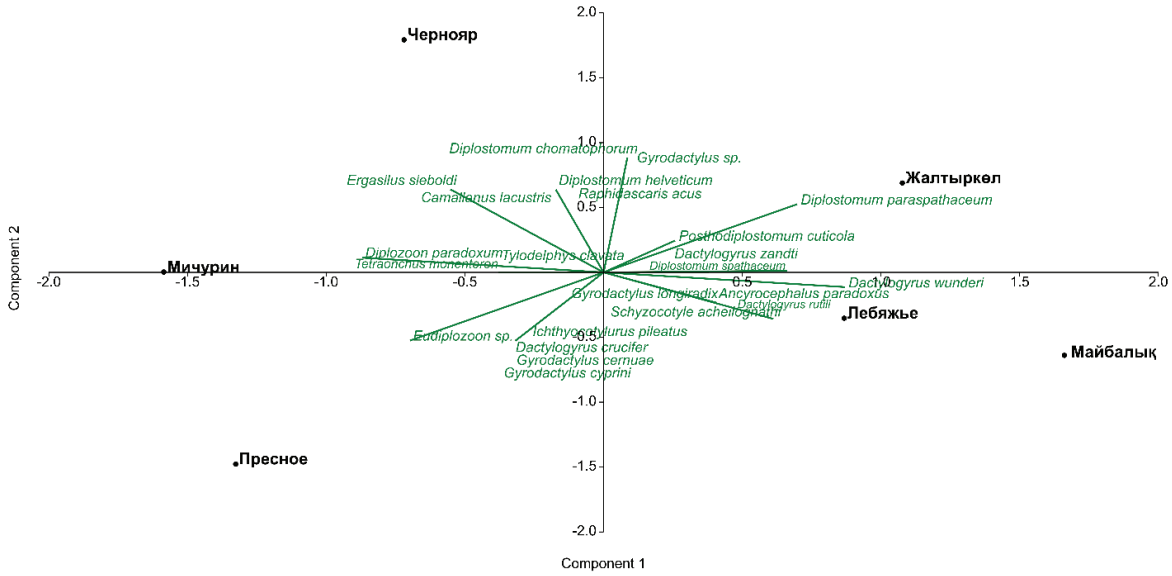
Паразит түрі	ЗБС	ЗДС	ИЭ	ИҚ (ИҚОК)	ПЖС	ҚИ
Бозша мөңке						
Dactylogyrus wunderi	5	2	40%	1-3 (2)	4	0,8
Schyzocotyle acheilognathi	5	4	80%	1-3 (1,5)	6	1,2
Diplostomum spathaceum	5	1	20%	16 (16)	16	3,2
Diplostomum paraspathaceum	5	1	20%	18 (18)	18	3,6
Tylodelphys clavata	5	2	40%	2-8	10	2
Барлығы	5	5	100%	1-18 (10,8)	54	10,8

Серенсен индексі бойынша жүргізілген кластерлік талдауға сәйкес суқоймалардың паразитофаунасының ұқсастығы 0,133-тен 0,714-ге дейінгі мәнді құрады. Құрастырылған кластерлік талдау нәтижесінде шартты түрде 2 топқа жіктелгендігін байқауға болады. Бірінші топта Ақмола (Жалтыркөл мен Майбалық) және Солтүстік Қазақстан (Лебяжье) облыстарының көлдерін біріктірсе, ал екінші топ Павлодар облысының суқоймаларымен ерекшеленді (1-сурет).

Жалпы зерттелген суқоймаларда паразиттердің түрлік құрамы 5-10 түр аралығында кездесіп отырды. Тіркелген паразиттердің суқоймаларда кездесу жиілігі бойынша келесідей түрлер ерекшеленді: *Tylodelphys clavata* (6) *Diplostomum spathaceum* (5) *Diplostomum paraspathaceum* (4). Басты компоненттер талдауы нәтижелеріне сәйкес тіркелген паразиттік ағзалардың суқоймалар бойынша таралуы 2-суретте көрсетілген. Бірінші компонент бойынша оң жүктеме Майбалық көліне түссе, теріс жүктеме Мичурин және Чернояр жығылмаларына түсті. Себебі *Ancyrocephalus paradoxus, Dactylogyrus rutili, Gyrodactylus longiradix* паразиттер Майбалық көлінде ғана тіркелсе, ал *Camallanus lacustris* және *Ergasilus sieboldi* Мичурин және Чернояр жығылмаларында кездесетін балықтарының негізгі паразиттері болып табылады.



1-сурет – Зерттелген суқоймалардың паразитофаунасы түрлік құрамының ұқсастығы (Серенсен бойынша)



2-сурет – Зерттелген суқоймалардың паразитофаунасы түрлік құрамының басты компоненттер талдауы

Далалық зерттеулер барысында диплостомидтердің бірінші аралық иелері болып табылатын, *Lymnaeidae* тұқымдасына жататын үлкен бөген ұлуының (*Lymnaea stagnalis*) жоғары биомассасы анықталып отыр. Осыған байланысты, бұл су айдынында әртүрлі эпизоотологиялық деңгейдегі балықтар көз трематодоздарының табиғи ошақтары шоғырланған [27].

Қорытынды

2022 жылдың шілде айында суқоймаларға жүргізілген ихтиопаразитологиялық зерттеулер нәтижесінде түрге дейін 21, туысқа дейін 2 паразиттік организмдер анықталды. Оның ішінде 1 түрі зоонозды (*Raphidascaris acus*) және 2 түрі (*Gyrodactylus cyprini*, *Schyzocotyle acheilognathi*) жоғары вирулентті гельминттер болып табылады. Солтүстік Қазақстанның су айдындары үшін алғаш рет *Gyrodactylus cyprini*, *Gyrodactylus cernuae*, *Eudiplozoon sp., Diplostomum paraspathaceum* және *Diplostomum chomatophorum* түрлері тіркелді. Ертіс өзені суалабы Чернояр жығылмасы эргазилез бойынша қолайсыз деп санауға болады.

Алғыс

Ғылыми зерттеу жұмыстары Қазақстан Республикасы Қазақстан Республикасы Ғылым және жоғары білім министрлігі 2021-2023 жылдарға арналған гранттық қаржыландыру шеңберінде AP09259969 «Солтүстік Қазақстан су қоймаларының экологиялық мониторингі» жобасы аясында жүргізілді.

Әдебиеттер

1. McCallister S.L., Ishikawa N.F., Kothawala D.N. Biogeochemical tools for characterizing organic carbon in inland aquatic ecosystems // Limnology and Oceanography Letters. – 2018. – N 3 (6). – P. 444–457. https://doi.org/10.1002/lol2.10097
2. Kansara K., Bolan S., Radhakrishnan D. A critical review on the role of abiotic factors on the transformation, environmental identity and toxicity of engineered nanomaterials in aquatic environment // Environ Pollut. – 2022. – Vol. 296. – P. 1–14. https://doi.org/10.1016/j.envpol.2021.118726
3. Киян В.С., Смагулова А.М., Катохин А.В. Меторхоз в Северном Казахстане: состояние изученности и распространение //Вестник КазНУ. Серия биологическая. – 2019. – №3. – С. 170–179.
4. Пугачев О.Н. Паразиты пресноводных рыб Северной Азии (фауна, экология паразитарных сообществ, зоогеография) // Автореферат дисс. … док. биол. наук. – Санкт-Петербург, 1999. – 42 с.
5. Scott M.E., Dobson A. The role of parasites in regulating host abundance // Parasitology Today. – 1989. – N 5 (6). – P. 176–183. https://doi.org/10.1016/0169-4758(89)90140-3
6. David J. Rapport; On the transformation from healthy to degraded aquatic ecosystems // Aquatic Ecosystem Health & Management. – 1999; – N 2 (2). – P 97–103. https://doi.org/10.1080/14634989908656945
7. Valenzuela-Sa´nchez A., Schmidt B.R., Uribe-Rivera D.E., Costas F., Cunningham A.A., Soto-Azat C. Cryptic disease-induced mortality may cause host extinction in an apparently stable host – parasite system // Proceedings of the Royal Society B: Biological Sciences. – 2017. – Vol. 284. – P. 1–8. http://dx.doi.org/10.1098/rspb.2017.1176
8. Kiyan V.S., Bulashev A.K., Katokhin A.V. *Opisthorchis felineus* and *Metorchis bilis* Metacercariae in Cyprinid Fish Leuciscus idus in Nura-Sarysu River, Kazakhstan. // Korean J Parasitol. – 2018. – Vol. 56. – N 3. – P. 267–274
9. Vidal-Martinez V.M., Pech D., Sures B., Purucker S.T., Poulin R. Can parasites really reveal environmental impact? // Trends of parasitology. – 2010. – Volume 26. – N 1. – P. 44–51. https://doi.org/10.1016/j.pt.2009.11.001
10. Kennedy C. The ecology of parasites of freshwater fishes: The search for patterns // Parasitology. – 2009. – N 12 (136). – P. 1653–1662. https://doi.org/10.1017/S0031182009005794
11. Abdusamadov A.S., Musayev P.G., Grigorian O.P., Barkhalov R.M., Akhmayev E.A., Taibov P.S. Perspective directions of the fishing development in Tersko-Caspian fish industrial subregion // South of Russia: ecology, development. – 2014. – N 3. – P. 36–43. https://doi.org/10.18470/1992-1098-2014-3-36-43
12. Sures B. Environmental parasitology: relevancy of parasites in monitoring environmental pollution // Trends in parasitology. – 2004. – Vol. 20. – N 4. – P. 170–177. https://doi.org/10.1016/j.pt.2004.01.014
13. Mijošek T. et al. Efficiency of metal bioaccumulation in acanthocephalans, gammarids and fish in relation to metal exposure conditions in a karst freshwater ecosystem //Journal of Trace Elements in Medicine and Biology. – 2022. – Vol. 73. – P. 1–9. https://doi.org/10.1016/j.jtemb.2022.127037
14. Stout L., Garenne A., de Montaudouin X. Marine trematode parasites as indicators of environmental changes // Ecological Indicators. – 2022. – Vol. 141. – P. 1–11. https://doi.org/10.1016/j.ecolind.2022.109089
15. El-lamie M., Abdel-Mawla H. I. Investigation of *Acanthocephalan* parasites in some marine fishes as a bio-indicator for heavy metals pollution // Egyptian Journal for Aquaculture. – 2018. – Vol. 8. – N 1. – P. 13–30. https://doi.org/10.21608/EJA.2018.68355
16. Yurlova N.I., Yadrenkina E.N., Rastyazhenko N.M., Serbina E.A., Glupov V.V. Opisthorchiasis in Western Siberia: Epidemiology and distribution in human, fish, snail, and animal populations // Parasitol Int. – 2017. – Vol. 66. – N 4. – P. 355–364.
17. Жумабекова Б.К. Паразиты рыб Казахстанского Прииртышья. Автореферат дисс. … док. биол. наук. – Алматы, 2009. 38 с.
18. Sultanov A., Abdybekova A., Abdibaeva A., Shapiyeva Z., Yeshmuratov T., Torgerson, P.R. Epidemiology of fishborne trematodiasis in Kazakhstan //Acta Tropica. – 2014. – N 138. – P. 60–66. https://doi.org/10.1016/j.actatropica.2014.04.030
19. Valtonen E., Pulkkinen K., Poulin R., Julkunen M. The structure of parasite component communities in brackish water fishes of the northeastern Baltic Sea // Parasitology. – 2001. – N 4 (112). – P. 471–481. https://doi.org/10.1017/S0031182001007491
20. Быховская-Павловская И.Е. Паразиты рыб: руководство по изучению. – Л.: Наука, 1985. – 121 с.
21. Justine J.L., Briand M.J., Bray, R.A. A quick and simple method, usable in the field, for collecting parasites in suitable condition for both morphological and molecular studies // Parasitol Research. – 2012. N 111. – P. 341–351. https://doi.org/10.1007/s00436-012-2845-6
22. Определитель паразитов пресноводных рыб фауны СССР. Т.1. / под ред. С.С. Шульмана. – Л.: Наука, 1984. – 431 с.
23. Определитель паразитов пресноводных рыб фауны СССР. Т.2. / под ред. А.В. Гусева. – Л.: Наука, 1985. – 425 с.
24. Определитель паразитов пресноводных рыб фауны СССР. Т.3. / под ред. О.Н. Бауера. – Л.: Наука, 1987. – 583 с.
25. Hammer Ø., Harper D. A., Ryan P. D. PAST: Paleontological statistics software package for education and data analysis // Palaeontologia Electronica. – 2001. – Т. 4. – №. 1. – С. 9.
26. Behrmann-Godel J., Roch S., Brinker A. Gill worm Ancyrocephalus percae (Ergens 1966) outbreak negatively impacts the Eurasian perch Perca fluviatilis L. stock of Lake Constance, Germany. – 2014. 37(10). – P. 925-930. https://doi.org/10.1111/jfd.1217
27. Niewiadomska K. Verification of the life-cycles of Diplostomum spathaceum (Rudolphi, 1819) and D. pseudospathaceum Niewiadomska, 1984 (Trematoda, Diplostomidae) //Systematic Parasitology. – 1986. – Т. 8. – №. 1. – С. 23-31. https://doi.org/10.1007/BF00010306

References

1. McCallister S.L., Ishikawa N.F., Kothawala D.N. Biogeochemical tools for characterizing organic carbon in inland aquatic ecosystems // Limnology and Oceanography Letters. – 2018. – N 3 (6). – P. 444–457. https://doi.org/10.1002/lol2.10097
2. Kansara K., Bolan S., Radhakrishnan D. A critical review on the role of abiotic factors on the transformation, environmental identity and toxicity of engineered nanomaterials in aquatic environment // Environ Pollut. – 2022. – Vol. 296. – P. 1–14. https://doi.org/10.1016/j.envpol.2021.118726
3. Kiyan V.S., Smagulova A.M., Katohin A.V. Metorhoz v Severnom Kazahstane: sostoyanie izuchennosti i rasprostranenie //Vestnik KazNU. Seriya biologicheskaya. – 2019. – №3. – S. 170–179.
4. Pugachev O.N. Parazity presnovodnyh ryb Severnoj Azii (fauna, ekologiya parazitarnyh soobshchestv, zoogeografiya) // Avtoreferat diss. … dok. biol. nauk. – Sankt-Peterburg, 1999. – 42 s.
5. Scott M.E., Dobson A. The role of parasites in regulating host abundance // Parasitology Today. – 1989. – N 5 (6). – P. 176–183. https://doi.org/10.1016/0169-4758(89)90140-3
6. David J. Rapport; On the transformation from healthy to degraded aquatic ecosystems // Aquatic Ecosystem Health & Management. – 1999; – N 2 (2). – P 97–103. https://doi.org/10.1080/14634989908656945
7. Valenzuela-Sa´nchez A., Schmidt B.R., Uribe-Rivera D.E., Costas F., Cunningham A.A., Soto-Azat C. Cryptic disease-induced mortality may cause host extinction in an apparently stable host – parasite system // Proceedings of the Royal Society B: Biological Sciences. – 2017. – Vol. 284. – P. 1–8. http://dx.doi.org/10.1098/rspb.2017.1176
8. Kiyan V.S., Bulashev A.K., Katokhin A.V. *Opisthorchis felineus* and *Metorchis bilis* Metacercariae in Cyprinid Fish Leuciscus idus in Nura-Sarysu River, Kazakhstan. // Korean J Parasitol. – 2018. – Vol. 56. – N 3. – P. 267–274
9. Vidal-Martinez V.M., Pech D., Sures B., Purucker S.T., Poulin R. Can parasites really reveal environmental impact? // Trends of parasitology. – 2010. – Volume 26. – N 1. – P. 44–51. https://doi.org/10.1016/j.pt.2009.11.001
10. Kennedy C. The ecology of parasites of freshwater fishes: The search for patterns // Parasitology. – 2009. – N 12 (136). – P. 1653–1662. https://doi.org/10.1017/S0031182009005794
11. Abdusamadov A.S., Musayev P.G., Grigorian O.P., Barkhalov R.M., Akhmayev E.A., Taibov P.S. Perspective directions of the fishing development in Tersko-Caspian fish industrial subregion // South of Russia: ecology, development. – 2014. – N 3. – P. 36–43. https://doi.org/10.18470/1992-1098-2014-3-36-43
12. Sures B. Environmental parasitology: relevancy of parasites in monitoring environmental pollution // Trends in parasitology. – 2004. – Vol. 20. – N 4. – P. 170–177. https://doi.org/10.1016/j.pt.2004.01.014
13. Mijošek T. et al. Efficiency of metal bioaccumulation in acanthocephalans, gammarids and fish in relation to metal exposure conditions in a karst freshwater ecosystem //Journal of Trace Elements in Medicine and Biology. – 2022. – Vol. 73. – P. 1–9. https://doi.org/10.1016/j.jtemb.2022.127037
14. Stout L., Garenne A., de Montaudouin X. Marine trematode parasites as indicators of environmental changes // Ecological Indicators. – 2022. – Vol. 141. – P. 1–11. https://doi.org/10.1016/j.ecolind.2022.109089
15. El-lamie M., Abdel-Mawla H. I. Investigation of *Acanthocephalan* parasites in some marine fishes as a bio-indicator for heavy metals pollution // Egyptian Journal for Aquaculture. – 2018. – Vol. 8. – N 1. – P. 13–30. https://doi.org/10.21608/EJA.2018.68355
16. Yurlova N.I., Yadrenkina E.N., Rastyazhenko N.M., Serbina E.A., Glupov V.V. Opisthorchiasis in Western Siberia: Epidemiology and distribution in human, fish, snail, and animal populations // Parasitol Int. – 2017. – Vol. 66. – N 4. – P. 355–364.
17. Zhumabekova B.K. Parazity ryb Kazahstanskogo Priirtysh'ya. Avtoreferat diss. … dok. biol. nauk. – Almaty, 2009. 38 s.
18. Sultanov A., Abdybekova A., Abdibaeva A., Shapiyeva Z., Yeshmuratov T., Torgerson, P.R. Epidemiology of fishborne trematodiasis in Kazakhstan //Acta Tropica. – 2014. – N 138. – P. 60–66. https://doi.org/10.1016/j.actatropica.2014.04.030
19. Valtonen E., Pulkkinen K., Poulin R., Julkunen M. The structure of parasite component communities in brackish water fishes of the northeastern Baltic Sea // Parasitology. – 2001. – N 4 (112). – P. 471–481. https://doi.org/10.1017/S0031182001007491
20. Быховская-Павловская И.Е. Паразиты рыб: руководство по изучению. – Л.: Наука, 1985. – 121 с.
21. Justine J.L., Briand M.J., Bray, R.A. A quick and simple method, usable in the field, for collecting parasites in suitable condition for both morphological and molecular studies // Parasitol Research. – 2012. N 111. – P. 341–351. https://doi.org/10.1007/s00436-012-2845-6
22. Opredelitel' parazitov presnovodnyh ryb fauny SSSR. T.1. / pod red. S.S. SHul'mana. – L.: Nauka, 1984. – 431 s.
23. Opredelitel' parazitov presnovodnyh ryb fauny SSSR. T.2. / pod red. A.V. Guseva. – L.: Nauka, 1985. – 425 s.
24. Opredelitel' parazitov presnovodnyh ryb fauny SSSR. T.3. / pod red. O.N. Bauera. – L.: Nauka, 1987. – 583 s.
25. Hammer Ø., Harper D. A., Ryan P. D. PAST: Paleontological statistics software package for education and data analysis // Palaeontologia Electronica. – 2001. – T. 4. – №. 1. – C. 9.
26. Behrmann-Godel J., Roch S., Brinker A. Gill worm Ancyrocephalus percae (Ergens 1966) outbreak negatively impacts the Eurasian perch Perca fluviatilis L. stock of Lake Constance, Germany. – 2014. 37(10). – P. 925-930. https://doi.org/10.1111/jfd.1217
27. Niewiadomska K. Verification of the life-cycles of Diplostomum spathaceum (Rudolphi, 1819) and D. pseudospathaceum Niewiadomska, 1984 (Trematoda, Diplostomidae) //Systematic Parasitology. – 1986. – T. 8. – №. 1. – C. 23-31. https://doi.org/10.1007/BF00010306

МРНТИ 69.25.13 https://doi.org/10.26577/eb.2023.v96.i3.010

Н.Б. Булавина[1], Г.М. Маратова[2*], С.Ж. Асылбекова[1], К.Б. Исбеков[1]

[1]Научно-производственный центр рыбного хозяйства, Казахстан, г. Алматы
[2]Казахский национальный аграрный исследовательский университет, Казахстан, г. Алматы
*e-mail. guldana.maratova.91@mail.ru

ОЦЕНКА АДАПТАЦИОННЫХ КАЧЕСТВ МОЛОДИ ОСЕТРОВЫХ РЫБ ПО РЕАКЦИЯМ ЦЕНТРАЛЬНОЙ НЕРВНОЙ СИСТЕМЫ

В статье приведены данные по оценке адаптационных качеств молоди осетровых рыб по реакциям центральной нервной системы при помощи теста «открытое поле». Применяемый тест позволяет оценить выраженность и динамику поведенческих реакций у молоди осетровых рыб в стрессогенных условиях. Тест проводили как индивидуально, так и в группе по несколько особей. Наиболее приемлемым вариантом оказалась группа из пяти особей любого вида осетровых, так как анализ по видеосъемке легко выполним и количество особей позволяет сократить серию экспериментов. Полученные данные по оценке адаптационных качеств молоди осетровых рыб (стерляди, русского осетра, белуги) по реакциям центральной нервной системы в целом показывают, что молодь стерляди обладает высокой подвижностью и острой реакцией на такие раздражители как яркий свет и высокочастотный звук, молодь белуги и русского осетра обладают остротой реакции на низко- и высокочастотные звуки. Все вышесказанное положительно характеризует предназначенную молодь для зарыбления естественных водоемов. Апробированные методики оценки качества выпускаемой молоди легко применимы в условиях осетровых рыбоводных хозяйств и рекомендуются к применению на осетровом заводе, так как можно по выборке дать оценку всей партии зарыбляемых рыб.

Ключевые слова: оценка; стерлядь; молодь; реакция; центральная нервная система; адаптация.

N.B. Bulavina[1], G.M. Maratova[2]*, S.J. Asylbekova[1], K.B. Isbekov[1]

[1]Scientific and Production Center of Fishery, Kazakhstan, Almaty
[2]Kazakh National Agrarian Research University, Kazakhstan, Almaty
*e-mail. guldana.maratova.91@mail.ru

Evaluation of the adaptive qualities of the fry of sturgery fishes by the reactions of the central nervous system

The article presents data on the assessment of the adaptive qualities of sturgeon fry according to the reactions of the central nervous system using the “open field” test. This test makes it possible to assess the severity and dynamics of elementary behavioral acts in fish under stressful conditions. The test was carried out both individually and in a group of several individuals. The most acceptable option turned out to be a group of five individuals of any sturgeon species, since video analysis is easy to perform and the number of individuals makes it possible to shorten the series of experiments. The obtained data on the assessment of the adaptive qualities of juveniles according to the reactions of the central nervous system as a whole show that sterlet juveniles have high mobility and an acute reaction to such stimuli as bright light and high-frequency sound, beluga and Russian sturgeon juveniles have a sharp reaction to low- and high-frequency sounds. All of the above positively characterizes the fingerlings intended for stocking natural water bodies. The proven methods for assessing the quality of released fry are easily applicable in the conditions of sturgeon fish farms and are recommended for use at a sturgeon hatchery, since it is possible to evaluate the entire batch of stocked fish from a sample.

Key words: assessment; starlet; juveniles; reaction; central nervous system; adaptation.

Н.Б. Булавина[1], Г.М. Маратова[2*], С.Ж. Асылбекова[1], К.Б. Исбеков[1]
[1]Балық шаруашылығының ғылыми-өндірістік орталығы, Қазақстан, Алматы қ.
[2]Қазақ ұлттық аграрлық зерттеу университеті, Қазақстан, Алматы қ.
*e-mail. guldana.maratova.91@mail.ru

Орталық жүйке жүйесінің реакциялары бойынша бекіре шабақтарының бейімделу сапасын бағалау

Мақалада «ашық өріс» сынағы арқылы орталық жүйке жүйесінің реакциялары бойынша бекіре шабақтарының бейімделу қасиеттерін бағалау деректері берілген. Бұл сынақ стресстік жағдайларда балықтардың қарапайым мінез-құлық әрекеттерінің ауырлығы мен динамикасын бағалауға мүмкіндік береді. Тест жекелей және бірнеше топтан тұратын особьтарғада жүргізілді. Ең қолайлы нұсқа кез келген бес бекіре тұқымдас балықтан тұратын топ болып шықты, өйткені бейне талдау жүргізу оңай және даралар саны эксперименттер қатарын қысқартуға мүмкіндік береді. Шабақтардың бейімделу қасиеттерін жалпы орталық жүйке жүйесінің реакциялары бойынша бағалау туралы алынған мәліметтер сүйрік балығының шабақтары жоғары қозғалғыштыққа, тікелей жарық пен жоғары жиіліктегі дыбыстарға, ал қортпа және орыс бекірелері төмен және жоғары жиіліктегі дыбыстарға өткір реакцияға ие. Жоғарыда аталған көрсеткіштер бойынша барлық шабақтармен табиғи суайдындарды балықтандыруға болады. Шығарылған шабақтардың сапасын бағалаудың дәлелденген әдістері бекіре тұқымдас балық өсіретін шаруашылықтар жағдайында оңай қолданылады және бекіре тұқымдас балық өсіру зауытында пайдалануға ұсынылады, өйткені сынама бойынша балықтандыратын балықтардың барлық партиясын бағалауға болады.

Түйін сөздер: бағалау; сүйрік; шабақтар; реакция; орталық жүйке жүйесі; бейімделу.

Введение

Растущая нагрузка на естественные популяции гидробионтов часто приводит к негативным изменениям их структуры, снижению численности, иногда даже к полному исчезновению. Весьма показательна ситуация, сложившаяся в настоящее время с представителями отряда осетрообразных Урало-Каспийского бассейна.

Для восстановления численности осетровых рыб в Урало-Каспийском бассейне необходимо повышать эффективность естественного и искусственного воспроизводства. Многими авторами проанализировано современное состояние естественного воспроизводства осетровых рыб и показано, что в силу целого ряда причин его эффективность сведена к нулю, в таких условиях возрастает роль и значение искусственного воспроизводства, эффективность которого в последние годы снижается по причине возрастающего дефицита производителей осетровых рыб природных популяций. Своевременное формирование продукционных стад в прудах на 2-х осетровых рыбоводных заводах (ОРЗ) позволяет обеспечивать рыбоводные процессы по искусственному воспроизводству качественными самками и самцами в условиях снижения их численности в природных водоемах. Помимо этого, необходимо проводить анализ пригодности, полученной от таких производителей молоди, предназначенной для выпуска в естественные водоемы.

Эффективность зарыбления естественных водоемов молодью осетровых рыб во многом зависит от состояния и качества получаемой молоди, ее жизнестойкости и физиологической полноценности. В связи с этим актуальной проблемой является оценка состояния выпускаемой молоди и способность ее к адаптации в условиях естественных водоемов. Одним из направлений решения вышеуказанной проблемы приобретает разработка и адаптация прижизненных методов оценки качества молоди осетровых рыб, планируемой к зарыблению. Одним из таких методов является оценка адаптационных качеств молоди по реакциям центральной нервной системы (ЦНС), позволяющий оценить реактивность молоди на внешние стимулы (зрительные, тактильные, гидродинамические), её пригодность для выживания в естественной среде.

Многими учеными тест «открытое поле» применяется для определения влияния биологических, физических и химических факторов (половые и типологические различия, сезонность, изоляция, пренатальная гипокинезия, ионизирующее и неионизирующее излучения, фитопрепараты и т.п.) на врожденные формы поведения грызунов и птиц [1-2].

Системная реакция на стресс, направленная на устранение или ослабление стресса, сопро-

вождается изменениями поведенческих, вегетативных, двигательных, сенсорных, когнитивных и других функций организма [1-10]. В тесте «открытое поле» изменения в исследовательском поведении являются фундаментальным изменением, обычно характеризующейся двигательной гиперактивностью и повышенным целенаправленным поведением в ответ на сигналы окружающей среды. В то время как двигательные нарушения часто упоминаются в качестве клинических проявлений этих расстройств, относительно немногие эмпирические исследования количественно оценивали исследовательское поведение человека. В этой статье представлен обзор литературы, характеризующей двигательное и исследовательское поведение, связанное с биполярным расстройством, а также генетические и фармакологические модели этого заболевания на животных. Несмотря на сложную оценку исследовательского поведения грызунов, объективная количественная оценка двигательной активности человека была ограничена в основном исследованиями актиграфии с низкой межвидовой трансляционной ценностью. Более того, симптомы, которые отражают кардинальные особенности биполярного расстройства, оказалось трудно установить на предполагаемых моделях этого заболевания на животных. Однако в последнее время новые инструменты, такие как Human Behavioral Pattern Monitor, обеспечивают многомерные трансляционные показатели двигательной и исследовательской активности, позволяя лучше понять нейробиологию, лежащую в основе психических расстройств [11, 12, 13].

Материалы и методы

Объекты исследований – молодь 3 видов осетровых рыб: белуга *Huso huso,* русский осетр *Acipenser gueldenstaedtii* и стерлядь *A. ruthenus*, полученная в условиях осетрового рыбоводного завода РГКП «Урало-Атырауский осетровый рыбоводный завод» (далее ОРЗ).

Исследования проводились на базе РГКП «Урало – Атырауский осетровый рыбоводный завод» в Атырауской области Республики Казахстан.

Цель исследований: Оценка качества полученной при искусственном воспроизводстве молоди осетровых рыб на ОРЗ.

Объём собранного и проанализированного материала по оценке качества полученной при искусственном воспроизводстве молоди осетровых рыб указан в таблице 1.

Таблица 1 – Объём собранного и проанализированного материала на РГКП «Урало-Атырауский осетровый завод» в 2022 году по оценке качества рыбопосадочного материала

Показатель	Вид рыбы, количество исследуемых рыб, шт		
	Стерлядь	Русский осетр	Белуга
Тест «открытое поле»	75	10	10
Рыбоводно-биологические показатели	340	105	22
Всего	415	115	32

Отбор и определение таких показателей воды как температура и содержание растворенного в воде кислорода, при проведении экспериментов проводилось по общепринятым методикам [1, 2]. Измерение температуры воды и содержания кислорода в воде проводили при помощи анализатора «МАРК-302Э». При анализе гидрохимических условий проведения экспериментов использовали зарубежную научно-методическую литературу [2, 3, 4, 5].

Обзор литературы

Результаты и их обсуждение

Мониторинг качества молоди осетровых рыб является одним из важнейших элементов искусственного воспроизводства осетровых в условиях товарных хозяйств и хозяйств воспроизводственного комплекса и его необходимо проводить не только перед выпуском молоди

в естественные водоемы, но и в течение всего технологического цикла выращивания или воспроизводства осетровых рыб [5].

В ходе мониторинга качества молоди осетровых рыб необходимо осуществлять контроль за соответствием всех рекомендованных нормативов. Помимо этого, полифункциональная оценка необходима для отбора молоди рыб в ремонтные стада в целях пополнения и обновления, выпуска молоди (зарыбления) и получения товарной осетровой продукции и пищевой икры. В случае товарного выращивания молодь осетровых рыб должна иметь высокие темпы роста, хорошую упитанность, пониженный кормовой коэффициент, в таких условиях жёсткость отбора по адаптивным фитнес показателям не требуется. Доместикационный эффект особей осетровых рыб в ремонтно-маточных стадах на осетровых заводах и хозяйствах, а также полученного от них потомства, обусловлен проводимым искусственным отбором, ориентированного на приспособленность к искусственным условиям и может неблагоприятно отразиться на выживании молоди и состоянии популяций в естественных условиях при ее зарыблении в естественные водоемы. Кроме того, доместикация может привести к ослаблению показателей реакции молоди на внешние раздражители, выражающемуся в снижении резистентности к заболеваниям и неблагоприятным экологическим воздействиям и т.д. Применяемые или рекомендуемые прижизненные методы оценки качества молоди осетровых рыб, выпускаемых с ОРЗ должны соответствовать следующим основным требованиям [5, 6, 7]:

• включать показатели вкупе характеризующих функциональное состояние выпускаемой молоди осетровых рыб;

• подразумевать сокращение временных отрезков проведения экспериментов, снижать травматизацию и гибель исследуемой молоди осетровых рыб;

• предусматривать возможность оценки информации о перспективах дальнейшего выживания, нормального развития, воздействии на жизнеспособность и генетическую структуру популяции осетровых;

• включать систему показателей, экологически адекватно связанных с основными факторами, определяющими выживаемость молоди после её выпуска в естественные водоемы [5].

Всем вышеперечисленным требованиям отвечает прижизненный тест «открытое поле». Всего исследовано 562 особи. В тесте «Открытое поле» оценивались следующие показатели:

- фоновая активность молоди осетровых рыб;
- ориентировочная активность молоди осетровых рыб;
- показатель реактивности молоди осетровых рыб;
- показатель активации молоди осетровых рыб.

При проведении эксперимента (теста «открытое поле») определяли остроту реакции молоди из тестируемой выборки на различные раздражители (свет и звук разной частоты). Сначала определяли величину двигательной активности (количество пересечений линий координатной сетки) в первые 30 секунд после воздействия первого раздражителя – низкочастотного прямоугольного сигнала (частота 20-40 Гц) определяли, как Р1, ед/мин. Затем использовался второй раздражитель (Р2, ед/мин) – высокочастотный прямоугольный сигнал (частота 300 Гц). Затем испытывали воздействие постоянного неяркого света (100 лк) – Р3, ед/мин (третий раздражитель), после этого применяли воздействие постоянного яркого света (500 лк) – Р4, ед/мин (четвертый раздражитель). Последним раздражителем Р5, ед/мин был переменный яркий свет [6]. Освещенность измеряли с помощью люксметра у поверхности воды и на краю бассейна (для чистоты эксперимента), затем сравнивали и корректировали яркость при помощи наклона штатива. Воздействие звука измеряли при помощи шумометра.

Тест проводили как индивидуально, так и в группе по несколько особей, помещая исследуемый объект (молодь осетровых рыб) соответственно методике в специальный бассейн с нанесенной координатной сеткой. Для этого использовался круглый бассейн (диаметром 1 м), дно которого разделено на 24 сектора, после выпуска объекта регистрировали количество пересечений рыбой линий дна за определенный период времени.

В течение эксперимента контролировали термический и кислородный режимы. Показатели варьировали в оптимальных пределах [2, 3]. При понижении уровня растворенного в воде кислорода открывали водоподачу с одновременным сбросом излишек воды.

Для обеспечения чистоты эксперимента и точного подсчета использовали камеру для записи всех экспериментальных групп, затем записи просматривались и подсчитывалось количество пересечений.

На оценку одной партии молоди уходило примерно 13 минут. Апробируемый способ нес-

ложен, однако такой анализ требует подготовки и соблюдения аналогичности в условиях проведения (при воздействии светом спектр должен быть одинаковым для всех партий рыб, звуковая волна также должна иметь одинаковую частоту и уровень шума). Тест «открытое поле» в условиях ОРЗ проводился впервые, поэтому для оптимизации процессов проводили эксперименты на группах с разным количеством испытуемой молоди – индивидуально, по три, пять и десять особей. Отработанная схема проведения теста «Открытое поле» с указанием таймингов приведена в таблице 2.

Основные показатели рассчитывали по формулам:

$$ПА\% = ОА/ФА \times 100\% \quad (1)$$

$$ПР = РА/ФА \times 100\% \quad (2)$$

где, ПА% – показатель активации, ОА (ед. мин.) – ориентировочная двигательная активность, ФА (ед. мин.) – фоновая двигательная активность, ПР% – показатель реактивности, РА (ед. мин.) – реактивность [5].

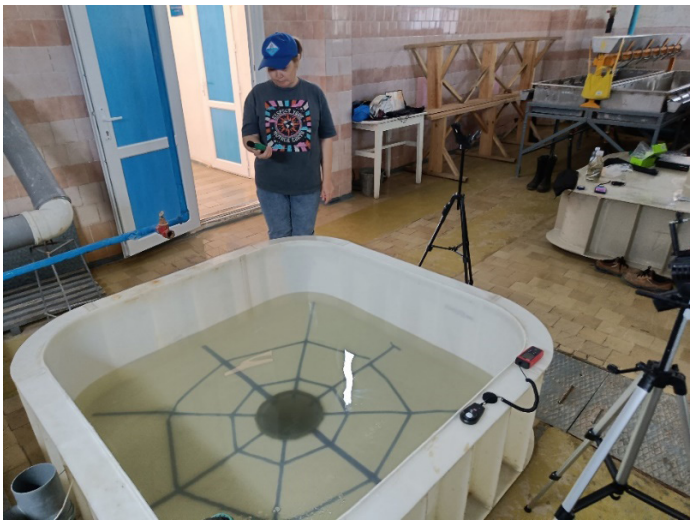
Таблица 2 – Хронологическая схема проведения теста «Открытое поле»

Время, мин	Стрессоры (раздражители)
1-3	Период адаптации
3-5	Воздействие низкочастотного прямоугольного сигнала (частота 20-40 Гц)
5-7	Воздействие высокочастотного прямоугольного сигнала (частота 300 Гц)
7-9	Воздействие постоянного неяркого света (100 лк)
9-11	Воздействие постоянного яркого света (450 лк)
11-13	Воздействие переменного яркого света (яркий – 450 лк, затемненный – 70 лк)

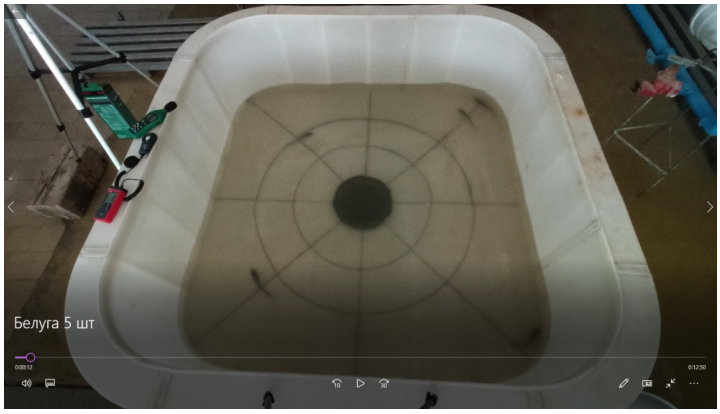
Для проведения анализа была разработана специальная форма фиксации первичных данных (таблица 3).

Таблица 3 – Предлагаемая форма ведения наблюдений и анализа теста «Открытое поле» на молоди осетровых рыб

Дата проведения	Вид рыбы	Наименование показателя	Тайминг	Метод получения	Полученное значение
8.07.2022 г	стерлядь	Ориентировочная двигательная активность (ОА, ед/3 мин)	Первые 3 мин	Наблюдение	95
		Ориентировочная двигательная активность (ОА, ед/мин)	Количество пересечений в мин	Расчет	32
		Фоновая активность (ФА, ед/мин) 1 мин после адаптации	Усредненное количество пересечений в мин (после адаптации)	Расчет (общ. групповой показатель)	21
		Реактивность низкочастотный звук (РА, ед/ 30 сек)	Первые 30 сек после воздействия	Наблюдение	10
		Реактивность низкочастотный звук (РА, ед/мин)	Количество пересечений в мин	Расчет	20
		Реактивность высокочастотный звук (РА, ед/30 сек)	Первые 30 сек после воздействия	Наблюдение	18
		Реактивность высокочастотный звук (РА, ед/мин)	Количество пересечений в мин	Расчет	36
		Реактивность постоянный свет 100 люмен (РА, ед/ 30 сек)	Первые 30 сек после воздействия	Наблюдение	4
		Реактивность постоянный свет 100 люмен (РА, ед/мин)	Количество пересечений в мин	Расчет	8
		Реактивность постоянный свет 450 люмен (РА, ед/30 сек)	Первые 30 сек после воздействия	Наблюдение	19
		Реактивность постоянный свет 450 люмен (РА, ед/мин)	Количество пересечений в мин	Расчет	38
		Реактивность кратковременные вспышки света 450 люмен (РА, ед/ 30 сек)	Первые 30 сек после воздействия	Наблюдение	11
		Реактивность кратковременные вспышки света (РА, ед/мин)	Количество пересечений в мин	Расчет	22



А



Б

А – подготовительные работы и контрольные замеры основных раздражителей,
Б – проведение оценки адаптационных качеств молоди белуги по реакциям центральной нервной системы

Рисунок 2 – Проведение оценки адаптационных качеств молоди осетровых рыб
по реакциям центральной нервной системы на РГКП «Урало-Атырауский осетровый рыбоводный завод»

При апробации разных вариантов наиболее приемлемым оказалась группа из пяти особей любого вида осетровых, так как анализ по видеосъемке легко выполним и количество особей позволяет сократить серию экспериментов (таблица 4).

У протестированной молоди осетровых рыб проводили сбор показателей длины и массы тела (таблица 5).

Молодь стерляди была самой подвижной и наиболее активно реагировала на раздражители, активно перемещаясь по бассейну. Наиболее активно реагируя на яркий свет ($РА_4$). Понижение активности наблюдалось при воздействии вспышек света и низкочастотным звуком ($РА_1$), что и отражено в таблице 6.

Ориентировочная двигательная активность (ОА) и фоновая двигательная активность (ФА) у стерляди также имеют самые высокие показатели – 34 ед/мин и 19 ед/мин соответственно, тогда как у белуги и русского осетра она составляет 18 ед/мин и 9 ед/мин (у русского осетра) и 12 ед/мин (у белуги) соответственно.

У молоди русского осетра наблюдалось повышение активности при воздействии яркого света до 24 ед/мин по сравнению с фоновой активностью в 2,6 раза и при воздействии низкочастотного звука (22 ед/мин), чего не наблюдалось у молоди стерляди. Также, как и у стерляди повышение активности наблюдалось и при воздействии высокочастотного звука и составила 17 ед/мин.

Таблица 4 – Количество протестированной молоди различных видов осетровых рыб РГКП «Урало-Атырауский осетровый рыбоводный завод»

Вид рыбы	Количество особей в группе	Количество испытанных групп
Стерлядь	1	1
	3	3
	5	5
	10	4
Русский осетр	5	2
Белуга	5	2

Таблица 5 – Показатели дины и массы тела тестируемой молоди осетровых рыб на РГКП «Урало-Атырауский осетровый рыбоводный завод»

Вид рыбы	Средний вес, г	Длина тела, см
Стерлядь	11,07	15,2
Русский осетр	13,3	15
Белуга	15,8	18,3

Таблица 6 – Результаты теста «Открытое поле» на молоди различных видов осетровых рыб на РГКП «Урало-Атырауский осетровый рыбоводный завод»

Показатель	Русский осетр	Стерлядь	Белуга
Ориентировочная двигательная активность (ОА), ед/мин			
ср	18	34	18
мин	11	29	15
макс	22	40	20
Фоновая двигательная активность (ФА), ед/мин			
ср	9	19	12
мин	8	16	10
макс	11	22	15
Реактивность на низкочастотный звук ($РА_1$), ед/мин			
ср	22	22	23
мин	18	16	20
макс	32	26	28
Реактивность на высокочастотный звук ($РА_2$), ед/мин			
ср	17	32	16
мин	10	22	12
макс	24	42	20
Реактивность на свет 100 лк ($РА_3$), ед/мин			
ср	15	12	22
мин	10	8	20
макс	24	16	24
Реактивность на свет 450 лк ($РА_4$), ед/мин			
ср	24	46	26

Продолжение таблицы

Показатель	Русский осетр	Стерлядь	Белуга
мин	14	38	20
макс	32	62	32
Реактивность на кратковременные вспышки света (PA_5), ед/мин			
ср	15	18	12
мин	8	14	8
макс	22	22	16

Молодь белуги активно реагировала только на воздействие яркого света, наблюдалось повышение активности до 26 ед/мин.

Показатель ориентировочной двигательной активности (ОА) характеризует адаптацию рыб к новым условиям и этот показатель весьма высок у стерляди, в сравнении с литературными данными аналогичными показателями обладает дикая форма севрюги [8 – 15]. Данный показатель низок у молоди русского осетра и белуги, однако возможно необходимо провести корреляцию с весовыми показателями, так как молодь стерляди и севрюги обладают схожими размерно-весовыми показателями в отличие от молоди белуги и русского осетра.

Заключение

Многими отечественными и зарубежными исследованиями показана связь пространственного и предметного зрения, оптического момента и акустической сигнализации с экологией молоди рыб, и с той ролью, которую органы зрения и чувства боковой линии, воспринимающей низкочастотные инфразвуковые колебания, играющие в общем рецепторном комплексе молоди осетровых рыб. Эти показатели играют роль в проявлении рыб реореакции и реакции рыб на свет, в пищевом, оборонительном и других типах поведения, характерных для рыб в естественных условиях [8]. Острота реакций на такие показатели характеризуют адаптивный потенциал молоди рыб. В результате одомашнивания происходит притупление реакций на раздражители, что очевидно связано с привыканием к стрессовым ситуациям являющихся следствием рыбоводных процессов и мероприятий. Полученные данные по оценке адаптационных качеств молоди по реакциям центральной нервной системы в целом показывают, что молодь стерляди обладает высокой подвижностью и острой реакцией на такие раздражители как яркий свет и высокочастотный звук, молодь белуги и русского осетра обладают остротой реакции на низкочастотные и высокочастотные звуки. Все вышесказанное положительно характеризует предназначенную молодь для зарыбления естественных водоемов. В свете расширения охвата искусственного воспроизводства в Казахстане данные исследования являются актуальными и возможно необходимо расширить спектр анализируемых реакций, например, воздействие электрических полей, химических веществ, температуры и пр. Апробированные методики оценки качества выпускаемой молоди легко применимы в условиях осетровых рыбоводных хозяйств и рекомендуются к применению на осетровом заводе, так как можно по выборке дать оценку всей партии зарыбляемых рыб.

Блогадарность

Выражаем благодарность за возможность проведения работ РГКП «Урало-Атырауский осетровый рыбоводный завод».

Конфликт интересов

Все авторы прочитали и ознакомлены с содержанием статьи и не имеют конфликта интересов.

Источник финансирования

Данные исследования финансируются Министерством экологии и природных ресурсов Республики Казахстан (*Грант № BR10264236*).

Литература

1. Васильева Л.М., Китанов А.А., Петрушина Т.Н. и др. Биотехнические нормативы по товарному осетроводству, Астрахань: Издательский дом «Астраханский университет», 2010. – 80 с.

2. Богерук А.К. Породы и одомашненные форма осетровых рыб (*Acipenceridae*). М: ФГУП «Федеральный селекционно-генетический центр рыбоводства». 2008. 152 с.

3. Чебанов М.С. Руководство по искусственному воспроизводству осетровых рыб. Анкара: ФАО. 2010. 325 с.

4. Sudakova, N.V.; Mikodina, E.V.; Vassiliyeva, L.M. Paradigm changeover in the artificial reproduction of sturgeons (Acipenseridae) in the Volga-Caspian basin in the conditions of a shortage of breeders of natural generations. Agric. Biol. 2018, 53, 698–711 DOI:10.15389/agrobiology.2018.4.698eng

5. Алёкин О.А. Методы исследования физических свойств и химического состава воды //Жизнь пресных вод СССР /акад. Е.Н. Павловский, проф. В.И. Жадин. – М.-Л., 1959. – Т. IV. ч.2. – 302 с.

6. Bell J.D., Leber K.M., Blankenship H.L., Loneragan N.R., R. Masuda. A new era for restocking, stock enhancement and sea ranching of coastal fisheries resources. Reviews in Fisheries Science, 16 (2008), pp. 1-9. DOI: 10.1080/10641260701776951

7. Holčik, J., Klindová, A., Masár, J., & Mészáros, J. (2006). Sturgeons in the Slovakian rivers of the Danube River basin: An overview of their current status and proposal for their conservation and restoration. Journal of Applied Ichthyology, 22, 17-22.

8. The Effect of the BCO2 Genotype on the Expression of Genes Related to Carotenoid, Retinol, and α-Tocopherol Metabolism in Rabbits Fed a Diet with Aztec Marigold Flower Extract [Text] Janusz Strychalski, Andrzej Gugołek, Zofia Antoszkiewicz, Dorota Fopp-Bayat, Edyta Kaczorek-Łukowska, Anna Snarska, Grzegorz Zwierzchowski Angelika Król-Grzymała and Paulius Matusevičius. Int. J. Mol. Sci. 2022, 23(18), 10552; https://doi.org/10.3390/ijms231810552

9. Красильникова А.А., Тихомиров А.М. Получение жизнеспособной молоди русского осетра (*Acipenser gueldenstaedtii*) при использовании криоконсервированной спермы и оценка поведенческих реакций у криопотомства* // Сельскохозяйственная биология, 2018, том 53, ¹ 4, С. 762-768.

10. Павлов Д.С., Касумян А.О. Изучение поведения и рецепции рыб в СССР// Вопросы ихтиологии. Т.27. вып 5. 1987 г.

11. Vernidub, M.F. Exchange of a developing fish embryo upon damage. I. Pasteur-Meyerhof reaction in normal and damaged eggs of some spring-spawning fish [Text]. *Arch. Anat. Histol. Embryol* **1939**, *22*, 106.

12. Novossadova, A.V. *Morphological Abnormalities in the Early Ontogenesis of Sturgeons in the Offspring of Cultivated Producers*; Russian Research Institute of Fisheries and Oceanography: Moscow, Russia, 2013.

13. Randelin, D.A.; Novokshchenova, A.I.; Kravchenko, Y.V. Study of anomalies in the structure of the body and external organs of valuable sturgeon breeds. Proceedings of the Lower Volga Agro-University Complex. *Sci. High. Prof. Educ.* **2018**, *4*, 251–256.

14. Детлаф Т.А., Гинзбург А.С. Зародышевое развитие осетровых рыб (севрюги, осетра и белуги) в связи с вопросами их разведения М., Изд-во АН СССР, 1954.216 с.

15. Левин А.В. Экологические аспекты поведения молоди осетровых // Осетровые на рубеже XXI века: Тез. докл. Международн. конф. Астрахань, 2000. С. 70-71.

16. Kaluyev A.V. Stress and grooming. Moscow: Aviks, 2002. 146 p.

17. Судаков С.К., Назарова Г.А., Алексеева Е.В. и др. Определение уровня тревожности у крыс в тестах «открытое поле», «крестообразный приподнятый лабиринт» и тесте Фогеля // Бюл. эксп. биологии и медицины. 2013. Т. 155, № 3. С. 268-270.

18. Амикшеева А.В. Поведенческое фенотипирование: современные методы и оборудование // Вестн. ВОГиС. Т. 13, № 3. С. 529-542.

19. Crawley J.N. Behavioral phenotyping strategies for mutant mice // euron. 2008. Vol. 57. P. 809-818.

20. Implementation of the modifi ed-SHIRPA protocol for screening of dominant phenotypes in a large-scale ENU mutagenesis program / Masuya H., Inoue M., Wada Yu., et al. // Mammalian Genome. 2005. Vol. 16. P. 829-837.

21. Лебедев И.В. Изучение функций каудальной части гиппокампа у мышей и полевок: автореф. дис. канд. биол. наук. М., 2012. 24 с.

22. Hall C.S. Emotional behavior in the rat. III. The relationship between emotionality and ambulatory activity // J. comp. physiol. Psychol. 1936. Vol. 22. P. 345-352.

23. C.S. Hall. Emotional behavior in the rat. III. The relationship between emotionality and ambulatory activity. 1936. J. comp. physiol. Psychol. vol. 22, pp. 345-352.

24. Я. Буреш, О. Бурешова, Д. П. Хьюстон. Методики и основные эксперименты по изучению мозга и поведения. 1991. Москва. “Высшая школа”. стр. 119 -122.

25. T.D. Gould (ed.), Mood and Anxiety Related Phenotypes in Mice, Neuromethods 42, DOI 10.1007/978-1-60761-303-9_1, Humana Press, a part of Springer Science+Business Media, LLC 2009

References

1. Amiksheeva A.V. Povedencheskoe fenotipirovanie: sovremennye metody i oborudovanie // Vestn. VOGiS. T. 13, № 3. S. 529-542.

2. Aljokin O.A. Metody issledovanija fizicheskih svojstv i himicheskogo sostava vody //Zhizn’ presnyh vod SSSR /akad. E.N. Pavlovskij, prof. V.I. Zhadin. – M.-L., 1959. – T. IV. ch.2. – 302 s.

3. Bogeruk A.K. Porody i odomashnennye forma osetrovyh ryb (Acipenceridae). M: FGUP «Federal'nyj selekcionno-geneticheskij centr rybovodstva». 2008. 152 s.

4. Bell J.D., Leber K.M., Blankenship H.L., Loneragan N.R., R. Masuda. A new era for restocking, stock enhancement and sea ranching of coastal fisheries resources. Reviews in Fisheries Science, 16 (2008), pp. 1-9. DOI: 10.1080/10641260701776951

5. C.S. Hall. Emotional behavior in the rat. III. The relationship between emotionality and ambulatory activity. 1936. J. comp. physiol. Psychol. vol. 22, pp. 345-352.

6. Crawley J.N. Behavioral phenotyping strategies for mutant mice // euron. 2008. Vol. 57. P. 809-818.

7. Detlaf T.A., Ginzburg A.C. Zarodyshevoe razvitie osetrovyh ryb (sevrjugi, osetra i belugi) v svjazi s voprosami ih razvedenija M., Izd-vo AN SSSR, 1954.216 s.

8. Ja. Buresh, O. Bureshova, D. P. H'juston. Metodiki i osnovnye jeksperimenty po izucheniju mozga i povedenija. 1991. Moskva. "Vysshaja shkola". str. 119 -122.

9. Implementation of the modifi ed-SHIRPA protocol for screening of dominant phenotypes in a large-scale ENU mutagenesis program / Masuya H., Inoue M., Wada Yu., et al. // Mammalian Genome. 2005. Vol. 16. P. 829-837.

10. Holčik, J., Klindová, A., Masár, J., & Mészáros, J. (2006). Sturgeons in the Slovakian rivers of the Danube River basin: An overview of their current status and proposal for their conservation and restoration. Journal of Applied Ichthyology, 22, 17-22.

11. Hall C.S. Emotional behavior in the rat. III. The relationship between emotionality and ambulatory activity // J. comp. physiol. Psychol. 1936. Vol. 22. R. 345-352.

12. Kaluyev A.V. Stress and grooming. Moscow: Aviks, 2002. 146 p.

13. Krasil'nikova A.A., Tihomirov A.M. Poluchenie zhiznesposobnoj molodi russkogo osetra (Acipenser gueldenstaedtii) pri ispol'zovanii kriokonservirovannoj spermy i ocenka povedencheskih reakcij u kriopotomstva* // Sel'skohozjajstvennaja biologija, 2018, tom 53, ¹ 4, S. 762-768.

14. Levin A.B. Jekologicheskie aspekty povedenija molodi osetrovyh // Osetrovye na rubezhe XXI veka: Tez. dokl. Mezhdunarodn. konf. Astrahan', 2000. S. 70-71.

15. Lebedev I.V. Izuchenie funkcij kaudal'noj chasti gippokampa u myshej i polevok: avtoref. dis. kand. biol. nauk. M., 2012. 24 s.

16. Novossadova, A.V. Morphological Abnormalities in the Early Ontogenesis of Sturgeons in the Offspring of Cultivated Producers; Russian Research Institute of Fisheries and Oceanography: Moscow, Russia, 2013.

17. Vasil'eva L.M., Kitanov A.A., Petrushina T.N. i dr. Biotehnicheskie normativy po tovarnomu osetrovodstvu, Astrahan': Izdatel'skij dom «Astrahanskij universitet», 2010. – 80 s.

18. Pavlov D.S., Kasumjan A.O. Izuchenie povedenija i recepcii ryb v SSSR// Voprosy ihtiologii. T.27. vyp 5. 1987 g.

19. Sudakov S.K., Nazarova G.A., Alekseeva E.V. i dr. Opredelenie urovnja trevozhnosti u krys v testah «otkrytoe pole», «krestoobraznyj pripodnjatyj labirint» i teste Fogelja // Bjul. jeksp. biologii i mediciny. 2013. T. 155, № 3. S. 268-270.

20. Sudakova, N.V.; Mikodina, E.V.; Vassiliyeva, L.M. Paradigm changeover in the artificial reproduction of sturgeons (Acipenseridae) in the Volga-Caspian basin in the conditions of a shortage of breeders of natural generations. Agric. Biol. 2018, 53, 698–711 DOI:10.15389/agrobiology.2018.4.698eng

21. T.D. Gould (ed.), Mood and Anxiety Related Phenotypes in Mice, Neuromethods 42, DOI 10.1007/978-1-60761-303-9_1, Humana Press, a part of Springer Science+Business Media, LLC 2009.

22. The Effect of the BCO2 Genotype on the Expression of Genes Related to Carotenoid, Retinol, and α-Tocopherol Metabolism in Rabbits Fed a Diet with Aztec Marigold Flower Extract [Text] Janusz Strychalski, Andrzej Gugołek, Zofia Antoszkiewicz, Dorota Fopp-Bayat, Edyta Kaczorek-Łukowska, Anna Snarska, Grzegorz Zwierzchowski Angelika Król-Grzymała and Paulius Matusevičius. Int. J. Mol. Sci. 2022, 23(18), 10552; https://doi.org/10.3390/ijms2318105524

23. Randelin, D.A.; Novokshchenova, A.I.; Kravchenko, Y.V. Study of anomalies in the structure of the body and external organs of valuable sturgeon breeds. Proceedings of the Lower Volga Agro-University Complex. Sci. High. Prof. Educ. 2018, 4, 251–256.

24. Vernidub, M.F. Exchange of a developing fish embryo upon damage. I. Pasteur-Meyerhof reaction in normal and damaged eggs of some spring-spawning fish [Text]. Arch. Anat. Histol. Embryol 1939, 22, 106.

25. Chebanov M.S. Rukovodstvo po iskusstvennomu vosproizvodstvu osetrovyh ryb. Ankara: FAO. 2010. 325 s

МРНТИ 34.33.33 https://doi.org/10.26577/eb.2023.v96.i3.011

Э.Б. Каримов[1,*], Б.К. Каримов[1], Martin Schletterer[2], Daniel S. Hayes[2]

[1]Национальный исследовательский университет «Ташкентский институт инженеров ирригации и механизации сельского хозяйства», Ташкент, Узбекистан
[2]Университет природных ресурсов и наук о жизни, Австрия, г. Вена
*e-mail: erkinkarimov92@gmail.com

ИХТИОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ В РЕКЕ КОКСУ, УЗБЕКИСТАН, ПО ВЫЯВЛЕНИЮ КЛЮЧЕВЫХ ОХРАНЯЕМЫХ ВИДОВ РЫБ В УСЛОВИЯХ РАЗВИТИЯ МАЛОЙ ГИДРОЭНЕРГЕТИКИ

Охрана биоразнообразия в ключевых районах биоразнообразия и природоохранных коридорах в центрально азиатском горном регионе становиться все более актуальным в свете широкомасштабных антропогенных интервенций в природную среду, в частности, интенсивное развитие малой гидроэнергетики приводит к изменению и фрагментации среды обитания и резкому сокращению разнообразия водных организмов. В то же время, наука не располагает достаточными сведениями о зоогеографии даже таких крупных водных организмов как рыб в горных водных экосистемах Средней Азии. В настоящей статье приводятся результаты полевых исследований экологии рыб, проведенных в 2021-2022 гг. в горной реке Коксу, бассейн реки Шахимардан, Фергана, Узбекистан. Вопреки утверждениям местного населения об отсутствии рыбы в этой реке вообще, нами впервые было установлено наличие в ней 2 видов рыб: маринки – Schizothorax eurystomus Kessler, 1872 и гольца – Triplophysa ferganaensis Sheraliev and Peng, 2021. Дальнейшие исследования должны быть направлены на оценке оптимальной среды обитания и изучению особенностей миграции с целью устранения фрагментации среды обитания и охраны ихтиофауны.

Ключевые слова: Гидроэнергетика, река Коксу, ихтиофауна, миграции рыб, фрагментация среды обитания.

E.B. Karimov[1*], B.K. Karimov[1], Martin Schletterer[2], Daniel S. Hayes[2]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National research University, Uzbekistan, Tashkent
[2]University of Natural Resources and Life Sciences, Vienna, Institute of Hydrobiology and Aquatic Ecosystem Management, Austria, Wien
*e-mail: erkinkarimov92@gmail.com

Ichthyological research in the koksu river, Uzbekistan to identify key fish species in the context of small hydropower development

The study of biodiversity in key areas and conservation corridors in the Central Asian mountainous region is becoming increasingly relevant in light of large-scale anthropogenic interventions in the natural environment. Particularly, the rapid expansion of hydropower development leads to extensive habitat alteration, fragmentation and degradation, reducing the biodiversity of aquatic organisms. At the same time, science does not have sufficient information about the biogeography of large aquatic organisms such as fish in mountain rivers of Central Asia. This study presents fish ecological data from field surveys conducted in 2021–2022 at Koksu River, Shakhimardan river basin, Fergana Valley, Uzbekistan. Contrary to statements about the absence of fish from Koksu River, we confirm the presence of two fish species: snow trout (Schizothorax eurystomus Kessler, 1872) and stone loach (Triplophysa ferganaensis Sheraliev and Peng, 2021). Further studies should assess habitat preferences and study fish migration patterns to support the conservation and elimination of habitat fragmentation.

Key words: Hydropower, Koksu River, ichthyofauna, fish migration, habitat fragmentation.

Э.Б. Каримов[1*], Б.К. Каримов[1], Martin Schletterer[2], Daniel S. Hayes[2]
[1]«Ташкент ирригация және ауыл шаруашылығын механикаландыру инженерлері институты» Ұлттық зерттеу университеті, Өзбекстан, Ташкент қ.
[2]University of Natural Resources and Life Sciences, Vienna, Department of Water, Atmosphere and Environment, Institute of Hydrobiology and Aquatic Ecosystem Management, Austria, Vienna
*e-mail: erkinkarimov92@gmail.com

Көксу өзенінде, Өзбекстанда шағын гидроэнергетиканың дамуы жағдайында негізгі қорғалатын балық түрлерін анықтау бойынша ихтиологиялық зерттеулер

Орталық Азия таулы аймағындағы биоалуантүрліліктің негізгі аймақтарында және табиғатты қорғау дәліздерінде Биоәртүрлілікті қорғау табиғи ортаға кең ауқымды антропогендік интервенциялар, атап айтқанда, шағын гидроэнергетиканың қарқынды дамуы тіршілік ету ортасының өзгеруі мен бөлшектенуіне және су организмдерінің әртүрлілігінің күрт төмендеуіне әкеледі. Сонымен қатар, ғылымда Орталық Азияның таулы су экожүйелеріндегі балықтар сияқты ірі су организмдерінің зоогеографиясы туралы жеткілікті ақпарат жоқ. Осы мақалада 2021-2022 жылдары Көксу таулы өзенінде, Шахимардан өзенінің бассейнінде, Ферғана, Өзбекстанда жүргізілген балық экологиясын далалық зерттеу нәтижелері келтірілген. Жергілікті халықтың бұл өзенде балықтың жоқтығы туралы мәлімдемелеріне қайшы, біз алғаш рет онда балықтың 2 түрінің болуын анықтадық: маринки – Schizothorax eurystomus Kessler, 1872 және чольца – Triplophysa ferganaensis Sheraliev and Peng, 2021. Әрі қарайғы зерттеулер тіршілік ету ортасының фрагментациясын жою және ихтиофаунаны қорғау мақсатында оңтайлы тіршілік ету ортасын бағалауға және көші қон ерекшеліктерін зерттеуге бағытталуы керек.

Түйін сөздер: Гидроэнергетика, Көксу өзені, ихтиофауна, балық көші-қоны, тіршілік ету ортасының бөлшектенуі.

Введение

Горные реки Центральной Азии поддерживают разнообразие местообитаний видов рыб и других организмов, которые еще не так сильно подвержены влиянию деятельности человека по сравнению с реками, протекающими по долинам и равнинам [1; 2]. Если горные реки и водоемы условно разделить на высокогорные, среднегорные и предгорные, то даже в их пределах многие виды встречаются в определенных высотах. Например, голый осман занимает среднегорье, не встречается в высокогорье и никогда не спускается на равнинные участки рек [3; 4]. Следовательно, происходит изоляция популяций одного и того же вида в пределах даже разных притоков одного речного бассейна. Данное обстоятельство приводило к формированию весьма своеобразной ихтиофауны горных рек Центральной Азии со множеством ценных эндемичных видов [5]. В то же время, анализ имеющихся литературных сведений показывает крайне недостаточную изученность ихтиофауны Центрально-Азиатского региона. Имеющиеся данные в основном сильно устаревшие, касаются исследований рыбной фауны и развитии рыболовства на равнинных водоемах до 1990-х годов [6; 7].

Международное законодательство также требует экологически устойчивое развитие современной гидроэнергетики, а именно недопустимость вредного воздействия антропогенной деятельности на экосистемы рек, которые составляют основу устойчивого развития гидроэнергетики, к примеру охрана биоразнообразия и оценки экологических стоков в окружающей среде. Технико-экономические обоснования объектов гидроэнергетики с самого начала должны включать экологическое обоснование [8; 9]. Однако, в течение последних десятилетий, начиная с 70-х годов прошлого столетия, антропогенное изменения гидрологического режима и качества воды рек путем практически полного регулирования стока, строительства огромного числа водораспределительных гидроузлов и водохранилищ, а также ирригационной сети тотально изменило условия обитания аборигенных видов рыб [10; 11]. Большинство объектов гидротехнического строительства в бассейнах рек малых, средних и больших рек производились без учета требования сохранения условий существования рыбных популяций.

Целью настоящей работы является смягчение и предотвращение возможных отрицательных эффектов гидротехнического строительства, путем проведения детальных ихтиологических исследований с применением современных инструментов для обеспечения сохранности разнооб-

разия рыб с выявлением ключевых охраняемых видов, охраны мест обитания рыб и миграционных коридоров в уникальной горной реке Коксу, на которой правительском Узбекистана предусмотрено строительство малой ГЭС [9]. Согласно предварительным сведениям, примерно 65% стока реки будет изъято для подачи в турбины генератора, а остальная часть стока будет сохранен в качества экологического попуска для сохранения условий обитания водных организмов и экологических требований.

Материалы и методы

Объектом ихтиологических исследований в данной работе была выбрана река Коксу (рис.1), являющаяся притоком реки Шахимардансай (Шахимардан), зона формирования стока, которая расположена на территории Кыргызстана и Узбекистана (Шахимарданский эксклав). В центре эксклава Шахимардан река Коксу соединяется с рекой Аксу и образует более крупную реку Шахимардан (39°59’25.78» 71°48’22.96»). Большая часть бассейна реки Шахимардан площадью 1300 км² является высокогорной, а длина составляет 112 км. В стоке реки Шахимардан имеется более десяти барьеров, особенно в ее среднем и нижнем течении, многие из которых полностью непроходимы для мигрирующей вверх по течению рыб.

Зона формирования стока реки Шахимардан находится в пределах Исфайрам-Шахимарданского КРБ (ключевого района биоразнообразия) и в 50 км от КРБ Сох (Сохский эксклав Узбекистана). Вся данная территория входит в природоохранный коридор Туркестанские и Алайские горы в пределах республик Киргизстан, Таджикистан и Узбекистан согласно определению Фонда CEPF [12] (Фонд сотрудничества для сохранения экосистем в критическом состоянии). Следовательно, проведение исследований по изучению и сохранению биоразнообразия в реке Коксу, входящий в КРБ приобретает важное международное значение.

Река Шахимардан был действующим притоком реки Сырдарья до 1960-х годов. До этого времени потамодромные виды рыб из нижних частей, вероятно, могли заплывать до верхнего течения реки Шахимардан и ее притокам. Однако, начиная с 1960-х годов, развитие интенсивного забора воды для монокультуры хлопка привело к трансформации русла реки. Сегодня русло реки изобилует каскадами водораспределительных сооружений и плотин на территории Киргизстана и Узбекистана без рыбопропускных и рыбозащитных сооружений, которые очевидно образуют непроходимые преграды для рыб, приводящих к фрагментации ранее единой системы рек и речных участков. В результате, ниже поселка Вуадил Узбекистана река полностью разбирается на орошение полей Киргизстана и Узбекистана.

Согласно сведениям Узгидромета, среднемесячный расход воды реки Коксу колеблется в пределах 1.5 – 3.5 куб.м/с при минимальных и максимальных его значениях разброса от 1.42 до 6.64 куб.м/с в период 1980-2020гг. Среднемноголетняя температура воды за период 2011-2020 гг. колеблется в пределах 9.3-9.7°С при ее минимальных и максимальных его значениях разброса: зимой от 8.1 (январь) до 9.0 (декабрь), а летом от 9.9 (июнь) 10.6 (август). В настоящее время эта река берет начало из горного озера Курбанкуль выше по течению на высоте около 1725 м над уровнем моря, которое образовалось в результате сильного землетрясения с образованием естественной наносной плотины в XVI веке. Озеро питается за счет таяния снега и ледников, часть его вод дренируя через наносную плотину внизу питает реку Коксу. Данное обстоятельство предопределяет уникальность реки Коксу, расход, годовой сток, и температура которой подвергается лишь незначительным колебаниям, а вода остается кристально прозрачной и чистой, а также не замерзает в течение года (за исключением лишь периода селевых потоков). Наверно поэтому с давних времен народ считает реку священной.

Исследования были проведены учеными кафедры экологии Национального исследовательского университета «Ташкентский институт инженеров ирригации и механизации сельского хозяйства (НИУ ТИИИМСХ) под руководством профессора Б.К. Каримова совместно с университетом природных ресурсов и наук о жизни в Вене (BOKU IHG), Австрия и научно-исследовательским институтом природы и леса в Бельгии (INBO). В течении 2021 и 2022 гг. организовали серию научных экспедиции в Шахимарданский эксклав. Были обследованы 8 разных участков реки начиная с верхнего течения до слияния с рекой Аксу и образования реки Шахимардан в центре одноименного поселка Шахимардан (см. рис. 1).

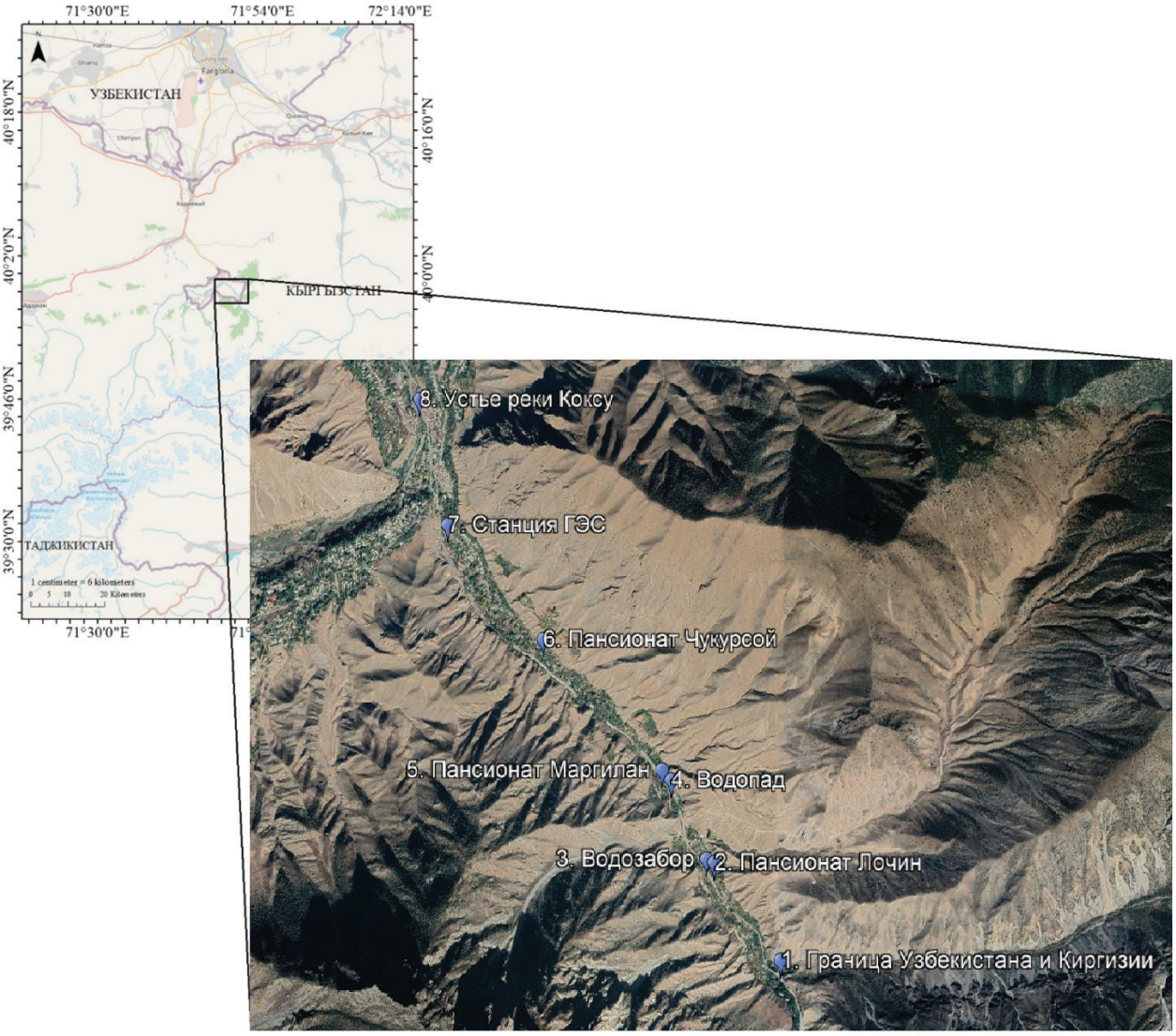


Рисунок 1 – Географическое расположение эксклава Шахимардан (слева) и космический снимок бассейна реки Коксу (высота н.у.м. – 1514 м – 1311м) с указанием точек исследования ихтиофауны.

В 2021 году исследования были проведены 4 экспедиции в зону реки Коксу в течение июля, августа, сентября и ноября месяцев с применением рыболовных сетей и мордушек, а в 2022 году с также применяли сертифицированные ранцевые электро-рыболовные инструменты Honda FEG 1500, 1.8 кВт, на применение которых было получено официальное разрешение государственного Комитета Республики Узбекистан по экологии и охране окружающей среды (письмо №03-02/1-711 от 01.04.2022). Данный инструмент не оказывает никакого вредного влияния на рыб. Наоборот, он предотвращает гибели рыб из-за травмирования или удушья при применении рыболовных сетей, позволяя при этом проводить быстрый и эффективный лов рыбы на исследуемом участке реки. В зарубежных странах (Европейский Союз, США и др.) лицензионные электро-рыболовные инструменты давно используются в научно-исследовательских целях (SIST EN 14011:2003) [13]. И действительно, во время лова рыбы в данном исследовании выловленные электроловом рыбы уже через несколько минут чувствовали себя опять вполне нормально и бойко уплывали при выпуске их обратно в реку. С учетом этого, Госкомэкологии Республики Узбекистан дал разрешение на применение этого инструмента в научно-исследовательских целях. После поимки особей подходящего размера, рыб анестезировали с применением гвоздичного масла для последующего выпуска в реку после возвращения их

в нормальное состояние. А часть рыб фиксировали в 4%-ном формалине и проводили определение показателей длины, веса и упитанности маринок, так как они являются ключевым видом рыб в данной реке. Изучение рыб проводили по общепринятым методикам [14; 15].

Результаты и обсуждение

В начале наших исследований вопрос стоял о том, имеется ли вообще рыба в этой реке. Так как до сих пор никто не подозревал, что в реке Коксу, расположенной в эксклаве Шахимардан в Узбекистане, есть рыба. Местное население опрошенное нами также в один голос утверждали, что здесь вода очень холодная и имеет в своем составе много серы (так как питается грунтовой водой), из-за чего рыба не может выжить. Все указали на обилие рыбы в соседней реке Аксу, в основном маринок (*Schizothorax* sp.). Эти утверждения также были подтверждены местной администрацией. Также, до сегодняшнего дня в литературе не было зарегистрировано сведений о нахождении рыбы в этой реке. В то же время, устойчивая гидроэнергетика требует обеспечение максимальной экологической безопасности в плане охраны биоразнообразия и экосистемных услуг водных экосистем. В связи с этим, перед нами было поставлена задача научно доказать, есть или нет рыба в данной реке.

В июле и августе 2021 г. для ловли рыбы были применены только ставные сети, которые оказались очень неэффективными, и мы не смогли словить ни одной рыбы. Однако, естественно, это еще не могло быть доказательством отсутствия рыбы. В ходе исследований в сентябре мы решили применить также несколько самодельных мордушек, которые оказались более эффективными, чем ставные сети. Действительно, во время исследований в сентябре 2021 г. у пансионата Чукурсай (станция 6) в установленные 3 мордушки в первый день попалась одна маринка, а во второй день две маринки в разные мордушки. Таким образом, нами было доказано существование рыбы в реке Коксу, однако, предположили, что плотность популяции очень низкая. Проведенный анализ показал, что все пойманные рыбы относится к виду *Schizothorax eurystomus* Kessler, 1872 [16; 17].

Позднее, во время нашей ноябрьской поездки мы визуально заметили скопление стайки рыб под мостом у санатория Маргилан (станция 5) на галечниковом дне реки под мостом. Тот же день там установили 3 мордушки и за 2 дня словили 24 экземпляров маринок. Однако, несколько выше этого участка, расположенного выше искусственного водопада (станция 4) высотою около 3.5 м до истоков реки вообще никакой рыбы не смогли найти. Все пойманные рыбы также относились к виду *S. eurystomus.* Возраст пойманных маринок колебался от 1 до 3 лет, при длине тела от 9.4 до 22 см и массе от 15.5 до 164.3 г. Основу улова (66%) составляли трех годовалые особи длинной от 13.2 до 22 см и массой 40.1-164.3 гр. Показатели упитанности как по Фультону (1.5-1.9), так и по Кларку (1.2-1.5) во всех возрастных группах были очень близки (Табл.1). По данным обратных расчислений, усредненный темп роста маринки составляла 7 см на 1 год жизни, 4.1 см на 2 год жизни, 3.3 см на 3 год жизни.

Таблица 1 – Темп роста маринки (S. eurystomus) из реки Коксу в 2021 г.

Показатели	**Возраст рыбы по годам:**		
	1+	2+	3+
Средняя длина (*l*), см	10.6	14.6	16.2
Колебание длины, см	9.4-11.5	14-17.5	13.2-22
Средний вес, г	20.5	54.1	74.7
Колебание веса, г	15.5-24.8	38.4-85.3	40.1-164.3
Средний коэффициент упитанности по Фультону – К(ф)	1.7	1.7	1.6
Пределы колебания К(ф)	1.6-1.9	1.6-1.8	1.5-1.7
Средний коэффициент упи танности по Кларку- К(к)	1.4	1.4	1.4
Пределы колебание К(к)	1.3-1.5	1.4-1.4	1.2-1.5
Кол-во экз. рыб	3	4	14

Наряду с этим следует отметить, что изучение зоо-, и фито-бентоса, а также перифитона реки показало существование богатой кормовой базы для маринки, которая питается в основном донными организмами, соскабливая их с помощью ротового чехлика с каменистого дна. Взрослая маринка питается в основном растительной пищей и детритом, которые составляют от 50% до 80% общей массы пищи. Поедает так же падающих на воду насекомых и остатки живых организмов, сносимых вниз по течением и мелкую рыбу (голец, подкаменьщик, маринка) до 4.9% от общей массы пищи [18, 19]. Большинство субстрата дна состояло из крупных и средних валунов, а также мелкого камня и песка, которые были довольно густо покрыты водорослями, которые служили отличным местообитанием для зообентоса.

В 2022 году первый поездка в район исследования проводилось в марте, однако на этот раз мы не предпринимали попыток ловить рыбу, а изучили расположение миграционных барьеров для рыб, как в реке Коксу, так и в реках Аксу и Шахимардан. В начале апреля интернациональная команда исследователей из Германии, Австрии, Бельгии и Узбекистана осуществили 10-дневную поездку в район исследования. На этот раз мы, совместно с учеными из Австрии применили сертифицированный ранцевый электрорыболовный аппарат, с помощью которого детально обследовали весь бассейн реки Шахимардан в пределах узбекского эксклава Шахимардан.

Применение электрорыболовного инструмента в реке Коксу на этот раз позволило нам в добавок к маринке, также обнаружить гольца (*Nemachilus* sp.) идентичного на того же вида в реке Шахимардан. Однако, здесь гольцы были найдены только в устьевой части реки (станция 8) и несколько выше. Здесь было поймано 65 особей маринок разного возраста, 3 особей гольцов. Проведенные тщательные исследования доказали, что рыба абсолютно отсутствует выше водопада. что подтвердило наши данные, полученные осенью 2021 г. Установлено, что вся рыба накапливаются в нижнем бьефе искусственного водопада. Это доказывает, что водопад является непроходимым барьером для рыб и не позволяет им мигрировать выше по течению. Согласно сведениям местных старожилов, данный водопад был образован в результате строительства дороги и связанной с этим проведения взрывных работ по переносу русла реки в 1970х годах. Вполне возможно, что до этого рыбы имели возможность мигрировать выше этой точки, до самых истоков реки.

Поскольку были пойманы всего 3 экз. гольца, мы решили не приводить их в табличной форме. Стандартная длина тела: от 113 до 130 мм, масса от 10 до 13 г Возраст и пол пойманных гольцов не определяли.

Таким образом, применение электрорыболовного инструмента позволил нам доказать, что в настоящее время что во всей системе реки Шахимардан обитают только 2 вида рыб: маринка (*S. Eurystomus*; рис.2) и голец пока неизвестного вида (*Nemachilus* sp.; рис.3). Следует отметить, что ранее Sheraliev & Peng [20] заявляли о находке нового вида гольцов – *Triplophysa ferganaensis Sheraliev & Peng, 2021* в верховьях реки Аксу в бассейне реки Шахимардан. Кроме того, эти же авторы обнаружили недалеко от реки Шахимардан другой вид – *Triplophysa strauchii*. Проведенное нами сравнение морфометрических показателей дает основание с некоторой уверенностью предполагать, что это *T.ferganaensis*. Однако, пока не будут известны результаты ДНК-анализа, невозможно с уверенностью сказать, к какому виду относится пойманный нами голец.

(a) (b)

Рисунок 2 – *Schizothorax eurystomus Kessler*, 1872 найденный в реке Коксу (a) и ее ротовой аппарат (b) с заметным острым ротовым чехликом.

(a) (b)

Рисунок 3 – *Nemachilus sp.* найденный в реке Коксу (a) и ее ротовой аппарат (b).

В связи с тем, что температура в реке Коксу была выше (9.5^{0}C) и количество пойманных рыб было значительно больше, чем после слияния с рекой Аксу (7.7^{0}C), мы предполагаем, что более высокая температура Коксу может являться более подходящей средой для зимования маринок и может играть ключевую роль в ее жизненном цикле. Кроме того, постоянные расходы и стабильно более высокая температура воды приводит к развитию кормовой базы реки Коксу в течение даже зимних периодов, что привлекает рыб к миграции в эту речную систему. Устранение двух полных миграционных барьеров: бетонного водораспределительного сооружения и искусственного водопада высотою около 3.5 м в русле реки Коксу приведет к еще большему увеличению ее значения для популяций рыб. Это предположение может быть научно подтверждено после дальнейшего отслеживания миграции рыб в будущем.

Заключение

Нами впервые установлено факт существование рыбы в реке Коксу, бассейн реки Шахимардан, в эксклаве Шахимардан Ферганского района Ферганской области Республики Узбекистан. Ихтиофауна реки Коксу состоит в основном из маринки (S. eurystomus Kessler, 1872), и гольца (*Triplophysa ferganaensis Sheraliev & Peng,* 2021). Последний вид встречается довольно редко и только в нижнем течении и устьевых участках. Местное население если раньше не знало об обитании рыбы в их реке, то сейчас они уже осведомлены о наличии рыбы в реке. Хотя население Шахимардана издревле славится своими традициями беречь эту реку как священную, случаи неконтролируемой любительской ловли рыбы, особенно в весенний нерестовый период встречаются довольно часто. В связи с этим, возникает необходимость принятия мер по охране рыбных ресурсов этой очень чувствительной речной экосистемы, особенно с учетом усиления гидроэнергетического строительства в будущем.

Нами рекомендовано обязательное строительство рыбозащитных и рыбопропусных устройств при намечаемом строительстве ГЭС в среднем течении реки Коксу. Кроме того, рекомендовано устранить все барьеры на пути миграции рыб по реке, что позволить восстановить единство уникального речного континуума.

Экологические условия реки Коксу, а также всего бассейна реки Шахимардан вполне подходят для существования рыбных популяций. Положительные стороны экосистемы реки в качестве местообитания рыб включает в себя: наличие круглогодичного стока воды с довольно стабильными расходами воды, постоянство температуры в пределах 8.1-10.6, отсутствие ледовых явлений, а также стабильное развитие кормовой базы в течение всего года.

Источники финансирования

Этот проект получил финансирование от исследовательской и инновационной программы Европейского союза "Горизонт 2020" в соответствии с грантовым соглашением № 101022905.

Благодарность, конфликт интересов

Авторы заявляют, что у них нет конфликта интересов.

Литература

1. Karimov, B. K., S. S. Shoergashova, Fadong Li, V. N. Talskikh, and L. N. Latisheva. "Impact of agricultural development on water quality in Zarafshan River, Uzbekistan, Central Asia: Trends since 1960s." In Current Directions in Water Scarcity Research, vol. 5, pp. 411-436. Elsevier, 2022. https://doi.org/10.1016/B978-0-323-85378-1.00021-0

2. Karimov, B. K., and V. N. Talskikh. "Biodiversity of Indicator Biocenoses of Lotic Ecosystems of the Aral Sea Basin, Central Asia, Used in Hydrobiological Monitoring." In Biodiversity, Conservation and Sustainability in Asia: Volume 2: Prospects and Challenges in South and Middle Asia, pp. 1031-1061. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-030-73943-0_57

3. Тимирханов, С. Р. "Экологическая изменчивость голого османа (gymnodiptychus dybowskii (kessler, 1874)) в водоемах средней азии и казахстана." Вестник КазНУ. Серия экологическая 28, no. 2 (2016).

4. Тимирханов, Серик Ракишжанович. "Морфоэкологическая характеристика популяций чешуйчатого османа (Diptychus maculatus Steindachner, 1866) в водоемах Центральной Азии." Астраханский вестник экологического образования 2 (36) (2016): 38-46.

5. Мамилов Н. Ш., Каримов Б. К., Jörg Freyhof. (2021). Статус аборигенных непромысловых рыб Центральной Азии. Selevinia. Т. 29. С. 137-138.

6. Берг, Лев Семенович. Рыбы пресных вод СССР и сопредельных стран. Vol. 27. Изд-во Академии Наук СССР, 1948.

7. Никольский, Г. В. "Рыбы Таджикистана." Тр. Тадж. базы АН СССР, М., Л., АН СССР (1938).

8. EU 2018. (2018). Guidance on the requirements for hydropower in relation to EU Nature legislation. Luxembourg: Publications Office of the European Union. P. 87

9. Jorde, Klaus, Bertalan Alapfy, Hannah Schwedhelm, Tobias Siegfried, Helmut Habersack, Jan De Keyser, Daniel S. Hayes, Anushik Purushottam, Matthias Schneider, and Oyture Anarbekov. "EU supports small hydropower in Central Asia." The International Journal on Hydropower & Dams 29, no. 5 (2022): 52-59.

10. Hayes, Daniel S., Julia M. Brändle, Carina Seliger, Bernhard Zeiringer, Teresa Ferreira, and Stefan Schmutz. "Advancing towards functional environmental flows for temperate floodplain rivers." Science of the Total Environment 633 (2018): 1089-1104.

11. Karimov, B. K., M. Matthies, V. Talskikh, M. A. Plotsen, and E. B. Karimov. "Salinization of river waters and suitability of electric conductivity value for saving freshwater from salts in Aral Sea Basin." Asian Journal of Water, Environment and Pollution 16, no. 3 (2019): 109-114.

12. Фонд CEPF. (2017). Очаг биоразнообразия в Центральноазиатском горном регионе. С. 230. https://www.cepf.net/sites/default/files/mountains-central-asia-ecosystem-profile-russian.pdf

13. Reynolds, J. B., A. L. Kolz, A. V. Zale, D. L. Parrish, and T. M. Sutton. "Electrofishing" Fisheries techniques, 3rd edition. American Fisheries Society (2012).

14. Зиновьев, Евгений Александрович, Сергей Анатольевич Мандрица. "Методы исследования пресноводных рыб." Пермь: Пермский университет (2003).

15. Freyhof, Jörg, and Maurice Kottelat. "Handbook of European freshwater fishes." (2007).

16. Fricke R., Eschmeyer W. N., and van der Laan R. 2019. Eschmeyer's Catalog of Fishes: Genera, Species, References, Version 05/2019, Eds. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

17. Karimov B. Schizothorax eurystomus. The IUCN Red List of Threatened Species 2020: T169838369A169838374, Version 30/2022. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T169838369A169838374.en

18. Турдаков Ф. А. (1963). Рыбы Киргизии. Фрунзе, Изд-во АН КирССР. С. 283.

19. Burnashev, M. S. "Snow trouts of the Zeravshan River." Proc. Kishinev State Univ.(Biol.) 4 (1952): 111-125.

20. Sheraliev, Bakhtiyor, and Zuogang Peng. "Triplophysa ferganaensis, a new loach species from Fergana Valley in Central Asia (Teleostei: Nemacheilidae)." Journal of Fish Biology 99, no. 3 (2021): 807-817. https://doi.org/10.1111/jfb.14764

References

1. Berg, Lev Semenovich. Ryby presnyh vod SSSR i sopredel'nyh stran. Vol. 27. Izd-vo Akademii Nauk SSSR, 1948. (In Russian)

2. Burnashev, M. S. "Snow trouts of the Zeravshan River." Proc. Kishinev State Univ.(Biol.) 4 (1952): 111-125.

3. EU 2018. (2018). Guidance on the requirements for hydropower in relation to EU Nature legislation. Luxembourg: Publications Office of the European Union. P. 87

4. Fond CEPF. (2017). Ochag bioraznoobrazija v Central'noaziatskom gornom regione. S. 230. https://www.cepf.net/sites/default/files/mountains-central-asia-ecosystem-profile-russian.pdf (In Russian)

5. Freyhof, Jörg, and Maurice Kottelat. "Handbook of European freshwater fishes." (2007).

6. Fricke R., Eschmeyer W. N., and van der Laan R. 2019. Eschmeyer's Catalog of Fishes: Genera, Species, References, Version 05/2019, Eds. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

7. Hayes, Daniel S., Julia M. Brändle, Carina Seliger, Bernhard Zeiringer, Teresa Ferreira, and Stefan Schmutz. "Advancing towards functional environmental flows for temperate floodplain rivers." Science of the Total Environment 633 (2018): 1089-1104.

8. Jorde, Klaus, Bertalan Alapfy, Hannah Schwedhelm, Tobias Siegfried, Helmut Habersack, Jan De Keyser, Daniel S. Hayes, Anushik Purushottam, Matthias Schneider, and Oyture Anarbekov. "EU supports small hydropower in Central Asia." The International Journal on Hydropower & Dams 29, no. 5 (2022): 52-59.

9. Karimov B. Schizothorax eurystomus. The IUCN Red List of Threatened Species 2020: T169838369A169838374, Version 30/2022. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T169838369A169838374.en

10. Karimov, B. K., and V. N. Talskikh. "Biodiversity of Indicator Biocenoses of Lotic Ecosystems of the Aral Sea Basin, Central Asia, Used in Hydrobiological Monitoring." In Biodiversity, Conservation and Sustainability in Asia: Volume 2: Prospects and Challenges in South and Middle Asia, pp. 1031-1061. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-030-73943-0_57

11. Karimov, B. K., M. Matthies, V. Talskikh, M. A. Plotsen, and E. B. Karimov. "Salinization of river waters and suitability of electric conductivity value for saving freshwater from salts in Aral Sea Basin." Asian Journal of Water, Environment and Pollution 16, no. 3 (2019): 109-114.

12. Karimov, B. K., S. S. Shoergashova, Fadong Li, V. N. Talskikh, and L. N. Latisheva. "Impact of agricultural development on water quality in Zarafshan River, Uzbekistan, Central Asia: Trends since 1960s." In Current Directions in Water Scarcity Research, vol. 5, pp. 411-436. Elsevier, 2022. https://doi.org/10.1016/B978-0-323-85378-1.00021-0

13. Mamilov N. Sh., Karimov B. K., Jörg Freyhof. (2021). Status aborigennyh nepromyslovyh ryb Central'noj Azii. Selevinia. T. 29. S. 137-138. (In Russian)

14. Nikol'skij, G. V. "Ryby Tadzhikistana." Tr. Tadzh. bazy AN SSSR, M., L., AN SSSR (1938). (In Russian)

15. Reynolds, J. B., A. L. Kolz, A. V. Zale, D. L. Parrish, and T. M. Sutton. "Electrofishing" Fisheries techniques, 3rd edition. American Fisheries Society (2012).

16. Sheraliev, Bakhtiyor, and Zuogang Peng. "Triplophysa ferganaensis, a new loach species from Fergana Valley in Central Asia (Teleostei: Nemacheilidae)." Journal of Fish Biology 99, no. 3 (2021): 807-817. https://doi.org/10.1111/jfb.14764

17. Timirhanov, S. R. "Jekologicheskaja izmenchivost' gologo ocmana (gymnodiptychus dybowskii (kessler, 1874)) v vodoemah srednej azii i kazahstana." Vestnik KazNU. Serija jekologicheskaja 28, no. 2 (2016). (In Russian)

18. Timirhanov, Serik Rakishzhanovich. "Morfojekologicheskaja harakteristika populjacij cheshujchatogo osmana (Diptychus maculatus Steindachner, 1866) v vodoemah Central'noj Azii." Astrahanskij vestnik jekologicheskogo obrazovanija 2 (36) (2016): 38-46. (In Russian)

19. Turdakov F. A. (1963). Ryby Kirgizii. Frunze, Izd-vo AN KirSSR. S. 283. (In Russian)

20. Zinov'ev, Evgenij Aleksandrovich, Sergej Anatol'evich Mandrica. "Metody issledovanija presnovodnyh ryb." Perm': Permskij universitet (2003). (In Russian)

IRSTI 34.21.17 https://doi.org/10.26577/eb.2023.v96.i3.012

D.D. Kozhakhmetova[1,2]*, D.T. Chekimbayeva[1,2], A.M. Tlenshiyeva[1,2], T.M. Shalakhmetova[1,2]

[1]Al-Farabi Kazakh National University, Kazakhstan, Almaty
[2]Scientific Research Institute of Biology and Biotechnology Problems, al-Farabi Kazakh National University, Kazakhstan, Almaty
*e-mail: ddiyeol@mail.ru

STUDY OF THE INFLUENCE OF NITRATES AND NITRITES ON EMBRYOGENESIS OF *DANIO RERIO*

An increase in the amount of environmental pollution caused by different hazardous elements and anthropogenic pressure complicates and decreases Kazakhstan's natural resources' stable ecological state. According to the Republic of Kazakhstan's bulletin on the state of the environment, the content of calcium and sodium nitrate and nitrite ions in water bodies grew by 13.5 and 7.5%, respectively, in the first half of 2022, indicating that their actual concentration exceeded the background class. At the same time, it was discovered that the level of nitrate and nitrite ions is surpassed not only in aquatic bodies, but also in the Republic of Kazakhstan's atmospheric air and soil. Furthermore, there was a decline in aquatic organism diversification and abundance in the analyzed water bodies, which could be attributed to nitrate-nitrite pollution and harmful effects on juveniles. As a result, the goal of this study was to look at the effects of nitrates and nitrites on Danio Rerio embryogenesis. This object was chosen over others for its lower maintenance expenses, rapid advancement of embryogenesis phases, transparency, and the comparatively small size of the embryos for successful visual observation. Based on our findings, the embryotoxic and teratogenic effects of calcium nitrate and sodium nitrite have been proven, resulting in the death of fish. Calcium nitrate and sodium nitrite at concentrations of 1, 10, and 100 MPC have been demonstrated to cause dose-dependent embryonic death. Furthermore, to a greater extent under the action of sodium nitrite. Teratogenic diseases were discovered in surviving larvae, including edema of the yolk sac and pericardium of the heart, curvature of the skeleton and asymmetry of the body, edema of the retina, and aberrant formation of the organs of the oral cavity. The findings acquired are theoretically and practically important in the fields of ecology, ecotoxicology, and aquatic organism biodiversity protection. They contribute to our understanding of the hazardous effects of naturally occurring nitrates and nitrites, as well as the need to employ Danio rerio embryos and larvae as test objects for bioindication of polluted water bodies.

Key words: ecology, zebrafish, nitrates, nitrites, emryotoxicity, teratogenicity, histostructure.

Д.Д. Кожахметова[1,2]*, Д.Т. Чекимбаева[1,2], А.М. Тленшиева[1,2], Т.М. Шалахметова[1,2]

[1]Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
[2]Биология және биотехнология мәселелері ғылыми-зерттеу институты Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
*e-mail: ddiyeol@mail.ru

Danio rerio эмбриогенезіне нитраттар мен нитриттердің әсерін зерттеу

Әртүрлі қауіпті факторлардың және антропогендік қысымның әсерінен қоршаған ортаның ластану деңгейінің артуы Қазақстанның табиғи ресурстарының тұрақты экологиялық жағдайын қиындатады және төмендетеді. Қазақстан Республикасының қоршаған ортаның жай-күйі туралы бюллетеніне сәйкес 2022 жылдың бірінші жартыжылдығында су айдындарындағы кальций мен натрий нитратының және нитрит иондарының мөлшері тиісінше 13,5 және 7,5%-ға өсті, яғни олардың нақты концентрациясы фондық деңгейден асып түсті. Сонымен қатар, нитрат пен нитрит иондарының деңгейі су айдындарында ғана емес, Қазақстан Республикасының атмосфералық ауасы мен топырағында да асып түсетіні анықталды. Оған қоса, зерттелетін су объектілерінде биологиялық алуантүрлілік пен су организмдерінің санының төмендеуі байқалды, бұл нитрат-нитритпен ластанумен және жас организмдерге токсикалық әсер етумен байланысты болуы мүмкін. Сондықтан бұл зерттеудің мақсаты нитраттар мен нитриттердің Danio rerio эмбриогенезіне әсерін зерттеу болып табылды. Басқа сынақ объектілерімен салыстырғанда бұл объектіні таңдау зерттеуге кететін шығындардың төмендігімен, эмбриогенез кезеңдерінің

леуімен, эмбрион қабықшасының мөлдірлігімен және сәтті визуалды бақылау үшін эмбриондардың салыстырмалы түрде кішкентай өлшемімен түсіндіріледі. Алынған нәтижелеріміз негізінде кальций нитраты мен натрий нитритінің эмбриотоксикалық және тератогенді әсері анықталды, бұл ақыр соңында балықтардың өліміне әкеледі.1, 10 және 100 ШРК концентрациясында кальций нитраты мен натрий нитритінің әсері дозаға тәуелді эмбриондық өлімді тудыратыны көрсетілген, оның ішінде, натрий нитритінің әсерінен көбірек дәрежеде. Тірі қалған дернәсілдерде тератогенді бұзылыстар эмбрионның сарыуыз қапшығы мен жүрек перикардының ісінуі, қаңқаның қисаюы және дене ассиметриясы, көз торының ісінуі, ауыз қуысы мүшелерінің аномальды түрде қалыптасуы түрінде анықталды. Алынған мәліметтер экология, экотоксикология және су организмдерінің биоалуантүрлілігін сақтау саласында теориялық және практикалық маңызы бар. Белгілі бір дәрежеде олар табиғатта кең таралған нитраттар мен нитриттердің токсикалық әсері туралы білімді кеңейтеді, сонымен қатар ластанған су объектілерін биоиндикациялау үшін сынақ объектілері ретінде Danio rerio эмбриондары мен дернәсілдерін пайдалану қажеттілігін растайды.

Түйін сөздер: экология, зебрафиш, нитраттар, нитриттер, эмбриотоксинділік, тератогенділік, гистоқұрылым.

Д.Д. Кожахметова[1,2]*, Д.Т. Чекимбаева[1,2],
А.М. Тленшиева[1,2], Т.М. Шалахметова[1,2]

[1]Казахский Национальный Университет имени аль-Фараби, Казахстан, г. Алматы
[2]Научно-исследовательский институт проблем биологии и биотехнологии,
Казахский национальный университет имени аль-Фараби, Казахстан, г. Алматы
*e-mail: ddiyeol@mail.ru

Исследование влияния нитратов и нитритов на эмбриогенез *Danio rerio*

Повышение уровня загрязнения окружающей среды под воздействием различных опасных факторов и антропогенной нагрузки осложняет и снижает стабильное экологическое состояние природных ресурсов Казахстана. По данным бюллетеня РК о состоянии окружающей среды в первом полугодии 2022 года содержание нитрат- и нитрит-ионов кальция и натрия в водоемах увеличилось соответственно на 13,5 и на 7,5%, то есть фактическая их концентрация превысила фоновый уровень. При этом установлено, что уровень нитрат- и нитрит-ионов превышен не только в водоемах, но и в атмосферном воздухе и почве РК. Помимо этого наблюдалось снижение биоразнообразия и численности гидробионтов в исследованных водоемах, возможно, связанные с нитрат-нитритным загрязнением и токсическим влиянием на молодь. Поэтому целью данного исследования явилось изучение влияния нитратов и нитритов на эмбриогенез Danio Rerio. Выбор данного объекта по сравнению с другими тест-объектами обусловлен более низкими расходами на содержание, быстрым протеканием стадий эмбриогенеза, прозрачностью и относительно небольшим размером эмбрионов для успешного визуального наблюдения. На основании полученных нами результатов установлено эмбриотоксическое и тератогенное действие нитрата кальция и нитрита натрия, приводящее, в конечном счете, к гибели рыб. Показано, что воздействия нитрата кальция и нитрита натрия в концентрации 1, 10 и 100 ПДК вызывают дозозависимую смертность эмбрионов. Причем при воздействия нитрита натрия в большей степени. У выживших личинок обнаруживались тератогенные нарушения в виде отека желточного мешка и перикарда сердца, искривления скелета и асимметрии тела, отека сетчатки глаза и неправильного формирования органов ротовой полости. Полученные данные имеют теоретическое и практическое значение в области экологии, экотоксикологии и в сфере сохранения биоразнообразия гидробионтов. Они в известной степени расширяют знания о токсическом действии широкораспространенных в природе поллютантов – нитратов и нитритов, а также подтверждают факт необходимости использования эмбрионов и личинок Danio Rerio в качестве тест-объектов при биоиндикации загрязненных водоемов.

Ключевые слова: экология, зебрафиш, нитраты, нитриты, эмбриотоксичность, тератогенность, гистоструктура.

Introduction

Nitrites and nitrates are widely employed in the preservation of meat and other consumable products. Because of their use in intensive agriculture, animal husbandry, and wastewater discharges, they may reach the food chain as chemical contaminants in water [1]. Plants use nitrates as their primary nutrition in nature. The majority of nitrates used in commerce are inorganic fertilizers. Nitrates and nitrites are also

employed in food preservation, some medications, and ammunition and explosives manufacturing [2]. Because decomposition or denitrification happens in modest amounts under aerobic circumstances, nitrate leaks into the aquifer in significant quantities. Nitrate is denitrified or nearly entirely degraded to nitrogen under anaerobic circumstances. Surface waters can also undergo nitrification and denitrification depending on temperature and pH. However, nitrate uptake by plants depletes nitrate stores in surface waters. Nitrates are found in the air mostly as nitrates and inorganic aerosols, but also as nitrate radicals and organic gases [3].

Nitrates are extremely mobile in soil and can migrate into groundwater due to their high water solubility and limited soil retention. Because nitrates and nitrites are not volatile, they can linger in water until they are absorbed by plants and other creatures [4]. Bacteria uptake ammonium nitrate, and nitrate decomposition is faster in anaerobic circumstances [5]. Nitrite can readily oxidize to nitrate, and nitrate is the more prevalent component in groundwater [6].

Calcium ions dominated precipitation by 13.5%, sodium ions by 7.5%, and actual concentrations of nitrite and nitrate anions, chemical oxygen consumption exceeded the background class, according to the Republic of Kazakhstan's information bulletin on the state of the environment in the first half of 2022. In urban wastewater discharges, exceeding quality criteria based on these indicators is most common [7].

The amount of nitrate and nitrite ions is exceeded not only in aquatic bodies, but also in the Republic of Kazakhstan's atmospheric air and soil, according to biotesting data. At the same time, the active expansion of industry, agriculture, and human life pollutes water, land, and the atmosphere even more [8-13].

Materials and reseach methods

The study's subject and the conditions for its content

The *Danio rerio* fish, which is widely used in science as a model object to establish various teratogenic effects of chemicals, pollutants, drugs, and so on, was chosen as the subject of study [14]. Individuals with sexual maturity and a length of 4 cm were used in the experiment. Females were distinguished from males by the presence of a large round belly and mild back lines, while males had a longer elongated body. The fish were kept in 15-liter aquariums with natural light, a saturation of about 80% oxygen, and a regular medium pH of 6.5-8. The ideal temperature for breeding *Danio rerio* fish is 25-28ºC. The diet consisted of dry food supplemented with vitamins and live A. crustaceans. To prevent fungal infections, methylene blue drops were added at each water change. 5 ml of the solution was added for every 10 l aquarium water for fish treatment. Males were kept apart from females and were only kept in the same aquarium during spawning.

Principles and conditions for obtaining embryos mastering the ZFET methodology

The Zebrafish embryotoxicity test (ZFET) is a method for determining the toxicity of compounds by observing their effects on zebrafish embryos.

It is based on the use of zebrafish embryos, which are extremely sensitive to harmful chemicals and grow quickly.

During testing, zebrafish embryos are immersed in a variety of hazardous solutions before their survival, growth, and development are assessed. Changes in these characteristics may indicate a substance's toxicity. The ZFET methodology, which can be used to analyze medications, insecticides, and other chemicals, is an alternative to established toxicity assessment methods such as animal testing. Figure 1 depicts the procedure for carrying out the ZFET methodology. The resulting embryos are first disseminated on Petri dishes, then fertilized embryos are picked using microscopy, and dead or coagulated eggs are eliminated. It is also useful for determining the environmental safety of substances and materials [15-19].

For the ZFET method to work properly, eggs must be quickly distributed among Petri dishes, and they must be at the zygote stage at the time of distribution (fertilized eggs) [20]. Embryos distributed, 10-15 pieces each, on prepared Petri dishes with a diameter of 90 mm that already contain solutions of the test substances in various concentrations. Every 12 hours, changes were observed. To compare, a portion of the eggs in the control filtered water were distributed. A Leica DMLB2 stereomicroscope and Micros MC20, were used to record and photograph each developmental change. The embryos' transparent chorion and the fry's transparent shell allow for observation of their development even after 72 hours.

Figure 1 shows photographs of *Danio rerio* embryos fixed at different stages of development, from an unfertilized egg to a hatched embryo at the 96-hour development stage.

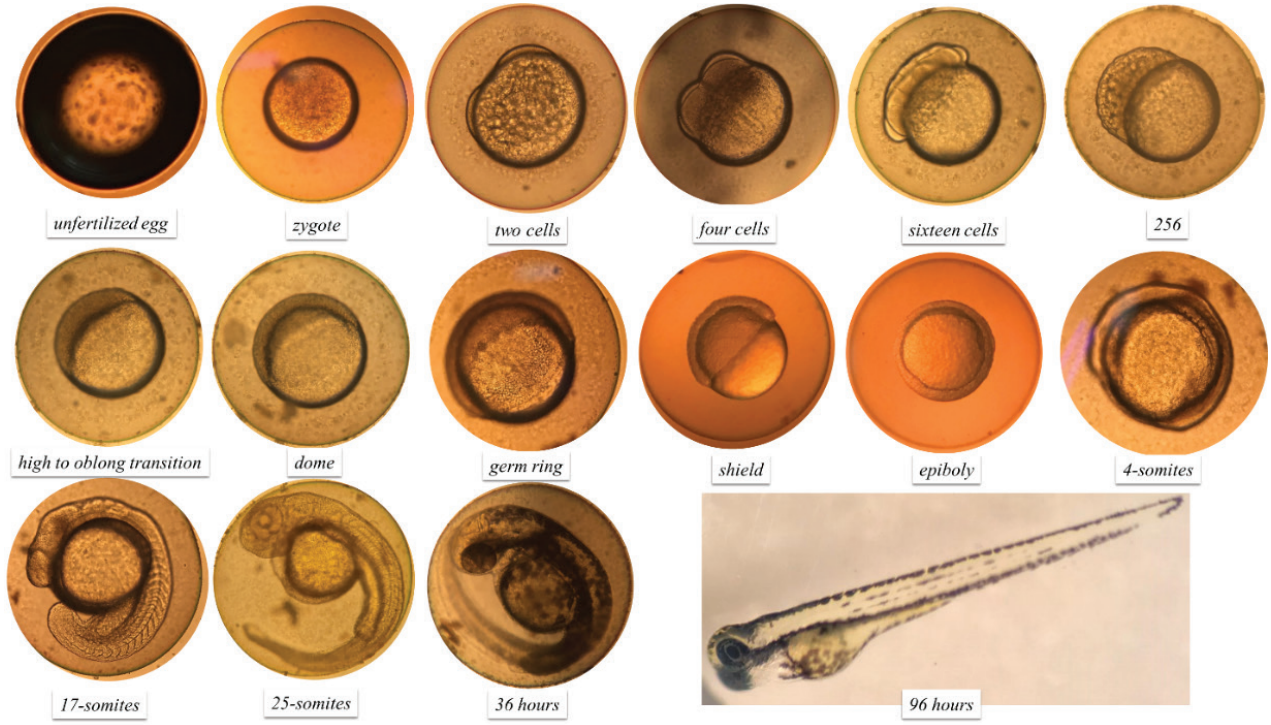


Figure 1 – *Danio rerio* fish embryogenesis at various stages berfore 96 hpf development

Method for preparation different concentrations of calcium nitrate and sodium nitrite solutions

$Ca(NO_3)_2$, also known as calcium saltpeter or calcium nitrate, is classified as dangerous to living organisms in the third class. The OECD recommended a maximum allowable concentration of 40 mg/dm^3 for them. Aqueous solutions of varying concentrations were prepared in accordance with the ecotoxicological protocol:

Control: pure filtered water
1 MPC: 40 (0.04) mg/dm^3 of $Ca(NO_3)_2$
10 MPC: 400 (0.4) mg/dm^3 of $Ca(NO_3)_2$
100 MPC: 4000 (4) mg/dm^3 of $Ca(NO_3)_2$

Calcium nitrate is used in the chemical industry, the match industry, industrial explosive production, and fertilizer production. It is used as a raw material in the production of reagents, as an additive to industrial concrete mixtures and mortars, and in the preparation of brines in industrial refrigeration. The amount of nitrates in Kazakhstan reservoirs exceeds 5.628 mg/dm^3.

$NaNO_2$, also known as the nitrite salt or sodium nitrite, is a white to slightly yellowish crystalline powder that is hygroscopic and readily soluble in water. It is a precursor to many organic compounds, including pharmaceuticals, dyes, and pesticides, but it is most well-known as the E250 food additive found in processed meats and fish products. Belongs to the first class of extremely dangerous substances. MPC of sodium nitrite is equal to 3.3 mg/dm^3:

Control: filtered water
1 MPC: 3,3 (0,0033g) mg/dm^3 of $NaNO_2$
10 MPC: 33 (0,033g) mg/dm^3 of $NaNO_2$
100 MPC: 330 (0,33g) mg/dm^3 of $NaNO_2$

The amount of nitrates in Kazakhstan reservoirs exceeds 0,342 mg/dm^3.

Marginal propensities to consume (MPCs) are established based on toxicological studies, risk assessments for human health, and environmental variables. Special experiments are carried out to study the hazardous qualities of the chemical as well as its influence on the human or animal body.

Based on the data acquired, safe levels of exposure to the chemical that do not result in harmful health effects are defined. MPCs can differ according on the type of substance, the mode of exposure to the body, the duration and frequency of exposure, and other factors. They are established at the legislative level and are used to control environmental and food quality [21-23].

Results of research and their discussion

Study the influence of calcium nitrate on the development of Danio Rerio

Table 1 illustrates the results of a study on the influence of calcium nitrates on the development of *Danio rerio* where the mortality rate of embryos in the control group is 3.3%, which is not higher than the OECD mortality rate [24-25].

In the experimental group exposed to $Ca(NO_3)_2$ at a concentration of 1 MPC, the lethality was 5.5%, which exceeded the control by 1.6 times. When exposed to $Ca(NO_3)_2$ at a concentration of 10 MPC, embryonic mortality was 11.2%, which exceeded the control values by 3.4 times. And when exposed to a higher dose of 100 MPC, the mortality of embryos was 32.6%, which is 9.9 times higher than the control level.

Table 1 – The percentage of mortality of *Danio rerio* embryos in the control group (clean filtered water) and varied amounts of calcium nitrate ($Ca(NO_3)_2$) observed every 12 hours

Period, hpf	Control	1 MPC	10 MPC	100 MPC
12	3.3%	3.3%	0%	4.4%
24	0%	2.2%	5.5%	0%
36	0%	0%	2.3%	5.8%
48	0%	0%	0%	6.9%
60	0%	0%	3.3%	6.6%
72	0%	0%	0%	8.9%
Total	3.3%	5.5% Mortality	11.2% Mortality	32.6% Mortality

Many variables and experimental groups were employed throughout the experiment to assure the experiment's reliability and repeatability. The arithmetic mean of mortality at 1, 10, and 100 MPC of calcium nitrate solutions was computed.

There was a control group and two different experimental groups in the experiment. The control group did not receive calcium nitrate, whereas the other experimental groups did. Throughout the experiment, many constants stayed constant. The time and duration that each zebrafish was exposed to calcium nitrate remained constant.

Study the influence of sodium nitrite on the development of Danio Rerio

The results of the study of the effect of sodium nitrites on the development of *Danio rerio* are shown in Table 2. The mortality of embryos in the control group is 3.3%, which does not exceed the mortality rate according to OECD data.

In the experimental group of $NaNO_2$ at a concentration of 1 MPC, the lethality of embryos was 5.5%, which is 1.6 times more than in the control; under the influence of $NaNO_2$ concentration of 10 MPC, the mortality of embryos was 14.8%, which is 4.4 times more than in the control. Moreover, exposure to a higher dose of 100 MPC resulted in a death rate of 42.5%, which is 12.8 times higher than in the control.

When compared to the previous table, the data clearly show that zebrafish exposed to sodium nitrite had a higher rate of mortality and physical deformities; however, both experimental groups experienced similar mortality rates, and embryos exposed to 100 MPC sodium nitrite had a much higher mortality rate. Embryos exposed to MPC 1 and 10 also hatched earlier than those that were not. These findings suggest that sodium nitrite contributed to aberrant embryonic development and inappropriate growth timing. These variables could have led to the failure of poorly developed organs, resulting in a greater death rate in embryos exposed to sodium nitrite.

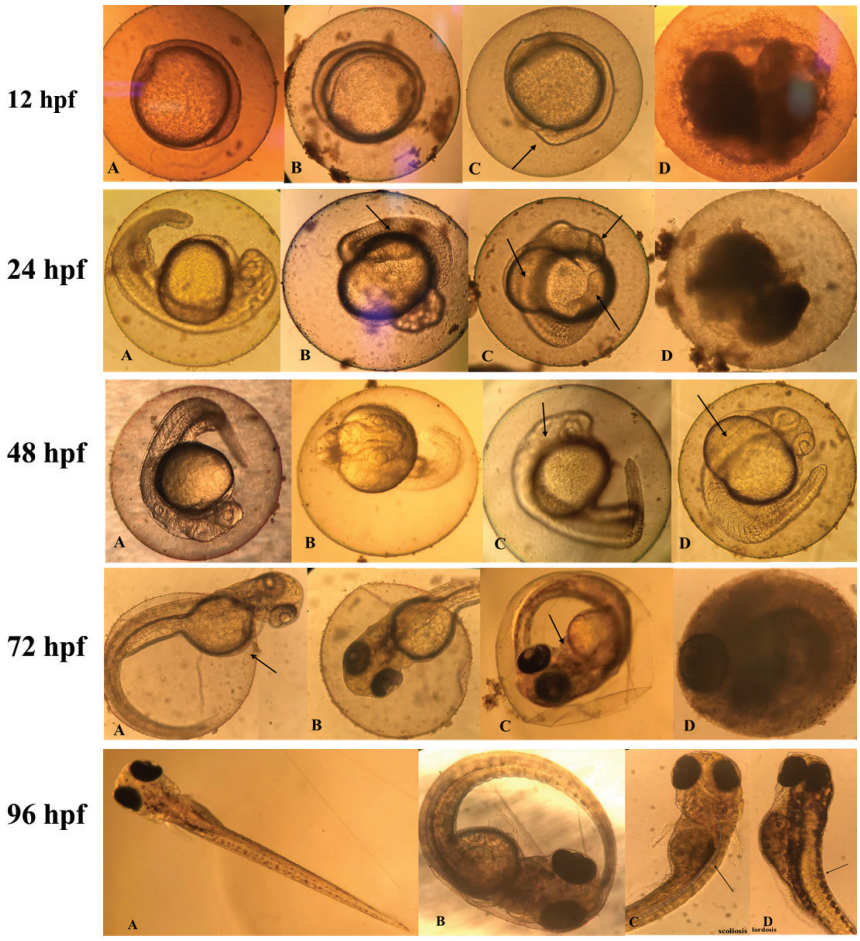


Figure 2 – *Danio rerio* embryos in a 12, 24, 48, 72, 96-hour developmental study at different concentrations of calcium nitrate. 12 hpf (A) – embryo in the control group, 12 hpf (B) – embryo at 1 MPC, 12 hpf (C) – embryo in the group with 10 MPC, start of protein coagulation, 12 hpf (D) – embryo at 100 MPC, complete coagulation and death of the embryo. 24 hpf (A) – embryo with normal development, 24 hpf (B) – embryo at 1 MPC solution, 24 hpf (C) – embryo at 10 MPC with yolk sac edema, 24 hpf (D) – dead embryo at 100 MPC. 48 hpf (A) – embryo in the control group with normal development, 48 hpf (B) – embryo at 1 MPC of calcium nitrate solution, 48 hpf (C) – embryo in the control group 10 MPC with developmental delay,48 hpf (D) – *Danio rerio* embryo at 100 MPC with yolk sac edema. 72 hpf (A) – control group at the hatching stage, 72 hpf (B) – group in 1 MPC solution, 72 hpf (C) – group with 10 MPC, the embryo with a developmental defect could not leave the chorion, 72 hpf (D) – group in 100 MPC solution completely coagulated. 96 hpf (A) – embryo in the control group with normal development, 96 hpf (B) – embryo at a concentration of 1 MPC with developmental delay, 96 hpf (C) – *Danio rerio* embryo in the group with 10 MPC, scoliosis is observed (indicated by an arrow), body asymmetry is indicated by a dashed line along the spine, 96 hpf (D) – *Danio rerio* embryo at 100 maximum concentration limit with observed lordosis.

Table 2 – The percentage of mortality of *Danio rerio* embryos in the control group (clean filtered water) and varied sodium nitrite ($NaNO_2$) concentrations observed every 12 hours

Period, hpf	Control	1 MPC	10 MPC	100 MPC
12	3.3%	5.5%	0%	6.7%
24	0%	0%	3.3%	8.9%
36	0%	0%	0%	0%
48	0%	0%	9.2%	4.7%
60	0%	0%	2.3%	13.9%
72	0%	0%	0%	8.3%
Total	3.3%	5.5% Mortality	14.8% Mortality	42.5% Mortality

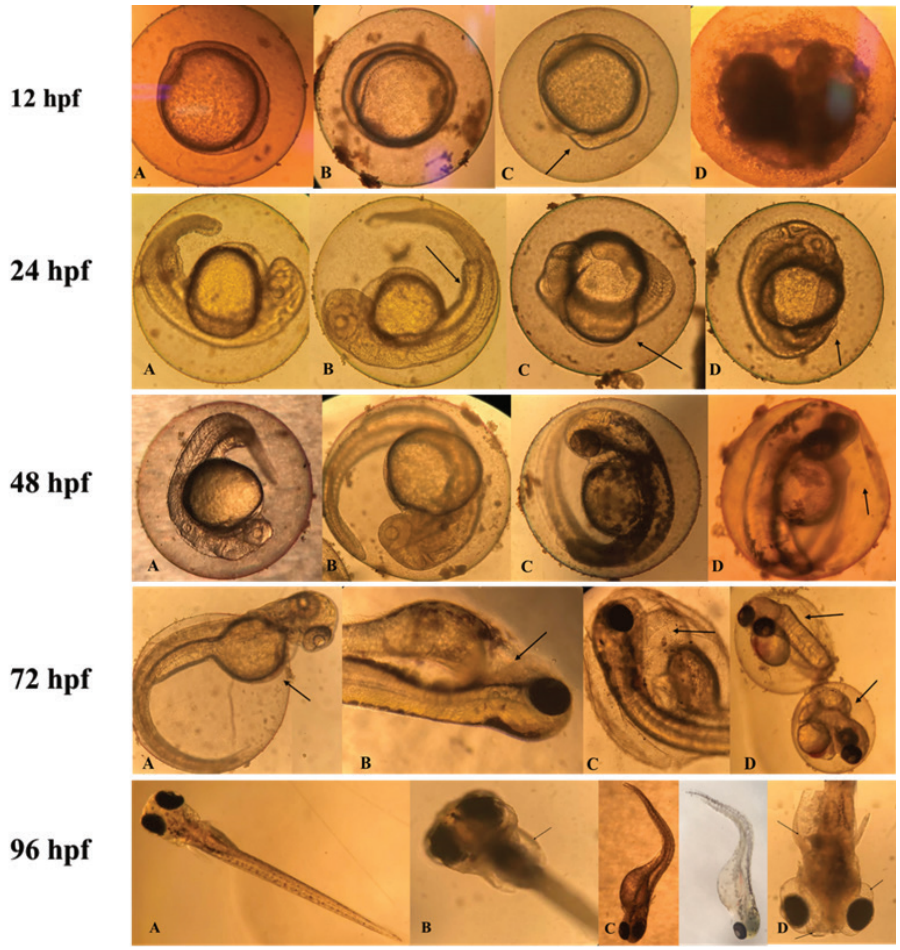


Figure 3 – Development of *Danio rerio* embryos after 12 hours, where A is the control group, B is the experimental group with 1 MPC $NaNO_2$, C is the group with 10 MPC $NaNO_2$ – the absence of somites is clearly visible, and D is the experimental group with 100 MPC $NaNO_2$, where the embryo perished due to coagulation. 24 hpf (A) represents normal development in the control group, 24 hpf (B) represents a group with 1 MPC $NaNO_2$ – yolk sac edema (marked by an arrow), 24 hpf (C) represents a group with 10 MPC $NaNO_2$ where yolk sac edema is visible (marked by an arrow), 24 hpf (D) represents an experimental group with 100 MPC $NaNO_2$ – developmental delay, abnormal somite division, the tail is not separated from the bodies. 48 hpf (A) represents normal development in the control group, 48 (B) represents 1 MPC $NaNO_2$, 48 (C) represents 10 MPC $NaNO_2$, and 48 (D) represents the experimental group with 100 MPC $NaNO_2$. MPC is the turbid content of the chorion (indicated by an arrow), the start of coagulation. 72 hpf (A) – a control group in which the embryo simply exits the shell (shown by an arrow). 72 hpf (B) – experimental group with 1 MPC of $NaNO_2$, there is pericardial edema and one eye is absent (shown by an arrow). 72 hpf (C) – 10 MPC $NaNO_2$ group, pericardial edema and yolk sac distortion (shown by an arrow), 72 hpf – 100 MPC group of $NaNO_2$, body curvature, tail deformity (indicated by an arrow), developmental delay. 96 hpf (A) – control group, 96 hpf (B) – experimental group 1 MPC of $NaNO_2$, immobile embryo, short fins (shown by an arrow), 96 hpf (C) – group of 10 MPC of $NaNO_2$, curvature of the body and tail, 96 hpf (D) – 100 MPC of $NaNO_2$, body asymmetry, fin length difference, enlargement of the eye, oral cavity malformations (marked by an arrow).

The arithmetic mean survival rates of zebrafish embryos in varied MPCs of calcium nitrate and sodium nitrite relative to the control are shown in Tables 3 and 4, with significant differences between control samples and solutions noted. The data were reported as a standard deviation, and $p \leq 0.05$ was utilized as the statistical significance level.

Table 3 compares the survival of *Danio rerio* embryos at various calcium nitrate concentrations to the control. The asterisks denote arithmetic means that differ significantly from the control group.

Table 4 compares the survival of *Danio rerio* embryos at various sodium nitrite concentrations to the control. The Student T-test method was employed to examine the significance of the differences between the control and experimental average groups.

Table 3 – Means of survival rate *Danio rerio* embryos at 12 hpf in different calcium nitrate MPCs in comparison with the control

	Control	1 MPC	10 MPC	100 MPC
12 hpf	10.0±0.00	9.6±0.13	10.0±0.00	9.3±0.27
24 hpf	9.6±0.13	9.3±0.13	9.6±0.13	9.0±0.23*
36 hpf	9.6±0.13	9.3±0.13	9.3±0.27	9.0±0.23*
48 hpf	9.6±0.13	9.3±0.13	9.0±0.23*	8.3±0.36*
60 hpf	9.6±0.13	9.3±0.13	8.6±0.13*	7.0±0.40*
72 hpf	9.6±0.13	9.3±0.13	8.6±0.13*	6.0±0.23*

Note: *p≤0.05, n=18 for each groups

Table 4 – Means of survival rate *Danio rerio* embryos in different sodium nitrite MPCs in comparison with the control

	Control	1 MPC	10 MPC	100 MPC
12 hpf	10.0±0.00	9.3±0.13	10.0±0.00	9.3±0.27
24 hpf	9.6±0.13	9.3±0.13	9.6±0.13	8.3±0.13*
36 hpf	9.6±0.13	9.3±0.13	9.6±0.13	8.3±0.13*
48 hpf	9.6±0.13	8.6±0.13*	8.6±0.13*	8.6±0.13*
60 hpf	9.6±0.13	8.6±0.13*	8.3±0.13*	6.3±0.36*
72 hpf	9.6±0.13	8.6±0.13*	8.3±0.13*	5.6±0.13*

Note: *p≤0.05. n=18 for each groups

The findings of this experiment are similar with previous studies in which zebrafish were exposed to nitrate or nitrite. Scientists discovered that exposing zebrafish embryos to nitrates and nitrites causes them to have aberrant developmental traits [26].

The data in photographs 2 and 3 show that embryos exposed to nitrates and nitrites are at risk of physical deformities such as curvature of the embryo's vertebral column, and the data in tables 3 and 4 show that the higher the concentration of the test substance, the greater the mortality. Embryos exposed to calcium nitrates and sodium nitrites hatched with bent dorsal canals, demonstrating that nitrates and nitrites caused the fish to develop improperly and the bone structure to develop differently than expected.

Conclusion

The investigation of the effects of calcium nitrates and sodium nitrites on the embryogenesis of the *Danio rerio* fish resulted in hypotheses. The embryotoxic and teratogenic effects of calcium nitrate and sodium nitrite were established based on the findings. Calcium nitrate and sodium nitrite at concentrations of 1, 10, and 100 MPC have been proven to cause dose-dependent embryonic mortality. Furthermore, calcium nitrates and sodium nitrites have been shown to impair the proper growth of fish in the following ways. Increased exposure to these toxins causes developmental defects such as yolk sac and pericardium swelling, spinal canal curvature, body asymmetry, immobility, eye edema and mouth malformations. Data comparison demonstrates that sodium nitrite is more embryotoxic and teratogenic than calcium nitrate. Thus, *Danio rerio* embryos, larvae, and mature species can be utilized as test items for bioindication of water pollution. The embryotoxic and teratogenic effects of calcium nitrate and sodium nitrite were established based on the results.

Funding

This work was supported by the Science Committee of the Ministry of Science and Higher Education Republic of Kazakhstan [AP14869740].

References

1. European Food Safety Authority (EFSA) rules on competing interest management. – 2017.

2. Scientists from the Agency for Toxic Substances and Disease Registry (ATSDR) (2015) Agency for Toxic Substances and Disease Registry: Nitrate/Nitrite Toxicity, September. – 2015. – P. 3-16.

3. World Health Organization. Guidelines for drinking-water quality. Addendum to Vol. 2. Health criteria and other supporting information. – 2003. – Vol. 2. – P. 313-320.

4. Nemade K., Attarde S. Development and validation of UV spectrophotometric method for simultaneous estimation of nitrate and nitrite in water, soil, drug and vegetable samples, International Journal of Advanced Chemistry. – 2014. – Vol. 2. – P. 74-79.

5. World Health Organization. "International Program on Chemical Safety, Environmental Health Criteria 5: Nitrates, Nitrites, and N-Nitroso Compounds". – 2006.

6. U.S. Agency for Toxic Substances and Diseases Registry. "Case Studies in Environmental Medicine: Nitrate/Nitrite Toxicity" ATSDR, Division of Toxicology and Human Health Sciences, Atlanta, GA. – 2001.

7. Newsletter on the state of the environment of the Republic of Kazakhstan, September. – 2022. – P. 13-21.

8. Newsletter on the state of the environment of the Republic of Kazakhstan, September. – 2021. – P. 12-16.

9. Newsletter on the state of the environment of the Republic of Kazakhstan, June. – 2022. – P. 11-16.

10. The danger of nitrates and nitrites. – Electron. Data. – Access mode: https://alfafiltr.com/opasnost-nitratov-i-nitritov.html

11. National report on the state of the environment and the use of natural resources in the Republic of Kazakhstan for 2021. – P. 14.

12. National report on the state of the environment and on the use of natural resources. Status of water resources of the republic of Kazakhstan. – 2016. – P. 10.

13. Order of the Chairman of the Water Resources Committee of the Ministry of Agriculture of the Republic of Kazakhstan. Registered with the Ministry of Justice of the Republic of Kazakhstan on December 13. – 2016. № 14513.

14. Ellett F. and Lieschke G.J. Zebrafish as a model for vertebrate hematopoiesis, Australia. – 2010. – Vol. 10. – P. 563–570.

15. Nizhnevart Publishing House. state un-ta. Biotesting as a modern method for assessing the toxicity of natural and waste waters: Monograph. – Nizhnevartovsk.– 2013. – P. 119.

16. Sobanska M., Scholz S., Nyman A., Cesnaitis R., Gutierrez Alonso S., Kluver N., Kuhne R., Tyle H., Knecht J., Dang Z., Lundbergh I., Carlon C. and De Coena W. Applicability of the Fish Embryo Acute Toxicity (FET), Test (OECD) in the Regulatory Context of Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH), Environmental Toxicology and Chemistry. – 2018. – Vol 37. № 3. – P. 657–670.

17. Zhukova A.A., Mastitsky S.E. Bioindication of the quality of the natural environment, Minsk: BGU. – 2014. – P. 112.

18. Bioindication and biotesting in environmental protection: textbook / SPbGTURP. – St. Petersburg. – 2012. – P. 67.

19. Avdesh A. Regular Care and Maintenance of a Zebrafish (*Danio rerio*) Laboratory: An Introduction, J Vis Exp. – 2012. –Vol. 69.

20. Simonetti R.B., Marques L.S., Streit Jr D.P., Oberst E.R. Zebrafish (*Danio rerio*): the future of animal model in biomedical research. – 2015. – Vol. 9.

21. World of tails and poisoning of aquarium fish. – 2019. – Electron. Data. – Access mode: https://www.hvoost.ru/mirh-vostatyh/articles/otravleniya_akvariumnykh_rybok/

22. Simmons A.E., Karimi I., Talwar M. and Simmons T.W. Effects of Nitrite on Development of Embryos and Early Larval Stages of the Zebrafish (*Danio rerio*). – 2012. – Vol. 9, № 4

23. Strong R., Martin F. L., Jones K. C., Shore R. F. & Halsall C. J. Subtle effects of environmental stress observed in the early life stages of the Common frog, *Rana temporaria*. – 2017. № 44438.

24. Tlenshieva, A.M., Witeska M., Shalakhmetova, T.M. Genotoxic and histopathological effects of the Ili River (Kazakhstan) water pollution on the grass carp *(Ctenopharyngodon idella)*, Environmental Pollutants and Bioavailability. – 2022. – P. 297-307.

25. Acute aquatic toxicity: Zebrafish Embryo Acute Toxicity Test (ZFET), OECD. – Electron. Data. – Mode of access: https://joint-research-centre.ec.europa.eu/

26. Keshari V., Adeeb B., Simmons A. E., Simmons T. W., Diep C. Q. Zebrafish as a Model to Assess the Teratogenic Potential of Nitrite. – 2016. № 108. – P. 5.

IRSTI 87.35.02 https://doi.org/10.26577/eb.2023.v96.i3.013

S.T. Nurtazin*, I.S. Galymzhanov, A.M. Baibagyssov,
M.K. Iklassov, I.E. Bolatbek, N.S. Undassyn

Al-Farabi Kazakh National University, Kazakhstan, Almaty
*e-mail: nurtazin.sabir@gmail.com

ECOSYSTEM SERVICES AND PROBLEMS OF REEDBED MANAGEMENT IN THE ILI RIVER DELTA

A characteristic feature of wetlands in the Ili River delta is the predominance of common reed (Phragmites australis) in the composition of their plant communities. Reedbeds are ecologically valuable ecosystems that play an important role in the nutrient cycle, carbon sequestration, oxygen production and maintenance of biodiversity. The Ili delta, the largest river delta in Central Asia, and its adjacent areas contain four protected areas of different conservation status, including Ramsar wetlands and the State Nature Reserve "Ili-Balkhash" with unique landscapes and biodiversity. At the same time, ecosystems in the Ili delta provide a wide range of ecosystem services and have been used by people for economic purposes for centuries. The main types of ecosystem services of reed wetland coenoses in the delta were investigated and various options for the management of reed communities were analyzed, the existing complexities and conflict potential between biodiversity conservation and the established economic activities of the local population and visiting hunters, fishermen and tourists were described. Some innovative options for more effective and sustainable use of reed biomass for economic purposes and ways of optimal management of reed coenoses, taking into account their functional importance in the maintenance of biodiversity, are proposed.

Key words: Ili River delta, Phragmites australis, Ramsar wetlands, ecosystem services, reed community management, importance of reed in protected areas.

С.Т. Нуртазин*, И.С. Галымжанов, А.М. Байбагысов,
М.К. Иқласов, І.Е. Болатбек, Н.С. Ундасын

Әл-Фараби атындағы Қазақ ұлттық университеті, Қазақстан, Алматы қ.
*e-mail: nurtazin.sabir@gmail.com

Экосистемалық қызметтер және Іле өзенінің дельта аумағындағы қамысты басқару мәселелері

Іле өзені дельтасының сулы-батпақты жерлеріне тән қасиет олардың өсімдіктер қауымдастығында қамыстардың (Phragmites australis) басым болуы. Қамыс алқаптары қоректік заттардың айналымы, көміртекті секвестрлеу, оттегі өндірісі және биоәртүрлілікті сақтауда маңызды рөл атқаратын экологиялық құнды экожүйелер болып табылады. Орталық Азиядағы ең үлкен өзен дельтасы Іле дельтасында және оған іргелес аумақтарда әртүрлі қорық мәртебесі бар төрт ерекше қорғалатын аумағында орналасқан, оның ішінде Рамсар сулы-батпақты жерлері мен бірегей ландшафттары мен биоәртүрлілігі бар "Іле-Балқаш" мемлекеттік табиғи резерваты. Сонымен қатар, Іле дельтасының экожүйелері экожүйелік қызметтердің кең спектрін қамтамасыз етеді және оны адамдар ғасырлар бойы шаруашылық мақсатта пайдаланып келеді. Дельтаның сулы-батпақты алқаптарының қамыс ценоздарының экожүйелік қызметтерінің негізгі түрлері зерттелді және қамыс ценоздарын басқарудың әртүрлі нұсқаларына талдау жасалды, биоалуантүрлілікті сақтау мен жергілікті тұрғындар мен келген аңшылар, балықшылар және туристердің белгіленген шаруашылық қызметі арасындағы бар қиындықтар мен қайшылық әлеуеті сипатталды. Шаруашылық мақсатта қамыс биомассасын неғұрлым тиімді және тұрақты пайдаланудың кейбір инновациялық нұсқалары және олардың биоалуантүрлілікті сақтаудағы функционалдық маңызын ескере отырып, қамыс ценоздарын оңтайлы басқарудың жолдары ұсынылған.

Түйін сөздер: Іле өзенінің атырауы, Phragmites australis, Рамсар сулы-батпақты жерлері, экожүйелік қызметтер, қамыс қауымдарын басқару, ерекше қорғалатын аумақтардағы қамыстың маңызы.

С.Т. Нуртазин*, И.С. Галымжанов, А.М. Байбагысов,
М.К. Икласов, И.Е. Болатбек, Н.С. Ундасын
Казахский национальный университет им. аль-Фараби, Казахстан, г. Алматы
*e-mail: nurtazin.sabir@gmail.com

Экосистемные услуги и проблемы управления тростниковыми зарослями дельты реки Или

Характерной чертой водно-болотных угодий дельты реки Или, является преобладание тростника (Phragmites australis) в составе их растительных сообществ. Тростниковые заросли – это экологически ценные экосистемы, выполняющие важную роль в круговороте биогенных веществ, в секвестрации углерода, выработке кислорода и в поддержании биоразнообразия. В дельте Или, крупнейшей из речных дельт Центральной Азии, и в прилегающих к ней территориях находятся четыре ООПТ различного природоохранного статуса, в том числе Рамсарские водно-болотные угодья и Государственный природный резерват «Или-Балхаш» с уникальными ландшафтами и биоразнообразием. Одновременно экосистемы дельты Или обеспечивают широкий спектр экосистемных услуг и используются людьми в хозяйственно-экономических целях на протяжении веков. Были исследованы основные виды экосистемных услуг тростниковых ценозов водно-болотных угодий дельты и дан анализ различных вариантов управления тростниковыми сообществами, описаны существующие сложности и конфликтный потенциал между сохранением биоразнообразия и сложившейся хозяйственно-экономической деятельностью местного населения и приезжих охотников, рыболовов и туристов. Предложены некоторые инновационные варианты более эффективного и устойчивого использования тростниковой биомассы для хозяйственных целей и пути оптимального управления тростниковыми ценозами с учетом их функционального значения в поддержании биоразнообразия.

Ключевые слова: дельта р. Или, Phragmites australis, Рамсарские ветланды, экосистемные услуги, менеджмент тростниковых сообществ, значение тростника в ООПТ.

Introduction

In the fundamental concept of the UN «The future we want», that defines the main directions of human development in the XXI century, «green economy» is named as the basis for the transition to sustainable development, which involves the preservation of natural ecosystems that provide a range of services necessary for human life. Great importance is given to ecosystem services in many of the UN Sustainable Development Goals for the period 2016-2030. In the era of globalization and the gigantic development of production forces, which have an increasingly tangible negative impact on the biosphere, came the understanding of the need for economic evaluation and the development of international and national mechanisms for payments for ecosystem services at all levels, without which it is impossible to preserve biodiversity as the basis of natural ecosystems and bioproductivity [1,2]. It is the economic valuation of ecosystem services that should underlie international and national mechanisms of payments for ecosystem services and consider the capacity of ecological donor countries [3].

Based on the negative effects of the growth of the global economy on the environment, much attention has recently been paid to the sustainable use of areas of little or no value for agriculture, including wetlands. Wetlands play an important role in regulating the global climate, maintaining the global hydrological cycle, protecting the diversity of ecosystems and ensuring human well-being [4]. Value of ecosystem services of wetlands per hectare is one of the highest among all types of ecosystems, including forests [5]. In addition, wetlands provide habitat for a large number of ecologically and economically important species [6], retain flood waters, absorb wind and tidal forces, protect land from erosion, provide recreational areas, complement the diversity and beauty of landscapes [7], replenish and maintain groundwater resources, prevent eutrophication of water and pollution of vegetation, sequester carbon and release oxygen [8].

An important component of wetlands is the common reed (*Phragmites australis* (Cav). Trin. ex Steud), widely represented in almost all zones of the globe [9]. Reed is the edificator and dominant of wetland phytocenoses and largely provides their most important ecosystem services: protection of the banks of watercourses and reservoirs from erosion by waves and currents, stabilization of soil and water level, capturing nutrients, improving water quality by sorbing various pollutants and heavy metals, forming favorable environmental conditions for other flora and fauna species [10,11,12,13,14].

At the same time, reed, being highly invasive,

can suppress the development of other plant species, often forming monodominant phytocenoses, thereby limiting biodiversity on the landscape scale [15]. At the same time, common reed can grow up to 4 or more meters in height, surpassing most other wetland macrophytes such as *Typha*, *Scripus*, or *Spartina* [16]. Terrestrial mass in reed phytocenoses varies widely depending on physical and geographic conditions, the nature of plant flooding, nutrient content in soil and water, total dissolved solids in water, etc. The annual growth of reed biomass in Kazakhstan averages 5-10 t/ha and sometimes reaches 30 t/ha [17]. The bioproductivity of common reed is due to the fact that this plant has an extremely high ability to grow quickly in the shallow waters of fresh and brackish reservoirs, as well as on soils with high groundwater table [18]. Kazakhstan is among the countries with the most extensive resources of common reed (*Phragmites australis*) in the world [9]. Moreover, the largest wetlands in the country with extensive reed phytocenoses are located in the delta of the Ili River – the largest in Central Asia, with an area of about 8,000 km^2, located in the arid zone in southeastern Kazakhstan. Four protected areas are located in the Ili delta and its adjacent territory, at the same time there is an active economic activity of the local population and infrastructure for recreation (amateur hunting, fishing, ecotourism) is developed.

The purpose of this study was to investigate the current state and trends of changes in the reed communities of the Ili delta wetlands, the features of the ecosystem services they perform, the effectiveness of reed management, the main risks and threats.

Materials and methods

Study area

The modern delta of the Ili River lies in the western part of the flat depression of the Ili-Balkhash basin (Fig. 1) and adjoins the southwestern coast of Lake Balkhash. Approximately 105-130 km away from Lake Balkhash, the Ili divides into three branches: east – Zhideli, central – Ili and west – Topar, each of them in its turn divides into a network of fan-like diverging to the west and north-west deltaic channels with interstream depressions and hummocky-ridgy sands as well as systems of oxbow lakes. Towards the Balkhash coast the delta increases in width up to 100-110 km.

According to the features of watering, the delta territory is subdivided into three parts. The upper narrow part is the zone of runoff formation, where the largest volume of water passes; the middle part is more deserted with wide inter-channel spaces; the lower part is the widest part of the delta with slow flow of Ili channels and water backflow from the side of Balkhash with high groundwater level, which forms small lakes in the relief depressions (Fig. 2). In the most high-water years (2000, 2010, 2015), all parts of the delta, especially the upper part, were flooded with water, contributing to the rapid growth of floodplain and meadow reed associations, especially in the following year.

Wetland soil cover is formed, as a rule, on lowered elements of relief, where it forms various combinations in conditions of more or less constant moistening under hydrophilic vegetation. The most numerous are marsh, meadow-marsh, floodplain meadow and floodplain meadow-tugay soils, as well as their dried variants. The state of hydrophilic intrazonal wetland and reed ecosystems is determined by fluctuations of water content in the complex hydrographic network of the Ili delta. According to climatic and geographical conditions, the territory in question belongs to the zone of cold deserts (BWk) with hot arid summer and cold winter. The location of the studied region in the center of Eurasia, its remoteness from seas and oceans, determine a pronounced continental climate with a large difference between day and night, summer and winter temperatures. The highest average monthly air temperature of +25 to +27 °C is observed in July, with an absolute maximum of +44 to +46 °C; the lowest average monthly temperature is noted in January -13 to -15 °C, with an absolute minimum of -45 °C. Sum of positive annual temperatures above +10 °C amounts to 3500 °C, which determines high potential evaporation capacity of 1000-1200 mm/year and pronounced aridity of climate on the background of average annual precipitation of 135-150 mm/year. Duration of the period with stable snow cover is 80-95 days, the highest average ten-day snow cover height is 10-15 cm. The sum of precipitation in a multi-year cycle is much less than air humidity. Sharp increase in moisture deficit is noted in early spring and decreases in autumn, which causes intensive evaporation of moisture from soil surface and drying of upper part of soil profile to air-dry state. This creates sharply expressed features of haloxeromorphism in the natural vegetation cover and is reflected in the evolution and transformation of soils in the delta. Climatic features determine high seasonal intensity of salinization of hydromorphic soils in the lower reaches with high groundwater table.

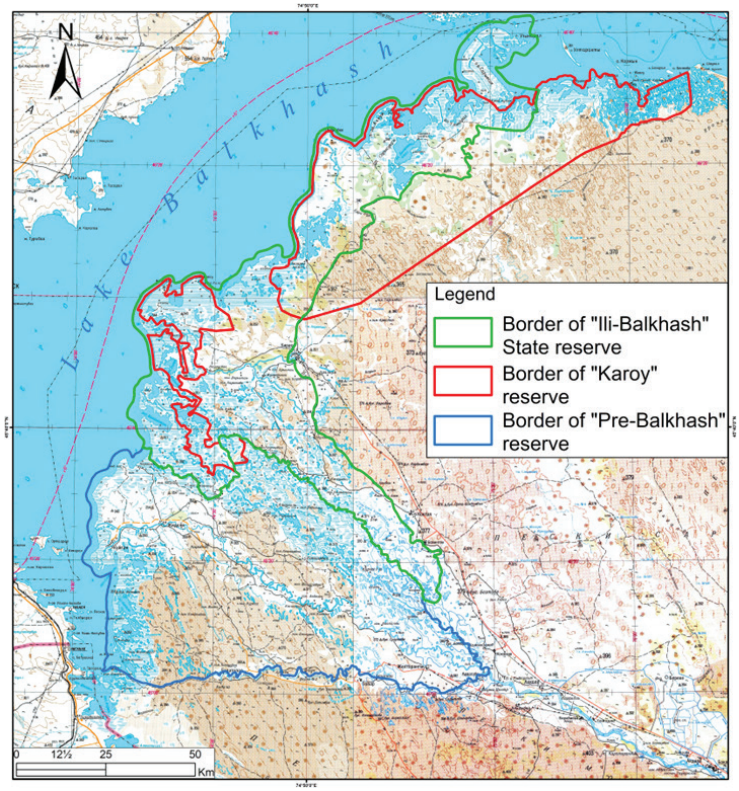


Figure 1 – Borders of Specially Protected Natural Areas in the study area

Figure 2 – A typical landscape of wetlands in the delta of the Ili River

Geobotanical methods

Geobotanical field surveys were conducted on the territory of the delta to study the current state of the wetland vegetation cover. The surveys were carried out with the route method in accordance with the Instruction on conducting large-scale (1:1000 – 1:100000) geobotanical surveys of natural forage lands of the Republic of Kazakhstan, developed in the land management system of the Republic of Kazakhstan (1995) [19]. In the course of field work, a previously prepared map of the region was geo-referenced to the soil-vegetation cover on the ground using handheld computers and Garmin Oregon 750 GPS navigators and the boundaries of the studied types of phytocenoses were delineated based on remote sensing data. As part of the study of soil cover, soil profiles and excavations were made, GPS-coordinating of description points, photography and collection of soil samples for further laboratory study were also conducted. During the study of wetlands, special attention was paid to the study of area fluctuations and transformations of reed phytocenoses as an edificator and dominant vegetation of the wetlands.

During reconnaissance detours, a route crossing the main types of wetlands was drawn and descriptions of the different reed communities were made. The determination of reed productivity was carried out by the mowing method on representative plots. At the description site, using 1x1 m square frames, the mowing plots were bordered and on 4 plots the reed shoots were cut at a height of 2-3 cm from the ground; the weight of stems and leaves was determined separately in the wet and later in the dry state. Shoot length and total leaf area per hectare were also measured. While determining the productivity, reed biomass was calculated in centners per hectare.

The profile, morphological, comparative-geographical, and comparative-historical methods were used in soil studies. On the main types of landscapes, the zonal type of soil was determined on which the soil section was made, the morphological description of the soil profile and sampling by genetic soil horizons were carried out.

Dynamics of hydrological characteristics in the lower reaches of the Ili River

Data from gauging station Kapchagai-37, located 37 km downstream of the dam of the Kapshagay hydropower station (43°58.864'N, 77°1.701'E) and gauging station Balkhash located near Balkhash city (46°46.730'N, 74°58.554'E) were used to analyse the dynamics of hydrological regime of the lower reaches of the Ile River and the level of Lake Balkhash (for the 2000-2020 period). The regime of atmospheric precipitation and surface temperature in the survey area was considered according to the data of two meteorological stations: MS Kuigan (45°22.984'N, 74°8.273'E) and MS Karaoy (45°51.471'N, 74°47.009'E).

Thus, when studying ecosystem services and management of wetlands and their constituent reed phytocenoses of the Ili delta, all main natural and anthropogenic factors affecting their changes were considered, including variations in the annual flow and hydrological regime, the dynamics of weather conditions, the impact of economic activities, in particular commercial fishing, cattle grazing, hay, reed and fuel harvesting, recreational hunting and fishing, recreational infrastructure, artificial fires, etc. the dynamics of meteorological conditions, influence of economic activities, in particular, commercial fishing, cattle grazing, hay, reed and fuel harvesting, recreational hunting and fishing, recreational infrastructure, artificial fires, etc. [20]. In addition, authors used survey data from the local population, ranging from farmers and professional fishermen to protected area workers, forestry employees, and tourists.

Results

Characteristic feature of arms, channels and lakes of Ili River delta hydrographic system is dominance of reed (*Phragmites australis*) along their banks in coastal zone up to 1.5-2 m depth and on the coast in form of extensive monodominant reedbeds, as well as in mixed plant communities with water macrophytes (Potamogeton pectinatus, Najas marina), cattail (Typha angustifolia), bulrushes (Scirpus lacustris), tamarisks (Tamarix ramosissima), as well as in meadow-marsh and meadow saline soils with high groundwater table. Depending on the long-term flow fluctuations in the lower reaches of the Ili River, the total area of plant communities where common reed is either dominant or an edificator varied in the period 2000-2021 according to authors' data between 1143.8 km^2 to 2259.5 km^2 of the total delta area of 8 000 km^2.

Reeded wetlands play an important role in the substance cycle and in supporting biodiversity. Authors studied the leading ecosystem services of reed communities in the delta and analyzed the main factors affecting them: the volume of flow and hydrological regime of the Ili River, as well as various scenarios of reed associations management.

According to the UN Report, ecosystem services are divided into four categories [3]: 1) Provisioning Services; 2) Regulating Services; 3) Cultural Services; and 4) Supporting Services.

Provisioning ecosystem services

First of all, the huge biomass of reed in terms of area and volume is an important component of pasture in traditional livestock grazing (Fig. 3) and in the creation of fodder reserves in winter for various types of farms in the Ili delta [21].

Also, phytomass of reed has long been used by the local population of Kazakhstan for various economic purposes, first of all, as a construction material in the manufacturing of wall insulating panels (kamyshit), wood-fiber boards for houses, outbuildings and fences for livestock (Fig. 4). Chopped dry reed from autumn and winter harvesting is used as a filler in the manufacture of concrete-based wall blocks. At the same time, chopped dry reed stalks are used as bedding in livestock buildings, and mixed with clay (for fire resistance) as wall and roofing material. It should be noted that in recent years, the use of reed as a construction material has somewhat decreased for various reasons, primarily due to the migration of the active part of the village population to the cities.

Figure 3 – Meadow-reed communities used for year-round pastures

Figure 4 – An example of the use of reed as a building material

Historically, reed has also served as a raw material for the production of pulp, paper and cardboard. Currently, negotiations are underway between Kazakh Invest and Chinese Qifeng New Material companies on the possibility of implementing a project to produce pulp and paper from reed. The investor plans to gradually invest in the project 320 million U.S. dollars. The production volume of pulp and paper from reed will be 200 thousand tons per year [22]. A small part of the reed from the Ili delta, selected according to the standards of the customer, is exported to Germany by MMReedGroop LLP (Fig. 5).

In recent years, one of the most valuable qualities of reed has been recognized as the rapid growth of green biomass, which provides reed associations with the ability to release large amounts of oxygen and sequester appropriate amounts of carbon (in the above-ground and underground parts of the reed) that would potentially be released into the atmosphere as greenhouse gases (carbon dioxide (CO2) and methane (CH4)).

Figure 5 – Reed bundles prepared by MMReedGroop LLP for export to Germany.

The great practical importance of reedbeds is also that they form a comfortable environment for various aquatic plant species, invertebrate and vertebrate fauna. In particular, water-logged

reed communities satisfy the basic needs of fish populations, providing them with food, shelter, and places for spawning and feeding. The Ili River flows into Lake Balkhash, one of the main fishery reservoirs of Kazakhstan. Between 1960 and 1966, an average of 18.1 thousand tons of fish were caught in Balkhash annually [23]. After 1990, the catches decreased 2-3 times, primarily because of overfishing and poaching [24]. Due to the specially protected status and prohibition of industrial fishing, the main spawning grounds of commercial ichthyofauna, providing replenishment of fish stocks in Balkhash, were the channels and lakes of the hydrographic network of the Ili delta.

At the same time, reedbeds of the delta are one of the main habitats of game fauna. Of these animals, such numerous species as wild boar (*Sus scorfa*) and muskrat (*Ondatra zibethicus*), whose main food in the Ili delta is reed all year round, should be especially noted [25,26]. The annual volume of fur hunting for muskrat introduced in the Ili delta in the 1930s once reached 5 million pelts [27].

Regulating ecosystem services

Pollution of water resources in the Ili-Balkhash basin by industrial, agricultural and domestic wastewater is a constant problem [28]. Moreover, the main sources of surface water pollution in the basin are metals [29,30,31]. Some of the above pollutants occur either in nature or are formed as a result of human economic activities on the territory of the Kazakhstan part of the Ili basin, but others, including significant loads on copper and zinc, are transported to the lower part of the Ili basin from China.

In recent decades, due to population growth and the intensification of industry which are accompanied by air and water pollution, reed associations have become increasingly important as natural biofilters. Being edificators and dominant phytocenoses of delta wetlands, reedbeds largely provide such an important ecosystem service as purification of hydrographic network water from various pollutants. Since the lower reaches and the delta are completely dependent on the surface waters of the upper Ili River, they are a recipient of pollutants coming in with water [32]. Of course, a filtering landscape element can contribute significantly to the total large-scale retention of pollutants only if most of the total transport of water-borne pollutants passes through this element [12]. The complex hydrographic network of the delta, including hundreds of arms, channels and lakes fringed with reeds, through which the runoff of the Ili River flowing into Lake Balkhash passes and is filtered, fully satisfies this condition.

It is also known that green spaces can significantly affect the microclimate by lowering the temperature and increasing the speed of air movement. Plants primarily affect the radiation regime, reducing the intensity of direct solar radiation. The cooling effect of green spaces is largely due to the expenditure of large amounts of heat for evaporation and increased relative humidity. Leaves of plants have a temperature well below the ambient air temperature. According to authors' data, 1 hectare of reed associations has a total leaf surface area of 5-10 hectares. The combination of extensive reedbeds and open water surfaces, with high albedo in the warm season has a great positive effect on the microclimate in the Ili River delta. At the same time, wetlands and reed coenoses within them perform protective functions for invertebrate and vertebrate fauna during strong winds and other natural phenomena.

Cultural ecosystem services

The picturesque landscape of the Ili delta, including a mosaic of zonal desert and intrazonal meso- and hydrophilic ecosystems, numerous channels, lakes, riparian forests and meadows, poorly fixed and loose sands, diverse invertebrate and vertebrate fauna attracts ecotourists and travelers. In a large part of the Ili delta, outside the protected zone of SPNA, recreational hunting and fishing are officially allowed, which has made these areas popular among avid hunters and fishermen. As a consequence, an infrastructure has appeared in the delta and is expanding year by year, including: parking lots, small guest houses and rest houses, tourist bases and shelters, camping villages, bivouac sites, country roads, services for renting motorboats and boats, jet skis, water skis, etc.

Cultural ecosystem services can also be called cultural-sociological services. These are those spiritual emotions and joyful experiences, which a person receives, enjoying communication with the surrounding nature, receiving some educational and scientific information, expanding one's horizon, understanding of the laws and interconnections in nature, comprehending those ecological and socio-economic problems, which are discovered when traveling to the given region. In this aspect, a visit to the Ili delta is interesting and informative.

Supporting ecosystem services affect human living conditions indirectly and, as a rule, over a long period of time. For example, in addition to the hydrographic network of the Ili, soil, trees, reedbeds,

and groundwater are also involved in maintaining the water balance of the delta.

In the reedbed area, apart from trophic relationships between plants and animals, there are other no less important ones – the use of plants as habitat, substrate for egg laying, as shelter and building material. Many species of various organisms are associated with coastal and aquatic plants. Thus, thousands of invertebrate and vertebrate species have food connections with reedbeds. In particular, coastal submerged reedbeds are of great importance for all 17 fish species living in the Ili delta. Reedbeds with their rich invertebrate fauna play a particularly important role for juvenile fish. In the course of authors' studies of ichthyofauna in the coastal part of the Ile River delta, in reed thickets using dragnet for fry, the juvenile fishes of the following species were caught: roach – *Rutillus rutillus*, Prussian carp – *Carassius gibelio*, pikeperch – *Sander lucioperca* and a rare species of Balkhash perch – *Perca scherenki*. Reedbeds play a special role in the reproduction process of Eurasian carp – *Cypruinus carpio* and common bream – *Abramis brama*, which hatch their sticky eggs on aquatic vegetation. Common reed in the Ili delta is an important food resource for the grass carp – *Ctenopharyngodon idella*. Due to its conservation status, water bodies and watercourses of the Ili delta hydrographic system play an important role in preservation of Lake Balkhash as one of the main fishery water bodies of Kazakhstan.

Depending on the orographic features of the terrain and groundwater table, the arrangement of biotopes often has the form of a "patchwork quilt" consisting of a mosaic of different phytocenoses. The characteristic composition of animal communities is formed according to the type of vegetation, in which a significant proportion of species are represented by birds, which are often not permanent residents of specific habitats. The Ili delta is recognized as a key ornithological area (IBA) [33]. Although, usually the stay in the reedbeds of the majority of birds is seasonally limited and associated with migration, breeding, molting and foraging during migration.

Traditionally, Ili delta wetlands are considered as the main habitat of aquatic and semi-aquatic, including rare and endangered bird species (Fig. 6). Moreover, in Ili delta wetlands, 70 bird species have their vital activity inseparably connected with reedbeds. Biological significance of reedbeds of wetlands in the Ili delta is due to the fact that being located in the arid zone, they provide production of a huge biomass of aquatic and above water invertebrates during the whole warm period, attracting representatives of local and migrating ichthyofauna and batrachofauna, which, in turn, are included in the trophic chains of waterfowl and water-related birds (pelicans, herons, geese, ducks, shepherds), regardless of the nature of their stay on water bodies – nesting or transit. At the same time, these biotopes provide a food base for many species of insectivorous birds (small thrushes, wrens, tits), or using seeds of reeds (bearded reedling – *Panurus biarmicus*, buntings), barberry – *Berberis iliensis*, Junghar hawthorn – *Crataegus songarica* and oleaster – *Elaeagnus angustifolia* (finches, greenfinches, redstarts). It is no coincidence that the above-mentioned birds willingly nest or form mass concentrations during the molt period in places of solid perennial reed growth. Last year's reedbeds, which were not destroyed by fires, are often places where herons, spoonbills, pelicans and cormorants set up mass nesting colonies.

Figure 6 – Semi-aquatic and waterfowl birds prefer reed and open water mosaic.

Discussion

Ecosystem services

Analysis of the main pressures on freshwater ecosystems at the beginning of the 21st century shows that the biodiversity crisis in the world's lakes, reservoirs, rivers, streams and wetlands is only deepening [34]. In recent years, innovative hybrid approaches have been proposed to conserve freshwater as critical ecosystems for human livelihoods as well as important foci of biodiversity and ecological functions [35].

Due to its high invasiveness and growth energy, common reed (*Phragmites australis*) is the edificator or dominant plant community of most hydrophilic plant communities in the azonal ecosystems of

the Ili delta, where it plays an important role in maintaining biodiversity and provides various ecosystem services, in particular: microclimate regulation, protection of channel and lake shores from erosion by waves and flows, stabilization of soil and water levels under fluctuating water availability, capture of nutrients and various pollutants including heavy metals, providing conditions for other plant species, forage for livestock, material for roofing and walls (Fig. 4), raw materials for pulp and paper, [10,11,12]. Reeds also play a habitat-forming role for dependent vertebrate and invertebrate fauna [13,14,36]. In particular, wetlands and reedbeds in the Ili delta have traditionally been the habitat of birds, primarily waterfowl and near-water birds, serving them as a food resource, shelter from wind, sun, waves and predators, nesting and resting places before migration. At the same time, reedbeds support the biodiversity of fish, especially spawning and juveniles, amphibians and reptiles, as well as 63 mammal species, five of which are included in the Red Book of Kazakhstan. Taking into account the exceptional landscape and biological diversity, 4 protected areas were organized in the Ili delta, as well as an Important Bird Area (IBA) [33]. Species diversity of birds is a good indicator of the overall state of the wetland ecosystem [37].

In 2010, the Conference of the Parties to the Convention on Biological Diversity [38] approved the Strategic Plan, the concept of which states that biodiversity "supports ecosystem services, maintains a healthy planet and brings benefits that are essential for all people". The most important function of wetlands is to maintain biodiversity, which is crucial for the sustainability of ecosystems, determines the full range of ecosystem services and among other things, representing of great economic value [39].

Ecosystem services are the benefits directly or indirectly received by mankind from ecosystem functions [2], including providing, regulating, supporting and cultural services [3], or other categories from different classification systems [40]. However, in recent decades, due to the growing anthropogenic pressure, almost 60% of global ecosystem services have been degraded to varying degrees [41]. The spatial richness of various ecosystem services in different regions has decreased, which has led to a decrease in their total cost [42] and may become one of the main problems for the sustainable development of mankind. The ecosystem services of the reedbeds of the Ili delta are of particular importance to pastoral farmers and the unemployed poor. Traditionally, all residents of the Balkhash region keep cattle of native breeds, which are grazed almost all year round in wetlands, where the bulk of pasture vegetation is reed. The main part of the insurance fodder for winter is also prepared here.

Reed is also widely used in the region in the construction of private houses and outbuildings for livestock as a wall and roofing material, for fences, bedding for livestock. At the same time, the region has experience of industrial production of forage pellets from reed, raw materials for pulp and cardboard production, packaging materials and reed bundles (Fig. 5) for export to Germany. Reed, as a plant with a huge potential for biomass growth and growing in unsuitable conditions for cultivated plants, has a great potential for economic use. The regulating ecosystem service of pollutant retention in the landscape is closely related and may even be critical to other types of ecosystem services, such as providing clean water to biota, nutrient cycling, and recreational water environments [3]. Thus, the value of each of these other ecosystem services depends on the service of pollutant retention at the landscape scale. New parallel studies require increased attention to trade-offs and synergies between different ecosystem services [43], issues of scale in the quantity and valuation of ecosystem services [44].

Common reed is seen as a promising wetland cultural plant [45] on wet or rewet peatlands it combines productive use with preservation of the peatland as a long-term carbon store [46]. Reedbeds as part of the wetlands with the picturesque landscape of the Ili delta areas, many channels, lakes, riparian forests and meadows, poorly fixed and unfixed sands, officially allowed outside protected areas for recreational hunting and fishing, with an actively developing infrastructure, attract an increasing number of tourists, hunters and fishermen, providing cultural, educational and recreational services to local residents and visitors.

Reed management in the Ili River delta

Like all plant communities, reed associations change over time. In various wetlands of the delta, authors observed degrading reed coenoses at different phases of succession, the final stages of which are shrubs and forests. It is known that the management of reedbeds is determined by two factors: the hydrological regime and the timely removal of the dying above-ground part of these plants. Numerous experiments and observations have established that common reed grows better in shallow water (≤10 cm) in fresh water and its growth slows down, especially

in the early stages of vegetation, if the water depth is increased [47]. A more or less stable and low water level is optimal for reeds [48]. The survival, height, density and biomass of cane shoots are strongly influenced by seasonal floods and their duration. Authors found that periodic floods in the Ili delta provide a high and stable for a long time (1-2 years) groundwater level with good reed productivity. According to hydrological conditions, determined by the volume of runoff in the lower reaches of the Ili and the terrain, a significant area of the delta is either constantly flooded or periodically flooded and dries up. Accordingly, the area and biological productivity of reed communities change. One of the simplest ways to restore a degraded site can be to change the hydrological conditions by increasing the water level [49].

The next important factor for the healthy state of reed communities is the timely removal of the above-ground part of reed that has finished the vegetation cycle, since last year's shoots and the thick layer of sediment (litter) sharply reduce the density of reed growth and its biomass. This is probably determined by the fact that the thick decaying layer of sediments hinders the germination of young shoots, and dead stems, which can persist for more than a year in the arid climate of the Ili delta, shade the light. Eutrophication, especially in stagnant water bodies, was a key factor due to the accumulation and decomposition of litter and allogenous organic matter [50]. Removal of green reed biomass can occur naturally when eaten by herbivorous animals (invertebrate phytophages, herbivorous fish, birds, and mammals). It has been shown that conservation and restoration of reedbeds under conditions of high density of gray geese is not feasible [51].

Options for artificial removal of last year's reeds are: burning, preferably in winter, mowing (by hand or mechanical means) and grazing by livestock. In particular, careful introduction of controlled fires is recommended. But reed harvesting and burning have reduced the number of passerine birds by about 60%, probably due to a reduction in insects. Therefore, the optimal reed management regime for the conservation of bird and invertebrate populations in reedbeds may be alternating short-term management (1-2 years). In rangeland biomes, fire usually promotes rapid increases in seed germination rates and above-ground biomass production. Fire can also increase ecosystem carbon stocks by stabilizing soil humus substances and producing biochar that can persist in the soil for centuries. In addition, fire can change the short- and long-term bioavailability of macro- and micronutrients. Fire has long been used as a management tool in natural areas of the southeastern United States.

It was shown that rotational mowing of reeds for 30 years has no detrimental effect on birds. However, the optimal mowing regime for birds should not be too frequent. It has been experimentally shown that it is better to mow every 3 years, and ideally even every 6 years. Reed harvesting promotes the growth of new shoots and even three years after harvesting, reed stems were still more abundant compared to reeds that had not been touched for 25 years. The maintenance of reedbeds of different ages leads to an increase in plant species diversity of habitat heterogeneity and an abundance of invertebrate fauna [52].

To summarize the above, authors emphasize the urgent need for regular management of reedbeds to avoid their degradation, especially in protected areas, where these labor-intensive activities are often neglected. Particularly great attention is needed to the organization of fires, which often get out of control. Much work should also be done on the zoning of protected area lands in accordance with the conservation functions performed and the allocation of ecologically significant natural landscapes and especially valuable ecosystems.

Conclusion

The management of reed communities by grazing does not require large labor costs and provides better growth of meadow vegetation than haymaking, since grazing animals, by fertilizing the soil, improve its fertility. At the same time, according to experienced livestock breeders, grazing requires regular monitoring, timely rotation of pastures, without which reed communities degenerate into grass communities with a predominance of poorly eaten annual species in 3-4 years under the pressure of overgrazing.

The state of reedbeds is also improved by regulated fires, which are recommended to be carried out regularly in the delta once every 2-3 years in winter. At the same time, the topsoil is enriched with ash elements, and the humus content increases. During winter fires, the death of entomofauna, batrachofauna and herpetofauna is practically excluded.

Rational management of reed biomass, in particular the practice of winter reed cutting, can significantly reduce the risk of landscape fires and bring economic benefits through the production of reed as a marketable product in demand. Authors' experiments on mowing reeds in the early stages of

vegetation (May-June), when the height of shoots slightly exceeds 1 m, showed that the aftergrass (grass grown in hayfield or pasture after mowing) have low growth energy and the total yield of reed stands decreases noticeably in this case. Practice shows that it is advisable to mow reeds once every two years.

Speaking about reed management in the Ili delta, it should be noted that for a variety of reasons (protected area status, difficult accessibility of many areas, high labor intensity of reed harvesting as fodder, construction material, raw material for industrial processing, etc.) the scale of this work is small. However, in many respects, the ideal conditions for both pristine wilderness with wetland ecosystems, protected areas, recreational areas, recreational hunting and fishing is to create a heterogeneous natural structure, including water bodies and watercourses, reedbeds and meadows, riparian shrub and forest vegetation, ridge sands, barchans, etc. Given the great landscape, ecosystem and species diversity, the presence of protected areas and land plots privately owned or leased in the delta areas, it is necessary to perform zoning taking into account the wide variability of habitat structure reedbeds should contain a mosaic of sites of different ages and with different management.

The growing anthropogenic pressure threatens the protected areas located in the Ili delta because the change in the system of land use and distribution of land into private ownership and long-term lease without regard for conservation interests has led to the fact that in the last decade the Ili delta has been intensively settled, and in the water protection zone along all the main channels there have been many farms, apiaries, tourist and fishing and hunting bases. As a result, anthropogenic pressure on all, even the most remote corners of the Ili River delta have increased. The intensity of motorboat and speedboat traffic increased many times along almost all main river channels and lake beds, which worsened the conditions for the growth of wetland vegetation.

To balance human needs and preserve conservation goals within protected areas, it is necessary to create mixed zoning schemes within the Ili delta, including strictly protected core zones, buffer zones that allow limited human use, and experimental zones that consider different land use and recreation options. The restrictions imposed by protected areas on the use of natural resources and land use options affect people's incomes and further exacerbate the abandonment of rural areas. There are now many initiatives to link protected areas with local social and economic development. The integration of conservation and rural development should focus on aligning protected area management with the social and economic needs of the local population.

Conflict of Interest

All authors have read and are familiar with the content of the article and have no conflict of interest.

Funding

This work was financially supported by the Ministry of Science and Higher Education of the Republic of Kazakhstan within the Project No: AP08857548: "A comprehensive study of common reed (*Phragmites australis*) resources, its ecosystem importance and potential for sustainable utilization in bioeconomy" (2020 – 2022).

Data Availability Statement

The official data on the hydrological characteristics of the Ili River from 1951 to 2020 and weather conditions in the study region from 1971 to 2021 were obtained from the website of Kazhydromet, the National Hydrometeorological Service of Kazakhstan, website and are freely available at: https://www.kazhydromet.kz/en/gidrologiya/basseyny-rek-oz-balkash-i-alakol.

References

1. IFC. *Performance standards on environmental and social sustainability*. International Finance Corporation (IFC), 2012
2. Costanza R., D'Arge R., Groot R.D., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., et al. "The value of the world's ecosystem services and natural capital". *World Environ* 25:3–15, (1997). doi:10.1038/387253a0.
3. UNEP. Millennium Ecosystem Assessment. Ecosystems and Human Well-being. Washington DC: Island Press; United Nations (2012)
4. Hu S.J., Niu Z.G., Chen Y.F., Li L.F., Zhang H.Y. "Global wetlands: Potential distribution, wetland loss, and status". *Sci. Total Environ.* (2017); 586: pp. 319–327. doi: 10. 1016/j.scitotenv. 2017.02.001.
5. Mitsch W.J., Gosselink J.G. *Wetlands.* New York, NY, USA: John Wiley & Sons, 2015.
6. Kopf, R. K., Finlayson, C. M., Humphries, P., Sims, N. C., and Hladyz, S. "Anthropocene baselines: assessing change and managing biodiversity in human-dominated aquatic ecosystems." *BioScience* (2015). 65, 798–811. doi:10.1093/biosci/biv092.

7. Neuvonen, M.; Pouta, E.; Sievänen, T.; Torvelainen, J. "Outdoor recreation in ecosystem service accounting: Pilot accounts from Finland." *Scand. J. For. Res*. (2020), 35, 186–197.

8. Van Roon, M.R. "Wetlands in The Netherlands and New Zealand: Optimising biodiversity and carbon sequestration during urbanisation." *J. Environ. Manag*. (2012), 101, pp.143–150.

9. Baibagyssov, A., Thevs, N., Nurtazin, S., Waldhardt, R., Beckmann, V., Salmurzauly, R. "Biomass Resources of Phragmites australis in Kazakhstan: Historical Developments, Utilization, and Prospects" *Resources Journal*, Volume 9, Issue 6, (2020), Pages 1-25 Resources 2020, 9, 74; doi:10.3390/resources9060074.

10. Kiviat, E. "Ecosystem services of Phragmites in North America with emphasis on habitat functions." *AoB Plants* (2013). 5:plt008. doi: 10.1093/aobpla/plt008.

11. Karstens, S., Buczko, U., Jurasinski, G., Peticzka, R., and Glatzel, S. "Impact of adjacent land use on coastal wetland sediments." *Sci. Total Environ*. (2016). 550, pp.337–348. doi: 10.1016/j.scitotenv.2016.01.079.

12. Quin, A., Jaramillo, F. & Destouni, G. "Dissecting the ecosystem service of large-scale pollutant retention: The role of wetlands and other landscape features." *AMBIO* (2015) 44 (Suppl1), 127–137. https:// doi.org/10.1007/s 13280-014-0594-8.

13. Morganti, M.; Manica, M.; Bogliani, G.; Gustin, M.; Luoni, F.; Trotti, P.; Perin, V.; Brambilla, M. "Multi-species habitat models highlight the key importance of flooded reedbeds for inland wetland birds: Implications for management and conservation." *Avian Res*. (2019), 10, pp.1–13.

14. Guareschi, S.; Abellán, P.; Laini, A.; Green, A.J.; Sánchez-Zapata, J.A.; Velasco, J.; "Millán, A. Cross-taxon congruence in wetlands: Assessing the value of waterbirds as surrogates of macroinvertebrate biodiversity in Mediterranean Ramsar sites." *Ecol. Indic*. (2015), 49, 204–215.

15. Köbbing, J., Thevs, N., and Zerbe, S. "The utilisation of reed (Phragmites australis): a review." *Mires and Peat* 13, (2013): pp.1–14.

16. Cronk, J. K., and Siobhan Fennessy, M. *Wetland Plants: Biology and Ecology*, 1st Edn. CRC Press, 2001

17. Thevs, N.; Beckmann, V.; Akimalieva, A.; Köbbing, J.F.; Nurtazin, S.; Hirschelmann, S.; Piechottka, T.; Salmurzauli, R.; Baibagysov, A. "Assessment of ecosystem services of the wetlands in the Ili River Delta, Kazakhstan." *Environmental Earth Sciences* 76 (2017), p. 30. doi: https://doi.org/10.1007/s12665-016-6346-2;

18. Luneva N. N. "Phragmites australis (Cav.) Trin. ex. Stend. — Common Reed." «Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries. Economic Plants and their Diseases, Pests and Weeds». http://www.agroatlas.ru/en/content/weeds/Phragmites_australis. (accessed 13.05.2023)

19. Инструкция по проведению крупномасштабных (1:1000 -1:100000) геоботанических изысканий природных кормовых угодий Республики Казахстан. Алматы, 1995, с. 4-5.

20. Gathman, J.P., Burton, T.M. "A great lakes coastal wetland invertebrate community gradient: Relative influence of flooding regime and vegetation zonation." *Wetlands*, 31 (2), (2011), pp. 329-341, doi: 10.1007/s13157-010-0140-9.

21. Baranowski, E., Thevs, N., Khalil, A., Baibagyssov, A., Iklassov, M., Salmurzauli, R., Nurtazin, S., Beckmann, V. "Pastoral Farming in the Ili Delta, Kazakhstan, under Decreasing Water Inflow: An Economic Assessment" *Agriculture journal*, Volume 10, Issue 7, (2020), Pages 1-29 http://dx.doi.org/10.3390/agriculture10070281

22. XINHUANET. Kitajskij investor planiruet postroit' zavod po proizvodstvu cellyulozy i bumagi iz kamysha v Kazahstane. https://finance.rambler.ru/markets/39899320-kitayskiy-investor-planiruet-postroit-zavodpo-proizvodstvu-tsellyulozy-i-bumagi-iz-kamysha-v-kazahstane. Accessed on 13.05.2023

23. Graham, N.; Pueppke, S.G.; Uderbayev, T. "The current status and future of Central Asia's fish and fisheries: Confronting a wicked Problem." *Water* 9, 701. (2017).

24. Pueppke SG, Iklasov MK, Beckmann V, Nurtazin ST, Thevs N, Sharakhmetov S, Hoshino B. "Challenges for Sustainable Use of the Fish Resources from Lake Balkhash, a Fragile Lake in an Arid Ecosystem." *Sustainability*, 10(4):1234. (2018). https:// doi.org/10.3390/su10041234

25. Слудский, А. А. Ондатра и акклиматизация её в Казахстане. Под ред. А. В. Афанасьева. Алма-Ата: Изд-во АН Каз. ССР, 1948.

26. Слудский А.А. Кабан (морфология, экология, хозяйственное и эпизоотологическое значение, промысел). Алма-Ата: Изд-во Академии наук Казахской ССР, 1956, с. 218.

27. Слудский А.А. Промысловые млекопитающие Казахстана, Алма-Ата: Изд-во АН Каз, 1973.

28. Amirgaliev, N.A., Opp, C., Askarova, M., Kulbekova, R.A., Ismukhanova, L.T. "About ratio and values of the empirical coefficient of alkali metals (Na+ and K+) in surface waters of Kazakhstan on the example of the Ile River" *NEWS of National Academy of Sciences of the Republic of Kazakhstan* 1; (2020), pp. 6-13;

29. Dostaj, Ž. D.,. "Wasserressourcen und deren Nutzung im Ili-Balchaš Becken" *Discussion Papers*, No. 34, (2007) 1-80.

30. Aytmukhanovich, D.M.; Aipovich, T.Y.; Suleimenovich, A.Y.; Zhanserkenovich, Y.I. "Assessment of pollution influence of bottom sediments on quality of water of the Ili River." *Life Sci. J.* 11; (2014):pp. 335–338;

31. Zhang N, Zhang J, Li Z, Chen J, Zhang Z, Mu C. "Resistance strategies of Phragmites australis (common reed) to Pb pollution in flood and drought conditions." *PeerJ* 6;(2018). e4188 https:// doi.org/10.7717/peerj.4188

32. Anzai, T., Kitamura, Y., & Shimizu, K. "The influence of seepage from canals and paddy fields on the groundwater level of neighboring rotation cropping fields: A case study from the lower Ili River Basin, Kazakhstan." *Paddy Water Environ.* 12 (2014): 387-392. DOI: 10.1007/s10333-013-0393-z

33. Скляренко, С.Л., Д.Р. Уэлш, и М. Бромбахер, ред. Ключевые орнитологические территории Казахстана. Алматы: Ассоциация охраны биоразнообразия Казахстана (АСБК), 2008.

34. Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J., Smol, J.P., Taylor, W.W., Tockner, K., Vermaire, J.C., Dudgeon, D., Cooke, S.J. "Emerging threats and persistent conservation challenges for freshwater biodiversity." *Biol Rev Camb Philos Soc* 94, no. 3 (2019): 849-873. doi: 10.1111/brv.12480

35. Ciska C. Overbeek, Sarah Faye Harpenslager, Jeroen P. van Zuidam, E. Emiel van Loon, Leon P. M. Lamers, Merel B. Soons, Wim Admiraal, Jos T. A. Verhoeven, Alfons J. P. Smolders, Jan G. M. Roelofs, and Harm G. van der Geest. "Drivers of Vegetation Development, Biomass Production and the Initiation of Peat Formation in a Newly Constructed Wetland." *Ecosystems* 23, no. 5 (2020): 1019–1036. DOI:10.1007/s10021-019-00454-x

36. Żmihorski, Michał, et al. «Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands.» *Journal of Applied Ecology* 53, no. 2 (2016): 587–595. Accessed May 15, 2023: http://www.jstor.org/stable/43869411..

37. Eglington, S. M., Noble, D. G., & Fuller, R. J. "A meta-analysis of spatial relationships in species richness across taxa: birds as indicators of wider biodiversity in temperate regions." *Journal for Nature Conservation* 20 (2012): 301-309

38. Convention on Biological Diversity (CBD). *The economic values of the world's wetlands (Environmental Science)*. Schuyt, K., Brander, L. WWF, Amsterdam, 2004

39. Intergovernmental Panel on Climate Change. *Climate Change 2022: Mitigation of climate change – Summary for Policy-makers*. Geneva, Switzerland: IPCC, 2022

40. Haines, Y.R., Potschin, M. *Common International Classification of Ecosystem Services (CICES, Version 4.1)*. Copenhagen, Denmark: European Environment Agency, 2012, pp. 1–17

41. Schaller, L., Targetti, S., Villanueva, A.J., Zasada, I., Viaggi, D. "Agricultural landscapes, ecosystem services, and regional competitiveness-assessing drivers and mechanisms in nine European case study areas." *Land Use Policy*, vol. 76 (2018): 735–745

42. Gao, F., Cui, J., Zhang, S., Xin, X., Zhang, S., Zhou, J., Zhang, Y. "Spatio-Temporal Distribution and Driving Factors of Ecosystem Service Value in a Fragile Hilly Area of North China." *Land*, vol. 11, (2022) 2242 https://doi.org/10.3390/land11122242

43. Queiroz, C., Meacham, M., Richter, K., Norström, A.V., Andersson, E., Norberg, J., Peterson, G. "Mapping bundles of ecosystem services reveals distinct types of multifunctionality within a Swedish landscape." *AMBIO*, Suppl. 1. (2015) DOI:10.1007/s13280-014-0601-0.

44. Andersson, E., Nykvist, B., Malinga, R., Jaramillo, F., Lindborg, R. "A social-ecological analysis of ecosystem services in two different farming systems." *AMBIO*, Suppl. 1. (2015) DOI:10.1007/s13280-014-0603-y

45. Geurts, J.J.M., van Duinen, G.-J.A., van Belle, J., Wichmann, S., Wichtmann, W., Fritz, C. "Recognize the high potential of paludiculture on rewetted peat soils to mitigate climate change: Position Paper." *J. Sustain. Org. Agric. Syst*., vol. 69, (2019): 5–8.

46. Wichtmann, W., Schröder, C., Joosten, H. "Paludikultur als integrative Systemlösung." In *Paludikultur: Klimaschutz—Biodiversität—Regionale Wertschöpfung*, Schweizerbart: Stuttgart, Germany (2016), pp. 1–2

47. Wang X, Zhang D, Guan B, Qi Q, Tong S. "Optimum water supplement strategy to restore reed wetland in the Yellow River Delta." *PLoS One* 12(5) (2017): e0177692. doi: 10.1371/journal.pone.0177692.

48. White S, Ganf G. "A comparison of the morphology, gas space anatomy and potential for internal aeration in Phragmites australis under variable and static water regimes." *Aquatic Botany* 73(2) (2002): 115–127. [Google Scholar]

49. Graham White. "The Future of Reedbed Management." RSPB. Information and Advice note Version 7 – July 2009 Compiled by Graham White. For further information, contact Graham White at RSPB on 01767 680551, or by e-mail at graham.white@rspb.org.uk.

50. Van der Putten W.H. "Dieback of Phragmites australis in European wetlands: an overview of the European Research Programme on Reed Dieback and Progression (1993–1994)." *Aquatic Botany* 59 (1997): 263–275.

51. Nemeth E, Dvorak M. "Reed die-back and conservation of small reed birds at Lake Neusiedl, Austria." *J Ornithol* 163 (2022): 683–693. doi: 10.1007/s10336-022-01961-w

52. Roth, N., Zoder, S., Zaman, A. A., Thorn, S., & Schmidl, J. Long-term monitoring reveals decreasing water beetle diversity, loss of specialists and community shifts over the past 28 years. *Insect Conservation and Diversity*, 13, (2020) 140-150.

References

1. Amirgaliev, N.A., Opp, C., Askarova, M., Kulbekova, R.A., Ismukhanova, L.T. "About ratio and values of the empirical coefficient of alkali metals (Na+ and K+) in surface waters of Kazakhstan on the example of the Ile River" *NEWS of National Academy of Sciences of the Republic of Kazakhstan* 1; (2020), pp. 6-13;

2. Andersson, E., Nykvist, B., Malinga, R., Jaramillo, F., Lindborg, R. "A social-ecological analysis of ecosystem services in two different farming systems." *AMBIO*, Suppl. 1. (2015) DOI:10.1007/s13280-014-0603-y

3. Anzai, T., Kitamura, Y., & Shimizu, K. «The influence of seepage from canals and paddy fields on the groundwater level of neighboring rotation cropping fields: A case study from the lower Ili River Basin, Kazakhstan.» *Paddy Water Environ.* 12 (2014): 387-392. DOI: 10.1007/s10333-013-0393-z

4. Aytmukhanovich, D.M.; Aipovich, T.Y.; Suleimenovich, A.Y.; Zhanserkenovich, Y.I. "Assessment of pollution influence of bottom sediments on quality of water of the Ili River." *Life Sci. J.* 11; (2014):pp. 335–338;

5. Baibagyssov, A., Thevs, N., Nurtazin, S., Waldhardt, R., Beckmann, V., Salmurzauly, R. "Biomass Resources of Phragmites australis in Kazakhstan: Historical Developments, Utilization, and Prospects" *Resources Journal*, Volume 9, Issue 6, (2020), Pages 1-25 Resources 2020, 9, 74; doi:10.3390/resources9060074.

6. Baranowski, E., Thevs, N., Khalil, A., Baibagyssov, A., Iklassov, M., Salmurzauli, R., Nurtazin, S., Beckmann, V. "Pastoral Farming in the Ili Delta, Kazakhstan, under Decreasing Water Inflow: An Economic Assessment" *Agriculture journal*, Volume 10, Issue 7, (2020), Pages 1-29 http://dx.doi.org/10.3390/agriculture10070281

7. Ciska C. Overbeek, Sarah Faye Harpenslager, Jeroen P. van Zuidam, E. Emiel van Loon, Leon P. M. Lamers, Merel B. Soons, Wim Admiraal, Jos T. A. Verhoeven, Alfons J. P. Smolders, Jan G. M. Roelofs, and Harm G. van der Geest. "Drivers of Vegetation Development, Biomass Production and the Initiation of Peat Formation in a Newly Constructed Wetland." *Ecosystems* 23, no. 5 (2020): 1019–1036. DOI:10.1007/s10021-019-00454-x

8. Convention on Biological Diversity (CBD). *The economic values of the world's wetlands (Environmental Science)*. Schuyt, K., Brander, L. WWF, Amsterdam, 2004

9. Costanza R., D'Arge R., Groot R.D., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., et al. "The value of the world's ecosystem services and natural capital". *World Environ* 25:3–15, (1997). doi:10.1038/387253a0.

10. Cronk, J. K., and Siobhan Fennessy, M. *Wetland Plants: Biology and Ecology*, 1st Edn. CRC Press, 2001

11. Dostaj, Ž. D.,. "Wasserressourcen und deren Nutzung im Ili-Balchaš Becken" *Discussion Papers*, No. 34, (2007) 1-80.

12. Eglington, S. M., Noble, D. G., & Fuller, R. J. "A meta-analysis of spatial relationships in species richness across taxa: birds as indicators of wider biodiversity in temperate regions." *Journal for Nature Conservation* 20 (2012): 301-309

13. Gao, F., Cui, J., Zhang, S., Xin, X., Zhang, S., Zhou, J., Zhang, Y. «Spatio-Temporal Distribution and Driving Factors of Ecosystem Service Value in a Fragile Hilly Area of North China.» *Land*, vol. 11, (2022) 2242 https://doi.org/10.3390/land11122242

14. Gathman, J.P., Burton, T.M. "A great lakes coastal wetland invertebrate community gradient: Relative influence of flooding regime and vegetation zonation." *Wetlands*, 31 (2), (2011), pp. 329-341, doi: 10.1007/s13157-010-0140-9.

15. Geurts, J.J.M., van Duinen, G.-J.A., van Belle, J., Wichmann, S., Wichtmann, W., Fritz, C. "Recognize the high potential of paludiculture on rewetted peat soils to mitigate climate change: Position Paper." *J. Sustain. Org. Agric. Syst*., vol. 69, (2019): 5–8.

16. Graham White. "The Future of Reedbed Management." RSPB. Information and Advice note Version 7 – July 2009 Compiled by Graham White. For further information, contact Graham White at RSPB on 01767 680551, or by e-mail at graham.white@rspb.org.uk.

17. Graham, N.; Pueppke, S.G.; Uderbayev, T. "The current status and future of Central Asia's fish and fisheries: Confronting a wicked Problem." *Water* 9, 701. (2017).

18. Guareschi, S.; Abellán, P.; Laini, A.; Green, A.J.; Sánchez-Zapata, J.A.; Velasco, J.; "Millán, A. Cross-taxon congruence in wetlands: Assessing the value of waterbirds as surrogates of macroinvertebrate biodiversity in Mediterranean Ramsar sites." *Ecol. Indic*. (2015), 49, 204–215.

19. Haines, Y.R., Potschin, M. *Common International Classification of Ecosystem Services (CICES, Version 4.1)*. Copenhagen, Denmark: European Environment Agency, 2012, pp. 1–17

20. Hu S.J., Niu Z.G., Chen Y.F., Li L.F., Zhang H.Y. "Global wetlands: Potential distribution, wetland loss, and status". *Sci. Total Environ.* (2017); 586: pp. 319–327. doi: 10. 1016/j.scitotenv. 2017.02.001.

21. IFC. *Performance standards on environmental and social sustainability*. International Finance Corporation (IFC), 2012

22. Instrukciya po provedeniyu krupnomasshtabnyh (1:1000 -1:100000) geobotanicheskih izyskanij prirodnyh kormovyh ugodij Respubliki Kazahstan [Instruction on large-scale (1:1000 -1:100000) geobotanical surveys of natural forage lands of the Republic of Kazakhstan. Almaty 1995.]. Almaty, 1995, pp. 4-5. (In Russian)

23. Intergovernmental Panel on Climate Change. *Climate Change 2022: Mitigation of climate change – Summary for Policymakers*. Geneva, Switzerland: IPCC, 2022

24. Karstens, S., Buczko, U., Jurasinski, G., Peticzka, R., and Glatzel, S. "Impact of adjacent land use on coastal wetland sediments." *Sci. Total Environ*. (2016). 550, pp.337–348. doi: 10.1016/j.scitotenv.2016.01.079.

25. Kiviat, E. "Ecosystem services of Phragmites in North America with emphasis on habitat functions." *AoB Plants* (2013). 5:plt008. doi: 10.1093/aobpla/plt008.

26. Köbbing, J., Thevs, N., and Zerbe, S. "The utilisation of reed (Phragmites australis): a review." *Mires and Peat* 13, (2013): pp.1–14.

27. Kopf, R. K., Finlayson, C. M., Humphries, P., Sims, N. C., and Hladyz, S. "Anthropocene baselines: assessing change and managing biodiversity in human-dominated aquatic ecosystems." *BioScience* (2015). 65, 798–811. doi:10.1093/biosci/biv092.

28. Luneva N. N. "Phragmites australis (Cav.) Trin. ex. Stend. — Common Reed." «Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries. Economic Plants and their Diseases, Pests and Weeds». http://www.agroatlas.ru/en/content/weeds/Phragmites_australis. (accessed 13.05.2023)

29. Mitsch W.J., Gosselink J.G. *Wetlands.* New York, NY, USA: John Wiley & Sons, 2015.

30. Morganti, M.; Manica, M.; Bogliani, G.; Gustin, M.; Luoni, F.; Trotti, P.; Perin, V.; Brambilla, M. "Multi-species habitat models highlight the key importance of flooded reedbeds for inland wetland birds: Implications for management and conservation." *Avian Res*. (2019), 10, pp.1–13.

31. Nemeth E, Dvorak M. "Reed die-back and conservation of small reed birds at Lake Neusiedl, Austria." *J Ornithol* 163 (2022): 683–693. doi: 10.1007/s10336-022-01961-w

32. Neuvonen, M.; Pouta, E.; Sievänen, T.; Torvelainen, J. "Outdoor recreation in ecosystem service accounting: Pilot accounts from Finland." *Scand. J. For. Res*. (2020), 35, 186–197.

33. Pueppke SG, Iklasov MK, Beckmann V, Nurtazin ST, Thevs N, Sharakhmetov S, Hoshino B. "Challenges for Sustainable Use of the Fish Resources from Lake Balkhash, a Fragile Lake in an Arid Ecosystem." *Sustainability*, 10(4):1234. (2018). https://doi.org/10.3390/su10041234

34. Queiroz, C., Meacham, M., Richter, K., Norström, A.V., Andersson, E., Norberg, J., Peterson, G. “Mapping bundles of ecosystem services reveals distinct types of multifunctionality within a Swedish landscape.” *AMBIO*, Suppl. 1. (2015) DOI:10.1007/s13280-014-0601-0.

35. Quin, A., Jaramillo, F. & Destouni, G. “Dissecting the ecosystem service of large-scale pollutant retention: The role of wetlands and other landscape features.” *AMBIO* (2015) 44 (Suppl1), 127–137. https:// doi.org/10.1007/s 13280-014-0594-8.

36. Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J., Smol, J.P., Taylor, W.W., Tockner, K., Vermaire, J.C., Dudgeon, D., Cooke, S.J. “Emerging threats and persistent conservation challenges for freshwater biodiversity.” *Biol Rev Camb Philos Soc* 94, no. 3 (2019): 849-873. doi: 10.1111/brv.12480

37. Roth, N., Zoder, S., Zaman, A. A., Thorn, S., & Schmidl, J. Long-term monitoring reveals decreasing water beetle diversity, loss of specialists and community shifts over the past 28 years. *Insect Conservation and Diversity*, 13, (2020) 140-150.

38. Schaller, L., Targetti, S., Villanueva, A.J., Zasada, I., Viaggi, D. “Agricultural landscapes, ecosystem services, and regional competitiveness-assessing drivers and mechanisms in nine European case study areas.” *Land Use Policy*, vol. 76 (2018): 735–745

39. Sklyarenko, S.L., D.R. Uelsh, and M. Brombaher, eds. *Klyuchevye ornitologicheskie territorii Kazahstana* [*Key ornithological territories of Kazakhstan*]. Almaty: Associaciya sohraneniya bioraznoobraziya Kazahstana (ASBK), 2008. (In Russian)

40. Sludskij A.A. *Kaban (morfologija, jekologija, hozjajstvennoe i jepizootologicheskoe znachenie, promysel)* [*Wild boar (morphology, ecology, economic and epizootic significance, and commercial trade)*]. Alma-Ata: Izdatel’stvo Akademii Nauk Kazahskoj SSSR, 1956, p. 218. (In Russian)

41. Sludskij A.A. *Promyslovye mlekopitayushchie Kazahstana* [*Commercial mammals of Kazakhstan*], Alma-Ata: Izd-vo AN Kaz, 1973. (In Russian)

42. Sludskij, A. A. *Ondatra i akklimatizaciya eyo v Kazahstane* [*The muskrat and its acclimatization in Kazakhstan*]. Edited by A. V. Afanas’ev. Alma-Ata: Izd-vo AN Kaz. SSR, 1948. (In Russian)

43. Thevs, N.; Beckmann, V.; Akimalieva, A.; Köbbing, J.F.; Nurtazin, S.; Hirschelmann, S.; Piechottka, T.; Salmurzauli, R.; Baibagysov, A. “Assessment of ecosystem services of the wetlands in the Ili River Delta, Kazakhstan.” *Environmental Earth Sciences* 76 (2017), p. 30. doi: https://doi.org/10.1007/s12665-016-6346-2;

44. UNEP. Millennium Ecosystem Assessment. Ecosystems and Human Well-being. Washington DC: Island Press; United Nations (2012)

45. Van der Putten W.H. “Dieback of Phragmites australis in European wetlands: an overview of the European Research Programme on Reed Dieback and Progression (1993–1994).” *Aquatic Botany* 59 (1997): 263–275.

46. Van Roon, M.R. “Wetlands in The Netherlands and New Zealand: Optimising biodiversity and carbon sequestration during urbanisation.” *J. Environ. Manag*. (2012), 101, pp.143–150.

47. Wang X, Zhang D, Guan B, Qi Q, Tong S. “Optimum water supplement strategy to restore reed wetland in the Yellow River Delta.” *PLoS One* 12(5) (2017): e0177692. doi: 10.1371/journal.pone.0177692.

48. White S, Ganf G. «A comparison of the morphology, gas space anatomy and potential for internal aeration in Phragmites australis under variable and static water regimes.» *Aquatic Botany* 73(2) (2002): 115–127. [Google Scholar]

49. Wichtmann, W., Schröder, C., Joosten, H. “Paludikultur als integrative Systemlösung.” In *Paludikultur: Klimaschutz—Biodiversität—Regionale Wertschöpfung*, Schweizerbart: Stuttgart, Germany (2016), pp. 1–2

50. XINHUANET. Kitajskij investor planiruet postroit’ zavod po proizvodstvu cellyulozy i bumagi iz kamysha v Kazahstane. https://finance.rambler.ru/markets/39899320-kitayskiy-investor-planiruet-postroit-zavodpo-proizvodstvu-tsellyulozy-i-bumagi-iz-kamysha-v-kazahstane. Accessed on 13.05.2023

51. Zhang N, Zhang J, Li Z, Chen J, Zhang Z, Mu C. “Resistance strategies of Phragmites australis (common reed) to Pb pollution in flood and drought conditions.” *PeerJ* 6;(2018). e4188 https:// doi.org/10.7717/peerj.4188

52. Żmihorski, Michał, et al. «Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands.» *Journal of Applied Ecology* 53, no. 2 (2016): 587–595. Accessed May 15, 2023: http://www.jstor.org/stable/43869411..

МРНТИ 34.33.33 https://doi.org/10.26577/eb.2023.v96.i3.014

Н.С. Сапаргалиева*, А.Л. Адильбекова, Е.Б. Кегенов, Э.Б. Кожабаева

Казахский национальный университет им. аль-Фараби, Казахстан, г. Алматы
*e-mail: sapargalyeva.nazym@gmail.com

МОРФОЛОГИЧЕСКАЯ И БИОЛОГИЧЕСКАЯ ХАРАКТЕРИСТИКА ПЕСКАРЯ *GOBIO CYNOCEPHALUS* ИЗ Р. БЕЙЫТТЫБУЛАК (бассейн р. Иртыш)

Пескари (Gobio) относятся к одному из самых широко распространенных в Евразии видов пресноводных костистых рыб. Пескари, наслеюящие водоемы Казахстана, Сибири и бассейна Амура, отличаются от европейских видов, их систематика нуждается в подробном изучении. Эндемичный вид пескаря G.acutipinnatus Men'shikov обитает в озере Маркаколь. Не ясным является таксономический статус пескаря, населяющего бассейн р.Иртыш. В Зайсанской котловине много малых рек, и подавляющее большинство из них почти не изучено. Целью данной работы являлось установление таксономического статуса и оценка состояния пескаря на примере реки Бейыттыбулак Восточного Казахстана. В 2022 г. пескарь являлся одним из массовых видов рыб в реке Бейыттыбулак. В изученной нами выборке рыбы имели типичную для пескарей форму и окраску тела. Пластические признаки варьируют в широких пределах. Внутри выборки особи различаются по положению плавников и их форме, форме головы и относительным размерам различных ее частей. Выборка пескарей из р.Бейыттыбулак представлена разновозрастными и разноразмерными рыбами, поэтому условия существования вполне удовлетворительны для всех стадий жизни этого вида рыб.

Ключевые слова: р. Бейыттыбулак, пескарь, показатели, пластические, счетные признаки.

N.S. Sapargaliyeva*, A.L. Adilbekova, E.B. Kegenov, E.B. Kozhabayeva

Al-Farabi Kazakh National University, Kazakhstan, Almaty
*e-mail: sapargalyeva.nazym@gmail.com

Morphological and biological characteristics gudgeon Gobio cynocephalus from the Beyittybulak river (Irtysh river basin)

Gudgeons (Gobio) belong to one of the most widespread species of freshwater bony fishes in Eurasia. Gudgeons inheriting the water bodies of Kazakhstan, Siberia and the Amur basin differ from European species and their systematics needs detailed study. The endemic species of gudgeon G.acutipinnatus Men'shikov inhabits Lake Markakol. The taxonomic status of the gudgeon living in the Irtysh River basin is not clear. There are many small rivers in the Zaisan Basin, and the vast majority of them are almost unstudied. The purpose of this work was to establish the taxonomic status and assessment of the gudgeon on the example of the Beyittybulak River of East Kazakhstan. In 2022, gudgeon was one of the mass fish species in the Beyittybulak River. In the sample we studied, fish had typical for gudgeons shape and body colouration. Plastic features varied widely. Within the sample individuals differ in the position of fins and their shape, head shape and relative size of its different parts. The sample of gudgeons from the Beyittibulak River is represented by fish of different ages and sizes, so the conditions of existence are quite satisfactory for all life stages of this fish species.

Key words: Beyittybulak River, gudgeon, parameters, plastic, counting features.

Н.С. Сапарғалиева*, А.Л. Әділбекова, Е.Б. Кегенов, Э.Б. Қожабаева

Әл-Фараби атындағы Қазақ ұлттық унисерситеті, Қазақстан, Алматы қ.
*e-mail: sapargalyeva.nazym@gmail.com

Бейіттібұлақ өзеніндегі (Ертіс өзенінің бассейні) Gobio cynocephalus теңге балығының морфологиялық және биологиялық сипаттамасы

Теңге балықтар (Gobio) тұщы суда мекендейтін Евразияда ең кеңінен таралған сүйекті балықтарға жатады. Бірақ Қазақстанда, Сібір мен Амур бассейнінде тіршілік ететін теңге балықтар еуропалық түрлерден ерекшеленеді, сондықтан олардың систематикасы терең зерттеуді талап

етеді. Эндемикалық теңге балық G.acutipinnatus Men'shikov Марқакөл көлінде таралған. Ал Ертіс өзенінің бассейнінде мекендейтін теңге балықтың статусы әлі белгісіз. Зайсан ойпатында зерттелмеген кіші өзендер өте көп. Сондықтан, бұл жұмыстың мақсаты Шығыс Қазақстандағы Зайсан ойпатында орналасқан Бейіттібұлақ өзенінің мысалында теңге балықтың тасономиялық статусын анықтау мен қазіргі экологиялық жағдайын бағалау болды. 2022 жылы теңге балық Бейіттібұлақ өзеніндегі басым таралған түрге жатты. Зерттелген теңге балықтардың формасы мен денесінің түсі сол балықтарға сәйкес сипатта болды. Пластикалық белгілер кең аумақта өзгерді. Іріктеменің ішінде даралар қанаттарының орналасуы мен формасы бойынша, басының формасы және оның бөлімдерінің салыстырмалы өлшемдерімен ерекшеленді. Зерттелген балықтар түрлі жастағы және түрлі өлшемдегі даралармен келтірілген, сондықтан біздің зерттеулеріміздің нәтижелері Бейіттібұлақ өзенінің тіршілік ету жағдайлары теңге балықтың барлық тіршілік кезеңдеріне қолайлы екендігін көрсетті.

Түйін сөздер: Бейіттібұлақ өзені, теңге балық, көрсеткіштер, пластикалық, саналатын белгілер.

Введение

Костистые рыбы являются самым разнообразным классом позвоночных животных. Несмотря на то, что пресноводные экосистемы занимают лишь 1% поверхности суши, в них сосредоточено огромное разнообразие костистых рыб. Изучение этого разнообразия необходимо для определения состояния каждого вида и поддержания благополучия водных экосистем в целом [3, 4].

Пескари (Gobio) относятся к одному из самых широко распространенных в Евразии видов пресноводных рыб [5]. Для этого рода характерна большая морфологическая изменчивость. На конец 2022 г в мире насчитывалось 48-50 видов пескарей [6]. Число выделяемых в разное время видов Gobio варьирует от 15 до 50 [7, 8]. Пескари, наслеюящие водоемы Казахстана, Сибири и бассейна Амура, отличаются от европейских видов, их систематика нуждается в подробном изучении [9]. В настоящее время для пределах Республики Казахстан А.Л.Мартынова и Е.Д.Васильева (2021) указывают 3 вида пескарей. Волжский пескарь *Gobio volgensis* Vasil'eva, Mendel, Vasil'ev, Lusk, Lusková, 2008 населяет реки Волга и Урал. Туркестанский пескарь *G.lepidolaemus* Kessler, 1872 населяет реки Южного и, возможно, Центрального Казахстана. Эндемичный вид пескаря *G.acutipinnatus* Men'shikov обитает в озере Маркаколь. Не ясным является таксономический статус пескаря, населяющего бассейн р.Иртыш. Одни авторы относят его к виду *G.cynocephalus* Dybowskii [10-13], другие для сибирского пескаря считают правильным название *G.sibiricus* Nikolskii, 1936 [14-16]. По последним данным G. cynocephalus был подтвержден как отдельный вид в бассейне р. Амур, поэтому необходимы дальнейшие исследования для уточнения его ареала [17].

В Зайсанской котловине много малых рек, и подавляющее большинство из них почти не изучено. Целью данной работы являлось установление таксономического статуса и оценка состояния пескаря на примере одной из рек Восточного Казахстана.

Материалы и методики

Рыбы для изучения были отловлены в июле 2022 г. в р.Бейыттыбулак – одном из левых притоков р.Иртыш выше оз.Зайсан. Координаты места отлова рыб: 47°29'25.9" с.ш. 85°11'01.3" в.д. Река Бейттибулак расположена в Восточно-Казахстанской области, протекает на солнечном востоке горы Саур, относится к бассейну Черного Иртыша. В весенние месяцы река наполняется снеговыми, ледниковыми водами. Грунт каменистый, песчаный. Скорость течения воды до 1,25 м/сек, глубина воды до 70 см. Вода относится к классу гидрокарбонатных, известковой группе, II типу SCaII. [18].

Изучение биологических и морфологических показателей проводили после 3-х месяцев хранения в фиксирующем растворе, когда завершились основные посмертные изменения. Биологический анализ проводили по стандартной методике [19]. Измеряли: TL – общую длину рыбы в мм, SL – длину тела без хвостового плавника в мм,: Q – полную массу тела в граммах, q – массу тела без внутренностей в граммах. Затем рассчитывали Fulton – коэффициент упитанности по Фультону и Clark – коэффициент упитанности по Кларк.

Рисунок 1 – Карта-схема района исследований с указанием места отлова рыб

Морфологический анализ был выполнен по модифицированной схеме [9, 20]. Для обозначения морфометрических признаков использованы символы:

H – наибольшая высота тела у начала спинного плавника, h – высота хвостового стебля, lpc – длина хвостового стебля, aD – антедорсальное расстояние, pD – постдорсальное расстояние, aV – антевентральное расстояние, aA – антеанальное расстояние, P-V – пектовентральное расстояние, V-A – вентроанальное расстояние, lP – длина грудного плавника, lV – длина брюшного плавника, hD – высота основания спинного плавника, hA – высота анального плавника, lD – длина основания спинного плавника, lA – длина основания анального плавника, w – толщина хвостового стебля у последнего луча анального плавника, c – длина головы, o – горизонтальный диаметр глаза, Hc – наибольшая высота головы, hc – высота головы на уровне середины глаза, ao – длина рыла, po – заглазничное расстояние, wc – ширина головы, io – ширина лба, lb – длина усика. Кроме того, нами были изучены: aP – антепектральное расстояние, ov – диаметр глаза вертикальный, hop – высота жеберной предкрышки, front – длина лобных костей, temp – длина теменных костей, wm ex – ширина рта снаружи, wm int – ширина рта изнутри, HTT – наибольшая ширина (толщина) тела, hmin – наименьшая высота тела, lCs, lCi, lCm – длина соответственно верхних, нижних и средних лучей хвостового плавника. Для счетных признаков использованы обозначения: Dr, Dsoft, Ar, Asoft, Pr, Psoft – число неветвистых и разветвленных лучей в спинном, анальном и грудном плавниках соответственно; cmd, cop, cio, cso, ctmp – число открытых пор сейсмосенсорной системы соответственно на нижней челюсти, жаберной предкрышке, подглазничном, надглазничном и теменном каналах; ll и llca – число чешуй в боковой линии всего и на хвостовом стебле; Vert corp – туловищных позвонков, Vert inter – переходных позвонков, Vert caud – хвостовых позвонков, Vert total – всего позвонков; SPOTS – число черных пятен на теле.

Статистическую обработку данных проводили унивариантным методом [21]. Статистические показатели обозначены: min – минимальное значение, max – максимальное значение, M – среднее значение, ±SD – стандартное отклонение, CV – коэффициент вариации.

Результаты и обсуждение

В 2022 г. пескарь являлся одним из массовых видов рыб в реке Бейитбулак. Биологические показатели исследованной выборки даны в таблице 1. Биология сибирского пескаря из водоемов Восточного Казахстана не изучена [11]. Максимальные и средние размеры для пескарей из бассейна р.Иртыш и сибирского пескаря не установлены. Река Иртыш является притоком реки Обь. Озеро Маркаколь расположено в бассейне р.Иртыш. В этом озере обитает эндемичный вид – маркакольский пескарь *Gobio acutipinnatus* [22]. Сравнение наших данных с имеющимися данными для других видов пескарей позволяют предположить, что

условия обитания в р.Бейыттыбулак являются в целом благоприятными для роста. Поскольку исследованная нами выборка представлена разновозрастными и разноразмерными особями, условия воспроизводства также следует считать удовлетворительными. Индивидуальная упитанность варьирует в широких пределах, что указывает на возможную пищевую конкуренцию внутри популяции. Однако полостной жир имелся у всех исследованных экземпляров, поэтому условия питания также следует считать удовлетворительными.

Таблица 1 – Сравнительная характеристика биологических показателей пескарей из бассейна р.Оби

Признаки	Наши данные					Уй (бассейн Оби) [Мартынова, Васильева, 2021]		Оз.Маркаколь (Меньшиков, 1938; Митрофанов, 1988)	
	min	max	M	±SD	CV	min	max	min	max
TL	54	120	91,0	18,78	20,64	99.1	126.2	70	174
SL	44	100	74,1	14,69	19,82	81.4	104.8	нет данных	
Q	1,31	16,88	8,09	4,425	54,67	нет данных		нет данных	
q	1,05	10,00	5,12	3,269	63,84	нет данных		нет данных	
Fulton	1,37	2,10	1,75	0,184	10,55	нет данных		нет данных	
Clark	1,13	1,74	1,39	0,190	13,62	нет данных		нет данных	

В изученной нами выборке рыбы имели типичную для пескарей форму и окраску тела (рисунок 2а). Тело на поперечном разрезе овальное, немного приплюснуто с брюшной стороны. Общий фон окраски серо-коричневый, более тёмный на спине, по направлению к брюху окраска светлеет, вдоль боков тела с каждой стороны 9-12 черных пятен. У некоторых особей пятна сливаются в полоску. От глаза к рылу идет темная полоска.

Грудные плавники не достигают основания брюшных плавников; брюшные плавники не доходят до основания анального плавника; края спинного и анального плавников слабо вогнутые; нижний край последней брюшной (аксиллярной) чешуйки соединяется с основанием брюшных плавников мембраной, достигающей далее ¾ длины чешуйки (рисунок 2б). Длина головы составляет более 1/3 длины тела; у большинства исследованных экземпляров длина рыла чуть меньше заглазничного расстояния; усики заходят за передний край глаза; горизонтальный диаметр глаза меньше ширины лба. Горло и грудь впереди линии, соединяющей задние концы оснований грудных плавников без чешуи; задняя часть каждой половины нижней губы отделена от передней небольшой выемкой (рисунок 2в); на спинном и хвостовом плавниках ряды черных крапинок. Спинной и анальный плавники слабо выемчатые, закруглены на вершине.

Пластические признаки варьируют в широких пределах (таблица 2). Внутри выборки особи различаются по положению плавников и их форме, форме головы и относительным размерам различных ее частей. Это объясняется различием в размерах исследованных рыб. С увеличением размеров пропорционально увеличиваются расстояния до плавников и размеры головы ($r \geq 0.95$, $p < 0.05$). В сравнении с опубликованными для сибирского пескаря из бассейна р.Оби данными в выборке из р.Бейыттыбулак есть особи с далеко отставленными назад спинным, анальным и брюшными плавниками, большими длинной усиков, рыла, диаметром глаза и заглазничным расстоянием. Форма спинного и анального плавников варьирует от почти квадратного, до высокого (высота плавника почти в 2 раза выше его длины).

а

б

в

Рисунок 2 – Общий вид пескаря из р.Бейыттыбулак (а),
аксиллярная брюшная чешуйка и мембрана (б), расположение чешуи на брюхе и форма губ (в).

Таблица 2 – Пластические признаки выборок пескарей из бассейна р.Обь

Признаки	Наши данные					Уй (бассейн Оби) [Мартынова, Васильева, 2021]		Оз.Маркаколь (Меньшиков, 1938; Митрофанов, 1988)	
	min	max	M	±SD	CV	min	max	min	max
В % от длины тела									
aD	45.0	53.3	47.6	1.89	3.98	45.5	49.5	43,0	52,0
pD	34.0	42.7	39.3	2.15	5.46	37.3	40.7	39,0	47,0
aP	26.0	33.3	28.9	1.61	5.59	нет данных		нет данных	
aV	48.0	56.4	51.7	2.50	4.85	49.2	52.2	нет данных	
aA	64.0	77.9	71.1	3.61	5.07	70.0	71.9	нет данных	
P-V	22.0	29.6	25.1	2.16	8.62	23.3	27.1	22,3	28,5
V-A	16.0	23.7	21.5	1.85	8.59	19.8	22.9	17,1	23,0
lpc	18.0	23.5	20.7	1.73	8.35	17.9	20.1	19,0	26,0
c	25.1	29.3	27.1	1.13	4.17	26.6	28.1	23,0	28,0
ao	9.3	13.6	11.9	1.09	9.18	нет данных		8.0	11,5
lb	5.0	9.9	7.1	1.27	17.88	нет данных		4.5	8,0
o	5.0	6.8	5.8	0.51	8.84	4.8	5.7	нет данных	
ov	4.0	6.8	5.3	0.68	12.92	нет данных		нет данных	
po	11.5	15.0	12.8	1.03	8.01	нет данных		9.0	13,0

Продолжение таблицы

Признаки	Наши данные					Уй (бассейн Оби) [Мартынова, Васильева, 2021]		Оз.Маркаколь (Меньшиков, 1938; Митрофанов, 1988)	
	min	max	M	±SD	CV	min	max	min	max
hop	8.5	14.1	11.3	1.77	15.66	нет данных		нет данных	
hc	11.7	16.7	13.7	1.12	8.18	нет данных		нет данных	
Hc	15.1	18.0	16.4	0.69	4.19	нет данных		12.0	17,0
io	7.1	9.6	8.5	0.66	7.83	нет данных		5.5	8,0
front	6.2	11.3	9.3	1.24	13.39	нет данных		нет данных	
temp	4.7	8.0	6.9	0.77	11.26	нет данных		нет данных	
wm ex	8.9	12.5	10.9	1.15	10.55	нет данных		нет данных	
wm int	5.7	8.0	6.5	0.70	10.74	нет данных		нет данных	
wc	**17.0**	**20.0**	18.6	0.90	4.83	8.1	9.6	нет данных	
HTT	15.1	20.0	17.3	1.43	8.31	нет данных		нет данных	
w	7.1	10.0	8.6	0.96	11.20	нет данных		нет данных	
H	17.9	22.9	20.6	1.43	6.92	18.9	20.7	13,5	20,5
h	10.0	12.7	11.1	0.65	5.84	нет данных		нет данных	
hmin	8.9	10.7	9.5	0.45	4.75	9.0	9.8	6,0	9,0
lD	13.6	17.3	15.2	0.94	6.19	12.4	13.9	нет данных	
hD	15.6	26.0	23.1	2.33	10.08	20.9	23.0	17.2	24.0
lA	8.3	12.3	10.1	1.16	11.49	7.5	9.2	5.0	8.5
hA	12.1	**20.8**	17.5	2.02	11.54	15.8	18.1	12.8	15.0
lP	17.8	24.7	20.9	1.97	9.43	17.9	21.8	17.0	23.0
lV	14.0	19.8	16.9	1.36	8.07	15.5	17.7	13.0	18.0
lCs	18.9	24.1	22.0	1.78	8.10	нет данных		нет данных	
lCi	18.5	23.7	21.8	1.87	8.56	нет данных		нет данных	
lCm	7.6	15.3	12.3	2.17	17.64	нет данных		нет данных	
В % от длины головы									
Hca	37.5	**47.6**	41.0	2.71	6.62	31.9	36.6	нет данных	
ao	33.3	52.6	43.8	4.29	9.81	41.8	46.0	нет данных	
oh	18.3	25.0	21.2	1.82	8.57	17.5	21.0	нет данных	
ov	15.4	25.0	19.5	2.50	12.85	нет данных		нет данных	
op	42.9	57.7	47.3	3.80	8.04	39.7	45.2	нет данных	
htc	60.0	76.5	68.8	5.12	7.45	56.7	70.6	нет данных	
hop	31.3	52.9	41.6	6.85	16.46	нет данных		нет данных	
hco	43.8	58.8	50.3	3.93	7.81	45.2	55.1	нет данных	
hc	53.3	66.7	60.6	3.16	5.21	54.4	62.3	нет данных	
io	25.5	**38.1**	**31.3**	2.68	8.56	25.5	29.9	нет данных	
front	22.2	42.1	34.2	4.91	14.36	нет данных		нет данных	
temp	17.4	30.8	25.3	2.91	11.49	нет данных		нет данных	
wm ex	33.3	47.1	40.4	4.77	11.78	нет данных		нет данных	
wm int	20.0	30.8	24.1	2.93	12.17	нет данных		нет данных	
wc	60.0	76.5	68.8	5.12	7.45	нет данных		нет данных	

Продолжение таблицы

Признаки	Наши данные					Уй (бассейн Оби) [Мартынова, Васильева, 2021]		Оз.Маркаколь (Меньшиков, 1938; Митрофанов, 1988)	
	min	max	M	±SD	CV	min	max	min	max
lb	19.1	34.8	26.2	4.43	16.95	19.8	33.3	нет данных	
Индексы, %									
hD/lD	100,0	183,3	152,4	15,78	10,35	157.0	179.8	нет данных	
hA/lA	100,0	205,9	174,2	21,93	12,59	184.3	230.0	нет данных	
lV/VA	68,4	92,3	78,8	6,81	8,64	68.8	85.1	нет данных	
lP/PV	65,1	100,0	84,0	10,16	12,09	66.7	93.5	нет данных	
htca/hca	**66,7**	87,5	76,9	7,09	9,22	85.0	98.8	нет данных	
o/io	56.3	83.3	68.1	6.93	10.17	63.7	79.4	нет данных	
h/c	37.5	47.6	41.0	2.71	6.62			нет данных	

Изменчивость счетных признаков у сибирского пескаря мало изучена. Так в работе А.Л.Мартыновой и К.Д.Васильевой (2021) для бассейна р.Оби данные не приводятся. В.П.Митрофанов (1988) обобщил известные на тот момент данные по изменчивости счетных признаков сибирского и маркакольского пескарей. Наши данные по изменчивости счетных признаков сибирского пескаря представлены в таблице 3 в сравнении ранее опубликованными [11]. Число лучей в плавниках, пор на голове, чешуй в боковой линии и пятен на боках тела у пескарей из р.Бейыттыбулак также варьирует в больших пределах, однако достоверной корреляции с размерами тела не выявлено. Сведения о числе пор в каналах сенсорной линии на голове приводятся нами впервые.

Таблица 3 – Счетные признаки выборок пескаря

Признаки	Наши данные					Сибирский пескарь [Митрофанов, 1988]		Маркакольский пескарь [Митрофанов, 1988]	
	min	max	M	±SD	CV	min	max	min	max
Dr	1	3	2.1	0.39	19.22	3		нет данных	
Dsoft	5	8	7.4	0.80	10.84	6	8	7	8
Ar	1	3	1.9	0.59	31.74	2	3	нет данных	
Asoft	5	7	6.0	0.54	8.97	5	7	7	
Pr	1	2	1.3	0.47	36.17	нет данных		нет данных	
Psoft	10	15	13.2	1.61	12.19	нет данных		13	16
cmd	3	4	3.8	0.45	11.77	нет данных		нет данных	
cop	6	10	8.2	1.64	20.04	нет данных		нет данных	
cio	9	14	12.4	2.30	18.57	нет данных		нет данных	
cso	4	8	6.8	1.89	28.04	нет данных		нет данных	
ctmp	2	5	4.0	1.73	43.30	нет данных		нет данных	
ll	37	44	40.3	2.13	5.28	34	45	41	42
llca	8	11	9.3	1.11	11.98	нет данных		нет данных	
Vert corp	13	17	15.6	1.26	8.11	нет данных		нет данных	
Vert inter	4	6	5.0	0.67	13.33	нет данных		нет данных	
Vert caud	16	20	18.1	1.20	6.61	нет данных		нет данных	

Продолжение таблицы

Признаки	Наши данные					Сибирский пескарь [Митрофанов, 1988]		Маркакольский пескарь [Митрофанов, 1988]	
	min	max	M	±SD	CV	min	max	min	max
Vert sum	35	41	38.7	1.70	4.40	нет данных		нет данных	
Vert total	37	40	38.4	1.17	3.06	нет данных		нет данных	
SPOTS	9	12	10.6	1.13	10.73	7	11	нет данных	

На основании проведенного анализа мы не выявили существенных различий между пескарем из р.Бейыттыбулак и ранее описанными выборками сибирского пескаря из бассейна р.Обь. Наши данные показали значительно большую изменчивость пластических и счетных признаков, что согласуется с данными [15] по изменчивости пластических признаков сибирского пескаря из Центрального Казахстана.

В научной литературе для пескарей из водоемов севера и северо-востока Казахстана были использованы два названия *Gobio cynocephalus* и *G.sibiricus.* [23, 24]считал пескарей из бассейнов Енисея и Амура разными подвидами, полагая что подвид *G.gobio cynocephalus* населяет реки бассейна Амура, а *G.gobio sibiricus* – реки Сибири. К этой точке зрения склоняются также А.Л.Мартынова и Е.Д.Васильева, 2021, но указывают на явную недостаточность опубликованных материалов и необходимость специальных морфологических и молекулярно-генетических исследований [14] считает, что *G.sibiricus* обитает в р.Нура, бассейне Енисея,Оби и в р.Селенга, но, только не в р.Иртыш. В качестве диагностического признака для двух этих двух форм пескарей P.Banarescu и T.Nalbant, 1973 [25] предложили форму спинного плавника: у сибирского пескаря *G.sibiricus* он прямой, а у амурского *G.cynocephalus* – выемчатый. В нашей выборке из р.Бейтиттубак у всех рыб спинной плавник был выемчатым (рис. 2а). Таким образом, мы считаем что в бассейне Черного Иртыша обитает именно *G.cynocephalus.*

Заключение

Выборка пескарей из р.Бейыттыбулак представлена разновозрастными и разноразмерными рыбами, поэтому условия существования вполне удовлетворительны для всех стадий жизни этого вида рыб.

Литература

1. Joseph S. Nelson, Terry N. Grande, Mark V.H. Wilson Fishes of the world. Fifth edition. – Hoboken, New Jersey: John Wiley-Sons. – 2016. – 752 p.
2. Gene S. Helfman Bruce B. Collette Douglas E. Facey Brian W. Bowen THE DIVERSITY OF FISHES Biology, Evolution, and Ecology.- Second Edition. – A John Wiley & Sons, Ltd., Publication. – 2009. – 737 p.
3. Isbell, F., Gonzalez, A., Loreau, M. *et al.* Linking the influence and dependence of people on biodiversity across scales. *Nature* 546, 65–72 (2017). https://doi.org/10.1038/nature22899
4. Blicharska, M., Smithers, R.J., Mikusiński, G. *et al.* Biodiversity's contributions to sustainable development. *Nat Sustain* **2**, 1083–1093 (2019). https://doi.org/10.1038/s41893-019-0417-9
5. Mendel J., Lusk S., Vasil'eva E. D., Vasil'ev V. P., Luskova V., Ekmekci F. G., Erk'akan F., Ruchin A., Košcˇo J., Vetešnik L., Halacˇka K., Šanda R., Pashkov A. N., Reshetnikov S. I., 2008. Molecular phylogeny of the genus Gobio Cuvier, 1816 (Teleostei: Cyprinidae) and its contribution to taxonomy// Mol. Phylogenet. Evol.. Vol. 47. P. 1061-1075
6. Fricke R., Eschmeyer W.N., Vanderlaan R. (Eds.) Eschmeyer's catalog of fishes: genera, species, references: http://researcharchive.calacademy.org/research/ichthyology/fishcatmain.asp – accessed 19 January 2023.
7. Nowak M., Koščo J., Popek W., 2008. Review of the current status of systematics of gudgeons (Gobioninae, Cyprinidae) in Europe//AACL Bioflux. Vol.1. P. 27-38.
8. Petrova A.V. Morphological characteristics of Siberian gudgeon Gobio cynocephalus Dybowski, 1869 (Cyprinidae: Gobioninae) from the Zeya River basin. Amurian zoological journal. V(4), 2013. – P. 460-463.
9. Мартынова А.Л., Васильева Е.Д. Проблемы таксономии и диагностики пескарей рода Gobio (Cyprinidae) Урала, Сибири, Казахстана и бассейна реки Амур// Вопросы ихтиологии. – 2021. – Том 61, №5. – С.529-544.
10. *Берг*, Л.С. *Рыбы пресных вод* СССР и сопредельных стран. 4-е изд., испр. и доп. [В 3 ч.] Ч. 1-3. М.; Л.: Издательство Академии наук СССР, 1948. Ч. 1: 465 с.
11. Митрофанов В.П. Род Gobio Cuvier, 1817 – Пескарь// Рыбы Казахстана. – Алма-Ата: Наука, 1988. – Т.3. – С.5-23.

12. Тагаев Д.А., Жапарова А.Т. 2018. Пескари рода Gobio (Pisces: Cyprinidae) Центрального и Восточного Казахстана: история описания, систематика и современное состояние изученности // Вестн. Евраз. нац. ун-та им. Л.Н. Гумилева. Сер. биол. науки. № 3 (124). С. 90–96. https://doi.org/10.32523/2616-7034-2018-124-3-90-96

13. Yevseyeva, A. A., Bolbotov, G. A., & Kirichenko , O. I. (2019). An annotated list of fish-like vertebrates and fishes of upper Irtysh River basin (Eastern Kazakhstan) with comments on their taxonomy and zoogeography. *Acta Biologica Sibirica*, *5*(4), 156-174. https://doi.org/10.14258/abs.v5.i4.7180

14. Kottelat M. 2006. Fishes of Mongolia. A check-list of the fishes known to occur in Mongolia with comments on systematic and nomenclature. Washington: The World Bank, 103 p.

15. Тагаев Д.А., Жапарова А.Т. 2019. Изменчивость пластических признаков сибирского пескаря (Gobio sibiricus Nikolskii, 1936) из р. Каркаралы (Центральный Казахстан) // Вестн. Карагандин. ун-та. Сер. биология, медицина, география. № 2 (94). С. 86–92.

16. Sheraliev B., Allayarov S., Peng Z. 2020. First records of Gobio nigrescens and Gobio sibiricus (Cypriniformes: Gobionidae) from the Amu Darya River basin, Uzbekistan // J. Appl. Ichthyol. V. 36. № 2. P. 235–239. https://doi.org/10.1111/jai.14019

17. Dyldin, Y.V., Orlov, A.M., Hanel, L. *et al.* Ichthyofauna of the Fresh and Brackish Waters of Russia and Adjacent Areas: Annotated List with Taxonomic Comments. 2. Order Cypriniformes, Suborders Catostomoidei, Cobitoidei and Cyprinoidei. *J. Ichthyol.* **63**, 636–686 (2023). https://doi.org/10.1134/S0032945223040045

18. Сапаргалиева Н.С., Маратова Г.М. Ертіс бассейніндегі зайсан талма және сұр талма балықтарының морфологиялық және асқорыту жүйесінің сипаттамасы. Материалы международной научной конференции «Зоологические исследования за 20 лет независимости Республики Казахстан», посвященной 20-летию независимости РК. – Алматы – 2011. – С. 281-283.

19. Правдин И.Ф. Руководство по изучению рыб. – М.: Пищевая промышленность, 1966. – 376 с.

20. Takács P. Morphometric differentiation of gudgeon species inhabiting the Carpathian Basin// Annales de Limnologie – International Journal of Limnology. – 2012. –V.48. – P.83-61. DOI: 10.1051/limn/2011058

21. Лакин Г.Ф. Биометрия – М.: Высшая школа, 1990. – 352 с.

22. Меньшиков М.И. Об ихтиофауне оз.Марка-Куль// Ученые записки Пермского университета. – 1938. – Т.3, вып.2. – С.-119-141.

23. Никольский Г.В. 1936. Материалы к познанию географической изменчивости пескарей Gobio gobio (L.) Северо-восточного Казахстана и Западной Сибири // Тр. ЗИН АН СССР. Т. 3. С. 457–473.

24. Никольский Г.В. 1956. Рыбы бассейна Амура. Итоги Амурской ихтиологической экспедиции 1945−1949 гг. М.: Изд-во АН СССР, 551 с.

25. Banarescu P., Nalbant T. Pisces, Teleostei: Cyprinidae (Gobioninae), Walter de Gruyter, 93, 105–164 (1973).

References

1. Berg, L.S. Ryby presnyh vod SSSR i sopredel’nyh stran. 4-e izd., ispr. i dop. [V 3 ch.] CH. 1-3. M.; L.: Izdatel’stvo Akademii nauk SSSR, 1948. CH. 1: 465 s.

2. Banarescu P., Nalbant T. Pisces, Teleostei: Cyprinidae (Gobioninae), Walter de Gruyter, 93, 105–164 (1973).

3. Blicharska, M., Smithers, R.J., Mikusiński, G. et al. Biodiversity’s contributions to sustainable development. Nat Sustain 2, 1083–1093 (2019). https://doi.org/10.1038/s41893-019-0417-9

4. Dyldin, Y.V., Orlov, A.M., Hanel, L. et al. Ichthyofauna of the Fresh and Brackish Waters of Russia and Adjacent Areas: Annotated List with Taxonomic Comments. 2. Order Cypriniformes, Suborders Catostomoidei, Cobitoidei and Cyprinoidei. J. Ichthyol. 63, 636–686 (2023). https://doi.org/10.1134/S0032945223040045

5. Gene S. Helfman Bruce B. Collette Douglas E. Facey Brian W. Bowen THE DIVERSITY OF FISHES Biology, Evolution, and Ecology.- Second Edition. – A John Wiley & Sons, Ltd., Publication. – 2009. – 737 p.

6. Isbell, F., Gonzalez, A., Loreau, M. et al. Linking the influence and dependence of people on biodiversity across scales. Nature 546, 65–72 (2017). https://doi.org/10.1038/nature22899

7. Joseph S. Nelson, Terry N. Grande, Mark V.H. Wilson Fishes of the world. Fifth edition. – Hoboken, New Jersey: John Wiley□Sons. – 2016. – 752 p.

8. Kottelat M. 2006. Fishes of Mongolia. A check-list of the fishes known to occur in Mongolia with comments on systematic and nomenclature. Washington: The World Bank, 103 p.

9. Lakin G.F. Biometriya – M.: Vysshaya shkola, 1990. – 352 s.

10. Mitrofanov V.P. Rod Gobio Cuvier, 1817 – Peskar’// Ryby Kazahstana. – Alma-Ata: Nauka, 1988. – T.3. – S.5-23.

11. Men’shikov M.I. Ob ihtiofaune oz.Marka-Kul’// Uchenye zapiski Permskogo universiteta. – 1938. – T.3, vyp.2. – S.-119-141.Pravdin I.F. Rukovodstvo po izucheniyu ryb. – M.: Pishchevaya promyshlennost’, 1966. – 376 s.

12. Mendel J., Lusk S., Vasil’eva E. D., Vasil’ev V. P., Luskova V., Ekmekci F. G., Erk’akan F., Ruchin A., Košcˇo J., Vetešnik L., Halacˇka K., Šanda R., Pashkov A. N., Reshetnikov S. I., 2008. Molecular phylogeny of the genus Gobio Cuvier, 1816 (Teleostei: Cyprinidae) and its contribution to taxonomy// Mol. Phylogenet. Evol.. Vol. 47. P. 1061-1075

13. 9Martynova A.L., Vasil’eva E.D. Problemy taksonomii i diagnostiki peskarej roda Gobio (Cyprinidae) Urala, Sibiri, Kazahstana i bassejna reki Amur// Voprosy ihtiologii. – 2021. – Tom 61, №5. – S.529-544.

14. Nowak M., Koščo J., Popek W., 2008. Review of the current status of systematics of gudgeons (Gobioninae, Cyprinidae) in Europe//AACL Bioflux. Vol.1. P. 27-38.

15. Nikol’skij G.V. 1936. Materialy k poznaniyu geograficheskoj izmenchivosti peskarej Gobio gobio (L.) Severo-vostochnogo Kazahstana i Zapadnoj Sibiri // Tr. ZIN AN SSSR. T. 3. S. 457–473.

16. Nikol’skij G.V. 1956. Ryby bassejna Amura. Itogi Amurskoj ihtiologicheskoj ekspedicii 1945−1949 gg. M.: Izd-vo AN SSSR, 551 s.

17. Pravdin I.F. Rukovodstvo po izucheniyu ryb. – M.: Pishchevaya promyshlennost’, 1966. – 376 s.

18. Petrova A.V. Morphological characteristics of Siberian gudgeon Gobio cynocephalus Dybowski, 1869 (Cyprinidae: Gobioninae) from the Zeya River basin. Amurian zoological journal. V(4), 2013. – P. 460-463.

19. Sheraliev B., Allayarov S., Peng Z. 2020. First records of Gobio nigrescens and Gobio sibiricus (Cypriniformes: Gobionidae) from the Amu Darya River basin, Uzbekistan // J. Appl. Ichthyol. V. 36. № 2. P. 235–239. https://doi.org/10.1111/jai.14019

20. Sapargalieva N.S., Maratova G.M. Ertis bassejnindegi zajsan talma zhəne sұr talma balyқtarynyң morfologiyalyқ zhəne asқorytu zhүjesinің sipattamasy. Materialy mezhdunarodnoj nauchnoj konferencii «Zoologicheskie issledovaniya za 20 let nezavisimosti Respubliki Kazahstan», posvyashchennoj 20-letiyu nezavisimosti RK. – Almaty – 2011. – S. 281-283.

21. Tagaev D.A., ZHaparova A.T. 2018. Peskari roda Gobio (Pisces: Cyprinidae) Central’nogo i Vostochnogo Kazahstana: istoriya opisaniya, sistematika i sovremennoe sostoyanie izuchennosti // Vestn. Evraz. nac. un-ta im. L.N. Gumileva. Ser. biol. nauki. № 3 (124). S. 90–96. https://doi.org/10.32523/2616-7034-2018-124-3-90-96

22. Tagaev D.A., ZHaparova A.T. 2019. Izmenchivost’ plasticheskih priznakov sibirskogo peskarya (Gobio sibiricus Nikolskii, 1936) iz r. Karkaraly (Central’nyj Kazahstan) // Vestn. Karagandin. un-ta. Ser. biologiya, medicina, geografiya. № 2 (94). S. 86–92.

23. Takács P. Morphometric differentiation of gudgeon species inhabiting the Carpathian Basin// Annales de Limnologie – International Journal of Limnology. – 2012. –V.48. – P.83-61. DOI: 10.1051/limn/2011058

24. Yevseyeva, A. A., Bolbotov, G. A., & Kirichenko , O. I. (2019). An annotated list of fish-like vertebrates and fishes of upper Irtysh River basin (Eastern Kazakhstan) with comments on their taxonomy and zoogeography. Acta Biologica Sibirica, 5(4), 156-174. https://doi.org/10.14258/abs.v5.i4.7180

25. Fricke R., Eschmeyer W.N., Vanderlaan R. (Eds.) Eschmeyer’s catalog of fishes: genera, species,references: http://researcharchive.calacademy.org/research/ichthyology/fishcatmain.asp – accessed 19 January 2023.

МРНТИ 69.01.11 https://doi.org/10.26577/eb.2023.v96.i3.015

А.С. Асылбекова[1]*, Г.К. Баринова[1], Г.А. Аубакирова[1], А.Д. Мусина[1], А.Б. Маханбетова[2], Ж.Б. Куанчалеев[1], С.Е. Мусин[1]

[1]НАО «Казахский агротехнический исследовательский университет имени С. Сейфуллина», Казахстан, г. Астана
[2]АО «Республиканский центр по племенному делу в животноводстве «Асыл тұлік», Казахстан, г. Косшы
*e-mail: gamily-05@mail.ru

ВЛИЯНИЕ СКОРОСТИ ЗАМОРАЖИВАНИЯ НА ПОКАЗАТЕЛИ КАЧЕСТВА СПЕРМЫ ОСЕТРОВЫХ РЫБ

В данной статье рассматриваются вопросы низкотемпературного консервирования спермы осетровых рыб. Цель работы – изучение влияния скорости замораживания на показатели качества спермы осетровых рыб и зависимость этих показателей между собой. Материалом для исследований послужили сперма заготовленных самцов стерляди и севрюги на Урало-Атырауском осетровом рыбоводном заводе. При изучении влияния скорости заморозки на качество спермы осетровых рыб, были определены оптимальные скорости на этапах ступенчатой заморозки. При заморозки спермы стерляди наивысший результат был получен при оптимальной скорости заморозки 17^{0}С/мин с подвижностью сперматозоидов 76,8±1,25% и времени жизни спермиев 216,2±1,44сек. Сперма самцов севрюги, замороженная в соломинках имели высокую скорость в начале заморозки в пределах 15-48^{0}С/мин, что повлияло на качество спермы севрюги, подвижность спермиев которых колебалась в пределах 12,0-19,5%, время жизни спермиев 228,5-373,75сек. Относительно хорошие результаты были получены от спермы самцов севрюги, замороженных в пробирках Эпиндорфа, которые имели самую высокую скорость заморозки до 20^{0}С/мин. Подвижность спермиев при этом колебалась в пределах 27,75-44,75%, время жизни спермиев 393,25-674,5сек. При изучении наблюдается прямая зависимость между подвижностью и времени жизни спермы осетровых рыб, а также из полученных результатов исследований видно, что наиболее оптимальной скоростью замораживания спермы данных видов осетровых рыб является скорость до 20^{0}С/мин, емкостью, в которой целесообразно замораживать образцы являются пробирки Эпиндорфа, объемом 0,5 мл, а режим замораживания многоступенчатый с использованием специального бокса.

Ключевые слова: криоконсервация, криопротектор, стерлядь, севрюга, сперма.

A.S. Assylbekova[1]*, G.K. Barinova[1], G.A. Aubakirova[1], A.D. Mussina[1,2], A.B. Makhanbetova[3], Zh.B. Kuanchaleyev[1], S.E. Mussin[1]

[1]«S.Seifullin Kazakh AgroTechnical Research University» NCJSC, Kazakhstan, Astana
[2]Al-Farabi Kazakh National university, Kazakhstan, Almaty
[3]Joint-Stock Company "Republican Center for Breeding in Animal Husbandry" Asyl Tulik", Kazakhstan, Kosshy c.
*e-mail: gamily-05@mail.ru

The effect of the freezing rate on the quality of sperm of sturgeon fish

This article discusses the issues of low-temperature preservation of sperm of sturgeon fish. The aim of the work is to study the effect of the freezing rate on the sperm quality indicators of sturgeon fish and the dependence of these indicators among themselves. The material for the research was the sperm of harvested males of sterlet and stellate sturgeon at the Ural-Atyrau sturgeon fish hatchery. When studying the effect of the freezing rate on the quality of sperm of sturgeon fish, optimal speeds were determined at the stages of stepwise freezing. When freezing sterlet sperm, the highest result was obtained at an optimal freezing rate of 17^{0}C/min with sperm motility of 76.8±1.25% and sperm lifetime of 216.2±1.44sec. The sperm of the male stellate sturgeon frozen in straws had a high rate at the beginning of freezing in the range of 15-48^{0}C/min, which affected the quality of the sperm of the stellate sturgeon, whose sperm motility ranged from 12.0-19.5%, the life time of the sperm was 228.5-373.75seconds. Relatively good

results were obtained from the sperm of male stellate sturgeon frozen in Epindorf tubes, which had the highest freezing rate up to 20^{0}C/min. The motility of the sperms ranged from 27.75-44.75%, the lifetime of the sperms 393.25-674.5seconds. When studying, there is a direct relationship between the mobility and the lifetime of sperm of sturgeon fish, and also from the obtained research results it can be seen that the most optimal freezing rate of sperm of these species of sturgeon fish is a speed of up to 20^{0}C / min, the capacity in which it is advisable to freeze samples are Epindorf tubes, 0.5ml in volume, and the multi-stage freezing mode using special boxing.

Key words: cryopreservation, cryoprotector, sterlet, stellate sturgeon, sperm.

А.С. Асылбекова[1]*, Г.К. Баринова[1], Г.А. Аубакирова [1], А.Д. Мусина[1,2], А.Б. Маханбетова [3], Ж.Б. Куанчалеев[1], С.Е. Мусин[1]

[1] «С. Сейфуллин атындағы Қазақ агротехникалық зерттеу университеті» КеАҚ, Қазақстан, Астана қ.

[2] «Әл-Фараби атындағы Қазақ ұлттық университеті» КеАҚ, Қазақстан, Алматы қ.

[3] «Республикалық мал шаруашылығын асылдандыру «Асыл түлік» АҚ, Қазақстан, Қосшы қ.

*e-mail: gamily-05@mail.ru

Бекіре тұқымдас балықтардың шәуеттерінің сапа көрсеткіштеріне мұздату жылдамдығының әсері

Бұл мақалада бекіре тұқымдас балықтардың шәуеттерін төмен температурада консервациялау мәселелері қарастырылады. Жұмыстың мақсаты – бекіре тұқымдас балықтардың шәуеттерінің сапа көрсеткіштеріне мұздату жылдамдығының әсерін және осы көрсеткіштердің өзара тәуелділігін зерттеу. Зерттеу материалы Жайық-Атырау бекіре балық өсіру зауытында дайындалған сүйрік пен шоқырдың шәуеттері болып табылды. Бекіре тұқымдас балықтардың шәуеттерінің сапасына мұздату жылдамдығының әсерін зерттеу кезінде сатылы мұздату кезеңдерінде оңтайлы жылдамдықтар анықталды. Сүйрік шәутін мұздату кезінде ең жоғары нәтиже оңтайлы мұздату жылдамдығы 17^{0}C/мин болғанда, сперматозоидтардың қозғалғыштығы 76,8 ± 1,25% және сперматозоидтардың өмір сүру уақыты 216,2 ± 1,44сек болды. Шоқырдың шәуетін түтікшеде мұздатылған мұздатудың басында 15-48^{0}C/мин аралығында жоғары жылдамдыққа ие болды, бұл шоқырдың шәуеттінің сапасына әсер етті, олар сперматозоидтардың қозғалғыштығы 12,0-19,5%, сперматозоидтардың өмір сүру уақыты 228,5-373,75сек аралығында болды. Салыстырмалы түрде жақсы нәтижелер Эпиндорф пробиркаларда мұздатылған шоқырдың шәуетінен алынды, олар 20^{0}C/мин дейін ең жоғары жылдамдыққа ие болды. Сперматозоидтардың қозғалғыштығы 27,75-44,75%, сперматозоидтардың өмір сүру уақыты 393,25-674,5сек аралығында болды. Зерттеу кезінде бекіре тұқымдас балықтардың сперматозоидтарының қозғалғыштығы мен өмір сүру уақыты арасында тікелей байланыс бар екені байқалады, сонымен қатар алынған зерттеу нәтижелерінен бекіре тұқымдас балықтардың осы түрлерінің шәуеттерін мұздатудың ең оңтайлы жылдамдығы 20^{0}C/мин дейінгі жылдамдық, үлгілерді мұздатуға болатын сыйымдылық көлемі 0,5мл Эпиндорф пробиркалары және мұздату режимі көп сатылы аранайы бокста қолдану арқылы екенін байқауға болады.

Түйін сөздер: криоконсервация, криопротектор, сүйрік, шоқыр, шәует.

Введение

В настоящее время нарастающее антропогенное воздействие на водные экосистемы не только оказывают влияние на физиологическое состояние гидробионтов, но и приводят к снижению численности видов. Особенно это заметно по численности осетровых рыб, если ранее русский осётр, севрюга и белуга в Каспийском бассейне имели промысловое значение, то в настоящее время их вылов запрещен. Белуга и севрюга в этих водоёмах стали настолько редкими, что перешли в разряд исчезающих видов, а популяции русского осётра резко сократились [1-7].

Для сохранения и восполнения численности отдельных популяций рыб разработаны биотехнологии искусственного воспроизводства на различных рыбоводных предприятиях. В их основу положены принципы содержания и использования производителей из маточных стад, содержащихся на предприятии, что, в свою очередь, ограничивает число особей, скрещивающихся между собой, и приводит впоследствии к инбридингу [8].

Криоконсервация спермы рыб является эффективным методом сохранения и восстановления генофонда не только редких и исчезающих видов, но и объектов аквакультуры позволяя ре-

шать многие природоохранные, селекционные и другие научные задачи. Создание банков геномных ресурсов, может привести к увеличению потенциальной численности размножающейся популяции и минимизации инбридинга, чтобы гарантировать получение надлежащих генетических комбинаций [9].

Несмотря на ряд достижений в криобиологии спермы рыб, продолжаются исследования по оптимизации методов криоконсервирования спермы рыб [10-15]. Они включают обычно сбор спермы, определение качества спермы, разбавление спермы растворами видоспецифичных протекторов, замораживание полученной суспензии по определенной программе, хранение в жидком азоте, размораживание в оптимальных условиях и оценку результата по подвижности оттаявшей спермы [16-18].

Успех криоконсервации, т.е. сохранение замороженными клетками жизнеспособности оплодотворяющей способности, зависит от множества факторов: качества нативной спермы, подбора, оптимальных для данного вида рыб, состава криозащитной среды, соотношения разбавления спермы средой, режимов замораживания и оттаивания, способа активации размороженной спермы и других технических деталей, поэтому потребность в оптимизации и совершенствовании технологий всегда остается актуальной. Гормональная стимуляция также играет важную роль в улучшении качества свежей спермы и спермы после оттаивания [19]. Активация размороженной спермы также влияет на успех процесса криоконсервации и качество размороженной спермы. У большинства видов рыб сперматозоиды, взвешенные в семенной плазме, неподвижны и активируются только при контакте с водой [20-21].

Немаловажным фактором в криоконсервации является подбор режима замораживания и оттаивания образцов спермы, обеспечивающий сохранность клеток. В процессе криоконсервации клетки подвергаются воздействию целого комплекса стрессовых факторов, которые вызывают их структурные и функциональные изменения. Результаты исследований структур клеток свидетельствуют о том, что влияние глубокой заморозки может затронуть любые из их составляющих. Оптимальная скорость заморозки обеспечивает баланс трансмембранного массообмена, в результате которого обезвоживание клеток, с одной стороны, является достаточным, чтобы исключить вероятность внутриклеточного льдообразования, а с другой стороны не достигает критического уровня, приводящего к неизбежному повреждению клеток [22].

Целью исследований является изучить влияние скорости замораживания на показатели качества спермы осетровых рыб и зависимость этих показателей между собой.

Материалы и методы исследований

Научные исследования по изучению криоконсервации спермы проведены от заготовленных самцов стерляди (*Acipenser ruthenus*) и севрюги (*Acipenser stellatus*) на Урало-Атырауском осетровом рыбоводном заводе в период нерестовой кампании.

Оценка качества свежеполученной спермы от стимулированных самцов осетровых рыб проводилась путем определения подвижности сперматозоидов с помощью микроскопа. Качество спермы определяли по шкале Персова, по результатам которых отбирались пробы с активностью 4 и 5 баллов [23]. Сперму оценивали по внешнему виду по цвету и консистенции. Время жизни устанавливали с помощью секундомера.

Криоконсервация проводилась по следующей схеме: разбавление спермы с криозащитной средой, эквилибрация, замораживание, дефростирование. В процессе криоконсервации были использован криопротектор, содержащий следующие компоненты: 30mM Tris, 23,4mM сахарозы, 0,25 KCl, 15% метанол. Отобранную после оценки сперму самцов в отдельных пластиковых тарах поместили в холодильник для охлаждения до температуры 10-12^{0}C в течении 15-20 мин. После выравнивания температуры сперму разбавляли охлажденной до той же температуры криозащитной средой в объемном отношении 1:1.

Полученная суспензия сперма – криозащитная среда разливалась в криопробирки Эпиндорфа объёмом по 0,5мл и соломинки объемом 0,2мл с помощью пипетки дозатора. Данная работа проводилась на охлажденной поверхности. С момента разлива до момента заморозки время не превышало 15 минут, которая составляла процесс эквилибрации.

Далее замороженный материал выдерживали в парах азота в течение 15 минут в специальном боксе из пенопласта размером 33,5х21см, высотой 26см с наружи и 20см внутри, в котором сверху был установлен плот из пенопласта размером 14,5х14,3см с толщиной 4см. Для контроля температуры в одну из пробирок поместили проводной датчик от низкотемпературного тер-

мометра. Плот с криопробирками выдерживали в течение 15 минут, затем все криопробирки были перенесены в сосуд Дьюара для длительного хранения при температуре -196^{0}С.

Размораживали криопробирки в дистиллированной воде при температуре 38^{0}С в течение 1 минуты, с помощью водяной бани.

Параметры дефростированной спермы были изучены в лаборатории АО «Республиканский центр по племенному делу в животноводстве «Асыл түлік». Подвижность и время жизни спермы регистрировали на мониторе персонального компьютера с использованием видеоприставки под тринокулярным микроскопом с камерой и программным обеспечением CEROS компьютерной технологии системы CASA (IMV-technologies, Франция). Активировали сперму с помощью воды в соотношении 1:300.

Статистическую обработку проводили по руководству Г.Ф. Лакина [24] и на ПК с применением программы «Excel» [25]. Результаты представлены в виде среднего значение (M) ± стандартного отклонения (m). Для определения значимости зарегистрированных различий в значениях подвижности сперматозоидов и времени двигательной активности между исследуемыми объектами использовали t-критерий Стьюдента.

Результаты исследований и их обсуждения

Исследования были проведены в два этапа. Первым этапом были изучены сперма стерляди, затем сперма севрюги. При экспериментальных работах были отобрано по 4 чипированных самца от каждого вида. После проведения оценки качества свежеполученной спермы, все самцы имели показатели по 5 баллов. От каждого самца получено 16-17 образцов криоматериала.

При изучении криоконсервации спермы осетровых рыб определены показатели качества нативной спермы, после эквилибрации (таблица 1,2) и после дефростации. Также изучено влияние скорости замораживания на показатели качества спермы осетровых рыб.

Таблица 1 – Качество спермы стерляди до заморозки

№ рыбы	№ чипа	Подвижность нативной спермы, %	Время жизни нативной спермы, с	Подвижность спермиев после эквилибрации, %	Время жизни спермиев после эквилибрации, с
1	6703	95,25±1,25	297,5±1,5	86,6±1,52	256,4±1,92
2	2644			84,2±0,75	242,4±1,68
3	0078			81,6±1,75	238,6±1,68
4	2583			88,6±1,25	258,2±1,84

По результатам криоконсервации спермы стерляди с использованием криопротектора метанола с концентрацией 15% наивысшей результат показал самец с чипом №2583 с подвижностью сперматозоидов 88,6% и времени жизни спермиев 258,2с после эквилибрации ($p<0,05$).

Таблица 2 – Качество спермы севрюги до заморозки

№ рыбы	№ чипа	Подвижность спермиев нативной спермы, %	Время жизни нативной спермы, с	Подвижность спермиев после эквилибрации, %	Время жизни спермиев после эквилибрации, с
1	4386	95,75±1,25	1200±4,7	82,75±0,9	751,5±1,3
2	4356			84,25±0,9	760,5±2,2
3	4371			84,75±1,5	742,5±1,7
4	0497			85,50±0,9	792,5±2,5

Рыбоводные качества спермы севрюги показали высокие показатели времени жизни сперматозоидов 1200с по сравнению со стерлядью. Из изученных самцов севрюги лучшие результаты были получены от самца №0497 с подвижностью 85,5% и времени жизни 792,5с.

Скорость заморозки осетровых рыб изучали в специальном боксе с помощью низкотемпературного датчика. Плот с криопробирками выдерживали в течение 15 минут в боксе, затем все криопробирки были перенесены в сосуд Дьюара для длительного хранения при температуре -196^{0}С.

Сперма самцов стерляди разливалась только в пробирки Эпиндрофа. Скорость заморозки спермы самца стерляди №6703 повышалась в течение первых четырех минут до 15^{0}С/мин, далее постепенно понижалась до 4^{0}С/мин. Сперма самца №0078 замораживалась первые три минуты со скоростью до 8^{0}С/мин, следующие 2 минуты понизилась до 2^{0}С/мин, далее повышалась в течение 6 минут до 14^{0}С/мин, с дальнейшим понижением до 6^{0}С/мин. Сперма самца №2644 замораживалась со скоростью в первую минуту 11^{0}С/мин, в течение следующих 3-х минут 6^{0}С/мин, в течение 4-х минут скорость была 8^{0}С/мин, далее в течение 5 минут 6^{0}С/мин и в последнюю минуту снизилась до 3^{0}С/мин при этом максимальная скорость была в начальном этапе заморозки и составила 11^{0}С/мин, что привело к повреждению клеток. Скорость заморозки самца №2583 в первую минуту составила 8^{0}С/мин, с понижением до 4^{0}С/мин во второй минуте, в течение следующих 3-х минут повысилась до 17^{0}С/мин, с последующим понижением до 6^{0}С/мин. При ступенчатой заморозки спермы стерляди оптимальная скорость заморозки была до 20^{0}С/мин в середине этапа замораживания, кроме самца №2644, с максимальной скоростью 11^{0}С/мин в начале заморозки.

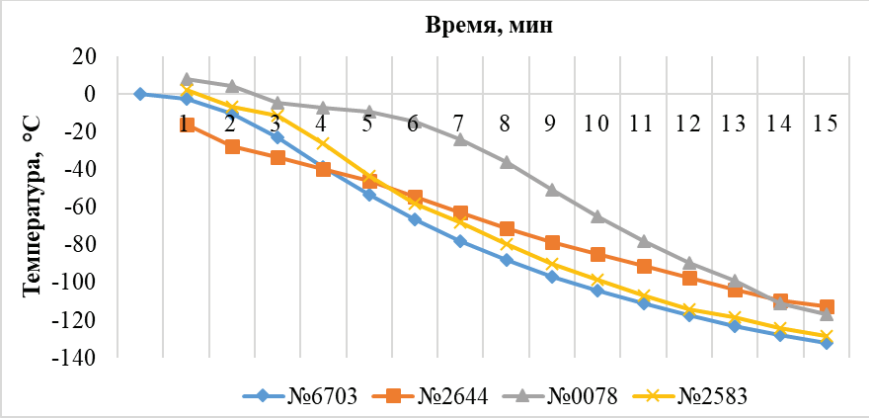


Рисунок 1 – Скорость заморозки спермы стерляди по самцам

Изучение скорости заморозки спермы севрюги проводили в зависимости от криопробирок и от расположения их в специальном боксе в течение 15 минут (рисунок 2). Скорость заморозки криоматериала в соломинках, расположенных на краю бокса, полученных от самца №0497 в первые три минуты составила 40^{0}С/мин, на четвертой минуте 20^{0}С/мин с понижением до 2^{0}С/мин. Похожая скорость заморозки наблюдается у самца №4386, сперма которого была разлита в соломинки и расположенного на краю бокса первые 2 минуты со скоростью 24^{0}С/мин, на третьей минуте 48^{0}С/мин с дальнейшим скачкообразным понижением от 11^{0}С/мин до 2^{0}С/мин. Сперма самца №4356 замороженных в соломинках, расположенной в центре бокса первые 4 минуты замораживалась со скоростью до 20^{0}С/мин с дальнейшим равномерным понижением от 10^{0}С/мин до 5^{0}С/мин. Сперма самца №4371 в соломинках в центре бокса замораживалась постепенно повышая скорость заморозки до 14^{0}С/мин в течение первых пяти минут с понижением в течение дальнейших четырех минут от 11^{0}С/мин до 7^{0}С/мин, далее три минуты скорость держалась 11^{0}С/мин с понижением до 8^{0}С/мин. При заморозки спермы самцов севрюги в соломинках наблюдается высокая скорость в начале заморозки. В соломинках, расположенных по краям бокса скорость заморозки доходила более 40^{0}С/мин, при расположении в центре бокса от 15^{0}С/мин до 20^{0}С/мин.

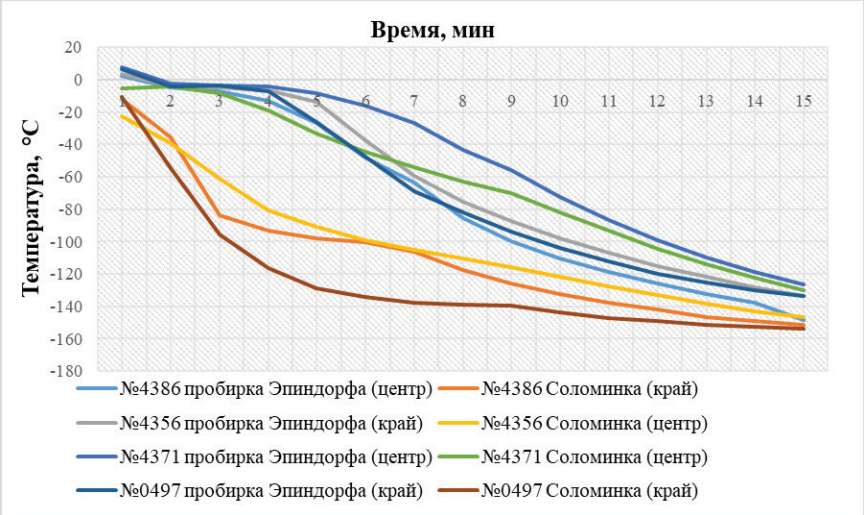


Рисунок 2 – Скорость заморозки спермы севрюги в зависимости от криопробирок и расположения в боксе

При заморозки спермы севрюги в пробирках Эпиндорфа высокая скорость заморозки наблюдается в середине замораживания с 5 по 10 минуты. Эпиндорфы расположенные по краям бокса имели скорость заморозки от 20^{0}С/мин до 25^{0}С/мин, в центре бокса от 15^{0}С/мин до 20^{0}С/мин. Сперма самца №4386 в пробирке Эпиндорфа, расположенного в центре бокса в течение 4 минут имели скорость заморозки более 5^{0}С/мин, в течение дальнейших 5 минут до 20^{0}С/мин, далее скорость заморозки была 5-10^{0}С/мин. Сперма самца №4371 в пробирке Эпиндорфа, расположенного в центре бокса имели скорость заморозки в течение первой минуты 10^{0}С/мин, в течение следующих двух минут 1^{0}С/мин, далее в течение 6 минут скорость повышалась до 16^{0}С/мин с понижением в последних минутах заморозки до 8^{0}С/мин. Заморозка спермы самцов №4356 и №0497 проходила аналогично в течение первой минуты скорость заморозки составила 7,5-10^{0}С/мин, далее 2 минуты 2-3^{0}С/мин, следующие три минуты более 20^{0}С/мин, с постепенным понижением в последующих минутах до 5-4^{0}С/мин соответственно.

Размораживание спермы осуществляли, извлекая пробирки с замороженной спермой из жидкого азота и помещая их в водяную баню с температурой 38-40°С, затем активировали дистиллированной водой. В размороженных образцах определяли количество подвижных сперматозоидов и время жизни (рисунок 3,4).

При изучении показателей качества дефростированной спермы стерляди по четырем самцам также показали хорошие результаты наименьший из которых показал самец с чипом №0078 с подвижностью сперматозоидов 53,4±0,75% и времени жизни 76,4±1,68сек при оптимальной скорости заморозки 14^{0}С/мин на 9-10 минутах заморозки. Наивысший результат показал самец с чипом №2583 по подвижности сперматозоидов 76,8±1,25% и времени жизни спермиев 216,2±1,44сек при оптимальной скорости заморозки 17^{0}С/мин на 5 минуте заморозки. Оптимальная скорость заморозки 11-14^{0}С/мин показали относительно не высокие результаты подвижности и времени жизни сперматозоидов стерляди ($p<0,05$). М.Белая и др. в своих исследованиях со спермой стерляди утверждают о меньшем повреждении после заморозки/оттаивания происходит при скорости заморозки 10^{0}С/мин [22]. У самцов стерляди при оптимальной скорости заморозки спермы до 20^{0}С/мин положительно повлиял на показатели качества спермы.

По результатам качества спермы после замораживания/оттаивания действие метанола в концентрации 15% показал положительные результаты. В исследованиях многих авторов особое внимание уделялось оптимизации качественного и количественного состава протективной среды как важнейший фактор обеспечения защиты сперматозоидов от повреждающего действия низких температур, по результатам которых установили, что наиболее подходящим криопротектором для спермы осетровых рыб (стерляди) является метанол обеспечивая наилучшую устойчивость к оксидативному стрессу [26].

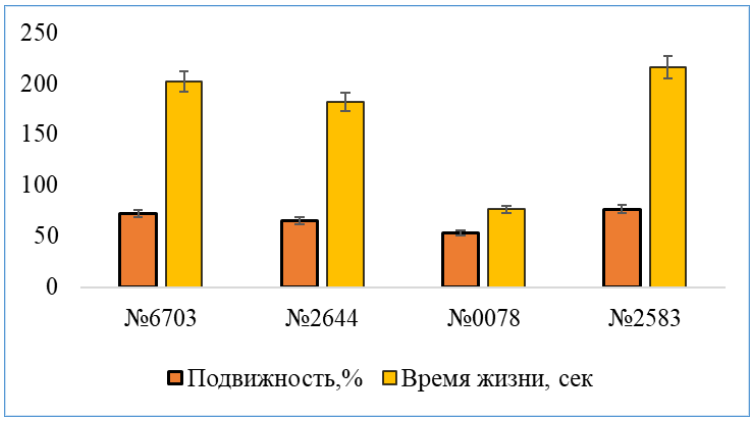


Рисунок 3 – Показатели качества дефростированной спермы стерляди

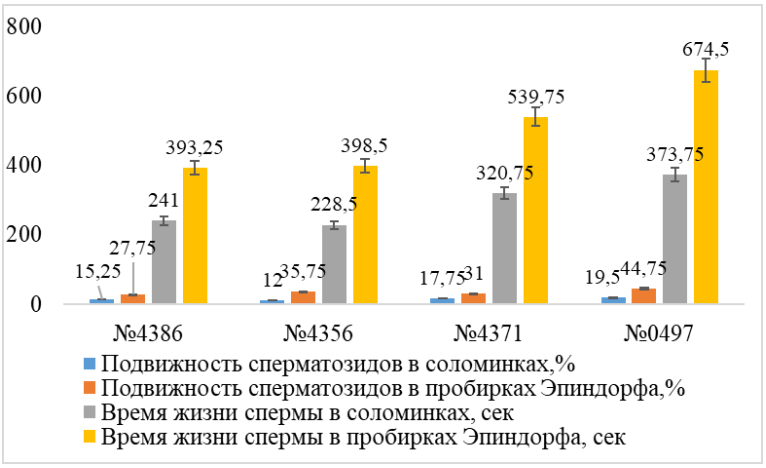


Рисунок 4 – Показатели качества дефростированной спермы севрюги

При изучении показателей качества дефростированной спермы севрюги наблюдаются не высокие результаты этих показателей по сравнению с нативной спермой ($p<0,05$). Из них высокие результаты были получены от спермы самца №0497, замороженного в пробирках Эпиндорфа при подвижности спермиев 44,7±1,25% и времени жизни 674,5±3,8сек, что обуславливается поэтапной кристаллизацией вне- и внутриклеточной водной среды. В целом сперма, замороженная в пробирках Эпиндорфа имела высокую скорость (до 20^0C/мин) в середине процесса замораживания, что минимизирует повреждение внутриклеточных структур при криоконсервации и показала относительно высокие показатели качества спермы, по сравнению со спермой, замороженной в соломинках ($p<0,05$). При этом подвижность сперматозоидов в пробирках Эпиндорфа колебались от 27,75% до 44,75%, а время жизни спермиев от 393,25сек до 674,5сек.

Сперма, замороженная в соломинках имела высокую скорость (15-48^0C/мин в зависимости от расположения) в начале процесса замораживания, что повлияло на ускорение процесса кристаллизации вне- и внутриклеточной водной среды. Подвижность сперматозоидов в соломинках при этом колебалась от 12% до 19,5%, а время жизни спермиев от 228,5сек до 373,75сек.

В ходе исследований изучены зависимость между подвижностью и времени жизни, замороженной/оттаянной спермы осетровых рыб, где наблюдается прямая зависимость между данными показателями (рисунки 5, 6, 7).

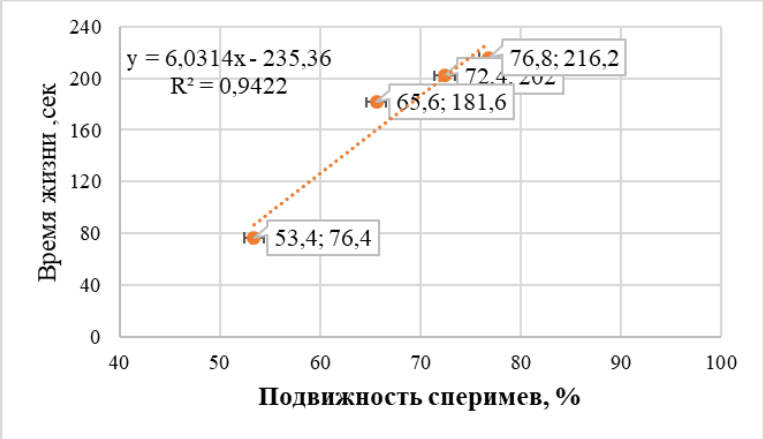


Рисунок 5 – Зависимость между выживаемостью и времени жизни сперматозоидов стерляди (n=4)

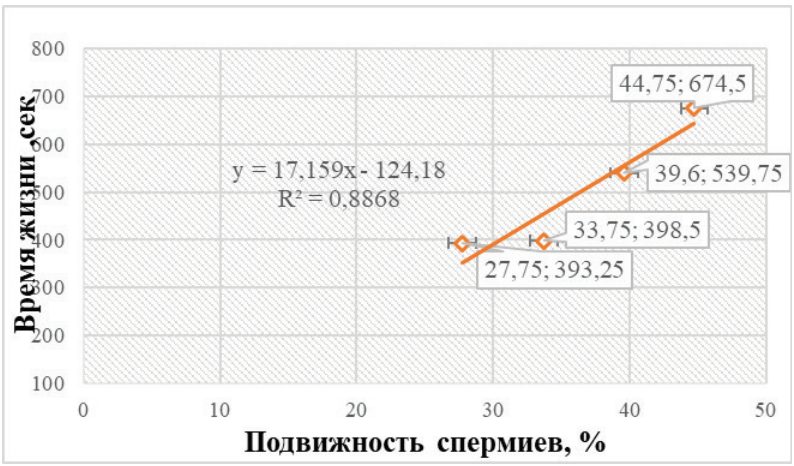


Рисунок 6 – Зависимость между выживаемостью и времени жизни сперматозоидов севрюги, замороженных в пробирке Эпиндорфа (n=4)

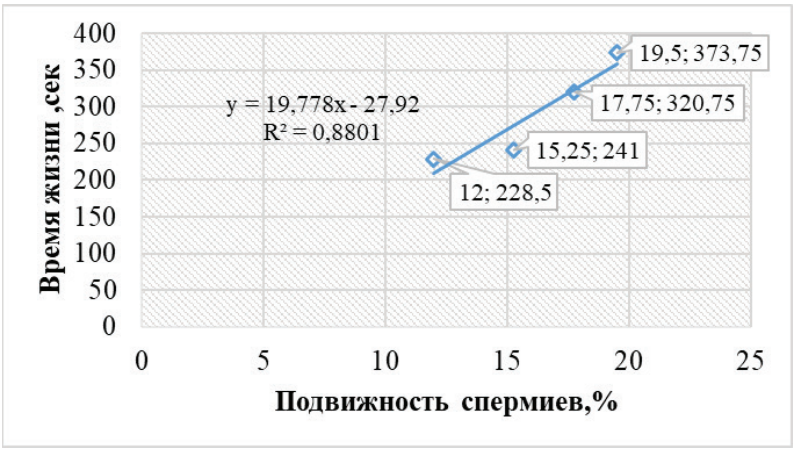


Рисунок 7 – Зависимость между выживаемостью и времени жизни сперматозоидов севрюги, замороженных в соломинках (n=4)

Заключение

По результатам исследований изучены влияние скорости заморозки на качество спермы осетровых рыб. Наблюдаются высокие результаты подвижности и времени жизни спермы стерляди при оптимальной скорости заморозки до 20^0С/мин в середине этапа заморозки.

При изучении влияния скорости заморозки на качество спермы севрюги, было установлено, что максимальная скорость заморозки спермы самцов зависела от вида пробирок, в которых замораживалась сперма и расположения их в специальном боксе, а также была разной на этапах ступенчатой заморозки. Сперма, замороженная в соломинках имели высокую скорость в начале заморозки в пределах 15-48^0С/мин в зависимости от самцов и места расположения в боксе, что повлияло на качество спермы севрюги, которая имела подвижность спермиев в пределах 12,0-19,5%, время жизни спермиев 228,5-373,75сек. Относительно хорошие результаты были получены от спермы самцов севрюги, замороженных в пробирках Эпиндорфа, которые имели самую высокую скорость в пределах до 20^0С/мин, в зависимости от самцов и места расположения в боксе. Подвижность спермиев была в пределах 27,75-44,75%, время жизни спермиев 393,25-674,5сек.

Кроме того, при изучении наблюдается прямая зависимость между подвижностью и времени жизни спермы осетровых рыб, а также из полученных результатов исследований видно, что наиболее оптимальной скоростью замораживания спермы данных видов осетровых рыб является скорость в пределах до 20^0С/мин, емкостью, в которой целесообразно замораживать образцы является пробирки Эпиндорфа, объемом 0,5мл, а режим замораживания многоступенчатый с использованием специального бокса из пенопласта размером 33,5х21см, высотой 26см с наружи и 20см внутри, сверху которого был установлен плот из пенопласта размером 14,5х14,3см с толщиной 4см.

Конфликт интересов

Все авторы прочитали и ознакомлены с содержанием статьи и не имеют конфликта интересов.

Благодарности

Авторы статьи выражают свою благодарность руководству Урало-Атырауского осетрового рыбоводного завода за оказание помощи при получение спермы осетровых рыб в период нереста, а также Республиканскому центру по племенному делу в животноводстве «Асыл түлік» при оценки качества дефростированной спермы осетровых рыб.

Источник финансирования

Работа выполнена в рамках проекта грантового финансирования молодых ученых по научно-техническим проектам на 2021-2023 годы №AP09058175 по теме «Создание криобанка репродуктивных клеток ценных видов рыб Казахстана».

Литература

1. Ходоревская Р.П., Калмыков В.А., Жилкин А.А. Современное состояние запасов осетровых Каспийского бассейна и меры по их сохранению. Вестник АГТУ. Серия: Рыбное хозяйство. 2012. № 1. С.99-106

2. Васильева Л.М., Смирнова Н.В., Юсупова А.З. К вопросу сохранения и восстановления запасов осетровых рыб в Волго-Каспийском бассейне // Юг России: экология, развитие. 2012. Т. 7, N1. С. 73-76. DOI:10.18470/1992-1098-2012-1-73-76

3. Ананьев, В.И. К вопросу о создании национальной системы генофондных коллекций рыб и других гидробионтов России для аквакультуры и сохранения редких и исчезающих видов: правовые и нормативнометодологические аспекты / В.И. Ананьев, М.С. Манохина // Ветеринарная патология. – 2007. – № 1. – С. 19-24.

4. Матишов Г.Г., Пономарева Е.Н., Белая М.М. Сохранение генетического разнообразия рыб методами низкотемпературного консервирования // Рыбное хозяйство. 2012. № 3. С. 59-62

5. Бапсанова, А.М. Криоконсервация генетического материала для сохранения редких и исчезающих видов животных / А.М. Бапсанова // Международный журнал прикладных и фундаментальных исследований. – 2012. – № 1. – С. 79.

6. Белая М.М., Красильникова А.А., Пономарева Е.Н. Разработки южного научного центра РАН в области криоконсервации репродуктивных клеток рыб / Известия Самарского научного центра Российской академии наук, т. 20, № 5(2), 2018 – С 280-286.

7. Чипинов, В.Г. Экономическая эффективность использования криоконсервированной спермы при выращивании осетровых видов рыб / В.Г. Чипинов, М.М. Богатырева // Актуальные проблемы обеспечения продовольственной безопас-

ности юга России: инновационные технологии для сохранения биоресурсов, плодородия почв, мелиорации и водообеспечения: материалы Международной научной конференции (27-30 сентября 2011 г., Ростов-на-Дону). – Ростов-на-Дону: Изд-во ЮНЦ РАН, 2011. – С. 133-135.

8. Белая М.М., Красильникова А.А., Пономарева Е.Н. Разработки южного научного центра РАН в области криоконсервации репродуктивных клеток рыб / Известия Самарского научного центра Российской академии наук, т. 20, № 5(2), 2018 – С 280-286.

9. Martinez-Paramo S., Horvath A., Labbe C., Zhang T., Robles V., Herraez P., Suquet M., Adams S., Viveiros A., Tiersch T.R., Cabrita E. Cryobanking of aquatic species. //Aquaculture, 2016. – V. 472. – P.156–177. https://doi.org/10.1016/j.aquaculture.2016.05.042.

10. Докина О.Б., Цветкова Л.И., Пронина Л.Д., Миленко В.А. Метод криоконсервации спермы осетровых рыб – объектов аквакультуры. Аквакультура осетровых рыб: достижения и перспективы развития: Материалы докладов IV Международной научно-практической конференции, 13-15 марта 2006 г. Астрахань. – М.: Изд-во ВНИРО, 2006, С.76-79

11. Пономарева Е.Н., Богатырева М.М., Антонова Н.А., Осипова В.П. Оптимизация процесса криоконсервации спермы осетровых рыб при использовании различных сред //Известия Самарского научного центра Российской академии наук, т.11, №1(2), 2009. – С.132-134

12. Dzyuba B. et al. Spermatozoa motility, cryoresistance, and fertilizing ability in starlet Acipenserruthenus during sequential stripping // Aquaculture, 2012. – V. 356-357. – P. 272-278.

13. Dzyuba B. et al. Motility and fertilization ability of starlet Acipenserruthenus testicular sperm after cryopreservation // Cryobiology. – 2014. – V. 69. – P. 339-341.

14. Пономарева Е.Н., Красильникова А.А., Тихомиров А.М., Фирсова А.В. Новые биотехнологические методы криоконсервации репродуктивных клеток осетровых видов рыб //Экология животных, т.11, №1, 2016– С.59-68

15. Sadeghi A. et al. Cryopreservation of stellate (Acipenserstellatus) sperm: Effect of diff erent concentrations of DMSO and dilution dates on sperm mobility and motility duration after longterm storage // Global Veterinaria. — 2013. – V. 10. – P. 26-30.

16. Asturiano J.F., Cabrita E., Horvath A. Progress, challenges and perspectives on fish gamete cryopreservation: a mini-review. //Gen. Comp. Endocrinol. – 2017. – V. 245. – P. 69–76. https://doi.org/10.1016/j.ygcen.2016.06.019.

17. Huang B. X.-R. et al. Effect of cryopreservation on the enzyme activity of Russian sturgeon (Acipenser gueldenstaedtii Brandt &Ratzeburg, 1833) semen //J. Appl. Ichthyol. – 2014. – V. 30. – P. 1585-1589.

18. Horvath A., Chevre P., Urbanyi B. Sperm cryopreservation in sturgeon with a special focus on A. sturio: chap. 35 // In: Biology and conservation of the European sturgeon Acipensersturio L. 1758: the reunion of the European and Atlantic sturgeons. Ed. by Williot P., Rochard E., DesseBerset N., Kirschbaum F., Gessner J. /Heidelberg, NLD: Springer, 2011. – P. 465-476.

19. Ciereszko A, Judycka S, Nynca J, Słowinska M, Dietrich M. Factors influencing milt quality in fishes and its usefulness to cryopreservation. //Cryopreservation of fish gametes. – 2020. – P. 25-67. https://doi.org/10.1007/978-981-15-4025-7_3.

20. Billard R., Cosson J., Crim L.W., Suquet M. //Sperm physiology and quality. In: Bromage, N.R., Roberts, R.J. (Eds.), Brood StockManagement and Egg and Larval Quality. Blackwell Science, London, England, 1995. – P. 25–52.

21. Cosson J., The ionic and osmotic factors controlling motility of fish spermatozoa. //Aquac. Int. – 2004. – V. 12. – P. 69–85. https://doi.org/10.1023/B:AQUI.0000017189.44263.bc.

22. Белая М.М., Краисльникова А.А. Влияние скорости замораживания на рыбоводные качества спермы осетровых рыб //Товарная аквакультура и искусственное воспроизводство гидробионтов, //Вестник АГТУ. Сер.: Рыбное хозяйство. 2019. №1. С.83-90 DOI: 10.24143/2073-5529-2019-1-83-90

23. Матросова И. В. Биологические основы рыбоводства: эколого-гистофизиологический подход : учебное пособие / И. В. Матросова. — Находка: Дальрыбвтуз, 2020. — 79 с. — URL: https://e.lanbook.com/book/156844

24. Лакин Г.Ф. Биометрия – М.: Высш.школа, 1990.-352 с.

25. Коросов А. В., Горбач В. В. Компьютерная обработка биологических данных. –Петрозаводск: Изд-во ПетрГУ,– 2007, –76 с.

26. Magyary I., Urbányi B., Horváth Á., Dinnyes A. Cryopreservation of gametes and embryos of Cyprinid fishes. Cryopreservation in Aquatic Species, 2 ndEd. Ed. Tiersch T.R., Green Ch.C. World Aquaculture Society. Baton Rouge, Louisiana, USA. 2011. P. 525-538.

References

1. Anan`ev, V.I. K voprosu o sozdanii nacional`noj sistemy` genofondny`x kollekcij ry`b i drugix gidrobiontov Rossii dlya akvakul`tury` i soxraneniya redkix i ischezayushhix vidov: pravovy`e i normativnometodologicheskie aspekty` / V.I. Anan`ev, M.S. Manoxina // Veterinarnaya patologiya. – 2007. – № 1. – S. 19-24.

2. Asturiano J.F., Cabrita E., Horvath A. Progress, challenges and perspectives on fish gamete cryopreservation: a mini-review. //Gen. Comp. Endocrinol. – 2017. – V. 245. – P. 69–76. https://doi.org/10.1016/j.ygcen.2016.06.019.

3. Bapsanova, A.M. Kriokonservaciya geneticheskogo materiala dlya soxraneniya redkix i ischezayushhix vidov zhivotny`x / A.M. Bapsanova // Mezhdunarodny`j zhurnal prikladny`x i fundamental`ny`x issledovanij. – 2012. – № 1. – S. 79.

4. Belaya M.M., Kraisl`nikova A.A. Vliyanie skorosti zamorazhivaniya na ry`bovodny`e kachestva spermy` osetrovy`x ry`b // Tovarnaya akvakul`tura i iskusstvennoe vosproizvodstvo gidrobiontov, //Vestnik AGTU. Ser.: Ry`bnoe xozyajstvo. 2019. №1. S.83-90 DOI: 10.24143/2073-5529-2019-1-83-90

5. Belaya M.M., Krasil`nikova A.A., Ponomareva E.N. Razrabotki yuzhnogo nauchnogo centra RAN v oblasti kriokonservacii reproduktivny`x kletok ry`b / Izvestiya Samarskogo nauchnogo centra Rossijskoj akademii nauk, t. 20, № 5(2), 2018 – S 280-286.

6. Belaya M.M., Krasil`nikova A.A., Ponomareva E.N. Razrabotki yuzhnogo nauchnogo centra RAN v oblasti kriokonservacii reproduktivny`x kletok ry`b / Izvestiya Samarskogo nauchnogo centra Rossijskoj akademii nauk, t. 20, № 5(2), 2018 – S 280-286.

7. Billard R., Cosson J., Crim L.W., Suquet M. //Sperm physiology and quality. In: Bromage, N.R., Roberts, R.J. (Eds.), Brood StockManagement and Egg and Larval Quality. Blackwell Science, London, England, 1995. – P. 25–52.

8. Chipinov, V.G. E`konomicheskaya e`ffektivnost` ispol`zovaniya kriokonservirovannoj spermy` pri vy`rashhivanii osetrovy`x vidov ry`b / V.G. Chipinov, M.M. Bogaty`reva // Aktual`ny`e problemy` obespecheniya prodovol`stvennoj bezopasnosti yuga Rossii: innovacionny`e texnologii dlya soxraneniya bioresursov, plodorodiya pochv, melioracii i vodoobespecheniya: materialy` Mezhdunarodnoj nauchnoj konferencii (27-30 sentyabrya 2011 g., Rostov-na-Donu). – Rostov-na-Donu: Izd-vo YuNCz RAN, 2011. – S. 133-135.

9. Ciereszko A, Judycka S, Nynca J, Słowinska M, Dietrich M. Factors influencing milt quality in fishes and its usefulness to cryopreservation. //Cryopreservation of fish gametes. – 2020. – P. 25-67. https://doi.org/10.1007/978-981-15-4025-7_3.

10. Cosson J., The ionic and osmotic factors controlling motility of fish spermatozoa. //Aquac. Int. – 2004. – V. 12. – P. 69–85. https://doi.org/10.1023/B:AQUI.0000017189.44263.bc.

11. Dokina O.B., Czvetkova L.I., Pronina L.D., Milenko V.A. Metod kriokonservacii spermy` osetrovy`x ry`b – ob``ektov akvakul`tury`. Akvakul`tura osetrovy`x ry`b: dostizheniya i perspektivy` razvitiya: Materialy` dokladov IV Mezhdunarodnoj nauchno-prakticheskoj konferencii, 13-15 marta 2006 g. Astraxan`. – M.: Izd-vo VNIRO, 2006, S.76-79

12. Dzyuba B. et al. Motility and fertilization ability of starlet Acipenserruthenus testicular sperm after cryopreservation // Cryobiology. – 2014. – V. 69. – P. 339-341.

13. Dzyuba B. et al. Spermatozoa motility, cryoresistance, and fertilizing ability in starlet Acipenserruthenus during sequential stripping // Aquaculture, 2012. – V. 356-357. – P. 272-278.

14. Horvath A., Chevre P., Urbanyi B. Sperm cryopreservation in sturgeon with a special focus on A. sturio: chap. 35 // In: Biology and conservation of the European sturgeon Acipensersturio L. 1758: the reunion of the European and Atlantic sturgeons. Ed. by Williot P., Rochard E., DesseBerset N., Kirschbaum F., Gessner J. /Heidelberg, NLD: Springer, 2011. – P. 465-476.

15. Huang B. X.-R. et al. Effect of cryopreservation on the enzyme activity of Russian sturgeon (Acipenser gueldenstaedtii Brandt &Ratzeburg, 1833) semen //J. Appl. Ichthyol. – 2014. – V. 30. – P. 1585-1589.

16. Korosov A. V., Gorbach V. V. Komp`yuternaya obrabotka biologicheskix danny`x. –Petrozavodsk: Izd-vo PetrGU,– 2007, –76 s.

17. Lakin G.F. Biometriya – M.: Vy`ssh.shkola, 1990.-352 s.

18. Magyary I., Urbányi B., Horváth Á., Dinnyes A. Cryopreservation of gametes and embryos of Cyprinid fishes. Cryopreservation in Aquatic Species, 2 ndEd. Ed. Tiersch T.R., Green Ch.C. World Aquaculture Society. Baton Rouge, Louisiana, USA. 2011. P. 525-538.

19. Martinez-Paramo S., Horvath A., Labbe C., Zhang T., Robles V., Herraez P., Suquet M., Adams S., Viveiros A., Tiersch T.R., Cabrita E. Cryobanking of aquatic species. //Aquaculture, 2016. – V. 472. – P.156–177. https://doi.org/10.1016/j.aquaculture.2016.05.042.

20. Matishov G.G., Ponomareva E.N., Belaya M.M. Soxranenie geneticheskogo raznoobraziya ry`b metodami nizkotemperaturnogo konservirovaniya // Ry`bnoe xozyajstvo. 2012. № 3. S. 59-62

21. Matrosova I. V. Biologicheskie osnovy` ry`bovodstva: e`kologo-gistofiziologicheskij podxod : uchebnoe posobie / I. V. Matrosova. — Naxodka: Dal`ry`bvtuz, 2020. — 79 s. — URL: https://e.lanbook.com/book/156844

22. Ponomareva E.N., Bogaty`reva M.M., Antonova N.A., Osipova V.P. Optimizaciya processa kriokonservacii spermy` osetrovy`x ry`b pri ispol`zovanii razlichny`x sred //Izvestiya Samarskogo nauchnogo centra Rossijskoj akademii nauk, t.11, №1(2), 2009. – S.132-134

23. Ponomareva E.N., Krasil`nikova A.A., Tixomirov A.M., Firsova A.V. Novy`e biotexnologicheskie metody` kriokonservacii reproduktivny`x kletok osetrovy`x vidov ry`b //E`kologiya zhivotny`x, t.11, №1, 2016– S.59-68

24. Sadeghi A. et al. Cryopreservation of stellate (Acipenserstellatus) sperm: Effect of diff erent concentrations of DMSO and dilution dates on sperm mobility and motility duration after longterm storage // Global Veterinaria. — 2013. – V. 10. – P. 26-30.

25. Vasil`eva L.M., Smirnova N.V., Yusupova A.Z. K voprosu soxraneniya i vosstanovleniya zapasov osetrovy`x ry`b v Volgo-Kaspijskom bassejne // Yug Rossii: e`kologiya, razvitie. 2012. T. 7, N1. S. 73-76. DOI:10.18470/1992-1098-2012-1-73-76

26. Xodorevskaya R.P., Kalmy`kov V.A., Zhilkin A.A. Sovremennoe sostoyanie zapasov osetrovy`x Kaspijskogo bassejna i mery` po ix soxraneniyu. Vestnik AGTU. Seriya: Ry`bnoe xozyajstvo. 2012. № 1. S.99-106

МАЗМҰНЫ – CONTENTS – СОДЕРЖАНИЕ