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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.

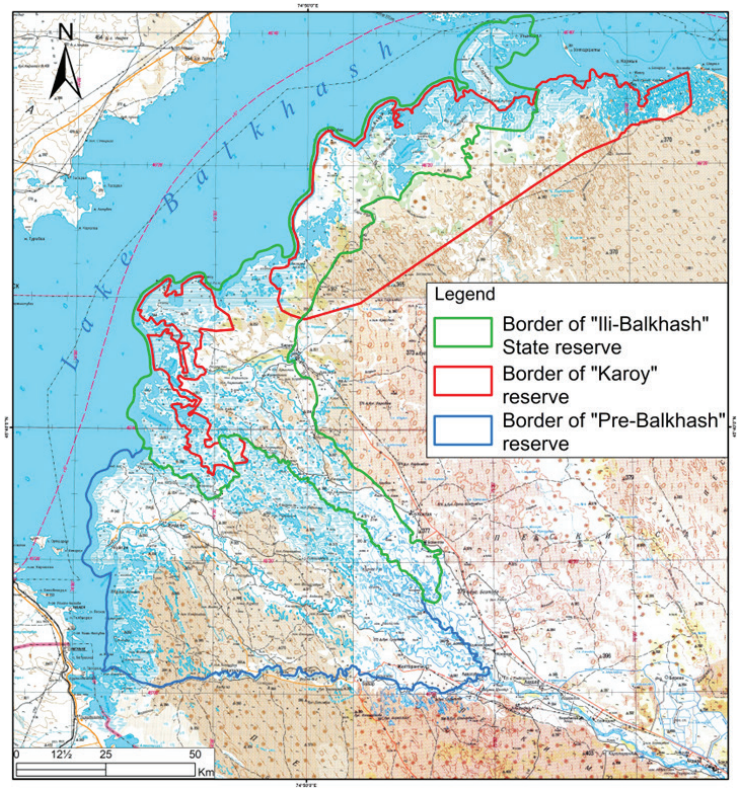

Figure 1 – Borders of Specially Protected Natural Areas in the study area

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.

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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.

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