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Migration Flyways and Geese Abundance in Central Siberia

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ABSTRACT

Observations of geese (Anser) abundance and migration in Central Siberia are especially relevant for international scientists due to the lack of objective data on this topic in English literature. The goal of this paper is to summarize the results of a long-term study (1980-2016) on geese in Central Siberia and to describe their migration routes in Continental Asia. The authors used a methodological complex comprising visual and instrumental observations at staging sites and along geese migration routes, registration of birds on the ground (travelling on foot, by boat or by car) and in the air (using aircraft). To clarify the subspecies, the authors performed banding of nesting geese in the Altai-Sayan Ecoregion (heads, wings, legs, n = 1032 units). They also analyzed scientific data available and reports on returns of rings from the Ringing Center of the Russian Academy of Sciences, as well as information from hunters and environmental specialists. In springtime between 51˚N and 56˚N, northern geese make a long stop (45-50 days) before flying further to nesting grounds; the places and dates of maximum geese concentration and the time of their departure are quite permanent which made it possible to carry out their definite registration using aircraft (25.5 thousand km). The works at each of the sites were performed annually with obligatory inclusion of the period of bird maximum concentration: May 9-15 (± 3 days) and October 7-15 (± 3 days). Out of 1732.3 thousand geese inhabiting Central Siberia, only 106.85 thousand (or 6.2% of the total number) winter in Asia; the Great Lakes Depression in Mongolia is a "migration dead end" for a great number of waterfowl in spring. The material contained in the paper can be used for the purpose of geese conservation and prevention of diseases associated with the spread of influenza A virus.

KEYWORDS

Central Siberia, Geese, Influenza A Virus, Migration.

Introduction

Central Siberia is a global crossroads for migratory birds. It is adjacent to Inner Asia - the most important center of speciation and a grand biogeographical barrier; it plays an important role in the study of birds and pathogens associated with them. Until recently, information on migration of Siberian bird in Continental Asia was fragmentary, and researchers often expressed diametrically opposite judgments.

Extensive studies of bird migration were made on the territory of Central Siberia in 1980-2016. However, their results have not yet been translated into English and published internationally. The global ornithological community still perceives Central Siberia as a "white spot" (Syroechkovskiy et al. 2006; Yerokhov et al. 2006; Schielzeth et al. 2008; Iverson et al. 2011; Prins & Grischenko 2015; Rogacheva & Syroechkovskiy 2015; Jia et al. 2016).

Geese (Anser), traditionally important for hunters, certainly deserve particular attention as an important biological resource. The southern part of the region is a nesting place for Eastern Siberian taiga been goose (*A. fabalis middendorffii* Severtsov, 1873), Eastern Eurasian graylag goose (*A. anser rubrirostris* Swinhoe, 1871), bar-headed goose (*A. indicus*) geese, and swan goose (*A. cygnoides*). In migration periods, West Siberian tundra bean goose (*A. fabalis rossicus*) is predominant (Buturlin 1933).

However, the events of recent decades have brought cardinal changes; today it is more important to talk about conservation measures for some species and their populations. The geese inhabiting the south of Central Siberia are currently experiencing a serious impact of anthropogenic factors, which leads to fragmentation and reduction of their habitats, and to a decrease in their abundance. Most of the species, subspecies and subpopulations of geese were included in the regional Red Lists of Threatened Species: Red Data Book … (2002), Red Data Book …

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(2014) and Red Data Book … (2012); some species are in the Red Data Book of the Russian Federation (Animals) (2001).

The densely populated Asian continent comprises transcontinental bird migration routes that cross all natural landscape zones. Thus, it plays a special role in occurrence and global transmission of especially dangerous infections related to water and swamp birds (Iverson et al. 2011; Yamaguchi & Higuchi 2008; Savchenko & Savchenko 2014). In this sense, studies of the geese migration range structure are important not only in terms of environment, but also in terms of people's safety.

The goal of this study was to compile the results of long-term observations (1980-2016) of geese migration and abundance in Central Siberia, as well as to distinguish and describe their migration routes in Continental Asia.

Materials and Methods

The research materials for this work were the observations made by the authors and the staff of the Hunting and Reserve Resources Chair of Siberian Federal University (Krasnoyarsk, Russia). The research on geese migration in Central Siberia began in 1980.

The total length of the itineraries was more than 60 thousand km, including 34.5 thousand km on land and 25.5 thousand km with the use of aviation. Stationary research was usually carried out at key sites. However, for the calculation of the total migration flow, the observation points were partly located outside of the congregation sites of migratory birds. Visual-optical and acoustic-optical observations were made in 91 point, ancillary registration of geese at their staging site – near 132 reservoirs. The total duration of geese registration along flyways and at staging sites was more than 15 thousand hours in the daytime (visual and instrumental observations) and 1422 hours at night (acoustic-optical observations).

The peculiarity of South-Central Siberia is that in spring, in the latitudes between 51 and 56°N, northern geese make a long (up to 45-50 days) stop before flying to the nesting grounds situated in taiga and tundra zones (Emelyanov & Savchenko 2006). The places and dates of maximal geese concentration, as well as the time of their departure, are quite constant. That allows making a full and definite registration, similar to bird count in wintering areas. In case of aerial survey, it was possible to count almost all individuals throughout the entire territory at once. Until 2006, birds were counted across the major part of the wetlands located in the south of Central Siberia. After identification of key stops and geese concentration, observations were made mainly in Khakassia and in the southern part of Krasnoyarsk Krai. The works at each of the most significant sites were performed annually, at the same time of the year. The works were carried out in April-May and September-October, with obligatory adherence to the periods of bird maximal concentration; according to average long-term data, such periods are May 9-15 (± 3 days) in spring and October 7-15 (± 3 days) in autumn.

In the Tuva Republic, considerable geese stopping places are preserved only in the eastern and southern parts; the key areas of migratory birds are still such lakes as Khadyn, Tore-Khol and Ubsunur. They were visited recurrently for registration and collection of survey information from local residents (hunters, biology teachers, biology students, including the students of the Hunting and Reserve Resources Chair at Siberian Federal University, hunting inspectors and representatives of other environment protection organizations).

The occurrence and population density of nesting geese were evaluated on the basis of census made along migration routes within wetlands. The records for the census were done at most important nesting grounds and concentration sites in both migratory and post-nesting periods.

In drawing up the maps of the routes, we used field observations, available literature sources (Gagina 1978; Migrations… 1989, 1997; MacKinnon & Phillipps 2000; Veen et al. 2005; Krivenko & Vinogradov 2008; Melnikov 2001, 2014) and data from the Ringing Center of RAS and information on found birds from local residents.

The study of bird migration was conducted with the help of a devised methodological complex (Savchenko 2009; Savchenko & Savchenko 2014), which was adjusted taking into account available technical equipment. This complex includes visual-instrumental (daytime) and acoustic-optical (nighttime) observations, bird capture, examination of living birds, aerial, car, boat and walking tracking, bird count at the sites of their congregation, registration of transit-

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flying bird flocks, as well as computer processing and data analysis.

To clarify the subspecies of geese, we carried out collection of birds or their body parts (heads, wings, legs); the total number of considered units is equal to 1032. In the last years of observations, video recording and photography at the places of bird concentration played an important role in collecting required information in the field. The number of photographs and video records of individual birds and geese congregations reached 12.9 thousand. Besides, in 2006-2015, we conducted the first large-scale laboratory research of wild and synanthropic birds living in the vast territory of Eastern Siberia (Krasnoyarsk Krai, Irkutsk Oblast, the Republics of Tuva, Khakassia, Buryatia). The research was conducted in response to the spread of influenza A virus (HAV) subtype H5N1. We collected more that 17 thousand samples for serological, virological and molecular-biological testing of 165 species of birds. That helped to make a list of species (birds - principal vectors of HAV), which included the geese *Anser albifrons* (Scop.), *A. fabalis middendorffii* (Sev.) and *A. f. rossicus* (But.) (Savchenko et al. 2015).

Results

Flyways

Nowadays, most scientists, including the authors of the present work, share a point of view that can be called as a synthetic one: birds fly in a broad front with increased concentration sections formed inside. These sections are called migration routes (flyways) that, in their turn, form migration corridors while merging (Grishchenko 1994). F.C. Bellrose (1968) proposed to differentiate several levels of flyways. Higher-order flyways traceable within the territory of 1-2 continents are usually called continental ones, smaller routes (of the II and III order) – regional and local ones correspondingly.

According to various estimates, researchers distinguish 5 to 8 or more flyways in Asia (Fisher & Peterson 1964; McClure 1974; Newton 2008; Rappole 2013). We believe that there are two main continental migration routes passing through the south of Central Siberia – *Eastern Asian-African* (17.3 thousand km) and *Western Asian-Australasian* (15.8 thousand km). The first route stars in the outermost northeast of Asia or even in Alaska, the second one –in the north of Eastern Europe. The *Central-Asian* route, which is used by the geese migrating through the south of Central Siberia (it is frequently mentioned in domestic and foreign literature), belongs to the category of the II order. In the last century, many geese flew along the Yenisei valley, north of the city of Yeniseisk. The Yenisei flyway was considered to be an extension of this route (Rogacheva & Syroechkovskiy 2002; Syroechkovskiy 2006).
Basing on the obtained data and analysis of available information, we prepared a general map for the migration territory of Inner Asia's birds and its adjacent areas, with allocation of the following migration routes: *Kazakhstan-Central Siberian (1) Ubsunur-Tarim (2) Ubsunur Gobi-Qinghai (3), East Tuva-Khubsugul-Chinese (4), Angara-Baikal-Gobi (5) and Tunguska -Baikal-Angara-Khingan (6)* (Figure 1).

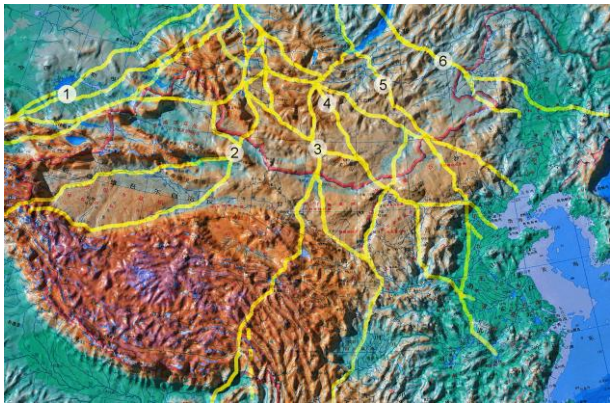

Figure 1. Migration routes of birds in Inner Asia: Kazakhstan-Central Siberian (1) Ubsunur-Tarim (2) Ubsunur Gobi-Qinghai (3), East Tuva-Khubsugul-Chinese (4), Angara-Baikal-Gobi (5) and Tunguska -Baikal-Angara-Khingan (6)
Many species have stable wintering areas and stable population distribution within them. These species usually do not migrate during winter, and their flocks spend over winters at the same place (Dolnik 1975). Wintering areas of a range of bird species are historically more conservative than nesting areas. In many ways, it is competitive

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relationships and separations of ecological niches in wintering that allow explaining the configuration of certain modern flyways in Asia.

The particular features of flyways trajectories and the migration area structure in the considered territory become clearly visible in the example of such species as *Anser albifrons* and *Anser fabalis.* Their migrations are very noticeable along the valleys of large water streams – the Yenisei and Angara Rivers. The Yenisei mainline flyway forms a number of branches, primarily to the southwest, partly south and southeast directions. At that, many bird migration routes (Eastern-Evenk, Taz- and Ob- Yenisei flyways) run along watershed interfluves areas; flying along these areas, birds usually do not follow the landscape patterns (Fig.1)

The typical «non-valley» migration routes of waterfowl birds are quite clearly visible in the eastern part of Central Siberia, in Evenkia and the territory bordered by the Yenisei and Angara rivers (Zaangarie). They are the extensions of the Angara-Yenisei and Evenk branches of the Khingan migration route made by the birds of the wetland complex of the Palearctic eastern part (Figure 2).

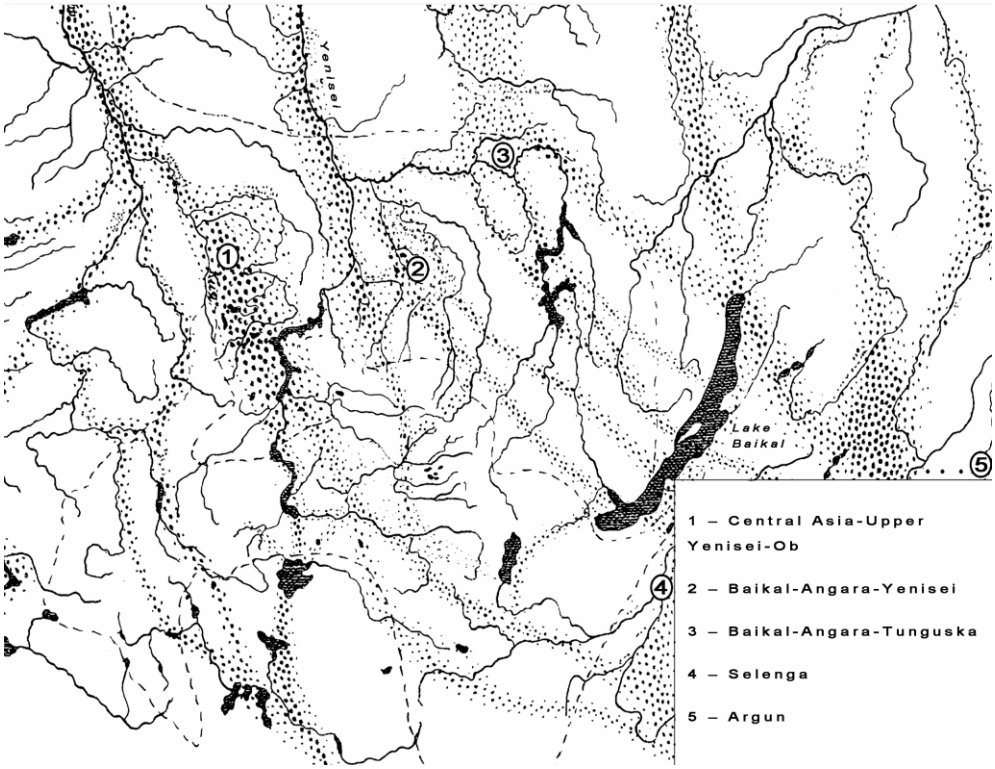

Figure 2. Continental flyway migrations of *Anser fabalis* (East-Asian populations)

The wintering areas of white-fronted geese and bean geese are located both in the western (Germany, the Netherlands, Hungary, Yugoslavia, Italy, the northern part of Spain, etc.) and eastern (China, South Korea, Japan) parts of Eurasia. East Asia, primarily China, is the wintering area for swan geese. Graylag and bar-headed geese winter in South Asia (India, Pakistan, partly Indochina); some portion of white-fronted and graylag geese, as well as lesser white-fronted geese (their West-Palearctic population) spend winters in the south of the Caspian Sea and in Middle and West Asia (Yerokhov et al. 2006; Delany & Scott 2007; Li et. al. 2009; Schielzeth et al. 2008).

The flyways of white-fronted geese that nest in Taimyr are directed to the west and southwest. They mainly stop at the places located close to the water reservoirs of Northern Kazakhstan and the North Caucasus. In the south of Krasnoyarsk Krai, in Khakassia and Tuva, we found only small groups of migratory white-fronted geese that use the migration routes of taiga bean geese.

The original structuring of migration routes of the bean geese subspecies was conducted by V. Emelyanov (2004) on the base of V. Impe's work (1987) and was later extended by joint research. Let us consider the migration routes of

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bean geese subspiecies.

Anser fabalis rossicus subspecies flies towards «West-European» and «East-Asian» wintering grounds along the following main routes:

1. The typical tundra zones of the Yenisei Gulf, West Taimyr, Gydan and Yamal - Malozemelskaya, Bolshezemelskaya tundra zones – the White Sea-Baltic corridor – Estonia – the southeast of Finland – West Poland, the east of Germany or polders in the Netherlands.
2. The tundra regions of the Gydan, Tazovskiy peninsula, partly the Lower Yenisei Region and West Taimyr – the junction of the Ob and Irtysh Rivers – the Middle Volga Region – the northern part of Russia's south – the east and central parts of Ukraine – the Pannonian Basin (Fig.2)
3. The West and Central Taimyr – the valley and bottom land of the Lower Yenisei River – the Lower Angara River – the Kansk Hollow – the upper part of the Bratsk Reservoir –Balaganskaya forest-steppe (the upper reaches of the Angara River) – Lake Baikal – the delta and valley of the Selenga River – the valley of the Tola River – the middle course of the Yellow (Huang He) River – Hubei – Lake Dongting (Hunan province).
4. The Tundra zones of West Siberia – the valley and bottom land of the Ob River – the Chulym River Basin – the Minusinsk Hollow – the Upper Yenisei River – Khangai – the middle course of the Huang He – Hubei - Lake Dongting (Hunan province).
5. The East Taimyr – the south part of the North-Siberian Lowland – the Kotuy River Basin – the upper and middle courses of the Lower Tunguska River – the upper reaches of the Lena River –the northern part of Lake Baikal – the Barguzin Hollow – the lakes of the Eravinskiy and Arahleiskiy Regions – Dauria – Torey Lakes, Lake Dalai-Nur and the the Argun River basin – the Khingan Range – the water reservoirs if Inner Mongolia - the lower reaches of the Yangtze River.

Anser fabalis fabalis subspecies mostly migrates along the more western routes:

1. The west regions of the White Sea and the Kola Peninsula – the Scandinavian Peninsula, the southern part of Sweden, Denmark.
2. The North-Taiga regions of the basins of the Ob, Taz and the left bank of the Yenisei Rivers – reservoirs of Zauralie – Volga-Kamskiy Region – the southern part of North-West Russia – Baltic countries – the northern part of Belarus – the seaside regions of the Baltic coast of Poland and North-East Germany – the north of the Netherlands.
3. The south of the Turukhan valley – the Middle-Taiga regions of the Yenisei-Ob interfluve / the river basins of the western flank of the Central Siberian Plateau – the northern part of Khakasiya and Kemerovo Region – the Ob River – the Novosibirsk Reservoir – the southwest part of steppe Altai – the Gilevo Reservoir – the Irtysh River – Lake Zaysan – Zhetysu and the south of Kazakhstan - Lake Issyk-Kul – the southwest of Xinjiang Uyghur Autonomous Region (West China).

To our opinion, the latter wintering route is used by the bean geese inhabiting the basins of the taiga's rivers of the Ob-Yenisei interfluves –the Ket, Tym, Sym, Elogui, Dubches Rivers, etc.

On the wintering grounds in East Asia, numerous tundra bean geese *(A.f. rossicus u A.f. serrirostris)* gather in the basin of the Yangtze River's lower reaches (Poyang, Dongting, Shenzhen Lakes, etc.). East tundra bean geese (*A.f. middendorffii*) and partly the birds of the East-Siberian tundra subspecies (*A.f. serrirostris*) are more frequent in the seaside regions of China, near Lake Dongting, as well as in South Korea and Japan (Goroshko 2001; Cao et al. 2008; Li et. al. 2009; Qiang Jia it. al. 2016). We found that the westernmost migration routes are used by the «south-Asian» west tundra bean geese, nesting sites of which are located both in Taimyr and Gydan and, possibly, in more western locations, including the Tazovskiy and Yamal Peninsulas (Emelyanov 2000; Savchenko et. al. 2003). The migration routes of the Siberian tundra bean geese are more distinct in East Tuva, near the Middle Angara River and in the areas to the east of Baikal (Gagina 1978; Emelyanov et al. 2006; Melnikov 2014).
The scattering area of both wintering grounds and nesting sites for different geese species and their population groups is very broad and diverse. However, the route direction of the predominant bird group is quite noticeable: N-W in spring and S-E in autumn. The exceptions are the flyways that pass through the Yenisei-Ob migration area where, in addition to the southern direction, one can observe the movements of *A.f. fabalis* and a part of *A. f. rossicus* species towards W and S-W. There is a quite noticeable autumn flyway of bean geese in the middle reaches of the Tym and Ket Rivers. In spring, many birds fly along the Eltyreva and Paydugina Rivers. In spring, in the Sym River

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basin, geese migrate towards both N-N-W and N-E. Some birds fly from the north-west towards southeast, using the riverbed as a guideline. In autumn, there are two apparent directions – W-S-W and S-S-E.

The *Central Asia-Upper Yenisei-Ob* flyway of bean geese passes through the continental regions of Inner Asia; it joins the Ubsunur Gobi-Qinghai and East Tuva-Khubsugul-Chinese routes in Inner Asia. The analysis of available information allows concluding that birds migrate to the basin of the Upper Yenisei, Mongolia and China through the Central Siberia from both Taimyr and the Middle Ob River basin. The main part of the birds using this flyway is the bean geese of the west tundra *A.f. rossicus* subspecies, which nest in the north of West Siberia and which can form, according to our opinion, a separate *Tuva-Minusinsk* subpopulation.

Generally, the registration of banded birds in Tomsk Region also confirms the flyway scheme of *A.f. rossicus*, which moves from the Middle Ob in the southeast direction. It was quite possible that the bean goose, banded in Netherlands and caught near Alexandrovskoye village in Tomsk Region, had also been flying to East Asia for wintering.

In autumn, bean geese arrive to the Minusinsk Hallow from the northwest. One branch of this route (*Tuva-Khakasiya*) proceeds from the Chulym River basin to the south-south-east almost parallel to the Yenisei River, and crosses the West Sayan at the angle 130-140˚, reaching the central part of the Tuva Hollow. Further, one part of the birds follows the east direction to the upper reaches of the Lower Yenisei River and the other one flies to the south east across East Tannu-Ola to the east edge of the Ubsunur Lake Hollow and then, up the Tes River, to Mongolia.
The other, *Upper Yenisei-Chulym*, branch of geese flyway goes through the Minusinsk Hollow directly to the southeast, along the line – city of Uzhur–Karatyzskoe village. Then, geese fly along the Amyl River valley that serves as a guideline and cross the east part of the West Sayan. Then, bean geese migrate to southeast along the north eastern foothills of Obruchev Range. They cross the Range at the Serlig-Hem River head, reach the Buseingol and Tere-Khol Hollows, continue flying along the Delgermörön River head to Mongolia. Through the upper reaches of the Eg and Selenga Rivers, bean geese follow the S-E direction and finally reach their wintering grounds located in the Yangtze River basin, China.

Current Status of Geese Abundance

According to available information, the number of white-fronted geese *Anser albifrons* (Scop.) in the Tundra of Taymyr and East Gydan is continuously growing; it may reach 1.0 million units nowadays (Iakushkin et al. 2012). At the same time, only a very small part of these birds migrate through the most developed part of Krasnoyarsk Krai, Khakassia and Tuva. In 2003, the abundance of this species in the southern half of the region could be estimated at 11.6 thousand units, including the birds of 'Western Palearctic populations" (7420 individuals), which was 1.6 % of the total number for the region. In recent years, there has been a reduction in the abundance of the *South-Siberian, Kansk-Yenisei and Lower-Angara bird groups* that totally amounted to less than one thousand individuals. The abundance of the *Angara-Tunguska* bird group also reduced from 2.7 thousand individuals in 2003 to 1.4 thousand individuals in 2007 (Emelyanov et al. 2005; Emelyanov et al. 2008). In 2010-2015, the total number of white-fronted geese, which fly along the south of Central Siberia in spring, did not exceed 2.0-3.5 thousand. In the adjacent areas of Irkutsk Oblast, the proportion of white-fronted geese was 15 % of all the geese that fly through that region (Melnikov et al. 2014).

Eastern graylag goose *Anser anser rubrirostris* (Swinhoe 1871) is rarely found in the region; it inhabits the insular steppe and forest-steppe of Central Siberia. The number of graylag geese living in the reservoirs of the South Minusinsk locus in 2002-2004 was 70–100 individuals. They are more common in the south of Tuva – in 1980-1900, the large Ubsunur-Teskhem aggregation consisted of 1200-1600 individuals only in Russia's part of the Ubsunur Hollow. To the north, in other graylag goose pockets, we face a decrease in its abundance and a reduction of its natural habitat, mainly because of direct extermination of birds, higher levels of disturbance, habitat degradation at breeding and wintering sites (Emelyanov & Savchenko 1997). According to the obtained data, as well as to testimonies from local residents and environmental organizations workers, graylag geese probably vanished in eastern Tuva (Todzha-Kaa Khem) in the late 20th century. Only single individuals of this species are preserved in the central Tuva, South Minusinsk and Kansk depressions. In Central Siberia, the influence of adverse natural and anthropogenic factors brought changes in the spatial structure of graylag geese natural habitat over 2006-2015.

In 2011–2015, the Upper-Chulym and South Khakassia pockets of this species came to different stages of

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degradation. Some nesting sites (we found layings and broods) still remain in the southern part of Lake Baloye (10-50 mates) and at Lake Salbat (2-10 mates). Few mates of geese that did not breed every year were found in the Chulym river basin: in inundated lands along the Serezh, Belyi Iyus, Uryup, Upper Chulym rivers. There are not more than 20 mates in northern Khakassia (they are separate and do not nest every year), not more than 15-20 mates on the left bank of the Yenisei within South Minusinsk depression. Graylag geese have not been found on the Yenisei right bank since 2006. Most threatened are the birds inhabiting the reservoirs of the Uibat Steppe where there are not more than 5 mates. Irregular nesting of up to 10 mate of graylag geese was observed in the Koybalsk steppe ('Sorokaozyorki' location) in the early 2000s; in 2011-2014 there were only 2-3 breeding mates. A brood of four under-yearlings were seen at Lake Okelkol on August 5, 2011. Four graylag geese were met at the same place and near Lake Orastai on May 12, 2012. Two broods consisting of six and four geese were found in the vicinity of Lake Sobachye on August 3, 2013; there were four birds at the same place at the end of May 2014.

After the breeding and molting season, flying young broods and non-breeding geese are concentrated in safe and abundant grounds. The only pre-migration aggregation of the Upper Chulym graylag geese is currently formed near Lake Salbat where 260 individuals were registered in August - September 2014 and 180 individuals - in 2015. A similar aggregation of up to 100 individuals was formed at Lake Pataga (Uibatsk Steppe) in the 1990s - early 2000s, but it vanished after the reservoir dried out.

In the autumn of 1980, there were not less than 90 thousand graylag geese in Tore-Khol and the Ubsunur Lakes basins (in the border area, to be exact); they made trophic flights to wheat fields (Savchenko & Emelyanov 1984). At present, in our estimation, there dwell 5 to 10 thousands of these geese, 15% of them – on Russia's territory. However, the abundance of graylag geese is preserved on the lower reaches of the Tes-Khem river and in the Lake Ubsunur basin. This fact is proved by our surveys and the surveys made by Russian Mongolian scientists in 2014 (Archimaeva et al. 2015).

We could find 570 adult bean geese (*Anser fabalis*) in the south of Central Siberia. An analysis of those samples showed predomination of *A.f. rossicus* (90-91% of the total sample number), smaller proportions of *A.f. middendorffii* (6%) and *A.f. serrirostris* (around 2 %), and single samples of *A. f. fabalis* (less than 1%).

The current abundance of East-Asian bean goose species in the region is considered to reach a critical value. Almost all of them are either included in the regional Red Data Books or are the candidates for inclusion in the second edition of All-Russia's Red Data Book (Savchenko et al. 2012; 2014). Thus, against the background of the natural habitat fragmentation, the abundance of eastern taiga bean goose *A.f. middendorffii* remains low. For the vulnerable *Sayan subpopulation*, it reaches 1.5-2.0 thousand individuals and keeps decreasing. Over the period of our study, the number of geese in their key habitats decreased by 1.5-2.0 times. This subspecies groups inhabiting Tuva are more stable. The main bird cluster of this region locates near the reservoirs of the Todzha Hollow, which accommodates up to 60% of all birds of the region.

Individual groups of these geese have survived on the northern macro-slope of the West Sayan and in the southwestern part of the East Sayan: in the Amyl basin, including Tyukhtet and Shadat swamps, (30-50 mates), in the basins of the Kazyr, Kizir Rivers, including adjacent lakes, (15-20 mates). In the upper reaches of the Bolshoy and Maly Abakan Rivers and in the Monagy river basin (the southern macro-slope of the West Sayan), there are up to 100-150 taiga bean geese.

These geese have almost vanished in the western part or on the northwestern macro-slope of the East Sayan and in Kuznetsk Alatau.

Thus, in the mentioned part of the Sayan mountains, there are only two pockets of eastern taiga bean geese: the Amyl-Kazyr-Kizir and the Upper-Abakan ones. They form the Sayan subpopulation. The largest aggregations of bean geese are near Tyukhtet swamp and Shadat swamp (with a lesser number of birds) that are situated in the middle basin of the Amyl river. The geese abundance dynamics was fluctuating over 2006-2015 and is negative at present. In 2014-2015, the total numbers, taking into account the molting geese, were 120-150 birds at the Tyukhtet swamp and 30-70 birds at the Shadat swamp. Vulnerability of birds to poachers and water tourists and the character of the threats (design and survey works on railway construction in the outskirts of the swamps, placer gold mining, berry picking) make a significant contribution to extinction of the Amyl-Kazyr-Kizir pocket of taiga bean geese, which is nearly 15% of the total Sayan subpopulation. The number of birds inhabiting this area in 2006-2015 ranged

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from 180 to 370 individuals.

The results of geese capture and tagging were as follows: July 2009 – 5 under-yearlings, 2010 - 5 adults and 3 under-yearlings, 2011 - one adult bird and 6 under-yearlings, 2012 - one under-yearling, 2013 - one adult bird. These data show territorial connections of this bird group with the geese inhabiting eastern Tuva and the northern part of Mongolia. In particular, in 2010 we captured an adult taiga bean goose male tagged by the ornithologists from an American-Mongolian expedition in the molting season of 2009 on Lake Erhel Nuur (49°56′N, 99°54′E).

Several dozen mates of Siberian taiga bean geese inhabit the basins of the Angara's right bank tributaries; however, their abundance is highly unstable and keeps decreasing. During the spring migration in 2011, in the region of Kezhemsky archipelago, there were no more than 1.5 thousand bean geese of the east taiga subspecies.

The number of the main migratory species of bean geese (*the Tuva-Minusinsk subpopulation of A.f. rossicus*) was, according to our data, not less than 100 thousand individuals in the 1970s (Savchenko & Emelyanov 1985). Currently, the number of birds in this group does not exceed 14-15 thousand, which is proved by spring bird registration at the key stopover areas in Krasnoyarsk Krai and Khakassia (Table 1).

Table 1. Dynamics of migratory bean geese abundance at the key stopover sites in Krasnoyarsk Krai and Khakassia in spring, 2006–2015

Wetland	**Range of abundance (individuals)**		
	2006–2010	**2011–2014**	2015
"Trekhozyorki" area, Lakes Bugayevo and Chernoye 53º18'N 91º30'E; 53º18'N 91º29E; 53º16 N91º29'E	400-8000	50-500	0
Tubinskiy Bay and upper dam of the Krasnoyarsk Reservoir 53º56'N 91º36'E	150-600	70-150	0
Lake Ulug-Kol' and its environs 53º48'N 90º39'E	50-150	0	0
Lake Belyo and its environs 54º39'N 90º11'E	70-200	0	0
Lake Sarat and its environs 54º46N 89º53'E	150-230	20-70	0
Lakes Chernoye and Oshkol 54º38'N 89º26'E; 54º44'N 89º17'E	800-2500	50-100	0
Lake Intikol and its environs 54º56'N 90º35'E	1100-1350	150-700	300
Lake Jirim and its environs 54º48'N 90º31'E	30-180	20-200	0
The floodplain of the Chulym River, "Dva Brata [Two Brothers]" area, and environs of Prirechye village 55º07'N 90º14' E	100-500	100-500	350
Lake Salbat and its environs 55º10'N 89º40'E	250-1500	1500-11000	13000
Lakes Beloye and Bolshoy Kosogol, and the floodplain of the Serezh River 55º35'N 89º33'E; 55º35'N 89º33'E 55º34'N 89º48'E	350-2300	100-500	100

Other nesting species of the region are bar-headed geese *Eulabeia indica* (Pall.) and swan geese *Cygnopsis cygnoides* (L.). In some areas, the bar-headed geese aggregation involved in avian influenza epizooty reduced by 4-5 times. The current total number of bar-headed geese in Tuva, according to our data, does not exceed 200–300 individuals.

A stable aggregation of san geese inhabits the middle and lower reaches of the Tes-Khem River; it is probably connected with the populations of Mongolia, where this species is quite widespread. In the early 2000s, there were 50 to 300 birds of this species in the south of Sentral Siberia (our estimation). At present, there are approximately not less than 100-200 such individuals within the Tes-Khem river floodplain. The number of swan geese to the north from the West Sayan is roughly not more than one or two dozen individuals. Over some years of the study, we registered visitations of these birds to central Tuva, the south of Khakassia and the

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southern part of Krasnoyarsk Krai.

Discussion

The species composition of geese migrating through the south of Central Siberia includes 7 species. Their proportions, like the representation of bean geese species with regard to the indicated flyways, are different (Table 2). This variation depends not only on migration routes genesis, but also on the nature of the present-day impact of natural and anthropogenic factors.

Until the mid-1980s, there were 3 species of bean geese, graylag (*Anser anser)* and bar-headed (*Eulabeia indica)* geese, and swan goose (*Cygnopsis cygnoides*) that could be found within the area of the Minusinsk, Central Tuva and Todzha Hollows. Big flocks of white-fronted (*A. albifrons*) geese began to appear in the 1990s in the region as far as the Minusinsk Hollow. Both geese agglomerations and stopover places are marked by occasional presence of lesser white-fronted geese (*Anser erythropus*) and red-breasted geese (*Rufibrenta ruficollis*).

In the XX century, due to a reduction in the most important bean goose aggregations, the once actively used migration routes of this species became abandoned and even diapered. For example, the number of bean geese in the Lower Angara region decreased 2-3 times over the past 15-20 years, or more than 15 times as compared to the mid-1960s. This happens because of continuous degradation of the key wetlands, which are important elements of migration routes for the birds of Central Siberia (Table 2).

Table 2. Species composition, abundance and distribution of geese migration routes in the south of Central Siberia

Species/subspecies	Number of Individuals	Proportion of migration routes* distribution, %					
		1	2	3	4	5	6
Rufibrenta ruficollis (Pall.)	500	36.5	0	10.0	12.0	25.5	12.0
Anser anser (L.)	2100	14.3	47.6	30.3	5.4	2.4	0
Anser albifrons (Scop.)	5000	23.5	0	3.0	4.0	20.5	50.0
Anser erythropus (L.)	750	53.3	0	6.7	6.7	6.7	26.6
Anser fabalis rossicus But., 1933	25000	2.0	0	6.0	58.0	26.0	8.0
Anser fabalis serrirostris Swin., 1871	13000	0	0	0	3.8	26.9	69.2
Anser fabalis middendorffii Sev., 1873	20000	0	1.0	2.5	10.0	26.5	60.0
Anser fabalis fabalis Lath., 1787	40000	62.5	12.5?	25.0?	0	0	0
Eulabeia indica (Lath.)	300	0	0	100.0	0	0	0
Cygnopsis cygnoides (L.)	200	0	0	40.0	60.0	0	0
Total	106850	27530	6200	13290	17530	16550	25760
%	100.0	25.8	5.8	12.4	16.4	15.5	24.1

Note: 1 – Kazakhstan-Central Siberian, 2 – Ubsunur-Tarim, 3 – Ubsunur Gobi- Qinghai, 4 – East Tuva-Khubsugul-Chinese, 5 – Angara-Baikal-Gobi, 6 – Tunguska-Baikal-Angara-Khingan migration flyways; ? – data need to be clarified.

The *Central Asia* migration route includes the flyways of grey geese that inhabit Central Siberia but migrate in different directions: from the Minusinsk Hollow to the west, and from the Ubsunur Hollow to the south.

The analysis of previously conducted collection works (Emelyanov 2004) revealed several morphological distinctions among graylag geese inhabiting these Hollows. It as ascertained that the geese of the Minusinsk Hollow are closely related to the birds inhabiting West Siberia (Lakes Chany and Kulundinskoye). It is possible to say that the territory north of the West Sayan is inhabited by graylag geese that belong to the *West Siberia-Kazakhstan-Caspian-Mesopotamia* geographical population (separated by A. Kischinsky in 1979). The Ubsunur hollow is inhabited by the geese that are related to West Mongolia and winter in India (the lower reaches of the Ganges) and Bengal (Shagdarsuren & Bold 1978). Within the South Minusinsk, Todzha, Uyuk and Central Tuva Hollows, there are birds occupying the outlying districts of these groups' habitat areas, which primarily explains their natural paucity in the past and rapid vanishing in the south of Krasnoyarsk Krai and Khakassia (Emelyanov & Savchenko

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1997; Savchenko et al. 2012; Savchenko et al. 2014). There are no more than 300 graylag geese left in the south part of Krasnoyarsk Krai, Khakassia and the surrounding areas of Kemerovo Oblast. Not more than 1.5-2.0 thousand individuals are left in the wetlands of South Tuva (mainly the basin of Lake Ubsunur). The total number of this species has decreased by more than 3 times over the past decade. The inclusion of this species into the Red Data Books of both Krasnoyarsk Krai and the Republic of Khakassia has not yet given results. The main reason of the abundance reduction is excessive bird catching in the neighborhood regions.

The migration locations of East Tuva and the West Sayan are characterized by autumn transit migrations. Pre-flying clusters of Siberian taiga bean geese (99.6%) are formed near some reservoirs in August and September; the total proportion of graylag, bar-headed and swan geese species is only 0.4%. According to the survey data, tundra bean geese prevail in the Todzha and Tere-Khol Hollows in migration periods. Their flocks sometimes include groups of white-fronted geese -with the ratio approximately 1:150 to bean geese.

The decrease of this species abundance ceased after these geese were included into regional Red Data Books (Red Data Book … 2012; Red Data Book … 2014 г.). A complex of environment-protecting measures made a positive impact on these bean geese abundance, which significantly increased and amounted to not less than 13 thousand individuals in the spring of 2015. Moreover, the absolute majority of birds from this group settled down near Lake Salbat, where the birds stop during their spring and fall migrations.

The number of bean geese migratory groups in the Lower Angara basin has dramatically decreased (more than 3-5 times). Their stops during migration through the Krasnoyarsk forest-steppe and the Kansk Hollow almost ceased.
The groups of bean geese that winter in the western part of Eurasia, primarily in Europe, are more stable.

Numerous tundra (Bewick's) swans of the *Gydan* subpopulation migrate by the *Tuva-Khakassia* branch of the *Central Asian* migration route. This species' flyways match the routes of the *A. f. rossicus* species in most parts of the considered region, but on the territory of Mongolia, one of the branches passes through the Great Lakes Hollow along the Mongolian Altai. At about 100ºE, tundra swans turn south where their route match the flyway of bar-headed geese tagged in the territory of Khövsgöl Province (Takekawa et al. 2009; Palm et al. 2015).

According to recent data (Qiang Jia et al. 2016), the number of bean geese in eastern Asia is 157-194 thousand individuals, 18 thousand of them are *A.f. middendorffii* species. We think that these quantity is underestimated, probably due to exclusion of geese wintering in western China, central Asia and, partly, India. Taking into account territorial links and the geese number along migration routes, these territories, to our estimation, may be wintering areas for 15-40 thousand A. *f. fabalis* that inhabit the Yenisei-Ob and Yenisei-Taz interfluves, as well as the western parts of the Putorana Plateau, Syverma Plateau and some other adjoining areas of the Yenisei right bank.

Besides, not less than 25 thousand *A.f. rossicus* migrate for wintering from West Siberia's tundra areas and Taimyr to China. 13 thousand geese of *A.f. serrirostris* subspecies fly to the same direction from East Taimyr tundra zones and the Khatanga-Lena interfluve. Eastern taiga bean geese (*A.f. middendorffii)* inhabiting Evenkia, Zaangarie, western Yakutia and the north of Irkutsk Oblast (at least 15 thousand individuals) and the geese inhabiting the Altai-Sayan Ecoregion (1.5-2 thousan individuals) follow to wintering grounds to the lower reaches of the Yangtze river, most likely to Lake Dongting environs.

Thus, if the number of geese on the territory of Central Siberia, in our estimation, is 1732.3 thousand individuals, the total number of birds migrating along the indicated routes in the southern Central Siberia is only 106.85 thousand individuals, or 6.2% of all geese in the region.

The geese abundance of southern Central Siberia is currently affected by flyways genesis, extremely uneven distribution of birds along migration routes, as well as by anthropogenic factors and, in particular, by the fact that the south of the region accommodates more than 95% of the human population. Direct seizure of that relatively small number of geese, the economic development of the territory, and recent significant recreational load lead to formation of great disjunctions of not only large-scale geographical populations (the Central Asian, Siberian-Kazakhstan and Amur-Chinese ones), but also of different groups within the populations, the totality of which previously formed an indivisible habitat of geese in Asia. In most exclaves, the state of birds is critical. In 2006–2015, the degradation of several geese species/subspecies local groups present in southern Krasnoyarsk Krai, Khakassia and Northern/Central Tuva became obviously irreversible.

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In addition, the abundance of geese in southern Central Siberia is affected by their neighborhood with the Ubsunur active focus of influenza A virus (Lvov et al. 2008; Savchenko & Savchenko 2014; Volkov et al. 2016; Shestopalov et al. 2016) or by flyway trajectories passing through it.

Conclusion

It is believed that the most important Siberia's stopover places for birds migrating from north to south and back are situated in the valleys of the Ob, Yenisei and Lena Rivers (Prins & Grischenko 2015). This is only partially true with regard to the Yenisei, especially to its upper part. Only a comparatively small number of species and individuals flies in the southern direction, keeping to the meridional line of the river bed, overpassing the Sayan Mountains and then the upland deserts of Inner Asia (Savchenko & Savchenko 2014). Geese are likely to be an exception interns of species composition; they are broadly represented on the continental flyways of the southern Krasnoyarsk Krai, Khakassia and Tuva (Ubsunur Gobi-Qinghai и East Tuva-Khubsugul-Chinese flyways), but in terms of quantity, they form only 1.7% of the total number of geese inhabiting Central Siberia.

The Great Lakes basin in Mongolia is currently a kind of "migration dead end" for a great number of waterfowl migrating in spring; this situation did not change with formation of large reservoirs in the south of the region. In this sense, we think that the question about the viability of the Yenisei basin river system is reasonable, because the system is used by the birds migrating to the Gobi Desert, the Pamirs and further south. We also believe that the Ob river system can become an alternative migration corridor for the bird flying to Western Europe (Prins & Grischenko 2015).
Obtaining the details of certain species/subspecies migration routes evidently requires using modern technologies or satellite tracking of tagged individuals. Unfortunately, such works were performed in the considered region for only few species, with a limited number of transmitters. At the same time, we have a substantial set of data on bird migration accumulated by traditional methods. This knowledge can now help in solving a number of problems related to conservation of several species of birds, as well as in ensuring the biological safety of the region.

Some well noticeable birds can be used as markers or tracers of migration routes, which was done in this study. For example, the flyways of *A.f. rossicus* (the *Tuva-Minusinsk* subpopulation) and *Cygnus bewickii* (the *Gydan* subpopulation) largely coincide. The tagging of tundra swans with satellite transmitters in Yamal in 2015 (http://casarca.ru/proekty-rgg/91-proekty-rgg) confirmed the correctness of the flyway layout made by us in 2004.

The study of geese territorial relations and the estimation of their current number enabled to corroborate the idea to stop hunting all types of geese in the south of the Krasnoyarsk Territory and the Republic of Khakassia; hunting in these areas is prohibited now. Hunting restrictions for the territory of Tuva are actively discussed. Within the Yenisei transect, environmental organizations create protected areas that play an important role in the life cycle of geese. However, protective measures must become systematic and have regulatory support; they must include comprehensive monitoring, ban of spring geese-hunting in the entire south of Siberia, and inclusion of the most important wetlands in the unified network of protected areas. Many of these questions will certainly require international integration in the preservation of geese in Continental Asia.

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