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Cover Photo: Camera trap picture of manul in the Kotbas Hills, Kazakhstan, 20. July 2016 (Photo A. Barashkova, I Smelansky, Sibecocenter)

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Distribution and status of the manul in Central Asia and adjacent areas

A significant portion of the manul's *Otocolobus manul* global range is situated in the Central Asian countries Mongolia, Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan, and several adjacent provinces of Russia. We estimated the manul current Extent of Occurrence EOO in the region at 1,225,313 km², which is about 84% of the predicted area of suitability calculated from the MaxEnt distribution model. Based on a conservative assessment of manul population density (4–8 cats/100 km²), we roughly estimated the regional population size at 49,000–98,000 manuls. Mongolia holds almost 60% of the estimated potential area of suitability in the region and over 50% of the estimated regional population. Kazakhstan and Russia both have relatively abundant manul populations while in Uzbekistan and Tajikistan the manul presence remains questionable. Killing by herding dogs, wildfires, and rodents poisoning are at present the main threats to the manul in this region. Manul is listed in the Red Data Books of Russia, Kazakhstan and Kyrgyzstan. Hunting ban or regulation, respectively, and protected areas are currently the main conservation instruments for the species. Protected areas cover approximately 15% of the manul habitats in Mongolia, 12% in Russia, 7% in Kazakhstan, and 6% in Kyrgyzstan. We recognise a lack of knowledge regarding manul ecology and biology in the region, its geographical distribution, and a lack of correct assessment of its population size. These gaps should be filled to raise conservation efficiency. Conservation efforts should include securing manul and its habitats in key areas, minimising dog attacks and poaching, and establishing a broad, long-term monitoring.

A significant portion of the manul's presumed global range is in the five Central Asian countries: Mongolia, Kazakhstan, Kyrgyzstan, Uzbekistan and Tajikistan, and in adjacent Russian provinces (Ross et al. 2016). The entire region shared a common political system until 1990, with similar patterns of land use and wildlife management. Steppe ecosystems throughout the entire region, including manul habitats, faced a common set of threats as a result of extensive agricultural development, state-induced relocation of people, and large-scale mining, coal extraction, and hydropower projects. After the breakup of the USSR in early 1990s manul populations were affected by economic transition (Fernandez-Gimenez 2006, Smelansky & Tishkov 2012, Kamp et al. 2016) which had a significant impact on some large carnivores (Bragina et al. 2015), resulting in general rise of poaching and wildfires, large-scale changes in human use of the species habitats, leading to extensive grassland rehabilitation in Russia and Kazakhstan, but degradation in Mongolia.

During the 20th century, several detailed regional reviews of the species' distribution and ecology were published: Ognev (1935), Fetisov (1937), Heptner & Sludskii (1972), Sludskii (1982). Current information on manul distribution and biology can be found in national and provincial Red Data Books in each range country (e.g. Dronova 2001, Clark et al. 2006, Toropova 2006, Kirilyuk 2012, Sokolov 2012, Borisova & Medvedev 2013, Barashkova 2017, Kuksin 2018) and in publications and reports from recent studies (see Supporting Online Material SOM). Moreover, the only comprehensive ecological studies of manul have been conducted in this region (Kirilyuk 1999, Kirilyuk & Puzansky 2000, Ross et al. 2010a, b, 2012).

However, the information remains insufficient and is partly outdated. There is a need for re-evaluating the status of the manul in the region. In this chapter we summarise actual data on the geographical distribution, abundance, habitats, prey, threats, and protection. We reveal the main gaps and ambiguities for further investigation and conservation.

Table 1. Number of historical (< year 2000) and contemporary (≥ 2000), C1 ("confirmed"), C2 ("probable") and C3 ("possible") manul records compiled in this study.

Country	Historical*			Contemporary			Total
	C1	C2	C3	C1	C2	C3	
Kazakhstan	0	5	48	44	16	74	187
Kyrgyzstan	0	1	2	43	9	11	66
Mongolia	0	2	1	128	0	1	132
Russia	2	13	62	145	204	306	732
Tajikistan	0	0	4	0	0	0	4
Uzbekistan	0	0	12	0	0	2	14
Total	**2**	**21**	**129**	**360**	**229**	**394**	**1,135**

**Due to time constraints, the analysis of historical data was carried out carefully only for Kyrgyzstan, Tajikistan, and Uzbekistan from which contemporary records are rare or absent. For the rest of the countries only the data available in the authors' databases are shown.*

Methods

We used multiple data sources to consolidate information on the manul in the region. Every co-author completed a standardised questionnaire developed by the IUCN SSC Cat Specialist Group, and provided data on the manul from their countries. We supplemented this information with occurrence data from the Small Wild Cats of Eurasia Database (http://wildcats.wildlifemonitoring.ru), created in 2004 and maintained by Sibecocenter and the Pallas's Cat Working Group PCWG. The database contains over 500 contemporary (2004–2018) distribution records of the manul (Barashkova 2016, Barashkova et al. 2018). In addition, we obtained by-catch records of manul from routine camera trapping surveys of snow leopards *Panthera uncia* (see Acknowledgements). To characterise manul habitats, feeding habits, threats, and national conservation statuses we reviewed about 70 contemporary and old publications in Russian and English. We analysed 15 unpublished reports of research and conserva-

tion projects completed be-tween 2006 and 2018 in Russia, Kazakhstan, Uzbekistan and Kyrgyzstan.

Manul records were categorised as C1 ("hard fact" or "confirmed"), C2 ("probable"), or C3 ("possible") according to Molinari-Jobin et al. (2012). We further allocated all records to two time periods: "historical" (< year 2000) and "contemporary" (≥ 2000). We estimated the manul's Predicted Area of Suitability PAS and the Extent of Occurrence. First, we built a species distribution model using the MaxEnt software package (MaxEnt 3.3.3k; Phillips et al. 2006, Phillips & Dudik 2008) to outline suitable habitats for the manul across the study region, i.e. areas where landscape and climatic characteristics are favourable for the manul (see SOM for details). The PAS was then calculated using a binary output of the MaxEnt model. Based on expert opinion, areas on the northern edge where the average long-term maximal snow depth exceeds 20 cm and areas where main prey species are supposed to be absent were excluded (Kirilyuk & Puzansky 2000, Kirilyuk & Barashkova 2016a). The EOO was calculated as minimum convex polygons of precisely located contemporary C1 and C2 records with precise geographical coordinates (n = 570) in each country and for the whole region with following modifications: We excluded unsuitable areas from the conventional estimates of EOO according to our prediction of suitable habitats (see SOM). All the cartographic data processing was performed with ArcInfo GIS 9.3 and QGIS 2.12.

We applied EOO figures to estimate population size speculating on the following. Manul density in Mongolia was estimated at 4–8 cats/100 km^2 and was considered to be quite low (Chapter 2). Higher figures were obtained in Dauria and other regions of Russia – up to 100 cats/100 km^2. We assume that the average manul density in Kazakhstan and Kyrgyzstan is significantly lower than in Russia (our data). Thus, we have used the low-density estimation (4–8 cats/100 km^2) and national (or sub-national) EOOs for the conservative estimate of the regional population size.

Table 2. Predicted Area of Suitability PAS and Extent of Occurrence EOO per country based on contemporary (≥ 2000) C1 and C2 manul records compiled in this study.

Country	PAS, km^2 (% of the regional PAS)	PAS % of the national territory	EOO, km^2
Mongolia	853,147 (58.6)	54.5	661,910
Russia	175,284 (12.0)	1.0	118,107
Altai-Sayan	64,751	–	52,079
Eastern Sayan	8,486	–	262
Western Trans-Baikal	25,434	–	6,821
Eastern Trans-Baikal (Dauria)	76,613	–	58,945
Kazakhstan	337,304 (23.2)	12.4	264,801
Kyrgyzstan	77,216 (5.3)	38.6	31,575
Tajikistan	9,845 (0.7)	6.9	NA
Uzbekistan	1,907 (0.1)	0.4	NA
Total	**1,454,703**	**6.6**	**1,225,313**

Distribution

We gathered a total of 1,135 observations with the highest number of records collected in Russia (n = 732, 64.5%; Table 1).

Mongolia holds more than half of the regional PAS and estimated regional EOO, followed by Kazakhstan and Russia (Table 2).

The PAS is 6.6% of the total area of the re-gion but the countries are dramatically different in regard to their suitability for the manul (Table 2). PAS occupies just over half of the national territory in Mongolia and more than one third in Kyrgyzstan while only 6.9% in Tajikistan, 1% in Russia and less than 1% in Uzbekistan. The PAS in Russia and Kazakhstan are divided into several fairly large fragments (Fig. 1; SOM).

Kazakhstan

Heptner & Sludskii (1972) and Sludskii (1973, 1982) reviewed the distribution of manul in Kazakhstan in 1940–50s .These reviews were mainly based on fur trade data. Historically, the species was considered to be widely distributed from the Caspian Sea in the west to the Lake Markakol in the east and north from the Kazakh highlands towards the southern borders with Turkmenistan, Uzbekistan and Kyrgyzstan. It is supposed that the species' range declined in the late 20th century in

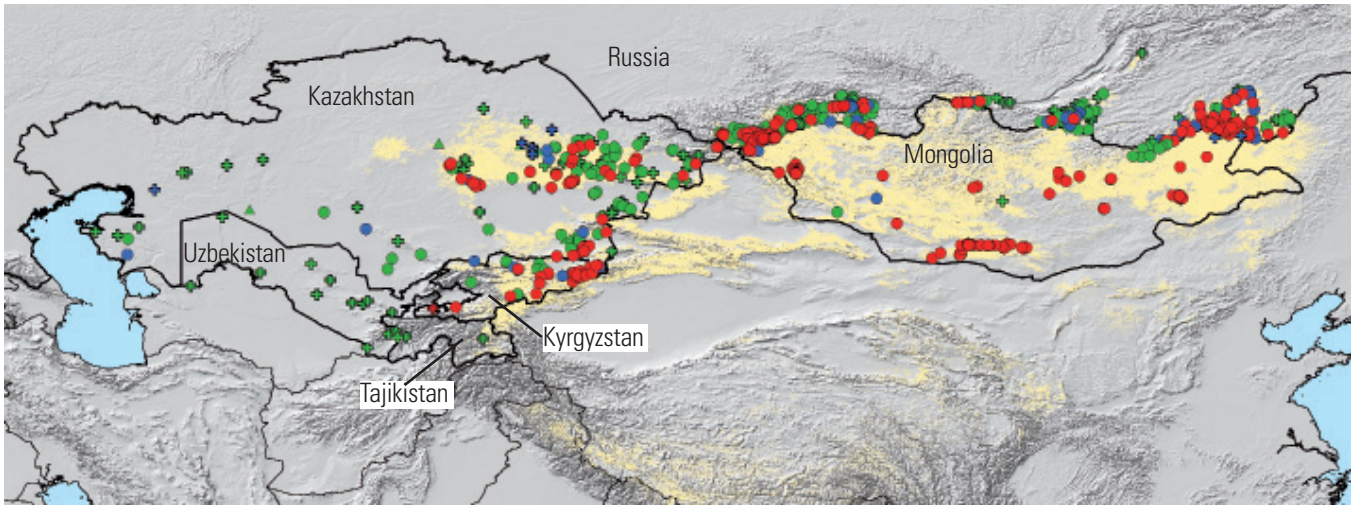

Fig. 1. Geographic distribution of the Pallas's cat in the study region, mapped according to historical (< year 2000; crosses) and contemporary (≥ 2000; circles) occurrence records collated in this study. Triangles = records where the timespan is unknown. Red = confirmed (C1); Blue = probable (C2); Green = possible (C3). Yellow polygons represent the Predicted Area of Suitability (see also SOM).

Kazakhstan (Belousova 1993, Nowell & Jackson 1996; see details of historical distribution in SOM and Fig. 1).

Between 2009 and 2018, studies confirmed the presence of manul in central and eastern Kazakhstan: in the South Altai, East Kazakhstan highlands (including Shynghystau), Tarbagatai Range, northern Balkhash, and central Kazakhstan highlands along the periphery of Betpakdala Desert (Chelyshev 2015, Barashkova & Smelansky 2017, Barashkova et al. 2018). Manuls were occasionally recorded in high mountain areas of Terskei Alatau, Ile Alatau and Jongar Alatau, and at low elevation in the eastern spur of Ile Alatau ridge (Barashkova et al. 2018). No contemporary data is available for the Ulytau, Karatau, and Chu-Ili Mountains. The status of the manul in western Kazakhstan remains unclear as contemporary evidence of the species is missing. Recent camera trap surveys on the Ustyurt Plateau failed to detect the species (Smelansky et al. 2017, Pestov et al. 2017, Pestov et al. in prep.).

The PAS includes the central Kazakh highlands (west to Ulytau low mountains), northern Balkhash, ranges of Kalba, Southern Altai, Tarbagatai, and Saur and its foothills, mountainous areas of the south-eastern and south Kazakhstan, in particular foothills and middle elevations of the Jongar Alatau, Kyrgyz Alatau, and Ile Alatau Ranges, the Chu-Ili and Karatau Mountains. Our model does not predict suitable habitat for manul in western Kazakhstan (Fig. 1; SOM).

Kyrgyzstan

Historically it was believed that the manul inhabits a large part of Kyrgyzstan, predominantly occupying the steppe vegetation belt, but also areas at higher altitude (Heptner & Sludskii 1972). The species was considered to occur in high-altitudinal belts of the Kemin Valley, Issyk Kul Depression, and the Central and Inner Tien Shan Mountains. There was speculation that the species could also occur on the Alai and Turkestan Mountain ridges, as well as the upper reaches of Kara-Kulja and Tar Rivers, but sources for the latter areas are not reliable (Sludskii 1973, Toropova 2006, Vorobeev & van der Ven 2003).

The majority of the contemporary manul data in Kyrgyzstan are camera trap records obtained during extensive studies on the snow leopard particularly in Sarychat Ertash State Reserve and its surroundings (Table 1; Fig. 1). These records are associated with high altitudes, while lower elevations remain unexplored. The other records are from illegally hunted or trapped animals (K. Zhumabai uulu, pers. comm.). Most of the collected data is from the eastern, central and northern parts of Kyrgyzstan. A recent study has shown that manuls also live in the south-western part of the country, although records are few (Barashkova & Gritsina 2018). Interview data suggest presence of manul in the area along the border between Talas and Jalalabad Provinces in the west of the country and in Atbashi District in the south (Gritsina et al. unpubl.). A camera trap picture of a manul in the foothills of the Alai Range in 2018 confirmed its presence in Osh Province (this location is only 10 km from the border with Uzbekistan; Fig. 1).

The predicted PAS includes most ranges of the Tien Shan (without high altitude zones) located in the central and eastern parts of the country, only the mid-mountain parts of the Talas and Ugam Ranges in the west and partially ridges bordering the Fergana Basin from the east and south-east (including Alai and Fergana Ranges; Fig.1).

Mongolia

Historically the manul was considered to occur throughout the country, except in coniferous forests of the Khentei Range and Khovsgol Lake region, alpine zones of Khangai and Mongolian Altai, and extra-arid desert areas in the south (Bannikov 1954, Clark et al. 2006). After 2000, studies on the manul in Mongolia focused on small-scale intensive ecological research in two or three sites (Munkhtsog et al. 2004, Murdoch et al. 2006, Reading et al. 2010, Ross et al. 2010a, b, 2012). The nationwide distribution of the manul has not been studied. Our prediction of suitable areas includes vast territories from eastern Mongolia to the ranges and foothills of the Mongolian and Gobi Altai in the west (excluding forest areas and plains of the Eastern Gobi Desert; Figs. 1–3).

Russia

Manul's distribution in Russia is probably the best studied and described in detail among the range countries (Heptner & Sludskii 1972, Kirilyuk & Puzansky 2000, Barashkova 2005, 2012, Barashkova et al. 2008, 2010, Barashkova & Kirilyuk 2011, Barashkova & Smelansky 2011, 2016, Istomov et al. 2016, Kirilyuk & Barashkova 2011, 2016a, b, Kuksin et al. 2016, Naidenko et al. 2007). Recently, Barashkova et al. (2017) reviewed status, distribution and habitat use of the manul and its presence in Russian protected areas.

Contemporary records confirm the species' historic distribution as described by Heptner & Sludskii (1972). Manul's range in Russia consists of several separate areas in the mountain belt of South Siberia adjacent to the continuous range mainly located in Mongolia: (1) the Altai-Sayan area including southeastern part of Russian Altai and Western Sayan Mountains, (2) Eastern Sayan Mountains (Tunka Mountains, or Tunkinskie Goltsy), and (3) Western and Eastern Trans-Baikal (Fig. 1).

Our PAS model predicted some places that have not yet been sufficiently studied, in particular the Argut River Valley, Ukok Plateau, and Shapshalsky Ridge in Altai, central Tyva (Eastern Tannu-Ola, Eastern Sayan), western Buryatia (Vitim Plateau), and south-eastern Dauria (Fig. 1). Recent records of the manul in the Shapshalsky Range and Eastern Sayan supports our prediction (Barashkova et al. 2018).

Fig. 2. Manul stalking a Brandt's vole in the true grassy steppe in Har Am place, Khalzan soum, Sukhbaatar Province, the east of Mongolia, 20 July 2017 (Photo B. Otgonbayar).

Uzbekistan

Historically the manul was reported to occur in the outcrop massifs of the Central Kyzylkum Desert and in the south-east along the borders with Turkmenistan, Afghanistan, Tajikistan, and Kazakhstan (Heptner 1956, Ishunin 1961, Sapozhenkov 1961, Heptner & Sludskii 1972, Lesnyak et al. 1984; SOM). Since the start of the manul survey in 2013, its presence in the country has not been confirmed. The species has not been recorded by 72 camera traps (> 7,000 trap days) deployed in Western Ghissar Alai, Western Tien Shan, Kyzylkum Desert, and Ustyurt Plateau (Gritsina et al. 2015, 2016, 2017). Camera trap surveys of snow leopards in the Western Ghissar Alai and Western Tien Shan implemented since 2013 did also not reveal manul presence (Esipov et al. 2016, Bykova et al. 2018). Regular inspections of markets with the purpose of finding manuls' skins have not yielded any results since 2006. The most recent, but unconfirmed (i.e. C3), data on manul were sighting claims of the cat by local people in Akbulak River watershed in the Chatkal Range near the border with Kyrgyzstan in 2005 and in the Ghissar Range in 2014 (Gritsina et al. 2017). Indeed, a recent camera trap record of manul in Kyrgyzstan, less than 10 km from the border with Uzbekistan (Barashkova & Gritsina 2018), gives hope that the species has not disappeared from the country. PAS for the manul in Uzbekistan includes the above mentioned outcrop massifs in Central Kyzylkum, Zeravshan and Turkestan Ranges, and the south-western spurs of the Ghissar Range, particularly Baisuntau Mountains (Fig. 1).

Tajikistan

In 1949, manul was caught in the mountains of Rangon, just south of Dushanbe (Heptner & Sludskii 1972). In the east, only one record of the cat was reported in the Central Pamir near the eastern shore of Sarez Lake and the mouth of the Murghab River (R. L. Potapov cited in Sludskii 1973; Fig. 1). Sokov (1973) declared the manul to be extinct or near extinct in Tajikistan.

Tajikistan is the only country in the region where no focused research on the manul has occurred to date. Contemporary data on the species do not exist. The manul has not been recorded by camera traps deployed since 2000 to monitor snow leopard and other wildlife (S. Michel, T. Rosen, R. Muratov, pers. comm.). PAS includes only the valleys and plateaus of Eastern Pamir in the eastern part of the country (including Sarez Lake and Murghab River; Fig. 1).

Fig. 3. Female manul with two kittens, as a part of the larger litter, near their den under rocks in Hustai National Park, Central Province of Mongolia, 30 June 2018 (Photo E. Mashkova).

Population number

No evidence-based assessment of manul population size has been made for the study region. A few attempts to estimate population numbers for several Russian provinces were based on snow tracking data in combination with expert opinions (see SOM). We estimated the potential population size in the region as approximately 49,000–98,000 manuls (Table 3). This estimation is highly speculative and the value is rough, but reveals the magnitude of the possible population until better estimations are available.

Habitat

The manul's range in Central Asia and adjacent territories covers a vast area with high climatic and landscape diversity. The manul's regional EOO covers mainly mountains and highlands (Fig. 1). All known contemporary C1 and C2 records (n = 589) are located between 440 and 3,730 m. The species occupies different habitats in different parts of its range. All habitat types have three common features: (1) continental cold, semi-arid climate with cold but low snow precipitation in winter and a hot dry summer; (2) presence of appropriate rocky shelter, both natural or constructed by other mammals or human-made; and (3) presence of colony-forming non-hibernating rodents or pikas.

Based on our observations and published data (Heptner & Sludskii 1972, Sludskii 1982, Kirilyuk & Puzansky 2000, Medvedev 2010, Munkhtsog et al. 2004, Ross et al. 2010a, b, 2012, Istomov et al. 2016) we identified two main habitat types: (1) Low erosion hills with rock outcrops and scree on slopes and crests, frequently granite, covered with petrophytic dry steppe or semi-desert vegetation. This habitat type is found throughout the range in Russia and Central Asia, on hilly plains, foothills, elevated plateaus and intermountain valleys in many mountain systems (Heptner & Sludskii 1972, Sludskii 1982, Kirilyuk & Barashkova 2011, 2016 b); (2) Ravines, rocks, and scree, covered with petrophytic dry steppe or semi-desert vegetation along slopes and pediments of mountainous ridges at higher altitudes of Inner Asia, Southern Siberia, and the Tien Shan Range (Kirilyuk & Puzansky 2000, Toropova 2006, Barashkova & Smelansky 2011, Kirilyuk & Barashkova 2011, Istomov et al. 2016). Accordingly to our observations (240 C1 and C2 locations) the vegetation cover in both types is typically semi-arid petrophytic grassland – dry steppe, desert steppe, or semi-desert (northern desert) dominated with low xerophytic and petrophytic grasses and low shrubs, particularly species of the genera *Stipa*, *Artemisia*, *Salsola*, *Nanophython*, and *Ephedra*. Steppe shrubs (e.g. *Caragana*, *Spiraea*, *Cotoneaster*, *Lonicera*) are also common in these habitats, forming distinctive shrub patches or scattered through the grasslands.

Five other habitat types can be recognised in the region (see SOM). They are marginal and situated only in the eastern part of the regional range, east of the Altai.

Table 3. Manul population size estimation based on the EOO and an assumed lower (4 cats/100 km²) and higher (8 cats/100 km²) density, respectively*.

Country	Lower bound (4/100 km²)	Upper bound (8/100 km²)
Mongolia	26,476	52,953
Russia	4,724	9,449*
Altai-Sayan	2,083	4,166
Eastern Sayan	10	21
Western Trans-Baikal	273	546
Eastern Trans-Baikal (Dauria)	2,358	4,716
Kazakhstan	10,592	21,184
Kyrgyzstan	1,263	2,526
Tajikistan	NA	NA
Uzbekistan	NA	NA
Total	**49,013**	**98,025**

**This estimate does not take into account the significant changes in the number of manul (up to 5-10 times) for several years, shown for example, for Russian Dauria (V. Kirilyuk, pers. comm.; see also SOM).*

Prey

The principal prey base of the manul in the region consists of small and medium-sized, non-hibernating colony-forming rodents and pikas (Heptner & Sludskii 1972, Sludskii 1982, Kirilyuk & Puzansky 2000, Jutzeler et al. 2010, Barashkova et al. 2017). In central Kazakhstan, Sludskii (1982) considered Kazakh pika *O. opaca* (referring as Mongolian pika *O. pallasii*) as the main prey and steppe pika *O. pusilla*, flat-headed mountain vole *Alticola strelzowi*, common vole *Microtus arvalis*, and birds such as common partridge *Perdix perdix* and larks (especially *Melanocorypha* spp.) as secondary prey for manul (Fig. 4; SOM). In the Tian-Shan highlands, Sludskii (1982) presumed the main prey to be Turkestan red pika *O. rutila*, large-eared pika *O. macrotis*, silvery mountain vole *A. argentata*, and narrow-headed vole *M. gregalis*. Daurian pika, Mongolian pika, and mountain voles (mainly flat-headed mountain vole) are considered key prey for manul in Russian Altai (Barashkova 2017). Other prey species here include long-tailed suslik *Spermophilus undulatus*, young marmots of various species, and tolai hare *Lepus tolai* (Sludskii 1982). Large-eared mountain vole *Alticola macrotis* and silvery mountain vole are referred as the most important prey on the northern edge of the manul's range, in the East Sayan Mountains, where the cats also consume alpine pika *O. alpina*, young snow hare *L. timidus*, rock ptarmigan *Lagopus mutus*, and other birds (Medvedev 2010). In years when the Daurian partridge population peaks, it is an important prey for manul in Dauria (V. Kirilyuk, pers. comm.). Daurian partridge is also considered key prey for manul in areas on the northern edge of the range, in the Western Sayan (Istomov et al. 2016).

Fig. 4. Kazakh pika (Photo A. Lissovsky).

Using 249 identified prey remains in 146 scats collected from radio-collared manuls in Hustai National Park in Central Mongolia, Ross et al. (2010) revealed that 85.5% of prey items were small mammals. Daurian pika *Ochotona dauurica*, Mongolian gerbil *Meriones unguiculatus*, and Mongolian silver vole *Alticola semicanus* were the most frequently consumed ones (frequency of occurrence was 60.9%, 35.6%, and 28.1% respectively). Prey selection analysis indicated a preference for Daurian pika irrespective of its density.

Another quantitative investigation in Russian and Mongolian Dauria analysed 490 manul scats and prey remains collected from radio-collared and snow-tracked manuls as well as close to dens (Kirilyuk 1999). Mammal remains occurred in 66.5% of the sample and Daurian pika was the most frequently consumed prey species (55.5%). No other mammal species exceeded 1.2%. Mongolian hamster *Allocricetulus curtatus*, Brandt's vole *Lasiopodomys brandti*, voles *Microtus* spp., and tarbagan marmot *Marmota sibirica* oc-curred each in 1.0–3.7% of manul scats. Other mammals (including Mongolian five-toed jerboa *Alactaga sibirica*, Siberian dwarf hamster *Phodopus sungorus*, and weasel *Mustella nivalis*) were recorded only once. Pacific swift *Apus pacificus* was present in 8.2% of the scats. Insects were consumed even more frequently than birds (22% in total), mainly large beetles Scarabaeidae and orthopterans. Daurian pika was especially important prey in winter (occurrence reached 95%). The prevalence of insects and birds in the summer diet and a large proportion of berries in the winter diet were possibly the consequences of unfavourable conditions regarding primary food sources such as Daurian pika and other small mammals (Kirilyuk 1999).

Threats

During the Soviet time in the mid-20th century, main threats to the manul in the region were habitat loss and habitat degradation (including overgrazing, soil erosion, habitat fragmentation, etc.) due to large-scale conversion of steppe grasslands into arable farmland. Over 452,000 km² of dry steppe grasslands were converted into permanent arable land during the Soviet "Virgin Land Campaign" from 1954–1963, mainly in Kazakhstan and Russia (Bragina et al. 2018, Reinecke et al. 2018). Similar campaigns in Mongolia affected over 10,000 km² in 1959–1980 (Davaajav 2017). After the USSR

collapsed in 1991, these threats dropped sharply in Russia and Kazakhstan as vast areas were abandoned (Smelansky & Tishkov 2012, Wesche et al. 2016, Kamp et al. 2016, Bragina et al. 2018, Reinecke et al. 2018). However, overgrazing and its secondary effects such as decreased habitat protection and increased disturbance by humans and herding dogs, is a persistent issue and has even worsened in Mongolia (Pfeiffer et al. 2018) and to a lesser extent in Uzbekistan (Yang et al. 2016). Over the last 15 years, arable land and livestock numbers partly recovered in the rest of the region (Priess et al. 2011, Kraemer et al. 2015, Meyfroidt et al. 2016, Wesche et al. 2016, Bragina et al. 2018, Reinecke et al. 2018).

Killing by herding dogs is one of the most important causes of human-related death of manuls (Ross 2009, Sokolov 2012, Barashkova 2012, 2017). In Russia about 25% of respondents interviewed in Altai Republic in 2006 and 2009 (n = 52) and 20% of respondents interviewed in Tyva Republic (n = 145) reported manul being killed by their herding dogs (Barashkova & Smelansky 2011, Barashkova 2012). In Dauria in 1990s killing by dogs caused manul's death in 8 of 33 known cases (Kirilyuk & Puzansky 2000). Nonetheless, manuls are capable to reoccupy human-disturbed habitats as soon as pastoralists abandon the rangeland, if there is a strong prey base and limited snow precipitation (V. Kirilyuk, pers. obs.).

Approximately a century ago, manuls were extensively hunted for their skins, specifically in Mongolia (Shnitnikov 1934, Bannikov 1953, 1954, Wingard & Zahler 2006; Table 4).

To the 1950s the manul's pelt export from Mongolia seems to have practically ceased despite ongoing hunting and continuing domestic trade (Wingard & Zahler 2006).

Mongolia' hunting records in 1958–1960 revealed that 5,500 individuals were killed annually (Clark et al. 2006). According to records from the National Archive Center in Ulaanbaatar, 5,537 manuls were hunted (and traded) in Mongolia in 1962, while the target figure was 7,500 (N. Battogtokh, unpubl. data). In the period 1965–1985, over 5,400 manul skins were traded in the country annually (Wingard & Zahler 2006). No contemporary data on trades of manul skins in Mongolia is available but legal hunting in the 2000s was estimated at 2,000–4,000 annually (approximately 1,000 manul hunters with a mean harvest of 2–4 cats per hunter; Wingard & Zahler 2006; Chapter 6).

Poaching takes place occasionally in every country – for pelts, to suppress predators, or just for entertainment (Fig. 5). Quantitative data do not exist, but poaching is considered to be the primary threat in Russian Dauria (Kirilyuk 2012). In the 1990s Kirilyuk & Puzansky (2000) reviewed 33 cases of human-related deaths of manuls in Dauria; 23 were victims of poaching. Unintentional killing of manuls during trapping for other mammals occurs almost everywhere in the study region (Toropova 2006, Sokolov 2012, Kirilyuk 2012, Borisova & Medvedev 2013, Kuksin et al. 2016, Barashkova 2012, 2017, our data).

We collected data on 50 contemporary (≥ year 2000) incidents of manul mortalities in Russia and Kazakhstan. Approximately half of them (22 of 50) were inflicted by herding dogs. In five cases (10%), manuls were accidentally trapped. There was a single confirmed intentional trapping for fur and six kills for unknown reasons. Other ascertained causes were starvation or disease (n = 3), vehicle accident (n = 2), and killing by eagle (n = 1).

Poisoning is recognised as a potentially important threat to manuls in the region (Barashkova 2017). Using poisoned bait as a predator control method has been banned or severely restricted for several decades. Yet, poisonings of the manul's primary prey (rodents and pikas) for pest (Brandt's vole in Mongolia; Tseveenmyadag & Nyambayar 2002) or disease control (several species of pikas and rodents are controlled as vectors of plague in the region) is an ongoing practice (A. V. Denisov, pers. comm., Popova et al. 2018). In 2001–2003 poisoning campaigns to control Brandt's vole in Eastern Mongolia using bromadialone had a devastating effect on both raptors and predatory mammals (Tseveenmyadag & Nyambayar 2002). This activity in Mongolia is currently being phased out as the effect on non-target species is better understood (N. Batsaikhan, pers. comm.). More recently bromadialone was in use in Russia as a part of a system of measures to prevent plague in the Kosh-Agach district of Altai Republic (A. V. Denisov, pers. comm., Popova et al. 2018). Similar incidents involving other pesticide or other countries are a continuous risk.

Mining is recognised as a potential significant threat to critical manul habitats in Russia, Kazakhstan, and Mongolia (Reading et al. 2010, Smelansky & Tishkov 2012, Kamp et al. 2016, Wesche et al. 2016). Steppe fires also appeared to be a limiting factor for the manul in several areas such as Buryatia (Borisova & Medvedev 2013), Trans-Baikal Territory of Russia, and North-Eastern Mongolia (V. Kirilyuk, pers. comm.).

Climate change is an emerging potential threat. Manul is strongly affected by harsh winter conditions, especially deep snow and ground surface icing (Sludskii 1973, 1982, Kirilyuk 2012, Kirilyuk & Barashkova 2016a, b, Barashkova 2017, Kuksin 2018). Deep snow with severe prey depression lead to a strong reduction in the number of manuls (Kirilyuk & Barashkova 2016a, b). Different climate change scenarios for the period 2020–2080 predict that climate in Southern Siberia and Inner Asia will generally become warmer, partly more humid and with higher winter precipitation (Tchebakova et al. 2009, Shvidenko et al. 2013, Lioubimtseva & Henebry 2009, Poulter et al. 2013). It could result in more snow, afforestation of steppes, and increased wildfires – all negative changes for the manul in the region.

Manul may come into contact with at least four different pathogens possibly transmitted by other wild mammals and domestic cats *Felis catus* (Naidenko et al. 2014, Pavlova et al. 2015). *Toxoplasma gondii* results in high mortality in young manuls in captivity (Dubey et al. 1988, Basso et al. 2005) and may threaten the survival of local populations in the wild, as 9% of manuls and 15% of sympatric feral/domestic cats are serum positive to this pathogen in Dauria (Pavlova et al. 2016). Toxoplasma antibodies were also found in wild rodents and pikas in the manul range (Pavlova et al. 2016). Feline panleukopenia virus and feline calicivirus are other potentially dangerous pathogens. In the vicinity of the Daursky Reserve 45–60% of tested domes-

Table 4. Export of manul pelts from Mongolia.

Period	Pelts per year on average	Reference
1900–1910	50,000	based on trade data in Urga, presented by V. Flanden 1912
1927–1929	6,400	Bannikov 1954
1931–1932	1,600	Bannikov 1954
1940s	600–650	Bannikov 1954

tic cats were serum positive to the viruses while no manuls were. This could be interpreted as extreme susceptibility of manuls to these viruses with a high degree of lethality (Naidenko et al. 2014, Pavlova et al. 2015; Chapter 9).

Conservation

Although formally strictly protected in most countries of the region (see Chapter 6) manul is not focus of special conservation efforts. In Russia, there have been attempts to incorporate manul research into official research plans in relevant protected areas. Nonetheless, only Daursky Biosphere Reserve is engaged in ongoing study and active protection of the manul. Other protected areas in Russia collect manul data opportunistically in the course of camera trap studies, routine winter snow-tracking censuses, and other field-based activities (Belov 2015, Istomov et al. 2016, Kuksin et al. 2016). In-situ conservation of the species occurs mainly through prohibition or regulation of hunting and trade, and habitat conservation within protected areas. Ka-zakhstan, Kyrgyzstan, and Russia prohibit hunting and trade in manul, Uzbekistan restricts it, and Mongolia restricts hunting and regulates trade; the situation in Tajikistan is unclear (see Chapter 6 for details).

At least 12% (approximately 180,000 km^2) of the regional PAS is situated in at least 170 protected areas of Russia, Mongolia, Kazakhstan and Kyrgyzstan; the species is documented in 36 of them. The percentage of the protected PAS per country varies from 5.6 to 14.7% (Table 5; see also SOM). The largest share of national suitable habitats is situated in the protected areas of Mongolia (almost 15%) that is almost 72% of the estimated PAS within the protected areas of the region.

Concluding remarks

Despite the long history of studying manul in the region there is lack of knowledge in many aspects of its ecology and biology. Thus, we still know little about home range, dispersal, competition with other predators, and population dynamics. Moreover, several significant gaps remain with regard to the species distribution. First, spatial pattern of the species range in Mongolia, presence status in Uzbekistan, Tajikistan, and western part of Kazakhstan should be revealed.

Correct assessment of population number and dynamics is another important future task. Increased knowledge will lead to more effective conservation measures including creation of targeted protected areas to secure manul and its habitats in key territories, mitigating dog collisions and poaching, and establishing a broad network to monitor manul populations and threats.

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Fig. 5. Fur-cap made of manul fur offering for sale in a souvenir shop in Ulaanbaatar, Mongolia, April 2007 (Photo A. Barashkova)

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Table 5. National Predicted Area of Suitability PAS and confirmed manul presence in protected areas.

Country*	Total (km²) and relative (%) share of national PAS within protected areas	Number of protected areas within PAS (Number of protected areas with contemporary C1 data)
Kazakhstan**	24,397 (7.2%)	31 (5)
Kyrgyzstan***	4,347 (5.6%)	20 (3)
Mongolia	125,126 (14.7%)	76 (13)
Russia**	16,329 (9.3%); 21,119 (12.0%) including buffer zones	43 (15)

** Except Tajikistan and Uzbekistan from where the data on protected areas were not processed in this study*

*** See SOM for details*

**** The strict protected areas and national parks only (without wildlife refuges)*

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Supporting Online Material is available at www.catsg.org.

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Recent studies of the manul

Not less than 30 projects especially devoted to the investigation of manul distribution, number, ecology and behaviour have been conducted in the region since 1990s (SOM T1, SOM F1).

SOM T1. Information on manul projects implemented in Central Asia and adjacent areas since 1990s.

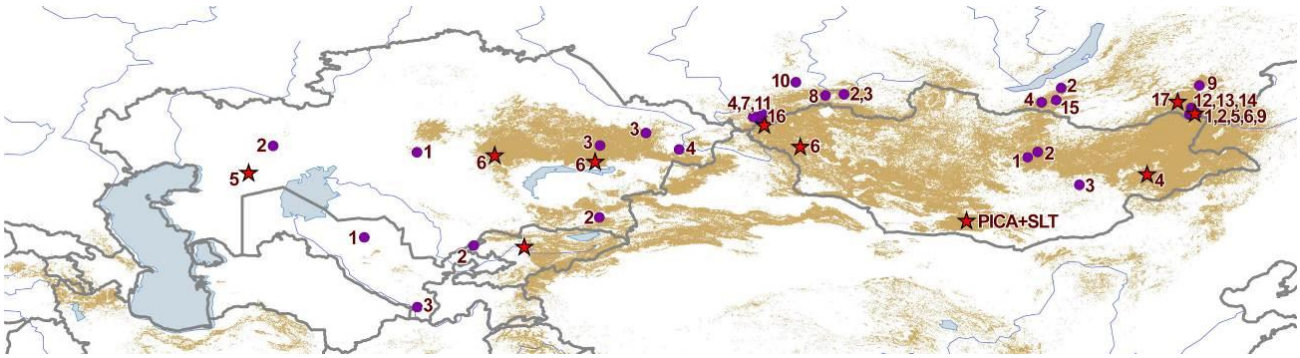
№	Period	Project name	Financing	Leader(s) / Organisation	Main achievements
Kazakhstan					
1	2009–2010	Clarifying conservation status of Pallas's cat in Kazakhstan	Rufford Foundation	Anna Barashkova / Sibecocenter	Reconnaissance research throughout Kazakhstan. Some data on past and modern Pallas's cat number and distribution and threats obtained. Spatial GIS database created. Educational posters on Pallas's cat distributed among local people (Barashkova 2010, 2011a; Barashkova et al. 2010a)
2	2011–2012	Creating a base for monitoring of Pallas's cat in Kazakhstan	Rufford Foundation, SWCCF, EARAZA Project	Anna Barashkova / Sibecocenter	First camera trap research in Kazakhstan (Aktobe and Almaty province). Analysis of distribution of manul in connection with distribution of main potential prey species and suitable habitats. Information on presence of manul in protected areas obtained (Barashkova & Smelansky 2012).
3	2013–2014	Pallas's cat in Kazakhstan: from investigation to conservation	Rufford Foundation	Anna Barashkova / Sibecocenter	Camera trap data on manul in eastern Kazakhstan obtained, data on threats updated (Barashkova et al. 2014).
4	2014–2016	Pallas's cat conservation status in the Zaissan Lake area - covering blanks	MbZSCF	Anna Barashkova / Sibecocenter	Presence of manul confirmed in most eastern Kazakhstan, in South Altai, and in low hills to the west of Zaissan Lake (Barashkova et al. 2015, 2016; Barashkova & Smelansky 2017).
5	2016–current	Study of distribution of felidae species on the Ustyurt plateau	ACBK, PICA	Ilya Smelansky / Sibecocenter	Camera trapping in western Kazakhstan, but no confirmation of presence of manul (Smelansky et al. 2017).
6	2017–2018	Pallas's cat in Kazakhstan: from investigation to conservation - Phase 2	Rufford Foundation	Anna Barashkova / Sibecocenter	Investigated new areas in the Central Kazakhstan (Karaganda province). Northern Balkhash Lake area was considered as place of great importance for the manul in Kazakhstan. Created a MaxEnt distribution model (Barashkova 2018).

№	Period	Project name	Financing	Leader(s) / Organisation	Main achievements
			Kyrgyzstan		
1	2017–2018	Clarifying conservation status of Pallas's cat in Kyrgyzstan	MbZSCF, PICA	Anna Barashkova, Maria Gritsina / PCWG	First special research of species distribution in Kyrgyzstan (interviews, camera trapping in western and central parts). The species presence confirmed for the first time in the western part of the country; data from interviews and camera trapping of other wildlife entered into national database on manul (Barashkova & Gritsina 2018).
			Mongolia		
1	2000–2001	Ecology and behavior of Pallas's cat in Mongolia	Ohio State University SOAR program and Alumni Society, Columbus Zoo and Aquarium, Cincinnati Zoo & Botanical Garden, Wild About Cats, Woodland Park Zoological Gardens, and Disney's Animal Kingdom	Meredith Brown & Bariushaa Munkhtsog / Cincinnati Zoo, Michigan State University & Mongolian Academy of Science	First study of ecology and behaviour, biomedical parameters of wild manuls in Mongolia (Altanbulag, Central Mongolia). Discovered that wild manuls are minimally exposed to *T. gondii* in natural habitat and are only infected with this parasite when brought into captivity (Brown et al. 2005). First investigation of home ranges of manuls in Mongolia (Munkhtsog et al. 2004).
2	2005–2007	Providing an ecological basis for the conservation of the Pallas's cat (PhD)	Leverhulme Trust, Panthera/Wildlife Conservation Society Kaplan Award, the Royal Zoological Society of Scotland, Royal Geographic Society, Small Cat Conservation Alliance, Dulverton Trust, Cincinnati Zoo and Botanical Gardens	Steve Ross	First comprehensive ecological study of manul. Home range size found to depend on year, season, sex, and habitat configuration. Data on habitat selection patterns, effects of competition and intra-species interactions, diet and feeding plasticity, mortality, seasonal body mass, reproduction and survival rates and other ecological traits obtained (Ross et al. 2010a, b, 2012).
3	2006	Evaluating the Impacts of Carnivore Hunting in the Grassland and Semi-Desert Steppes of Mongolia	Denver Zoological Foundation, Rufford Foundation, Trust for Mutual Understanding, Small Cat Conservation Alliance	James Murdoch / Wildlife Conservation Research Unit, University of Oxford	Preliminary data on home ranges, diet and other ecological traits of carnivore species inhabiting Ikh-Nart Nature Reserve. Impacts of carnivore hunting evaluated (Murdoch et al. 2006).
4	2018-current	Breeding and none breeding habitat occupancy and movement of Pallas' cat: implication for conservation of wild cat. Manul education programme	Rufford Foundation	Buyandelger Suuri & Otgonbayar Baatargal / Institute of General and Experimental Biology, Mongolian Academy of Sciences	Occupancy survey in Sukhbaatar aimak, eastern Mongolia, revealing that 69% of habitat occupancy are associated with rocky areas (Buyandelger 2018, unpub. data).

№	Period	Project name	Financing	Leader(s) / Organisation	Main achievements
5	2018–current	Pallas' cat distribution and habitat suitability in Western Mongolia	MUSE, Panthera, University of Lausanne	Ibra Edoardo Monti, Francesco Rovero (supervisor) / Green Initiative	Aim of study: identification of manul habitats using camera traps and DEM (digital terrain model) data to improve conservation. The project implemented as part of a snow leopard programme.
			Russia		
1	1992–1997	Manul research in Trans-Baikal Area (Zabaikalsky Krai)	Federal budget, private donors	Vadim Kiriliuk / Daursky Biosphere Reserve	Data on distribution and abundance, habitat preferences and diet in Russian Dauria obtained (Kirilyuk 1999; Kirilyuk & Puzansky 2000)
2	2004–2005	Save the manul: initial step.	GGF	Anna Barashkova / Sibecocenter	Special programme on manul research and conservation initiated. Website SaveManul http://savemanul.org created. Reviews of status of Pallas' cat in Russia and Kazakhstan, measures needed for conservation of the species prepared (Barashkova 2005). Information and organisational basis for long-term programme for study and conservation of manul in the wild created.
3	2005–2006	Monitoring of animal species listed in the Red Book of Russia in the Republic of Tuva: manul	Regional budget	Ubsunurskaya Kotlovina Biosphere Reserve, Tyva State University	Data on distribution and abundance of the manul and threats in Tyva Republic summarised; increase in both concluded (Anonymous 2006).
4	2006–2007	Pallas' s cat: investigation for saving (Clarifying conservation status in Russia)	PTES	Anna Barashkova / Sibecocenter	First special census of manul conducted in Republics of Altai and Buryatia, hot spots of the species in Russia identified (Naidenko et al. 2007, Barashkova et al. 2008, 2010b).
5	2006–2010	Radiotelemetry research in Daursky reserve		Vadim Kirilyuk / Daursky Biosphere Reserve	Preliminary data on habitat use, sizes of home ranges and dispersal of manul in Russia (Barashkova & Kirilyuk 2011; unpub. data).
6	2008–2010	Study of Pallas's cat ecology and behavior in wild	Explorers Club, Daursky Bioshpere Reserve	Alina Baranova & Aldar Dambain; V. Kirilyuk & T. Tkachuk (supervisors)	Data on maternal behaviour (activity patterns, home range, number and development of cubs) in Daursky reserve (Dambain et al. 2011)
7	2009–2010	Pallas's cat in Altai mountain area; update of conservation status	Panthera Foundation	Anna Barashkova / Sibecocenter	Repeated snow-tracking census in Altai Republic, number estimation, specifying threats and educational campaign (Barashkova et al. 2010b, Barashkova & Smelansky 2011).

№	Period	Project name	Financing	Leader(s) / Organisation	Main achievements
8	2010–2011	Base for Pallas's cat populations monitoring in Tyva Republic and adjacent territories	Panthera Foundation	Anna Barashkova / Sibecocenter	Winter snow-tracking, density estimation, interviewing of locals, and hot spots evaluation in Tyva Republic (Barashkova 2011bc, 2012).
9	2010–2011, 2016	Estimation of number and main factors influencing population status of Pallas's cat in Zabaikalsky Krai	UNDP/GEF Project "Improving the coverage and management efficiency of protected areas in the steppe biome of Russia"	Vadim Kirilyuk / Daursky Biosphere Reserve	Repeatedly in 5-year period data on number and distribution, threats in Russian Dauria were obtained through snow-tracking census and interviewing (Kirilyuk & Barashkova 2011, 2016ab).
10	2012–2013	Wild Cats of South Siberia	Russian Geographic Society	Sayano-Shushensky Biosphere Reserve, Khakassky Nature Reserve	Unknown
11	2012–2014	Pallas's cat monitoring in Altai Republic	SWCCF, EARAZA Project, GGF, Altai Project, Biosphere Expedition	Anna Barashkova / Sibecocenter	Special camera trap research in Altai Republic (Barashkova & Smelansky 2016). Online database on small wild cats in Eurasia (http://wildcats.wildlifemonitoring.ru) created (Barashkova 2016).
12	2013–2014	Pallas's Cat conservation in Trans-Baikal Area	Russian Geographic Society	Vadim Kirilyuk / Daursky Biosphere Reserve, Severtsov Institute of Ecology and Evolution	Data on distribution, biology and threats of the Pallas's cat.
13	2014–2016	Ecological background and factor risk of pathogen infections in felines inhabiting extreme areas (Pallas's cat as example)	Russian Foundation for Basic Research	Sergey Naidenko / Severtsov Institute of Ecology and Evolution, Daursky Reserve	Seroprevalence to 15 pathogens estimated for Pallas's cat and sympatric domestic cats (Naidenko et al. 2014, Pavlova et al. 2015, 2016)
14	2015–2016	Comparative estimation of physiological indicators of infection resistance in felidae	Russian Foundation for Basic Research	Sergey Naidenko / Severtsov Institute of Ecology and Evolution, Daursky Reserve	The innate immune response in Pallas's cat was less than in domestic and Amur cats. Home range of Pallas's cat may be up to 450 km² (S. Naidenko, pers. comm.).

№	Period	Project name	Financing	Leader(s) / Organisation	Main achievements
15	2016–2017	Study of manul in the Altachei Wildlife Refuge, Buryatia Republic	Baikalsky Reserve (in the frames of scientific programme)	Eugenia Shelest / Baikalsky Reserve	Manul presence confirmed in the Altachei Wildlife Refuge and its vicinity (Shelest & Khidekel 2016, Shelest 2018).
16	2016–2018	Monitoring of the manul in Sailugem National Park and adjacent areas	PICA, SWCCF, Rufford Foundation, Sailughem NP	Anna Barashkova / Sibecocenter, Sailughem National Park	Started the monitoring of species in the Sailughem ridge using camera trapping.
17	2017–current	Study and conservation of snow leopard and other rare animals in Eastern Siberia	No data	Snow Leopard Fund - Irkutsk	Camera trap data on manul in Trans-Baikal area obtained.
			Uzbekistan		
1	2013–2015	Specification of the status of the Pallas's cat and sand cat in Central Kyzylkum desert (Uzbekistan)	MbZSCF	Maria Gritsina / Institute of Zoology, Academy of Science of Uzbekistan	Camera trapping and interview survey did not confirm the presence of the manul in Central Uzbekistan (outcrops of Central Kyzylkum Desert; Gritsina et al. 2015).
2	2015–2016	Specification of the status of the Pallas's cat (*Otocolobus manul*) in Uzbekistan	Rufford Foundation	Maria Gritsina / Institute of Zoology, Academy of Science of Uzbekistan	Camera trapping and interview survey did not confirm presence of manul in east of country. In western Tien Shan and western Gissar-Alai Mountains only C3 data obtained (Gritsina et al. 2016).
3	2016–2017	Specification of the status of the Pallas's cat (*Otocolobus manul)* in the south of Uzbekistan	PICA	Maria Gritsina / Institute of Zoology, Academy of Science of Uzbekistan	Camera trapping and interview survey did not confirm presence of manul in the south of country – in the spurs of Gissar-Alai Ridge (Gritsina et al. 2017).
			Range-wide		
1	2016–2019	Conservation of the Pallas's cat through capacity building, research, and global planning	Segre Foundation	Emma Nygren & David Barclay / PICA	First global strategy for Pallas's cat conservation developed with key species specialists; increased financing and field project support, education and global awareness. Camera trap data on manul summarised in collaboration with Snow Leopard Trust (PICA+SLT).



SOM F1. Map of projects (violet circles – completed, red stars – ongoing). Projects are numbered per country (№ in SOM T1).

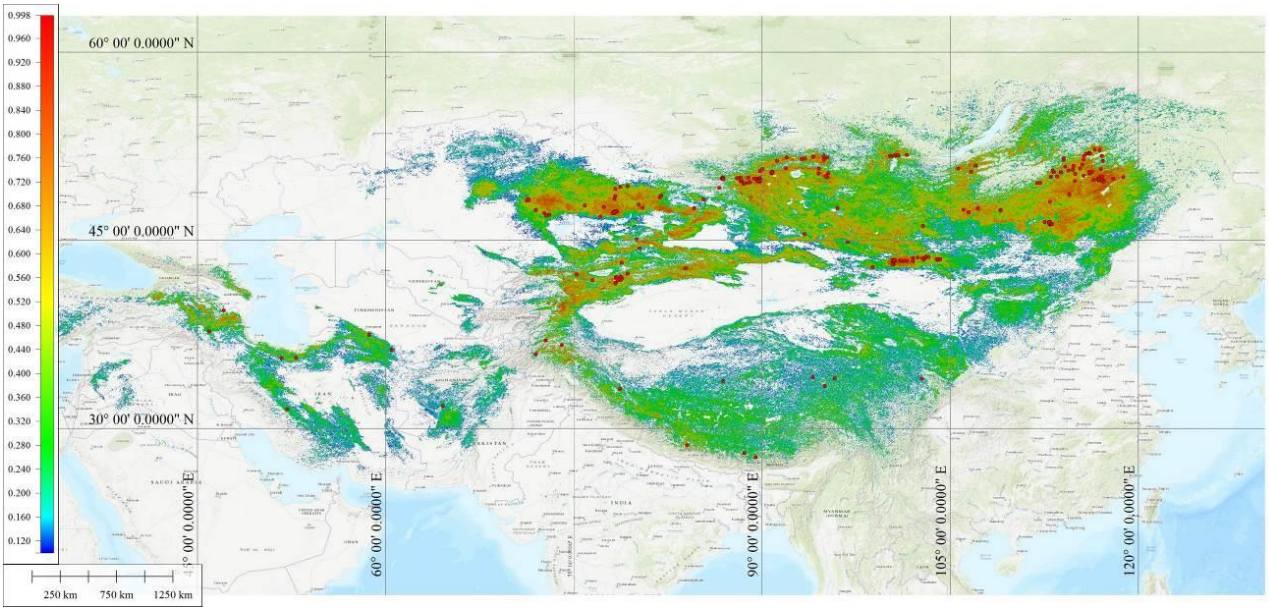
Methods: Mapping of potentially suitable habitats

Mapping of potentially suitable habitats for manul was performed using MaxEnt 3.3.3k (Phillips et al. 2006, Phillips & Dudik 2008) on the basis of analysis of three kinds of spatial data as well as a set of records with accurate geographical coordinates (data source described under Methods of the article). The major data set (377 records) represented observations mainly from Russian territory. Additional records (232) were taken from positive camera trap locations across Kazakhstan, Kyrgyzstan, Mongolia and Russia. The spatial distribution of the whole data set (609 records) was neither random nor homogenous. For example, two distribution patches in Altai Mountains and Trans-Baikal region in Russia were studied with incomparably higher density of observation efforts than other parts of the range. In order to smooth the distribution of the records, we covered all the manul range with a 50 x 50 km grid. After that, we selected randomly only one occurrence record per grid cell. Thus, the final dataset used in the analysis contained 398 records (SOM F2).

Since observation efforts in looking for the manul were not randomly distributed, using of random selection of background points for analysis may distort the results. Therefore, we prepared an additional layer for MaxEnt "bias file". We set the value 1 for each cell of this layer but the value 10 for the cells situated within 5 km buffer zones around all records and around locations of camera traps that did not register manul in the region.

The following environmental layers were used for modelling: (1) a remote survey from the Terra satellite's MODIS scanning system, 77 layers at a resolution of 500 m (http://glcfapp.glcf.umd.edu:8080/esdi/): 7 spectral bands for 11 subsequent months of 2004; (2) 19 "bioclimatic" variables hypothetically relevant to the distribution of biological objects (Hijmans et al. 2005; WorldClim data at a resolution of 30 minutes (>1 km); http://www.worldclim.org); (3) topographic data (altitude, slope gradient and curvature). All layers were converted to the same extent and grid cell of 0.02° in WGS84 longitude/latitude projection. Raster processing was done in Scanex Image Processor v.4.2.14. Mapping was performed using Mapinfo 11.0.

The resulted area of suitable habitats was obviously larger than the real confirmed manul distribution (SOM F2). We applied maximum training sensitivity plus specificity logistic threshold (Liu et al. 2013) and our expert data on the manul presence in the northern periphery (see Methods in Chapter 3) to remove extra territory (see Fig. 1 in Chapter 3). Resulted distribution was similar to our expert evaluation.



SOM F2. Spatial distribution of suitable habitats (red = well suited) for the manul from MaxEnt analysis. No threshold applied. Records used in the analyses are shown as red dots.

Historical distribution

Kazakhstan

Heptner & Sludskii (1972) and Sludskii (1973, 1982) reviewed the distribution of Pallas's cat in Kazakhstan. This detailed review represented the situation in the 1940 and 50s and was based mainly on fur trade data (i.e. number of harvested skins by province). The species was considered to be widely distributed from the Caspian Sea in the west to the Lake Markakol in the east and north from the Kazakh highlands to the republic's border on the south. These and other (Zaletaev 1976) authors reported the Pallas's cat as a rare species in western Kazakhstan namely occurring on Manghyshlak (now Manghystau) Peninsula, on cliffs of the Ustyurt plateau, in the middle Emba river and Mugodzhary hills. In the south the presence of the species was speculated to occur in small outcrops situated in the Kyzylkum Desert and the Karatau Mountains. In south-eastern Kazakhstan, it was rarely harvested in Chu-Ili Mountains, mountains of Trans-Ili Alatau (=Ile Alatau), Terskei Alatau, Dzungarian Alatau (also known as Jongar Alatau) and Ketmen ranges, Arganaty and Kzyl-Torgai erosion hills, and in the Saikan Mountains. In the north-east, the Pallas's cat was found in the South Altai, Tarbagatai, and Saur mountain ranges. The species was considered to be common in the Shynghystau range and relatively frequent in the central Kazakhstan highlands.

Uzbekistan

Heptner & Sludskii (1972) and Ishunin (1961) reported the presence of manul in south-eastern Uzbekistan in the upper Surkhandarya River valley near Saryassiya and in south-western spurs of the Ghissar Range, Baisuntau and Kughitangtau Mountains near Shirabad. They suggested that the species also inhabits the northern and western foothills of Zeravshan and Turkestan Ranges, namely Aktau, Karatau, Malguzar, and Nuratau Mountains, but no confirmed records existed. They speculated that the species inhabits the outcrop massifs of Bukantau, Tamdytau, and Kuljuktau situated in the Kyzylkum desert between Amudarya and Syrdarya rivers, and also in the Sultanuizdag Mountains east of the Amudarya Delta. Mitropolsky (1979) and Lesnyak et al. (1984) reported occasional skins brought to Bukhara for the fur industry from the area of Shirabad and Saryassiya and from the outcrops of the mountains near the Kyzylkum Desert. The Pallas's cat was also reported from the Karakalpakstan part of the Ustyurt Plateau: from both cliffs (*chink*s) and inselbergs of the southern and western Ustyurt as well as from the Kaplankyr cliffs (Heptner 1956,

Ishunin 1961, Sapzhenkov 1961, Heptner & Sludskii 1972, Lesnyak et al. 1984). With the exception of the Central Kyzylkum Desert, these areas are situated along international borders with Turkmenistan, Kazakhstan, Tajikistan, and Afghanistan. Mitropolsky (2005) reported the capture of a Pallas's cat by hunting dogs in the Keles River valley (foothills of the Western Tien Shan) in 1980, but no evidence of this finding has been preserved.

Population number

SOM T2. Estimations of Pallas's cat population numbers for several specific provinces (sub-regions) in the region published since 2000.

Area / sub-region	Area of estimation (km^2)	Population number	Density (ind./100 km^2)	Basic data came from	Year	Reference
Dauria (Trans-Baikal Territory, Russia and adjacent part of Mongolian Dauria)	63,500	2,400–3,000	3.8–4.7	Expert estimation	Late 1990s	Kirilyuk & Puzansky 2000
Dauria (Trans-Baikal Territory, Russia)	58,000	13,750	23.7	Snow-tracking, expert estimation	2010	Kirilyuk & Barashkova 2011a
Dauria (Trans-Baikal Territory, Russia)	58,000	4,000–5,000	6.9–8.6	Snow-tracking, expert estimation	2016	Kirilyuk & Barashkova 2016a
Buryatia Republic, Russia	1,500	200–280	13.3–18.7	Snow-tracking, expert estimation	2007	Barashkova et al. 2008
Kosh-Agach District of Altai Republic, Russia	3,500	650–680	18.6–19.4	Snow-tracking, expert estimation	2009	Barashkova & Smelansky 2011
Tyva Republic, Russia	27,000	2,200	8.2	Snow-tracking, survey, expert estimation	2006	Anonymous 2006
Tyva Republic, Russia	37,000	4,300–5,800	11.6–15.7	Snow-tracking, survey, expert estimation	2011	Barashkova 2011c, 2012

Habitats of minor types

In addition to the two main types of habitats that are discussed in the habitat section (a-type and b-type; SOM F3.1– 3.3) of the article, we recognise five more minor types (c–g) in the region. These habitat types are not rare throughout the whole region, but manul occupies them only in the eastern part of the region:

(c) Flat or gently rolling hill plains (SOM F3.4) covered with grassy steppe vegetation, lacking rocks (crevasses), but shelters provided by burrows of marmots, corsac foxes, or badgers, or humans (ruined and abandoned structures, abandoned agricultural machinery, etc.);
(d) Large clearings and forest edges in pine and/or larch woodlands (SOM F3.5), covered with steppe-like grasslands, located on river terraces or on slopes and low mountains;
(e) High-mountain areas with permafrost (SOM F 3.6), covered with cryophytic steppe, *Cobresia* grasslands, or various montane tundra types, often located on steep slopes and sharp ridges but also on rolling hills of highland plateaus;
(f) Sand dunes landscapes (SOM F3.7) with sparse vegetation of sand desert or psammophytic steppe located on watersheds or large terraces of rivers or lakes;
(g) Flat bottoms of wide valleys covered with steppe shrubs and wetland shrubs (SOM F3.8).

Occurrence records of the (c) type are typical for the easternmost part of the manul range, including the Daurian steppe in Russia, Mongolia, and China (Kirilyuk & Puzansky 2000, Kirilyuk 2012, Kirilyuk & Barashkova 2011, Barashkova et al. 2017). To the west, such habitats remain common, but the manul, as far as we know, does not occupy them. In some regions, the species uses this habitat type even if highly degraded due to heavy overgrazing (even down to bare soil), as long as prey remains sufficiently abundant (SOM F4.1–4.4).

Habitats of the (d) type are used by manul mainly in the forest-steppe region of Trans-Baikal area – in Buryatia (Barashkova et al. 2008, Medvedev 2007, 2010) and occasionally in Dauria (Barashkova et al. 2017), and probably in northern Mongolia (Litvinov & Bazardorzh 1992). Shnitnikov (1934) referred to anonymous reports of manul inhabiting the spruce woodlands of Ile Alatau Mountains, but there is no recent confirmation. We assume that the reference does not apply to forest habitats as such, but rather to the altitude level of spruce, where the landscape pattern includes not only forest but also steppe grassland on southern slopes, and canyons with rocks and scree.

The (e) type is typically connected to high mountains in Southern Siberia, like Altai and Sayan, highlands of Tibet and Tien Shan (Heptner & Sludskii 1972, Medvedev 2010, Barashkova & Smelansky 2011, Toropova 2006, Barashkova 2017). Probably this type is more important as transit habitat for cats moving between other habitats.

It is extremely uncommon for manul to occupy the (f) type. The only presence in such habitat has been documented in a limited area at the border between Tyva (Russia) and Mongolia (Barashkova 2012, Kuksin 2018). It can probably also be found in Mongolia. Further to the west, this type of habitat is broadly occupied by Asiatic wildcat, a species that is not found in Tyva and Mongolia.

The (g) type is known to be occupied in the east and northeast of the regional range, in Dauria, Buryatia, and Tyva (Russia), and northern Mongolia.

The (c) and (g) types play an important role particularly in Dauria, where manul often uses grassy steppes and steppe shrubs on low hill slopes and valley bottoms instead of rocky habitats on hilltops and in narrow ravines (Kirilyuk & Barashkova 2011).

3.1. Type (a). Desert steppe in Ayirtau Hills at average altitude 800 m, Central Kazakhstan Uplands, Karaganda Province, Kazakhstan (Photos I. Smelansky & A. Barashkova).


3.2. Type (a). True steppe in Adon Chelon Hills at average altitude 900 m, Dauria, Russia (Photos left I. Smelansky, right V. Kirilyuk).


3.3. Type (b). Montane dry steppe in the Taldura R. Valley at approximately 2,200-2,500 m altitude, North Chuya Ridge, Altai, Russia (Photos left I. Smelansky, right A. Barashkova)


3.4. Type (c). True grassy steppe on the terraces of the Borzya R. valley, Dauria, Russia. One of old abandoned pillboxes that manuls commonly use as shelters in the habitats of such type (Photos left Ilya Smelansky, right V. Kirilyuk).


3.5. Type (d). Pine forest contacting with meadow steppe, Buryatia, Russia (Photos left A. Barashkova, right courtesy presented by Yu. Kelberg).

3.6. Type (e). Mountain tundra at approximately 3,700 m altitude, Terskey Alatau, Kazakhstan/Kyrgyzstan border (Photo A. Grachev).

3.7. Type (f). Sand dunes covered with psammophythic dry and desert steppe along the Tes-Khem R. valley in Uvs Nuur Depression, Tyva, Russia. Track of manul on sand in the site (Photo A. Barashkova).

3.8. Type (g). Flat bottom of wide valley covered with large grass, steppe shrubs and wetland shrubs in Dauria, Russia (Photo A. Barashkova).

SOM F3. Common and occasional types of manul habitats in Central Asia and adjacent areas. For the habitat type definitions see the text above.

Prey

4.1. Mongolian pika *Ochotona pallasii* (Photo I. Smelansky).

4.2. Kazakh pika *Ochotona opaca* (Photo A. Lissovsky).

4.3. Flat-headed mountain vole *Alticola strelzowi* (Photo A. Barashkova)

4.4. Brandt's vole *Lasiopodomys brandti* (Photo B. Otgonbayar)

SOM F4. Some of the most important prey species for manul in the Central Asia and adjacent areas.

Conservation in protected areas

SOM T3. Representation of potential manul habitats and actual manul presence within protected areas in Russia and Kazakhstan (other countries not assessed so far).
Manul presence after 2000 means contemporary C1–C3 records of the species inside the protected area and/or its buffer zone.
PA portion – portion of the protected area occupied by (appropriate) manul habitats.
PAS portion – portion of the national predicted suitable area PAS located inside the protected area.
BR – Biosphere Reserve, NR – Strict Nature Reserve, NP – National Park, FWS – Federal Wildlife Sanctuary (Russia only), NaP – Nature Park, RWS – Regional (Provincial) Wildlife Sanctuary (Russia only), RZ – Reserve Zone (Kazakhstan only), WS – Wildlife Sanctuary (Kazakhstan only).

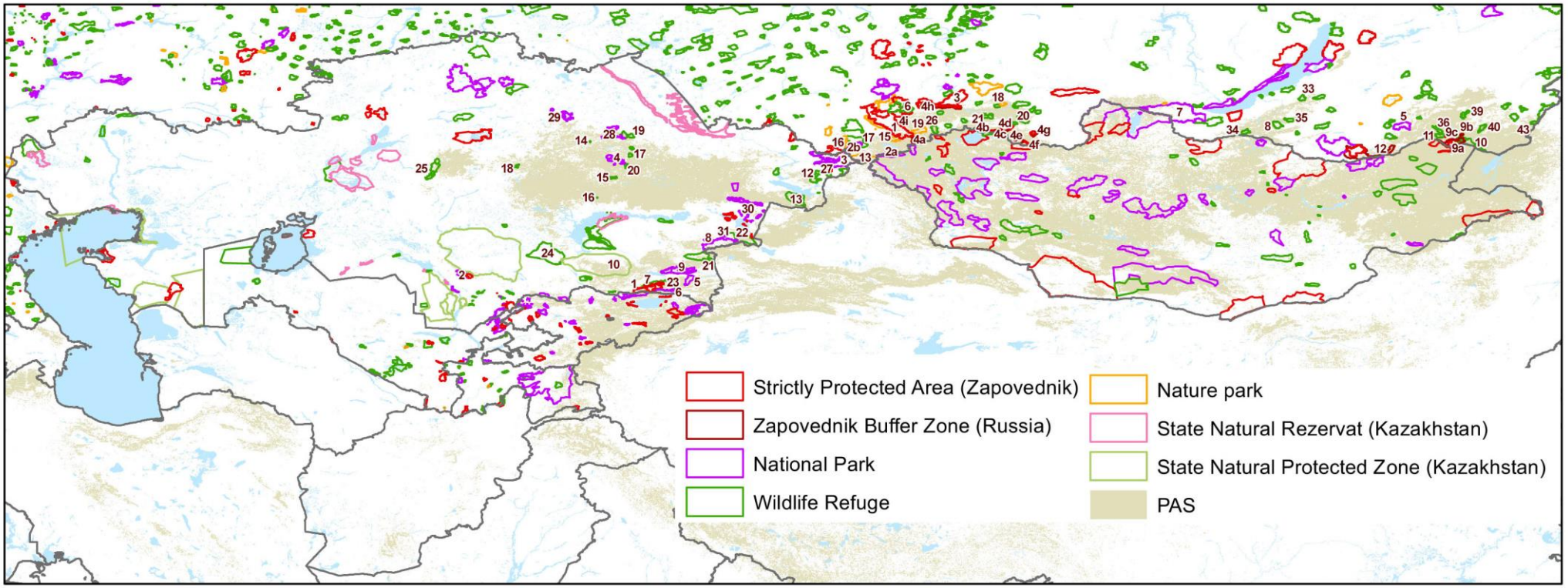
№	Protected area, site, type	Protected area size*, km^2	IUCN category	Manul presence after 2000	PA portion*, %	National PAS portion*, %
	Russia: Federal Protected Areas					
1	Altaisky BR	8,712.1	Ia	C1	7.5	0.23
2a	Sailyugemsky NP: Argut site	807.3	II	C1	57.2	0.26
2b	Sailyugemsky NP: Sailyugemsky and Ulandryk sites	376.5	II	C1	92.9	0.20
3	Sayano-Shushensky BR	3,903.7	Ia	C1	2.4	0.05
4a	Ubsunurskaya Kotlovina BR: Mongun-Taiga site	158.9 (1,015.1)	Ia	C1	64.8 (87.8)	0.06 (0.51)

4b	Ubsunurskaya Kotlovina BR: Uvs Nuur site	44.9 (130.4)	Ia	C2	70.2 (77.2)	0.02 (0.06)
4c	Ubsunurskaya Kotlovina BR: Oruku-Shynaa site	287.5 (638.4)	Ia	C3	77.0 (88.6)	0.13 (0.32)
4d	Ubsunurskaya Kotlovina BR: Aryskannyg site	150.0 (264.6)	Ia	C2	17.5 (53.2)	0.02 (0.08)
4e	Ubsunurskaya Kotlovina BR: Yamaalyg site	8.0 (54.5)	Ia	C1	91.3 (99.6)	<0.01 (0.03)
4f	Ubsunurskaya Kotlovina BR: Tsugeer Els site	49.0 (506.9)	Ia	C1	95.9 (85.5)	0.03 (0.25)
4g	Ubsunurskaya Kotlovina BR: Ular site	180 (405.4)	Ia	No data	63.7 (44.6)	0.07 (0.10)
4h	Ubsunurskaya Kotlovina BR: Khan-Deer site	1,129.2 (2,302.5)	Ia	No data	8.0 (14.1)	0.05 (0.19)
4i	Ubsunurskaya Kotlovina BR: Kara-Khol site	1224.5	Ia	No data	10.6	0.07
5	Alkhanai NP	1,382.3	II	No data**	20.9	0.17
6	Pozarym FWS	2537.4	IV	No data	1.3	0.02
7	Tunkinsky NP	11,836.6	II	C1	10.8	0.73
8	Altacheisky FWS	783.7	IV	C1	47.4	0.21
9a	Daursky BR: Toreisky, Imalkinsky, Chikhalan, Ereldzhi, and Kuku-Khodan sites	426.7 (1620.0)	Ia	C1	30.0 (70.7)	0.07 (0.65)
9b	Daursky BR: three sites at Adon-Chelon area	43.4 (155.5)	Ia	C1	100 (100)	0.03 (0.09)
9c	Daursky BR: Lesostepnoy site	3.0 (45.6)	Ia	C1	100 (97.1)	<0.01 (0.03)
10	Dzerens' valley FWS	2,138.4	IV	C1	93.4	1.14
11	Tsasucheisky Bor FWS	578.7	IV	C1	31.1	0.06
12	Sokhondinsky BR: buffer zone	(3,180.5)	Ia	C1	(39.3)	(0.71)
	Total for Federal PAs:	**36,779.6 (46,618.4)**			**21.4 (28.0)**	**4.49 (7.13)**
	Russia: Regional Protected Areas					
13	Ukok Quiet Zone NaP	2,542.0	V	No data**	60.1	0.87
14	Uch-Enmek NaP	811.2	V	No data	6.1	0.03
15	Ak-Cholushpa: NaP Kalbakaya site	789.5	V	C3	73.0	0.33
16	Belukha NaP	1,312.7	V	No data	28.1	0.21
17	Shavlinsky RWS	2,466.0	IV	C1	33.7	0.47
18	Tyva NaP: Taiga site	233.0	V	C3	10.7	0.01
19	Tyva NaP: Shui site	980.0	V	C1	68.2	0.38
20	Balgazynsky RWS	1500.0	IV	C3	48.2	0.41
21	Kaksky RWS	600.0	IV	C3	46.9	0.16
22	Ondumsky RWS	470.0	IV	C1	3.2	<0.01
23	Chaa-Kholsky RWS	200.0	IV	C3	41.5	0.05
24	Sut-Kholsky RWS	100.0	IV	No data	52.0	0.03
25	Chagytaisky RWS	53.5	IV	No data	37.4	0.01
26	Ayangatinsky RWS	510.0	IV	No data	80.9	0.24
27	Eerbeksky RWS	290.0	IV	C3	7.5	0.01
28	Khudaksky RWS	500.0	IV	No data	6.3	0.02
29	Sheminsky RWS	250.0	IV	No data	20.8	0.03
30	Durgensky RWS	350.7	IV	No data	10.8	0.02
31	Gagulskaya Kotlovina RWS	246.3	IV	No data	8.7	0.01
32	Tapsinsky RWS	1090.0	IV	No data	5.0	0.03

33	Angirsky RWS	403.8	IV	C3	21.0	0.05
34	Borgoysky RWS	421.8	IV	C2	95.4	0.23
35	Tugnuisky RWS	393.6	IV	C2	96.5	0.22
36	Aginskaya Steppe RWS	457.6	IV	C1	93.4	0.24
37	Argaleisky RWS	109.7	IV	No data	49.3	0.03
38	Gornaya Steppe RWS	52.7	IV	C2	64.1	0.02
39	Semenovsky RWS	476.2	IV	No data	56.5	0.15
40	Oldondinsky RWS	514.0	IV	C1	92.4	0.27
41	Borzinsky RWS	604.3	IV	No data	2.0	<0.01
42	Akshinsky RWS	665.4	IV	No data	20	0.08
43	Sredneargunsky RWS	2013.9	IV	No data	16.9	0.19
	Total for Regional PAs:	**21407.8**			**39.5**	**4.83**
	Total for Russia (12 Federal PAs and 31 Provincial PAs):	**58,187.4 (66,026.2)**			**28.1 (31.8)**	**9.32 (11.96)**
	Kazakhstan					
1	Almaty NR	717.0	Ia	C3	43.6	0.09
2	Karatau NR	343.0	Ia	No data	4.8	<0.01
3	Katon-Karagai NP	6,434.8	II	C1	5.2	0.10
4	Karkaraly NP	1121.2	II	C2	68.2	0.16
5	Charyn NP	1270.5	II	C1	65.0	0.18
6	Kolsai Kolderi NP	1,610.5	II	No data	53.5	0.26
7	Ile Alatau NP	1,986.7	II	No data	30.1	0.18
8	Jongar Alatau NP	3,560.2	II	C1	21.2	0.25
9	Altyn-Emel NP	3,076.5	II	C3	46.8	0.43
10	Jusandala RZ	27,775.0	Ib	C3	37.0	2.49
11	South-Kazakhstan RZ	62,580.0	Ib	No data	0.1	0.03
12	Ontustik-Altai WS	1,971.8	IV	C1	33.2	0.19
13	Tarbagatai WS	2,400.0	IV	C1	96.2	0.87
14	Belagash WS	15.0	IV	No data	59.4	<0.01
15	Kyzylaray WS	182.0	IV	No data	93.2	0.06
16	Bektauata WS	5.0	IV	C3	100.0	<0.01
17	Kuvsky WS	335.0	IV	No data	59.3	0.06
18	Karaagash WS	68.0	IV	No data	86.5	0.02
19	Kyzyltau WS	600.0	IV	No data	51.8	0.13
20	Beldeutas WS	466.6	IV	No data	69.6	0.03
21	Verhnekoksuisky WS	2,400.0	IV	No data	35.8	0.28
22	Toktinsky WS	1,870.0	IV	C3	72.3	0.47
23	Almaty WS	5,424.0	IV	C3	55.0	0.59
24	Andasai WS	10,000.0	IV	No data	1.2	0.03
25	Ulytau WS	193.0	IV	No data	62.2	0.04
26	Urochische Karakunuz WS	30.7	IV	No data	34.8	<0.01
27	Markakol NR	1,029.7	Ia	No data**	4.2	0.01
28	Bayanaul NP	684.5	II	No data**	47.6	0.09
29	Buyratau NP	889.7	II	No data**	22.0	0.06
30	Tarbagatai NP	1,435.50	II	No data**	25.3	0.13
31	Lepsinsky WS	2,580.00	IV	No data**	1.9	<0.01
	Total for Kazakhstan	**143,055.84**			**16.2**	**7.2**

* Data in parentheses represent the habitat area or percentage of potential habitat for the manul in the PA given together with its buffer zone (if any exist).

** Old (before 2000) C3 records are known: in Russia – from Alkhanai NP and Ukok Quiet Zone NaP, in Kazakhstan – from modern area of Markakol NR, Bayanaul NP, Buyratau NP, Tarbagatai NP, and Lepsinsky WS.



SOM F5. Map of protected areas on the background of predicted area of suitability for the manul (Numbers refer to № in SOM T3).

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