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ORIGINAL PAPER

Persistent and novel threats to the biodiversity of Kazakhstan's steppes and semi-deserts

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Abstract Temperate grasslands have suffered disproportionally from conversion to cropland, degradation and fragmentation. A large proportion of the world's remaining near-natural grassland is situated in Kazakhstan. We aimed to assess current and emerging threats to steppe and semi-desert biodiversity in Kazakhstan and evaluate conservation research priorities. We conducted a horizon-scanning exercise among conservationists from academia and practice. We first compiled a list of 45 potential threats. These were then ranked by the survey participants according to their perceived severity, the need for

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research on them, and their novelty. The highest-ranked threats were related to changes in land use (leading to habitat loss and deterioration), direct persecution of wildlife, and rapid infrastructure development due to economic and population growth. Research needs were identified largely in the same areas, and the mean scores of threat severity and research need were highly correlated. Novel threats comprised habitat loss by photovoltaic and wind power stations, climate change and changes in agriculture such as the introduction of biofuels. However, novelty was not correlated with threat severity or research priority, suggesting that the most severe threats are the established ones. Important goals towards more effective steppe and semi-desert conservation in Kazakhstan include more cross-sector collaboration (e.g. by involving stakeholders in conservation and agriculture), greater allocation of funds to under-staffed areas (e.g. protected area management), better representativeness and complementarity in the protected area system and enhanced data collection for wildlife monitoring and threat assessments (including the use of citizen-science databases).

Keywords Horizon scanning · Protected area · Land-use change · Grazing · Agriculture · *Saiga tatarica*

Introduction

Conversion, degradation and fragmentation of habitat are major drivers of biodiversity loss (Pereira et al. 2010). Grasslands have suffered disproportionally (Hoekstra et al. 2005), especially in the temperate zone where up to 70 % of all native steppe grasslands have been converted to cropland or are seriously degraded (Viglizzo et al. 2011; Wright and Wimberly 2013).

The western part of the Eurasian steppe belt comprises the Pontic Steppe in Ukraine and European Russia, and the Kazakh steppe which stretch from Ukraine to the Altai Mountains (Olson et al. 2001). The Altai acts as a biogeographical barrier, separating western animal and plant communities from those of the eastern Eurasian steppes in Mongolian, South Siberian and China. The steppes of Ukraine and European Russia were almost completely converted into cropland in the eighteenth and nineteenth century. Thirty-five million ha of steppe grasslands were transformed into cereal cropland between 1953 and 1961 in Kazakhstan and Asian Russia during the 'Virgin Lands Campaign' initiated by the Soviet Union (Durgin 1962). Despite widespread conversion, the combined Pontic and Kazakh steppes still contain a very large share of the world's remaining near-natural, temperate grasslands (Dixon et al. 2014).

The steppes and semi-deserts of Kazakhstan are of high conservation importance: They harbour a large number of globally threatened and biome-restricted species (Venter et al. 2014), including a suite of characteristic steppe birds (Kamp et al. 2011), large ungulates such as the Critically Endangered Saiga Antelope *Saiga tatarica* (Bekenov et al. 1998; Milner-Gulland et al. 2001) and distinct steppe plant communities (Demina and Bragina 2014). They are also home to many species known in Europe as 'farmland biodiversity', i.e. open country species that can to some extent adapt to agricultural management (Benton et al. 2003). Examples include birds such as the Skylark *Alauda arvensis*, or small mammal species such as ground squirrels *Spermophilus* spp. While large losses of farmland biodiversity over the last decades in Europe have mainly been attributed to agricultural intensification (Donald et al. 2001), the near-natural steppe and low-input agricultural systems of Kazakhstan still harbour very large and healthy populations of these farmland species (Kamp et al. 2011). Finally, the steppes and semi-deserts of Kazakhstan are dotted with wetlands of international importance (Sklyarenko et al. 2008). These freshwater and saline steppe lakes serve as important stopover sites for millions of Siberian waterbirds migrating on the Central Asian flyway to their wintering areas in Arabia and on the Indian subcontinent (Schielzeth et al. 2008, 2010).

Despite the high conservation importance of the steppes and semi-deserts of Kazakhstan, very few robust, quantitative data are available on population sizes, trends and conservation status except for some conspicuous species. The first biodiversity assessments for the country were produced as part of the National Biodiversity Strategy and Action Plan (Convention on Biological Diversity, CBD) reporting obligations (Ministry of Environment and Water Resources of the Republic of Kazakhstan 1999) and by USAID (Chemonics International 2001). National CBD biodiversity reports in Russian and English have been published between 2001 and 2014 (Ministry of Environment and Water Resources of the Republic of Kazakhstan 2014). Finally, the Association for the Conservation of Biodiversity of Kazakhstan (ACBK) produced an inventory of Important Bird Areas, including a threat assessment for every site (Sklyarenko et al. 2008). These assessments routinely mentioned persistent and new threats to steppe and semi-desert biodiversity. However, threats were not ranked according to their severity, knowledge gaps and research priorities were not systematically identified, and in most cases threats were based on expert opinion or government information rather than empirical data.

The lack of robust information on the status of and threats to habitats and biodiversity limits management options, as Kazakhstan is now a fast-developing country. After an economic downturn during the 1990s following the break-up of the Soviet Union, human population size reached a low around the year 2000 (caused by declines in fertility and an exodus of ethnic Russians and Germans during the 1990s to the countries of their ancestors; Rowland 2001), after which a period of population and economic growth began (Fig. 1). Since that time fertility rates have risen, emigration almost stopped, and human population size now already exceeds that of Soviet times (Fig. 1). International predictions suggest that GDP growth will continue at annual rates of 5–7 % until at least 2017 (The World Bank 2016). Growth is also observed and predicted to continue in oil and gas exports, mining of coal and raw minerals and agriculture, although this will always depend on the global oil price (Fig. 1).

To address the lack of knowledge about threats faced by Kazakhstan's steppes and semi-deserts, we conducted an expert-based evaluation using horizon scanning (Sutherland et al. 2011). This complements and extends a similar evaluation for the Russian steppes that was conducted in the framework of an UNDP/GEF project aiming at the designation of new protected areas (Siberian Environmental Center 2013). We aimed (i) to identify persistent and novel, emerging threats to steppe biodiversity in Kazakhstan and rank their importance; (ii) to identify priority areas of research related to these threats and (iii) to evaluate the degree of agreement between perceived threat severity and research priority. We used a participatory approach involving fellow scientists and conservationists to collect opinions about threats and research priorities.

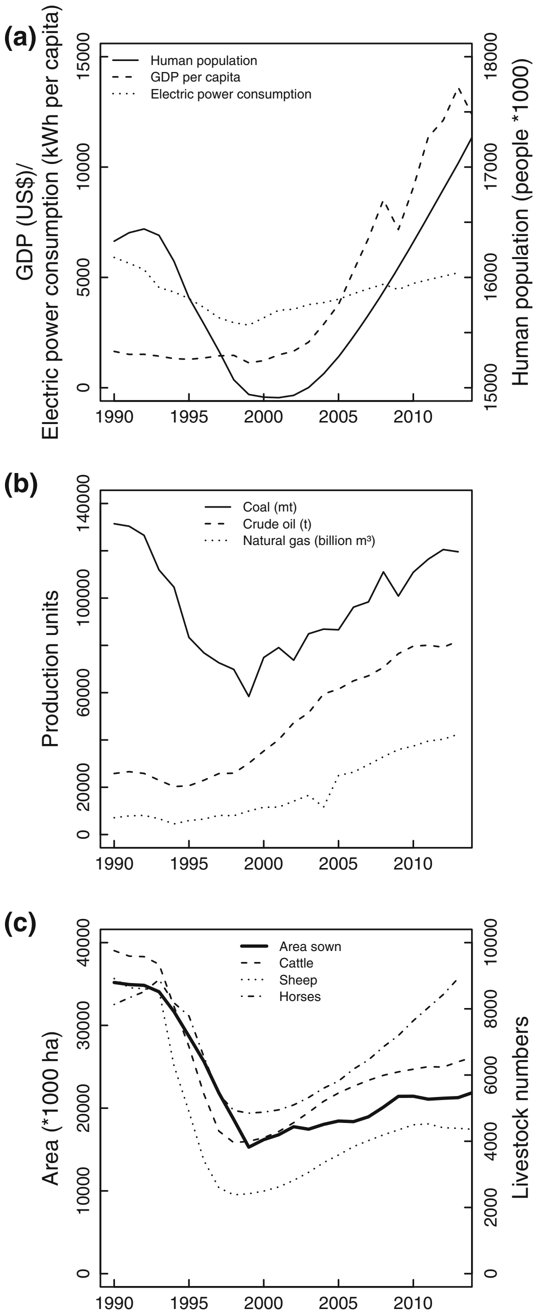

Fig. 1 **a** Trends in human population size, per-capita-GDP and electric energy consumption, **b** trends in coal, crude oil and gas production (The World Bank 2016) and **c** trends in area sown for crops and livestock numbers in the period 1990–2013 in Kazakhstan (Kazakhstan State Statistics Agency 2016a)

Materials and methods

Horizon scanning

We used a horizon scanning approach which is defined as "the systematic search for potential threats and opportunities that are currently poorly recognized" (Sutherland and Woodroof 2009). It has been adopted in various areas such as macro-ecology, agriculture and medicine, and also has been successfully employed in conservation biology (Sutherland et al. 2014). The outcomes of horizon scanning exercises, especially those that prioritize emerging issues, are useful to policymakers, decision makers and practitioners in public, private and non-profit organisations. They have also repeatedly been used by scientists to plan future research agendas, and by funding agencies to identify priority research and conservation projects (Sutherland et al. 2011).

Data collection

The geographical scope of our study were the ecoregions 'Kazakh steppe', 'Kazakh semi-desert' and 'Kazakh upland' (Olson et al. 2001). The time scale for threats considered as novel, or becoming relevant in the near future, was the period of ca. 2012 to ca. 2025.

To create an evidence basis for discussion, authors J. Kamp and M. A. Koshkin compiled an initial list of 23 potential threats. This list was based on readings of peer-reviewed and 'grey' literature, social network platforms, blogs and online Kazakhstan newspaper archives, on informal discussions with fellow scientists and conservationists, and on governmental statistics and policy documents such as the strategic planning documents 'Kazakhstan-2030′ and 'Kazakhstan-2050' and the latest CBD report (Ministry of Environment and Water Resources of the Republic of Kazakhstan 2014). Threats were grouped into thematic categories. This list, which also contained short descriptions with references for each threat, was then sent out by e-mail to a total of 24 conservation scientists and conservation practitioners working for NGOs, governmental and intergovernmental agencies within Kazakhstan or internationally. The survey participants had worked on one or several biodiversity conservation aspects in Kazakhstan during the past 5 years, and most of them were involved in ongoing conservation or research projects. The participants were first asked to briefly list additional threats and provide references for each threat. These were then added to the existing list of threats, resulting in a total of 45 threats (Online Resource 1). This final list was circulated among all experts together with a score sheet (in English and Russian). All participants were asked (i) to score the potential severity of each threat on a 10-point scale, (ii) to score the need for research on a 10-point scale, and (iii) to state for each threat if they considered it to be novel (binary answer, yes = 1, no = 0). Participants were also asked to comment on threats and research priorities during the ranking process. Suggestions detailing research needs were compiled and are summarized in the results section.

Data analysis

The scores for threat severity and research need were averaged across all participants, considering our scale an interval rather than an ordered-categorical scale. Two shortlists were created that contained the ten threats with the highest mean scores for threat severity and research need, respectively, and a third list which contained the ten threats with the highest mean ranking for ‘novelty’. Threats featuring on either (or all) of the lists were compiled and are discussed in detail below.

To evaluate the degree of agreement between perceived threat severity and research priority, we evaluated the correlation between mean threat severity and mean research need using Spearman’s correlation coefficient. We also correlated the score of novelty with mean threat severity and research priority for all threats to evaluate if novel threats were perceived differently than persistent ones, and if more research need was suggested for novel threats compared to established ones. To evaluate the degree of agreement between rankers, we calculated Cronbach’s α using function ‘cronbach’ in the R package ‘psy’ (Falissard 2016).

Results and discussion

Nineteen people commented on the initial list and added threats, and 11 people were involved in the final ranking and compilation of the threats. The taxonomic expertise covered by them was in the groups of birds (6 participants), large mammals (2), small mammals (3), insects (1) and plants (2). Further areas of work were protected area management, landscape planning, ecotourism and conservation policy.

The threats to steppe and semi-desert biodiversity in Kazakhstan with the highest mean ranking were mainly in three areas, namely (i) changes in agriculture leading to habitat loss and deterioration, (ii) direct persecution of wildlife, and (iii) rapid infrastructure development due to economic growth (Table 1). Research needs were largely identified in the same areas (Table 1). Threat severity was highly correlated with perceived research need (Spearman’s $r = 0.87$, $p < 0.001$, Fig. 2). Threats identified as novel included habitat loss, disturbance and direct mortality caused by novel infrastructure (e.g. renewable energies), climate change, and several emerging conservation issues of narrower relevance (e.g. new ways of species exploitation not observed earlier, Table 1). Novelty was not correlated with research need (Fig. 2), suggesting that persistent threats need similar attention as emerging ones. The degree of agreement in the ranking was high among participants (threat severity: Cronbach’s $\alpha = 0.855$, research need: Cronbach’s $\alpha = 0.737$).

Detailed suggestions related to the ten highest-ranked research priorities were received from participants during the review of the initial threat list and are presented in Table 2.

The threats featuring on either of the lists (severity, research need, novelty) among the ten highest ranked ones are summarized and discussed in the following section, in the order of their perceived severity.

Poaching, harvest and trade of endangered species

Large grazers are umbrella species of Kazakhstan’s steppes and semi-deserts and influence vegetation and food chains by their grazing activities. Only tiny populations of Kulan (*Equus hemionus*) and Goitered Gazelle (*Gazella subgutturosa*) survive in Kazakhstan. Saiga Antelopes (*Saiga tatarica*) were hunted for meat in Soviet times, but although populations have fluctuated greatly over the years from disease (see below) and hunting, they remained at relatively high levels (Bekenov et al. 1998). The collapse of the Soviet Union in 1991 meant an end to government-controlled hunting management, and increasing poverty in rural regions led to high poaching levels (Milner-Gulland et al. 2001). Saiga were targeted for their meat. Even more important, their horn is used for

Table 1 Mean threat severity and research need (±SD) as well as novelty (% respondents considering a threat novel) for those threats that were among the ten highest ranked in one or several of the categories (italic fields)

Threat	Threat severity	SD	Research need	SD	Novelty (%)
Expansion of arable agriculture: biofuels	*7.82*	*2.27*	5.43	2.37	*86*
Expansion of arable agriculture: food production and fodder crops	*7.80*	*2.30*	*8.50*	*2.10*	55
Changing livestock grazing patterns	*7.70*	*2.30*	*8.00*	*2.30*	27
Poaching, harvest and trade of endangered species	*7.60*	*1.90*	*7.50*	*1.90*	0
Fragmentation of habitats by new roads and railroads	*7.30*	*1.30*	*7.60*	*1.40*	*64*
Intensification of arable agriculture	*6.50*	*2.30*	*7.80*	*2.60*	45
Changes in the hydrological regime of steppe lakes and rivers	*6.50*	*2.10*	*7.20*	*1.70*	43
Changes in land ownership	*6.40*	*2.20*	6.14	1.57	*86*
Electrocution of birds at powerlines	*6.30*	*2.10*	6.09	2.12	9
Increase in the area and number of steppe fires	*6.20*	*2.00*	*7.40*	*2.10*	50
Habitat loss due to increasing mining activities	5.90	2.20	6.09	3.08	27
Biome shift and desertification	5.89	2.71	*7.40*	*2.00*	*73*
Illegal harvest of *Artemia salina* (brine shrimp) eggs at wetlands for medical industry in China	5.89	2.71	*7.30*	*1.70*	*78*
Increase of weather extremes and drought	5.80	1.99	6.60	2.27	*80*
Increase of spring temperatures	5.50	1.96	6.90	2.08	*90*
Saiga antelope mass die-offs	5.20	2.20	*7.20*	*1.90*	20
Habitat loss, disturbance and increased mortality of wildlife at new wind power stations	3.82	1.66	5.45	2.50	*91*
Introduction of GM crops	3.57	1.51	5.13	2.70	*86*
Habitat loss by large-scale photovoltaic power stations (solar parks)	2.91	1.87	4.50	3.37	*100*

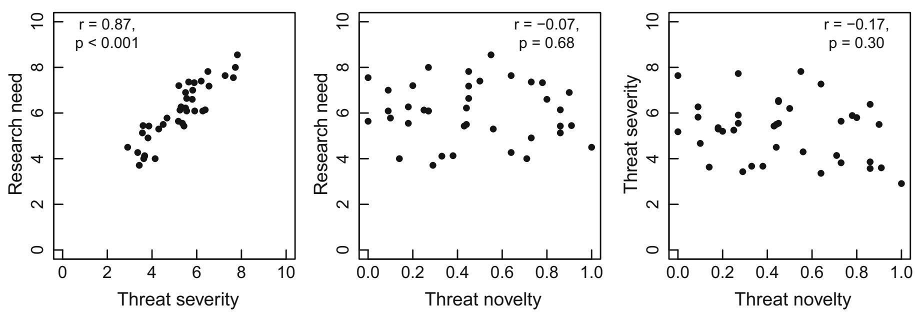

Fig. 2 Scatterplots of the mean threat severity ranking plotted against the mean research need ranking, and mean severity and mean research need rankings against the mean novelty ranking (n = 37 threats)

medical purposes in China, leading to high levels of export-led poaching of males (females do not bear horns). Due to poaching, Saiga populations collapsed during the 1990s, and by 2003 only 30,000 animals were estimated to be left in Kazakhstan (Milner-Gulland et al.

Table 2 Priority research actions received from participants during the review of the initial threat list for the ten highest ranked threats in the category research needs

Research area	Priority research actions
Expansion of arable agriculture	Model and map biodiversity hotspots, Saiga migration routes, and areas suitable for agricultural expansion/recultivation, quantify overlap and potential conflicts; communicate findings to key stakeholders in agriculture and conservation
Changing livestock grazing patterns	Quantify relationships between grazing pressure and abundance/distribution for key steppe species; quantify grazing levels for wild and domestic ungulates that accelerate restoration of abandoned cropland to steppe; communicate findings to stakeholders in livestock management
Intensification of arable agriculture	Evaluate how likely cropland intensification by increased fertilizer and pesticide use is, and how likely the establishment of more intensive livestock systems is in the near future; monitor abundance and reproductive success of key species inhabiting used cropland (e.g. Steppe Marmot) that could serve as indicators of land-use intensity
Electrocution of birds at powerlines	Carry out environmental impact assessments and put mitigation in place according to international best practices
Fragmentation of habitats by new roads and railroads	Initiate and continue satellite tracking of key steppe species potentially affected (e.g. Saiga antelope, Wolf) to identify conflicts between infrastructure development and migration routes; investigate which technical measures (e.g. bridges or tunnels) are suitable to minimize impact, communicate results to stakeholders in infrastructure authorities
Poaching, harvest and trade of endangered species	Conduct surveys to establish harvest rates of endangered species, used population models to define critical harvest levels, communicate findings to responsible wildlife management authorities
Increase in the area and number of steppe fires	Use remote sensing to evaluate fire recurrence rates in relation to weather and grazing pressure, establish grazing levels mitigating high fire recurrence rates, relate fire-recurrence rate to abundance and distribution of key biodiversity
Biome shift and desertification	Analyse existing biodiversity distribution data to detect biome shifts and relate to predicted biome-shifts patterns from climate research, identify species and regions most affected, predict effectiveness of protected areas under different climate change scenarios
Illegal harvest of *Artemia salina* (brine shrimp) eggs at wetlands for medical industry in China	Conduct surveys using information from successful anti-poaching actions to establish scale of the problem, if significant, initiate monitoring of waterbird species dependent on *Artemia* at key poaching sites
Saiga antelope mass die-offs	Continue investigations on the causes of the die-offs

Table 2 continued

Research area	Priority research actions
Changes in the hydrological regime of steppe lakes and rivers	Use remote sensing to evaluate temporal changes in the hydrological regime of steppe lakes. Quantify changes in community structure of aquatic organisms along a gradient of lake/river degradation

2001, 2003). Tremendous efforts by the government of Kazakhstan and conservation NGOs to combat poaching resulted in a population recovery to 262,000 in 2014 (Nicholls 2015b). However, poaching is still common, with e.g. 4470 smuggled horns worth 22 Million USD confiscated in September 2013 in NW China (Saiga Conservation Alliance 2013).

There is evidence of increasing recreational hunting pressure on large mammals such as Grey Wolf (*Canis lupus*), which results from increasing wealth of the local population and the development of hunting tourism (e.g. Trophy Club 2016). Wolves are also still controlled, and the Kazakh government now pays financial rewards for hundreds of wolf skins annually (Kazinform 2014). It is likely that this affects the species on a population level, as recently suggested for Russia (Bragina et al. 2015).

Increasing rates of unsustainable trapping of Saker Falcon *Falco cherrug* for falconers in the Middle East, including the overharvest of females, have been identified as a major threat to Kazakhstan's populations, despite the species being listed on both CMS and CITES (Kovács et al. 2014).

The export of the globally threatened Horsfield's Tortoise *Agrionemys horsfieldii* in the pet trade and venomous snakes for medical reasons is thought to be substantial (Chemonics International 2001). Between 2009 and 2013, more than 20,000 illegally traded tortoises were confiscated at the borders of Kazakhstan by customs (Chirikova 2015).

Brine Shrimp (*Artemia* ssp.) is the main food source for millions of shorebirds migrating on the Siberian–Central-Asian–African/Indian flyway and stopping over at Kazakhstan's steppe lakes, a bottleneck on migration (Andrusenko 1979; Schielzeth et al. 2008, 2010). Illegal harvesting of brine shrimp eggs at saline steppe lakes has massively increased in recent years, and poachers have been regularly detained across Kazakhstan (Astana TV 2013 and many other national newspaper articles and broadcasts). Most of the stocks harvested in Kazakhstan are illegally sold for medical purposes to China, the sackful for ca. 1400 US$ (Astana TV 2013; Koshkin 2014). It is currently unclear if the scale of the poaching is sufficient to affect the food resource of waterbird populations and lead to declines, and research is needed.

Expansion and intensification of arable agriculture

In Kazakhstan, 35 million ha of steppe grasslands were transformed into cereal cropland between 1953 and 1961 in Kazakhstan and Asian Russia during the 'Virgin Lands Campaign' initiated by the Soviet Union (Durgin 1962). This lead to large-scale steppe habitat loss. In contrast, after the break-up of the Soviet Union in 1991, cropland area in Kazakhstan declined dramatically from about 24 million ha in 1990 to 12 million ha in 1999 (Kazakhstan State Statistics Agency 2016a) due to the collapse of the state farm systems and rural depopulation (Fig. 1). This resulted in population recovery in many steppe bird species (Kamp et al. 2011), and possibly also in other taxa, such as Steppe Marmot

Marmota bobac (Nerger 2007). However, since 2000, about 6 million ha of abandoned farmland have been re-cultivated (Petrick et al. 2013), and this upward trend seems to be continuing (Fig. 1), leading to new pressures for steppe areas which had been recovering. The potential to expand agricultural production in Kazakhstan is high (Lioubimtseva and Henebry 2012), but the likelihood of recultivation varies with soil-type and accessibility (Kraemer et al. 2015). Pressure on agricultural land has increased globally over the last decades due to increasing crop cultivation for biofuels, with often negative implications for biodiversity (Koh and Ghazoul 2008). Kazakhstan has opened its first biofuel plants running on ethanol from wheat in 2006 (Russian Biofuels Association 2007), but production remained negligible since then (Kazakhstan State Statistics Agency 2016a). While an expansion of agriculture for biofuel production seems unlikely at the moment, increased global demand could change this in the future and lead to reclamation of abandoned farmland.

Agricultural intensification is considered one of the main global drivers of biodiversity loss (Donald et al. 2001; Giller et al. 1997; Tscharntke et al. 2005). Over 90 % of Kazakhstan's cropland is sown with wheat. Mean wheat yield across the steppe zone increased from ca. 0.8 t/ha in 1990 to ca. 1.1 t/ha in 2013 (Kamp et al. 2015). This suggests an intensification of cropping systems, but the increase in yield is also caused by the abandonment of the least productive areas, leading to a country-wide increased mean yield (Kazakhstan State Statistics Agency 2016a). Significant cereal yield gaps (differences between current and attainable yields) have been modelled for the region (Mueller et al. 2012). However, it is unclear how realistic it is to close these yield gaps. The government of Kazakhstan plans to invest 17 billion US$ into the the modernisation of the agro-industrial sector by 2020 within the 'Kazakhstan-2020' and 'Kazakhstan-2050' development strategies (Ministry of Agriculture of the Republic of Kazakhstan 2012, 2014). The main strategy is to support effective, very large farms rather than smallholders and medium-sized businesses (Ministry of Agriculture of the Republic of Kazakhstan 2012, 2014). It seems likely that increasing efficiency in the agricultural sector in Kazakhstan will also be achieved by increased pesticide and fertilizer application and increased mechanisation (Kamp et al. 2011). Extensive use of agrochemicals has caused significant losses of insects, small mammals, and birds populations in steppe habitats of European Russia in the Soviet era (Belik 1997, 2000).

Changing livestock grazing patterns

Grassland ecosystems are shaped by large grazers, which create niches for plant and animal species (Knapp et al. 1999). In Kazakhstan, this role has been taken over by domestic livestock, as, apart from Saiga Antelope, large herds of wild ungulates were lost long ago. Livestock numbers were high in Soviet times, but declined sharply during the 1990s due to the disintegration of the state farms and rural depopulation (declines of up to 80 % in sheep and 50 % in horse and cattle numbers, Kamp et al. 2011; Robinson and Milner-Gulland 2003; Fig. 1c). Since 2000, livestock numbers have been recovering (Kerven et al. 2016). However, most livestock are now owned privately (Robinson et al. 2016), although often grazed on state-owned rangelands and communal pastures. As private owners lack the financial means and infrastructure for seasonal migrations, very imbalanced grazing pressure is observed: Within 10 km of human settlements, on communal pastures, the steppe and semi-desert is overgrazed in many areas, while large areas are not grazed at all (Kamp et al. 2012; Robinson et al. 2016). Heterogeneity in grazing levels, including very heavy local grazing, seems to be crucial for species-rich steppe bird and mammal communities (Kamp et al. 2012, 2015; Shmalenko 2013). Also, a cessation of grazing by wild and domestic ungulates can change ecosystem functioning: First results suggest that ungrazed steppe on former pastures is 'locked' in a stage of rather monotonous, grassy swards dominated by various feather grass (*Stipa* ssp.) species and *Leymus ramosus* rather than recovering into species-rich steppe communities (Brinkert et al. 2016, this issue). Overgrazing on the one hand and 'undergrazing' of vast areas can lead to changes in abundance and community composition in birds and small mammals (Kamp et al. 2012; Lameris et al. 2016 (this issue); Oparin et al. 2011), but little quantitative evidence is available. The currently recolonisation of previously abandoned pastures (Kerven et al. 2016) might be beneficial for steppe biodiversity. Similarly, recent efforts to reintroduce native wild ungulates such as Przewalski's Horse in Kazakhstan (Tengri News 2014) might be an opportunity for steppe restoration (Liu et al. 2014).

Similar to crop production, the government of Kazakhstan is now implementing policies to reactivate the livestock sector and increase intensity in livestock production (Vorotnikov 2013). Immediate changes will include a higher proportion of animals being kept in stables year-round (rather than ranging free in summer), and due to this an increased demand for fodder crops rather than hay. This could in turn increase the expansion and intensification of arable cropland, if fodder is to be produced domestically and not imported.

Habitat loss due to increasing mining activities

In Kazakhstan, coal and other minerals are mostly mined in open cast mines, meaning that steppe and semi-desert habitat will be lost where new mines are opened or existing ones extended. The amount of mined coal and minerals declined in Kazakhstan between 1990 and 2000, but has since recovered to or even exceeds Soviet levels (Fig. 1). It is projected that production will grow to more than 158 million tons per year by 2020. Iron, copper, bauxite, and zinc are the minerals with the largest production amounts after coal. The combined total production of these four minerals increased from 56 to 76 million tons per year in the period 2000–2013 and has surpassed Soviet levels recently (Kazakhstan State Statistics Agency 2016b). Coal is mostly consumed domestically, but Chinese investors have recently increased their involvement in Kazakhstan, which could further increase the amount of coal produced in the country (Suleimen 2014; Tengri News 2013). The area used for mining increased from 580,000 ha in 2000 to 910,000 ha in 2012 (and by 110,000 ha from 2008 to 2012 alone, Ministry of Environment and Water Resources of the Republic of Kazakhstan 2014). So far, no official restoration policy for disused mining sites is in place.

Habitat fragmentation by new roads and railroads

Kazakhstan plans to massively increase the volume of rail freight from 2500 to 7.5 million standard rail containers by 2020. Three new rail connections with a total length of ca. 1300 km are currently being constructed or have been opened since 2014 (Kazakhstan Temir Zholy 2015). Further expansion is expected, as direct rail connections between China and Western Europe are planned (ECE-ESCAP 2008), and China plans to build a new high-speed rail link between Astana and Almaty (Lu 2011).

Fragmentation of habitats by roads and railroads is a major conservation issue for large ungulate populations in neighbouring Mongolia (Batsaikhan et al. 2014; Ito et al. 2008, 2013). In Kazakhstan, all three new railroads mentioned above cross the range of core populations of the critically endangered Saiga Antelope (Singh et al. 2010a; Zuther 2014). Adverse effects of roads and railroads due to increased mortality have recently been suggested for other vertebrate groups and also invertebrates (Muñoz et al. 2014). There might also be indirect effects, as new railroads in formerly remote steppe areas might be followed by further infrastructure, industry and mining projects, poachers, and altered land-use.

Electrocution of birds on power lines

Large numbers of birds are killed through electrocution and collisions with power lines in Kazakhstan (Dixon et al. 2013; Karyakin 2008; Lasch et al. 2010; Levin and Kurkin 2013; Saraev and Pestov 2011; Voronova and Pulikova 2013; Voronova et al. 2012) including globally threatened birds of prey such as Saker Falcon, Steppe Eagle *Aquila nipalensis*, and Eastern Imperial Eagle *Aquila heliaca*. Electric power consumption has steadily increased since 2000 (Fig. 1). Between 2009 and 2012, three new long distance power lines were built in Kazakhstan. At least seven new projects are in the planning stage (Kazakhstan Electricity Grid Operating Company (KEGOC) 2015), including smaller (6–10 kV) power lines at which most electrocution happens. Population-level effects of electrocution have been shown empirically (e.g. Angelov et al. 2013; Hernández-Matías et al. 2015), but no quantitative assessment has been provided yet for raptor populations in Kazakhstan.

Habitat loss, disturbance and increased mortality of wildlife at new wind power stations

Kazakhstan's first wind power stations are currently built (Government of Kazakhstan 2014a) and wind power is planned to reach 5 % in Kazakhstan's energy balance in 2024 (Government of Kazakhstan 2014b). About 50 % of Kazakhstan's territory has average wind speeds about 4–5 m/sec at a height of 30 m, resulting in a wind potential of Kazakhstan around 1820 billion KW/h per year spread over most of the country (Kazakhstan Electricity Association 2008). The potential for electricity created from wind energy exceeds Kazakhstan's current energy consumption tenfold (Nabiyeva 2014), and there is a possibility to install thousands MW of wind farms in Kazakhstan (Cochran 2008; Renewable Market Watch 2014). European and Chinese investors are currently actively targeted by programs of the government of Kazakhstan (Nabiyeva 2014). The effects of wind power stations on the environment depend on their location, but there is evidence available for negative effects (e.g. habitat loss, disturbance, increased mortality through collisions of birds and bats; Everaert 2014; Loss et al. 2013; Marques et al. 2014; Villegas-Patraca et al. 2014).

Habitat loss by large-scale photovoltaic power stations

Although solar parks cover already millions of hectares worldwide, few studies on their biodiversity impacts are available. A great potential is seen for solar energy in Kazakhstan, as it receives 2200–3000 h of annual sunshine and an insolation (direct radiation from the sun) of 1300–1800 kWh/m^2 × year (Cochran 2008). The first solar farms have been opened in Kazakhstan, and investment in solar farms is actively promoted (The Astana Times 2015). Bird habitat loss has been suggested as large tracts of land are needed for the installation. Hundreds of insects per hour were incinerated in the intense light reflected from solar panels at a station in the United States (Turney and Fthenakis 2011). Birds that crossed Concentrated Power Solar Parks (CSP) have also been incinerated mid-air (NBC News 2014). Solar farms might reduce insect populations locally, and by this have cascading effects on the food chain.

Climate change

Global scenarios predict an increase in mean annual temperature by 1.5–2° by the year 2035 across northern and central Kazakhstan, an increase in drought frequency, but little change in precipitation patterns (IPCC 2013). Between 1941 and 2011, annual mean temperature and precipitation, as well as the number of very hot day days increased, while days with frost decreased across Kazakhstan (Salnikov et al. 2015). Comparing the period 1990–2006, Akhmadiyeva and Groisman (2008) found pronounced increases in mean annual, spring and winter temperature, weak increases in precipitation and near-surface air humidity, and a decrease in near surface wind in all seasons, across the Kazakh steppes. In contrast, a decrease in spring temperatures has also been suggested for years after 1990 (Mohammat et al. 2013). An increase in summer drought and a decrease in precipitation in the steppe zone was apparent for the period 2000–2008 (de Beurs et al. 2009; Lioubimtseva and Henebry 2009; Mohammat et al. 2013). Regional climate change scenarios suggest that mean annual temperatures will further increase by 2.3–4.5 °C in all months until 2030, but especially in spring (Pilifosova et al. 1997).

An increase in spring temperatures could lead to an earlier start of the growing season. This might make more land at the current southern border of agriculture in Kazakhstan suitable for cultivation and could lead to agricultural expansion. A future increase in winter temperatures might allow farmers in northern and central Kazakhstan to sow more winter cereals, a trend already observed (Kazakhstan State Statistics Agency 2016a). The change from spring-sown to autumn-sown cereal varieties, and the associated earlier ploughing of stubble and earlier crop growth, has caused significant losses of agricultural biodiversity in Europe (Gillings et al. 2005; Newton 2004).

Assuming ongoing global warming, a northward shift of vegetation zones has been proposed until the year 2080 (Tchebakova et al. 2009). North Kazakhstan steppe habitats, already depleted through agriculture, might become characterised by vegetation associated with arid zones presently found further south. Migration routes in large mammals might change (Singh et al. 2010b). However, there is much uncertainty about such patterns, as alternative research suggests an increase in humidity and no changes in precipitation patterns across Kazakhstan (Akhmadiyeva and Groisman 2008). Biome shifts from semi-desert to steppe have also been connected with changing land-use, namely a decrease in grazing pressure resulting in more frequent wildfires (Smelansky et al. 2015). A decrease in winter snow cover could have consequences for populations of small mammals (Bilodeau et al. 2013).

Increase in the area and number of steppe fires

On the steppes of Kalmykia in neighbouring Russia, increasing temperatures have led to more frequent and severe steppe fires, especially in areas where livestock numbers have collapsed and a lack of grazing has allowed plant litter to accumulate (Dubinin et al. 2010, 2011). In Kazakhstan, large steppe areas burn every year (e.g. 7.6 million ha in 2005, 9.9 mha in 2006 and 2.8 mha in 2007 across W Kazakhstan, Aktyubinsk and Karaganda provinces combined, Arkhipkin and Sagatdinova 2008). Increasing temperatures could lead to an increasing steppe fire risk in the future (Tchebakova et al. 2009), especially in areas that are currently not grazed and where large biomass stocks built up. This might have implications for the restoration of abandoned farmland, where a natural restoration to climax steppe vegetation communities is inhibited by high fire recurrence rates, but also for near-natural steppe grassland. Species-poor 'novel' or 'hybrid' grassland ecosystems (Hobbs et al. 2009) have emerged and will persist if no wild ungulates or domestic livestock return and certain grazing levels can be maintained (Brinkert et al. 2016, this issue).

Changes in the hydrological regime of steppe lakes and rivers

Increasing temperatures and evaporation could lead to lowering of water tables and increased salinity of freshwater steppe lakes. This might induce changes in vegetation, and cause a loss of habitat for birds and possibly invertebrates. Apart from climate change, saline steppe lake water levels could also decrease because of the increasing extraction of water from tributaries (Bai et al. 2011; Hwang et al. 2011; Kezer and Matsuyama 2006; Propastin 2008). Low water tables have been perceived as problematic in several Important Bird Areas in Central Kazakhstan, and even snow accumulation techniques have been used to restore these lakes to important waterbird stopover sites (Urazaliev 2013). An increase in mining activities could also lead to higher water demand, as observed in Mongolia (Priess et al. 2011).

Wildlife disease

Saiga antelopes as umbrella steppe species have been affected by several recent mass die-offs in Kazakhstan: in 2010, 12,000 animals died, an estimated 1/3 of the affected population in the Ural region (Grachev and Bekenov 2010), and in May 2015, at least 150,000 (nearly 50 % of the estimated world population) perished over a short period in the Betpak Dala area (Nicholls 2015a, b; Nutt 2015). Saiga die-offs have occurred historically, and were mostly attributed to infections with *Pasteurella* spp. or foot-and-mouth disease (Bekenov et al. 1998). Field sampling was inadequate for a full diagnostic analysis in 2010, however one potential cause which was discussed was that Saigas entered a huge area of former abandoned fields at a time of rapid vegetation growth. Foraging mostly on annuals, which are typical for abandoned fields (*Lepidium perfoliatum* and others; Dieterich and Sarsenova 2013), Saigas appeared to have developed problems with their rumen function and finally to have died from bloat (Kock et al. 2011; Sapanov 2011). Given that Saiga populations are vulnerable to poaching and other threats (such as infrastructure development), large losses due to disease could severely hamper population recovery.

Conclusions

The threats perceived as most severe in our study were mainly persistent rather than novel threats, and often apparent already in Soviet times, for example overgrazing by livestock or conversion of the steppe for agriculture. This might indicate that effective conservation and sustainable land management on the Kazakh steppes are hindered by ongoing structural problems. Comments received by participants of the horizon scan exercise suggested limited awareness about conservation issues among Kazakhstan's population, but also decision makers in policy and management. While conservation NGOs in the country are already very active in some areas to raise awareness (e.g. anti-Saiga antelope-poaching campaigns including TV broadcasts), other management-related issues might simply be unknown to key decision makers, and might benefit from multi-stakeholder approaches. For example, the second highest-ranked issue in our exercise was the 'undergrazing' of large steppe areas, thereby impacting ecosystem functioning. Restoring free-ranging livestock on the Kazakh steppes, coupled with management advice on ecologically sustainable stocking rates and the heterogeneity of grazing patterns, might result in conservation benefits, but also be desirable from a development perspective for Kazakhstan's agricultural sector (Vorotnikov 2013). Scientists and practitioners may wish to think 'out of the box' and seek collaboration with stakeholders e.g. from agriculture.

A number of very large new protected areas in Kazakhstan has been created in recent years, increasing the total area from 6.94 to 11.3 million ha since 1990 (2.6–4.3 % of the Kazakhstan's terrestrial area, IUCN category I–IV) and from 0.77 to 3.87 million ha in the steppe zone (1.0–5.1 % of the steppe zone terrestrial area (Kamp et al. 2015). The large size of these areas increases their value for conservation, as key steppe species rely on large, undisturbed habitat patches (e.g. Saiga antelope, large raptors). However, most of these are situated in areas of low opportunity costs for economic use (Venter et al. 2014) and hardly any have been created in the productive steppes used for agriculture. Many of the Soviet-era protected areas comprise 'scenic' areas of extra-zonal features (e.g. forests, wetlands) and not much grassland. Grassland reserves are lacking in areas of vast near-natural steppe, e.g. in Aktyubinsk and West Kazakhstan Provinces. To date, no systematic assessment of existing protected areas based on representation or complementarity criteria (using reserve selection algorithms, e.g. Possingham et al. 2000) has been performed. Comments of the horizon scanning exercise suggested that scientific evidence is rarely used to guide management plans. It is hence unclear whether the current set of protected areas effectively preserves biodiversity, although initial evaluation seems to suggest that this might well be the case, e.g. for Important Bird Areas (Schweizer et al. 2014) and Saiga Antelope populations (Singh and Milner-Gulland 2011).

In Kazakhstan, there are few country-wide, efficient biodiversity monitoring systems, making it difficult to assess temporal trends in species abundance and distribution. This results in large uncertainty in population estimates, which are needed for threat assessments such as red data books. Due to the extremely large land area and the very low human population density, the installation of country-wide biodiversity monitoring schemes presents challenges. However, an increasing number of global citizen science databases are now available that could be exploited to model species' distribution and abundance in time and space (Schmeller et al. 2009). Additionally, there are a number of local initiatives to collect biodiversity data. Spatially referenced bird observations are shared via the website http://www.birds.kz and available for analyses of bird distribution and phenology in Kazakhstan. Elusive species are monitored in citizen science approaches using camera traps (e.g. wild cats, http://wildcats.wildlifemonitoring.ru/?lang=en#). A country-wide database on small mammals is currently being set up (A. Shmalenko pers. data). Participatory monitoring schemes have also been established with success for Saiga antelope (Chilton 2011). Wider promotion of such facilities among amateur natural history recorders and in academia might result in better availability of biodiversity data for conservation-oriented research. This seems especially promising as the interest in biodiversity recording has grown steadily among amateurs during past years.

While conservation efforts have increased tremendously in Kazakhstan over the last decade, there is still limited research and management capacity to implement conservation research findings, including a very low number of independent conservation-related NGOs. Government incentives are to increase the manpower, and staff qualifications e.g. in protected areas, or wildlife management and monitoring schemes could have high conservation benefits. Such programs could be accompanied by increased education and training in conservation-related fields at universities, and more incentives to keep young specialists in conservation after graduation.

Our study provides a first assessment and priority ranking of conservation issues on the steppes and semi-deserts of Kazakhstan. However, it has several limitations. The sample size of opinions presented here is still small, affecting the precision of the quantitative threat ranking. There might be bias in the opinions of experts as these represent specific areas of expertise. However, we have assembled experts covering a broad range of conservation and research directions (see results), and the internal consistency in ranking threats among experts was high, suggesting that the results reflect general consensus.

As is typically the case in horizon scanning exercises, there was little empirical evidence available on the likelihood of some threats becoming relevant in the future, or their severity (e.g. biofuels). The ranking therefore mirrors largely perception of these issues based on anecdotal information, and by selecting the 10 highest ranked threats in each category, we might have dropped potentially important threats. However, the lack of robust information on the potential threats discussed here can serve as a starting point for future research, and can be refined later. Similarly, a further refinement of the initial threats list and a standardized characterisation of the threats prior to discussion would be desirable: threats could be classified e.g. by the area affected, the number and status (threatened, endemic) of species to be lost, and the likelihood of the phenomenon occurring.

We did not include opinions of policy makers. These might have differed from those presented here due to different backgrounds and policy priorities. Future assessments should ideally include a workshop enabling face-to-face communication, and invite more policy makers. We see this exercise as a first step to stimulate discussion, and as a baseline reference for conservation in Kazakhstan. It would be desirable to repeat it with a larger and more balanced group of experts. Ideally, a threat assessment would also be extended to the entire country of Kazakhstan, as many economic, conservation and management decisions are made on the state level.

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