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Abstract

Species conservation is currently underutilising proactive, forward-looking methods that could help manage the increasingly complex and unpredictable pressures facing species globally. Horizon scanning, which fits into broader strategic foresight cycles, could identify potential future threats and opportunities for species. Enabling early action before impacts accumulate or windows of opportunity pass could facilitate progress towards species conservation targets. This study explores the potential of horizon scanning to inform species conservation planning using a Delphi-like approach to synthesise geographically dispersed insights into potential futures for the saiga antelope (*Saiga tatarica*) from a diversity of actor types. Through rounds of scoring, evidence, and discussion involving 42 participants, the six highest-priority issues for saiga conservation over the next decade were determined. '*Wildlife health and disease*', '*Development and infrastructure*', and '*Climate and environmental change*' were the highest-scoring 'Driver' themes that emerged from the process. The effectiveness of the Delphi-like method was demonstrated by broadly consistent prioritisation across participants and between-round changes, despite significant background-specific differences, suggesting that a collective judgement emerged. As the first species-level horizon scan, this study provides vital lessons for when and how the methodology should be implemented.

1. Introduction

Twenty-eight percent of species assessed for the IUCN Red List are threatened with extinction (IUCN, 2025), reflecting immense and growing global pressures altering the threat and opportunity landscape for wildlife. These pressures are increasingly shaped by rapid ecological and socio-economic change, which interact to produce additive impacts that cannot be forecast from past trends alone (Yang et al., 2021). A less predictable future is one that is much harder to manage, posing a risk of unpreparedness and ineffective conservation action.

Change is often preceded by early warning signals that provide a critical window for intervention but are frequently missed or ignored. This is exemplified by the crash of the Chiru (*Pantholops hodgsonii* Abel, 1826), driven by a surge in poaching for its underfur to meet spiking demand for luxury shahtoosh shawls (Schaller, 1998; Mills, 1999). The fashion craze was only recognised once it was well established, and thousands of animals had been lost. Delayed response contributed to a ~90% loss of the global population (Schaller, 1998). Allowing impacts to accumulate makes intervention more resource-intensive and potentially less effective (**Figure 1**), highlighting the need for forward-looking approaches that not only identify emerging issues but also prioritise them to ensure timely action.

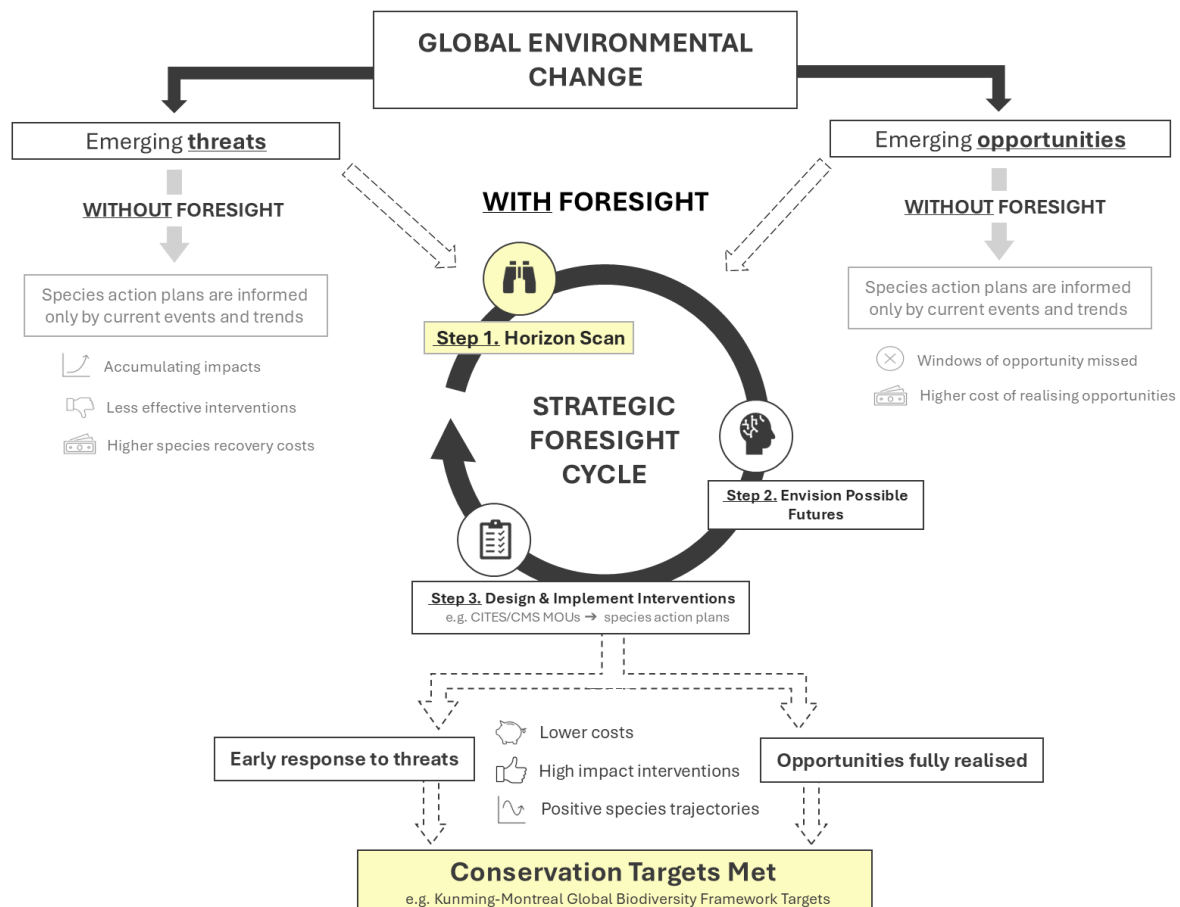


Figure 1. How integrating horizon scanning and wider foresight processes into species conservation processes can accelerate progress toward conservation targets. Solid arrows = existing pathways. Dashed arrows = proposed pathways.

Global species conservation is strongly shaped by two Multilateral Environmental Agreements (MEAs): the Convention on Migratory Species (CMS) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which produce species-specific Memoranda of Understanding (MOUs) implemented through action plans. These are informed by scientific evidence on current species trajectories, provided by CMS and CITES themselves, as well as IUCN Species Survival Commission (IUCN-SSC) Red and Green List assessments. Given that action plans outline future strategy, the lack of formal forward-looking approaches in this process is striking. Species conservation can draw lessons from other sectors facing similarly high-impact, hard-to-predict risks that have already developed effective forward-looking approaches. Sectors like EU policymaking and global public health (Van Woensel, 2024; World Health Organisation, 2022) have shown that approaches like strategic foresight can inform decision-making by considering possible, probable, and desirable future conditions (Cook et al., 2014). Strategic foresight can identify emerging issues (both threats and opportunities) before they fully materialise, enabling earlier, more effective interventions and the ability to capitalise on time-sensitive opportunities (Cook et al., 2014). Greater uptake of foresight methods in species conservation could support a shift toward proactive action, reducing pressure on limited resources while advancing progress towards global targets, for example, those outlined in the Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity, 2022) (**Figure 1**).

Strategic foresight processes are often initiated through a horizon scan (Cuhls, 2020), which involves systematically searching data or untapped expert knowledge for signals of change (Sutherland & Woodroof, 2009). Horizon scanning has proven effectiveness in global conservation (e.g. Sutherland et al., 2010; Sutherland et al., 2019) and is increasingly used on narrower conservation topics such as pollination, the illegal wildlife trade (IWT), and climate change impacts on Aotearoa New Zealand (Brown et al., 2016; Esmail et al., 2020; Macinnis-Ng et al., 2024). However, its use at the level of individual species remains unexplored.

Horizon scanning provides a tool for capturing potentially rich but dispersed expert insights and integrating them into existing species conservation planning processes. Species, particularly those with large or border-spanning ranges, often have several management authorities and a disconnected cohort of experts working on them. Experts develop deep, population- or sector-specific knowledge of their species, including early signs of change, but these insights may not reach decision-makers. If species conservation processes were restructured to more closely resemble strategic foresight cycles (**Figure 1**), horizon scanning could funnel this untapped knowledge into species action plans, informing targeted interventions.

The saiga antelope (*Saiga tatarica* Linnaeus, 1766), hereafter 'saiga', is a valuable case study for species-level horizon scanning because of its highly uncertain future and its geographically and institutionally dispersed stakeholder network. The saiga is a nomadic migratory ungulate with five

distinct populations across Kazakhstan, Uzbekistan, Russia, and Mongolia that undertake large-scale, often transboundary migrations (IUCN, 2023). The horns of males are traded internationally for use in Traditional Chinese Medicine (TCM) (Chan et al., 1995), which extends the relevance of the saiga beyond its range states. The species has a volatile past, having narrowly avoided extinction twice in recent history: once in the mid-1990s after a post-Soviet spike in poaching for TCM drove a global population crash (Milner-Gulland et al., 2001), and a second time in 2015 following a bacterial outbreak which was potentially linked to climatic anomalies (Kock et al., 2018). The global saiga population has now overshot pre-crash levels thanks to its remarkable resilience and fecundity (Kühl et al., 2009), and the species was downlisted to Near Threatened in 2023 (IUCN, 2023). However, this should not be mistaken for security. Global success is not range-wide, and the saiga's 2024 Green List Assessment classifies it as Largely Depleted (Milner Gulland & Mallon, 2024), meaning that recovery is incomplete. While the Betpak-Dala and Ural populations are booming, the Ustyurt, Pre-Caspian, and Mongolian populations have not recovered to the same extent and remain particularly vulnerable (IUCN, 2023). Saigas are highly exposed to global change due to their expansive range (Kühl et al., 2009), and there is much uncertainty about how they might be impacted by multiple interacting stressors, including extreme weather events, linear infrastructure expansion, human-wildlife conflict (HWC), and the recently partially reopened legal saiga horn trade (ACBK, 2025; CITES, 2025). Opportunities, including what conservation 'success' looks like, are also shifting as the saiga's position in social, economic, and political contexts evolves, leading to further uncertainty about what comes next. The saiga's multidisciplinary conservation network, with a strong culture of trust and collaboration, offers an ideal environment for horizon scanning to reduce uncertainty and inform responses to emerging shifts in the socio-ecological system.

The saiga also provides a clear pathway for actionable change. The Medium-Term International Work Programme (MTIWP) is a five-yearly action plan developed under CMS that outlines population-specific conservation priorities for the saiga. This framework represents a major step towards proactive conservation, but it remains primarily informed by issues with current impacts. Despite deadly outbreaks of foot-and-mouth disease impacting saigas in the latter half of the 20th century (Orynbayev et al., 2016), the 2007-2011 MTIWP (CMS, 2006) failed to include action points relating to disease, contributing to widespread unpreparedness for die-offs that struck saiga populations in the 2010s (Fereidouni et al., 2019). Integrating horizon scanning could supplement the MTIWP with lesser-known emerging issues, facilitating early action to help ensure the saiga's success going forward.

In this research, I apply horizon scanning to identify and prioritise emerging issues for saiga conservation. I also explore whether diverse perspectives can be brought together to produce a collective judgement at the species level. To my knowledge, this is the first application of horizon scanning at the species level, providing important insights into whether and how forward-looking

approaches can support species conservation. The study's specific aims and hypotheses are as follows:

AIM A: Identify and prioritise emerging threats and opportunities likely to impact saiga conservation over the next ten years.

AIM B: Analyse how participant backgrounds influence prioritisation and how priorities change between rounds to assess whether a collective judgement can emerge from diverse perspectives at the species-level.

H1: Participants who are based in range states and/or have experience working on abundant saiga populations (Ural and Betpak-Dala) will assign greater importance to overabundance-related drivers than participants working on other populations or non-range-state contexts.

H2: Participants who use media and public reporting as sources of information about saigas will prioritise drivers differently from participants who do not use these information sources.

H3: Participants with wildlife trade expertise will assign greater importance to trade-related drivers than participants without trade expertise.

AIM C: Evaluate the appropriateness of horizon scanning at the species-level and provide guidance for its future use.

2. Methods

I applied Delphi-like horizon scanning to identify priority emerging issues (threats and opportunities) likely to affect the saiga over the next decade (**Figure 2**). I collected ideas of potential issues, then invited participants to score these based on (1) likelihood, (2) novelty, and (3) potential impact. I produced evidence summaries of top-scoring issues, hosted discussion workshops to inform another scoring round, and identified the top issues based on those scores. I then examined whether issues with common drivers were prioritised differently across participant backgrounds and analysed changes between scoring rounds.

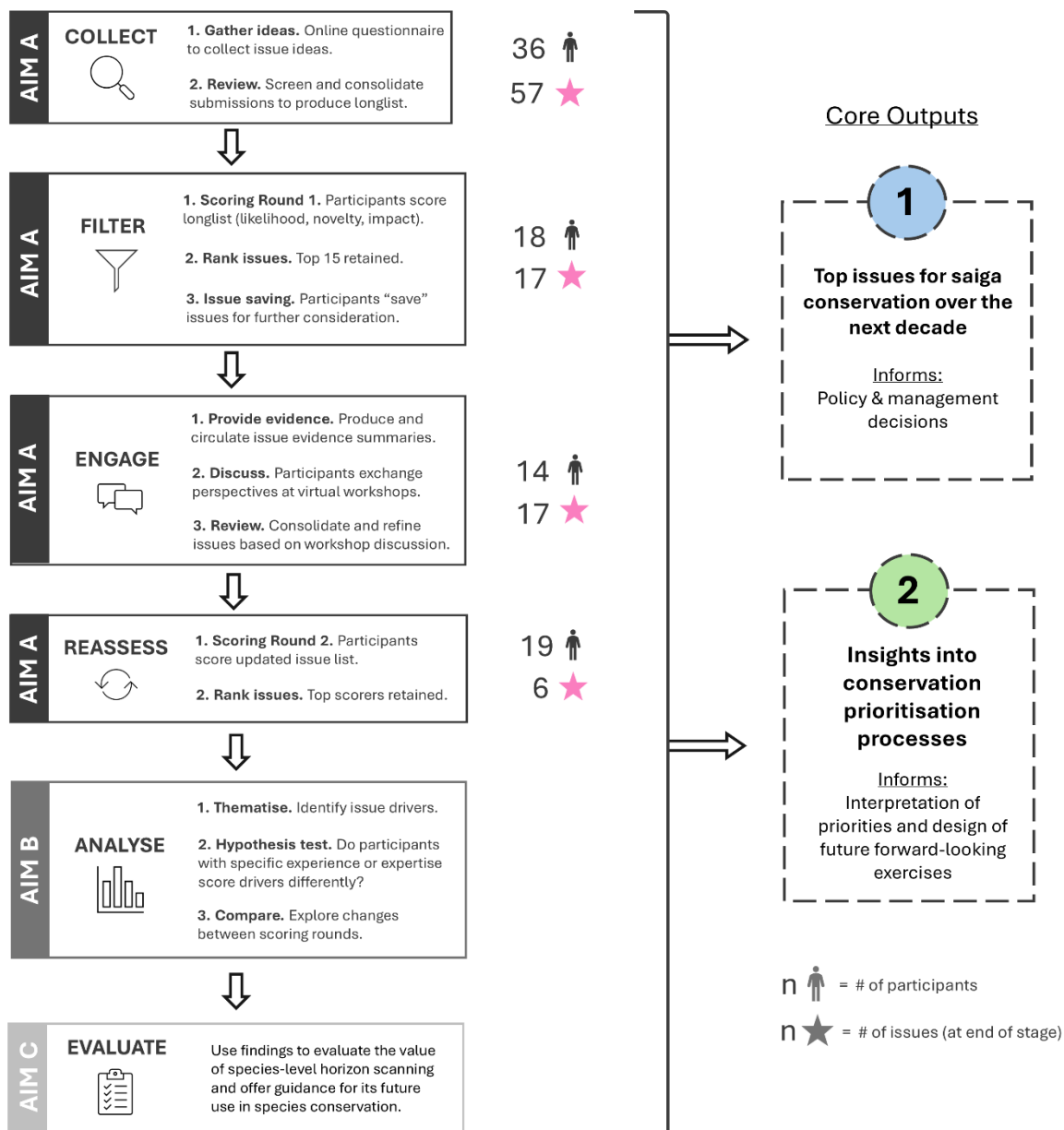


Figure 2. Methodological overview of the Delphi-like horizon scan used to address aims A (identify priority issues for saiga), B (analyse how backgrounds shape prioritisation and whether diverse perspectives can produce collective judgement across rounds), and C (evaluate and provide guidance for species-level horizon scanning). Participant numbers and the numbers of issues involved at the end of each stage are shown.

2.1 Delphi-like horizon scanning

In conservation contexts, where empirical evidence may be limited, horizon scanning can draw on specialist knowledge and experience (Wintle et al., 2020). Delphi-like methods bring structure to the process by collating scattered and diverse perspectives to identify a set of priorities (**Figure 3**) (Mukherjee et al., 2015; Nowack et al., 2011; Sutherland & Woodroof, 2009). Past findings that groups improve their best guesses through learning and judgement refinement support the use of this method (Burgman et al., 2011). As do Sutherland et al.'s annual global conservation horizon scans since 2010, with retrospective analyses showing that most issues identified in their first scan subsequently emerged (Sutherland et al., 2019).

Delphi-like Horizon Scanning for the Saiga Antelope

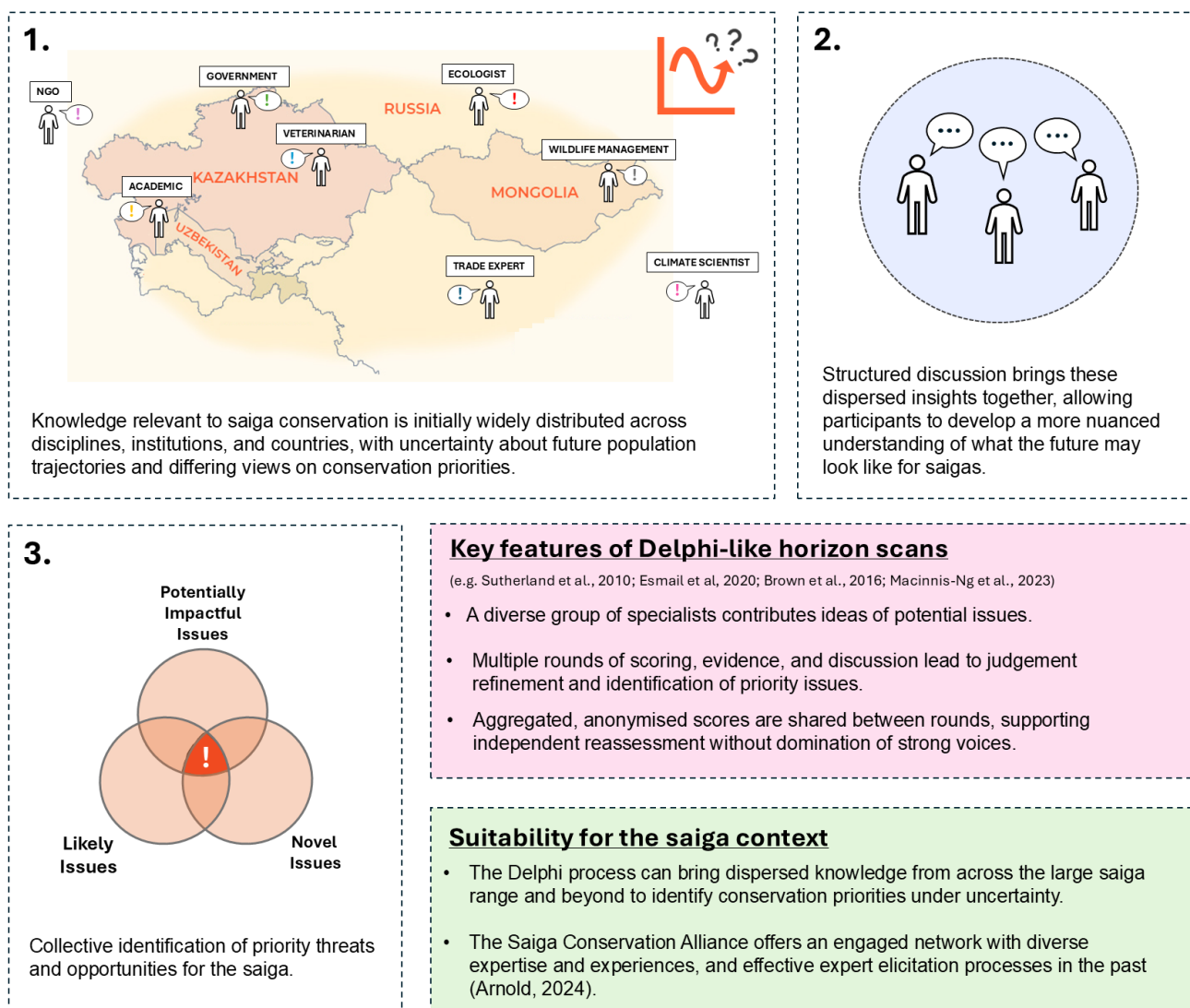


Figure 3. Rationale for applying a Delphi-like horizon scanning approach to the saiga antelope, to synthesise dispersed expertise and identify likely, novel, and impactful issues.

In the absence of a species-level methodology, I adapted the methods of Esmail et al.'s (2020) horizon scan of the IWT. This study provides a robust methodological basis because it successfully prioritised issues in a specific conservation context and drew on a highly international cohort. Major deviations from the Esmail et al. methodology are outlined in **Appendix B**.

2.2 AIM A: Identifying priority issues

2.2.1 Participant recruitment

I cast a wide net across the saiga conservation network and beyond to incorporate diverse perspectives. I first approached participants at the 20th meeting of the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES CoP20), where I used flyers and presentation slides to advertise the horizon scan at saiga-related events attended by many relevant stakeholders (~40 reached) (see **Appendix M**). I then recruited additional participants online through snowball sampling (Kirchherr & Charles, 2018), using targeted emails (~70 individuals reached) and a LinkedIn post (>1200 users reached).

To maximise inclusion, I made all materials available in English and Russian and distributed Word versions of online questionnaires to address internet restrictions in Russia. I did not restrict participation to only saiga experts, recognising that those with less experience or in adjacent fields (e.g. broader wildlife trade policy or species conservation more generally) could offer important insights. I permitted participants to join late or skip stages of the entirely remote process. This flexibility allowed me to use targeted emails to address emerging gaps in representation, an important methodological step to ensure a broad range of viewpoints shaped issue prioritisation. Overall, cohort composition was recorded as 26% based in saiga range states, 50% outside range states, 24% of unknown location; 24% Academic/Researcher, 52% Conservation Practitioner, 14% Policy/Government/IGO, 10% Other or unknown.

2.2.2 Producing an issue longlist (COLLECT)

Questionnaire Design

I used an online questionnaire to capture ideas about what the future may look like for saigas. Following best practice (Lavrakas, 2008), I invited participants to propose one to three issues that could affect saiga populations positively or negatively over the next decade, encouraging consideration of both threats and opportunities (**Appendix C**). I also solicited a “wild card” issue to capture high-impact, low-likelihood “black swan” events that forecasting methods often miss (Goodwin & Wright, 2010; Kemp et al., 2020). I chose a ten-year time horizon for its balance of

realism and forward-thinking (Hines et al., 2019) and made this explicit throughout to ensure responses matched the scope of the study.

Issue Consolidation

Many of the 125 raw issue responses were too vague, contained multiple distinct ideas, or overlapped with other responses, so I screened and refined them prior to scoring. I removed ambiguous responses (e.g., “climate”, “infrastructure”, “drought”) and split responses containing multiple distinct ideas into ‘chunks’. I inductively coded the 193 resulting chunks (Braun & Clarke, 2006), then merged chunks with the same driver code. This resulted in a longlist of 57 issues for Scoring Round 1.

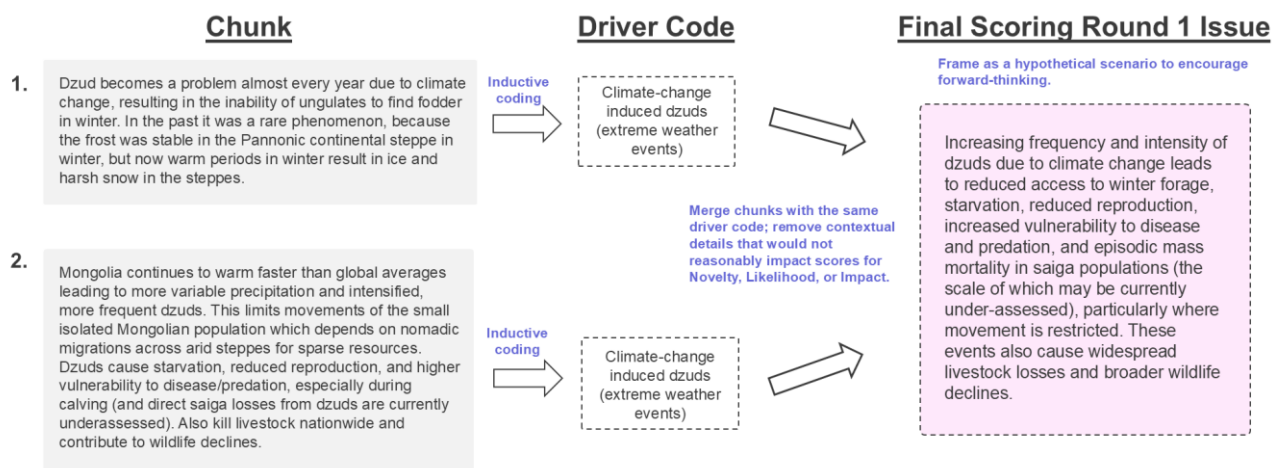


Figure 4. Example of the inductive coding and merging process used to condense raw-response chunks into distinct issues (longlist) for Scoring Round 1. Chunks were coded to the highest-order driver explicitly stated by respondents. For example, climate-change-induced dzud was coded separately from dzud. Dzuds are anomalous climatic events characterised by extreme cold, snow, and ice that reduce access to fodder and can cause mass mortality in livestock and saigas (UNDRR, 2025; Khanyari et al., 2021b).

2.2.3 Scoring Round 1 (FILTER)

Questionnaire Design

I invited participants to Scoring Round 1 (SR1), in which they scored the longlist to filter out issues which were not of sufficiently high priority. I used an online questionnaire (see **Appendix M**) to present the longlist issues in a fixed order that I had randomly determined to minimise ordering effects (Lavrakas, 2008). Participants scored based on three criteria (adapted from Esmail et al., 2020):

- (1) **Likelihood of emergence** (how likely is it that this issue will occur in the next 10 years?)
- (2) **Novelty** (how well-known is this issue among relevant stakeholders today?)
- (3) **Potential impact** (if this issue were to occur, how large would its impact on saiga populations be, and would that impact be positive or negative?)

I designed these criteria with later stages of the horizon scan in mind, drawing on the characteristics of suitable horizon scan issues (Hines et al., 2018). I kept the criteria separate rather than combining them into a composite score (e.g. Sutherland et al., 2010; Esmail et al., 2020) because per-criterion scores could support workshop discussion and subsequent analyses. I included 'do not know/prefer not to score' options to reduce random scoring that could bias results (Lavrakas, 2008) and provided a comments box for concerns or additional insights. I asked several background questions (see **Appendix E**) to categorise participants into 'background groups' relating to their professional experience, so I could identify patterns in scoring.

Issue Progression

I aggregated SR1 scores to determine which would progress to the ENGAGE stage. I calculated participant-level issue totals, equally weighting Likelihood, Novelty, and Impact to prioritise issues that scored highly across all three dimensions. I standardised raw scores by converting them into z-scores (**Figure 5**), which account for differences in how participants use the scoring scale (Esmail et al., 2020; Kemp et al., 2020). This approach centred each participant's scores for each criterion around zero, allowing comparison between issues; e.g., a positive 'Likelihood' z-score would indicate that a participant deems the issue more likely than most other issues. I used the absolute values of impact scores at this stage because potentially high-impact threats (-) and opportunities (+) are equally important to the horizon scan.

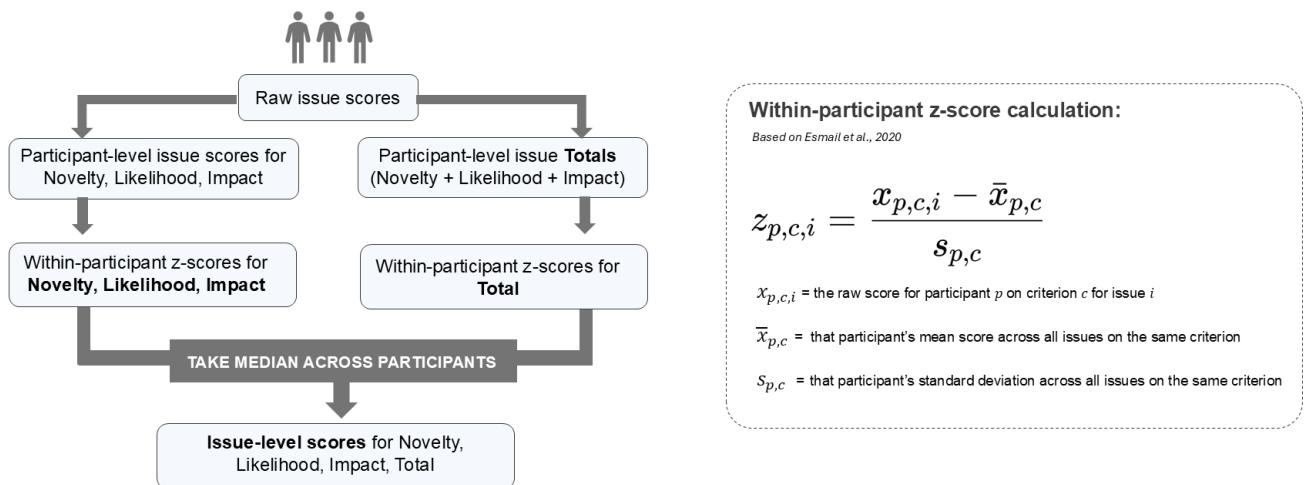


Figure 5. Aggregation of raw SR1 and SR2 scores into issue-level Total, Novelty, Likelihood, and Impact scores, with within-participant z-score standardisation shown.

I merged two pairs of issues with identical scoring profiles that had been flagged as similar during SR1, then selected the top 15 issues, which I had ranked by Issue Total (Kemp et al., 2020). This number was small enough to enable me to produce sufficiently in-depth evidence summaries while retaining a diversity of issues.

I gave participants the chance to “save” any eliminated issues they believed deserved further consideration. I circulated a summary of the SR1 results with scores grouped into bands and a ‘perceived impact direction’ metric to allow easy comparison between issues (see **Appendix F**). Two issues were saved, resulting in a ‘midlist’ of 17 issues.

2.2.4 Evidence and discussion phase (ENGAGE)

Evidence Summaries

I produced and circulated seventeen ~400-word evidence summaries of the midlist issues to support informed discussion. Some horizon scans employ a ‘cynics’ model, in which participants independently and critically research a subset of midlist issues before discussing their findings in workshops (Kemp et al., 2020; Esmail et al., 2020). In this study, however, I took on the role of cynic for all issues to reduce participant burden and ensure all issues were interrogated with the same rigour. The summaries were mini-literature reviews that drew on >90 publications to present current evidence and knowledge gaps (**Appendix M**). I asked participants to critically review these, guided by prompting questions I circulated (**Appendix G**).

Discussion Workshops

I hosted two one-hour online workshops. During these, each issue was interrogated in turn, guided by the evidence summaries and SR1 outputs (**Appendix M**). I offered various time slots and live translation to maximise participation. To allow enough discussion time for each issue, eight issues were covered in one workshop and nine in the other, split evenly by driver code, so participants not attending both sessions could still engage with the full range of topics. For each issue, I presented its evidence summary, banded per-criterion scores, and anonymised comments from SR1, then opened the floor for five minutes of discussion. Peter Damerell (Saiga Conservation Alliance) facilitated discussion, using the scoring outputs and his own expertise to prompt participant reflection, and I provided clarity when requested or I deemed necessary.

I produced bullet-point summaries of the discussions, incorporating comments from those who could not attend, for participants to refer to during Scoring Round 2 (**Appendix M**).

2.2.5 Scoring Round 2 (REASSESS)

In Scoring Round 2 (SR2), participants scored a revised set of 17 issues using the same criteria as in SR1. Concerns about issue overlap and wording had led me to merge two issues into one, split another into two, and simplify the wording of all issues. The SR2 questionnaire (**Appendix M**) presented each issue along with its evidence and discussion summary. I encouraged participants to consider this information while scoring, and to take more time deliberating their scores than in SR1.

I aggregated SR2 scores (**Figure 5**) and ranked them based on Issue Total. I used a natural break in these values to select a final shortlist of the highest-priority issues for saiga conservation over the coming decade.

2.3 AIM B: Identifying trends in prioritisation

I investigated whether participant backgrounds influenced driver prioritisation and whether priorities shifted between rounds, to determine whether a collective judgement had emerged from diverse perspectives during the process (**Figure 6**).

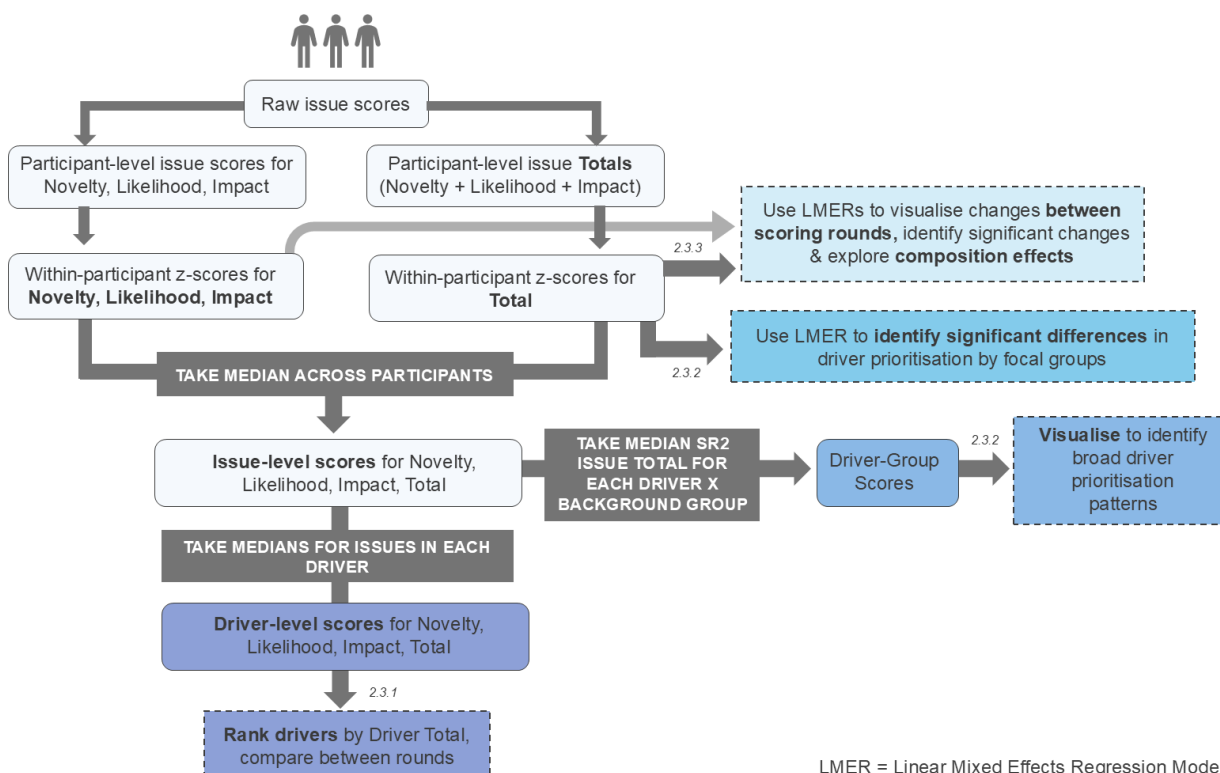


Figure 6. Analytical pipeline for ranking drivers, visualising prioritisation patterns, testing differences among focal groups using LMERS, and assessing changes between scoring rounds.

2.3.1 Identifying and ranking Drivers

I categorised issues using an inductive thematic analysis (Braun & Clarke, 2006). I coded issues based on their primary drivers (as in 2.2.2), grouped similar codes, and then refined these groupings until they were distinct and internally consistent. This resulted in a set of ‘Driver’ themes. I took medians of issue-level scores for each Driver and ranked Drivers by Driver Total (**Figure 6**).

2.3.2 Identifying background-specific trends in driver prioritisation

I converted multi-select responses into binary indicators (0/1) to produce independent focal groups for heatmap visualisation and hypothesis testing (**Table 1**). I formulated these hypotheses to include a range of factors likely to influence Driver prioritisation, including population-specific experience, information exposure, and professional expertise. Despite being likely to shape prioritisation, I did not attempt to test whether participants’ level of saiga knowledge affected prioritisation, because it was difficult to objectively quantify. I also did not test sector (e.g. ‘Policy/Gov/IGO’, ‘Academic/Researcher’) because the categories were too broad and overlapping to analyse as distinct groups.

Table 1. *The focal groups used to test hypotheses and the rationale behind each hypothesis.*

	Focal Group	Rationale
H1	Participants with experience working on abundant populations (Ural and/or Betpak-Dala)	Selected because these two large populations have dynamics that differ from others (e.g. a history of mass mortality from disease, potential human-wildlife conflict; ACBK, 2025), so working on them may shape perspectives about the future for saigas differently to other populations.
H2	Participants who use media/public reporting as an information source	Selected because media influences perspectives on species conservation (Le Busque et al., 2021), so participants using it as a source of saiga information may prioritise issues differently.
H3	Participants with wildlife trade expertise	Selected because trade was expected to be an important topic in the horizon scan, due to the recent CITES CoP20 decision (CITES, 2025) and previous population declines caused by poaching (Milner-Gulland et al., 2001), allowing a direct test of whether trade expertise shaped prioritisation of trade issues.

I applied linear mixed-effects regression (LMER) models to these focal groups to test the study's hypotheses. I used within-participant z-score (Total) as the response variable, background group and Driver as fixed effects, and Participant as a random intercept because participants had each given many non-independent scores. I also included interaction terms to test whether differences between groups varied across Drivers and used post hoc pairwise comparisons of estimated marginal means (EMMs) to determine which pairings differed significantly. I used a Benjamini-Hochberg correction to reduce the risk of false positives (Benjamini & Hochberg, 1995), given many comparisons across Drivers and criteria.

2.3.3 Examining changes between scoring rounds

I also analysed changes between SR1 and SR2 to assess the impact of the ENGAGE phase on prioritisation and whether group composition influenced those changes. I used LMERS to estimate round-specific EMMs and post hoc pairwise comparisons to test differences between rounds, first across all participants and then for participants who scored in both rounds. I modelled Total and the three criteria (Likelihood, Novelty, and Impact) separately, included Round and Driver (and Criterion in the criteria models), used participant as a random intercept, and used Benjamini-Hochberg correction to identify which Driver $\times$ Total and Driver $\times$ Criterion combinations changed significantly between rounds.

A summary figure of my full analytical pipeline is provided in **Appendix H**.

2.4 Statistical analyses

All statistical analyses were conducted in R (v. 4.5.3), using lme4 for LMERS and emmeans for post-hoc comparisons. I used dplyr, tidyr, stringr, tibble, gt, ggplot2, patchwork, htmltools, and webshot2 for data organisation and visualisation. I used large language models to assist with coding and troubleshooting.

2.5 Ethical approval

This study received ethical approval from the University of Oxford Central University Research Ethics Committee (CUREC), reference MS IDREC-2388552.

3. Results

3.1. Participation

Participation varied across the study: Of the 42 individuals who participated, 24 took part in two or more stages, 13 in three or more, and 5 in all four. 34 participants proposed issues, 18 participated in SR1, 19 in SR2, and 14 in the ENGAGE phase.

3.2 AIM A: Priority issues

3.2.1 SR1: initial issue landscape

Consolidation of questionnaire responses yielded 57 issues (**Table 2**). Most (35/57) were classified as threats. Five of the 35 threats and 8 of the 18 opportunities had complete consensus on impact direction (whether they were threats or opportunities), indicating greater agreement on opportunities. Four issues had complete non-consensus on impact direction. Progressing issues (**Table 2**, in bold) were commonly characterised by high-medium Likelihood and Impact scores, but neutral Novelty scores. Only three criterion scores were rated as high, a surprisingly low number that may reflect the scoring banding used.

Table 2. Scoring Round 1 Issues 1-24 with their Drivers, Impact Directions, and SR1 scores.

Scoring Round 1 Issues (1-24)								
Rank	Issue wording	Driver	T/O	Likelihood	Novelty	Impact	Total	
1	Cumulative stress from resource scarcity, climatic extremes, habitat fragmentation, human disturbance, infrastructure, and regional instability weakens immune function, reduces reproductive success, and increases vulnerability to disease, undermining overall population resilience.	Wildlife health and disease	~T	Neutral (0.05)	High-medium (0.95)	Neutral (0.23)	1.54	
2	Increasing aridity and poorly anticipated climate-adaptation responses (e.g. expanded irrigation, groundwater extraction, intensified livestock production) shift saiga distributions and movement pathways, increasing contact with people and infrastructure and elevating human-wildlife conflict, while limited understanding of these pressures and insufficient monitoring constrain effective anticipation and mitigation.	Climate and environmental change	T	High-medium (0.60)	High-medium (0.73)	Neutral (0.10)	1.45	
3	Linear infrastructure and hard borders isolate saiga subpopulations and reduce genetic exchange, limiting movement during extreme weather events and weakening adaptive capacity to climatic variability, with long-term consequences for population size, resilience, and recovery.*	Development and infrastructure	T	High-medium (0.88)	Neutral (-0.39)	High-medium (0.78)	1.42	
4	Expanded traffic networks increase wildlife-vehicle collisions, hinder effective enforcement, and improve access to remote areas which facilitates targeted poaching and enables greater livestock movement risking pathogen spillover into previously isolated saiga habitats.	Development and infrastructure	~T	High-medium (0.57)	High-medium (0.73)	Neutral (-0.02)	1.35	
5	Changes in land use and management - including agricultural expansion, extractive activities, infrastructure development, and altered grazing pressure - degrade and fragment steppe habitats, reducing habitat quality and the extent of suitable saiga range.	Development and infrastructure	~T	High-medium (0.82)	Neutral (-0.07)	Neutral (0.26)	1.35	
6	Rapid expansion of linear infrastructure - including roads, railways, mining access routes, fencing, agricultural lands, and hard borders - creates physical and functional barriers that fragment habitat and restrict saiga access to key forage areas, water sources, calving grounds, and recolonisation areas, increasing human-wildlife conflict and exposure to targeted poaching.*	Development and infrastructure	T	High-medium (0.68)	Neutral (0.10)	High-medium (0.96)	1.15	
7	Scarce food and water forces saigas closer to settlements and shared water points, increasing contact with livestock and people, creating pathways for pathogen transmission.†	Land-use practices and resource systems	~T	High-medium (0.70)	Neutral (0.14)	Neutral (0.47)	0.97	
8	Growing saiga numbers, agricultural impacts, mass die-offs that leave communities to manage carcasses, and the absence of local benefits shift perceptions of saigas from valued wildlife to pests, reducing tolerance for coexistence with a large, highly mobile herbivore and weakening public support for conservation.	Human-saiga interactions and social acceptance	~T	High-medium (0.70)	Neutral (-0.34)	Neutral (0.42)	0.92	
9	Climate change contributes to slow yet irreversible ecosystem changes - including shifting natural boundaries, degradation of permafrost, shrinkage of peatlands, wetlands, and natural springs - which degrade and fragment habitat, undermining saiga survival.	Climate and environmental change	~T	High-medium (0.57)	Neutral (-0.02)	Neutral (0.47)	0.91	
10	Disease outbreaks, including new or previously absent pathogens such as PPR and pasteurellosis, trigger rapid, large-scale mass die-offs in saiga populations, particularly in large or naïve herds and where limited wildlife disease surveillance means outbreaks are detected too late.	Wildlife health and disease	~T	High-medium (0.53)	Low-medium (-0.55)	High (1.11)	0.86	
11	Practical measures are implemented to reduce human-saiga conflict.	Human-saiga interactions and social acceptance	O	High-medium (0.56)	Neutral (-0.26)	Neutral (-0.08)	0.70	
12	Economic collapse and armed conflict undermine regulated wildlife management, disrupt or destroy habitat, and increase poaching and mass killing, as enforcement weakens and saigas are increasingly perceived as “fair game” due to their commercial value.	Political instability and geopolitical change	~T	Low-medium (-0.85)	Neutral (0.50)	High-medium (0.67)	0.65	
13	Climate change and land-use change reduce water and pasture availability, forcing saigas to alter migration patterns and move into agricultural areas, increasing competition with livestock and conflict with farmers.†	Climate and environmental change	~T	High-medium (0.57)	Neutral (-0.44)	Neutral (0.07)	0.61	
14	An unexpected catastrophic die off occurs, as people made the dangerous assumption that the sheer number of saiga meant die offs would have limited impacts on population numbers.	Population dynamics and management	~T	Neutral (0.49)	Neutral (0.35)	High-medium (0.67)	0.60	
15	As saiga populations expand, human-wildlife conflict generates political pressure where management prioritises horn value over coexistence and lacks compensation, dialogue, local incentives, and transparent benefit-sharing. Pressure from influential agricultural producers and legal trade without community-sensitive frameworks increases the risk of poorly justified decisions, weakened regulation, and renewed poaching, undermining sustainable saiga management.	Human-saiga interactions and social acceptance	T	High-medium (0.59)	Neutral (-0.05)	Neutral (0.20)	0.59	
16	Integrating research across wildlife health, pathogens, parasites, nutrition, climate, and weather improves understanding of the mechanisms driving saiga mass mortality events.	Conservation action and knowledge systems	O	Neutral (0.09)	Neutral (0.25)	High-medium (0.57)	0.49	
17	A craze or a new use for saiga horn emerges.	Trade, demand, and markets	~T	Low-medium (-0.59)	High (1.58)	Neutral (-0.02)	0.47	
18	Increasing frequency and intensity of dzuds due to climate change leads to reduced access to winter forage, starvation, reduced reproduction, increased vulnerability to disease and predation, and episodic mass mortality in saiga populations (the scale of which may be currently under-assessed), particularly where movement is restricted. These events also cause widespread livestock losses and broader wildlife declines.	Climate and environmental change	T	Neutral (0.22)	Neutral (0.14)	Neutral (0.10)	0.47	
19	Policy and management systems designed for scarcity are not prepared for the shift from emergency protection to routine abundance management, as large herds increasingly interact with agriculture, infrastructure, and grazing systems and require active, day-to-day land-use coordination.	Population dynamics and management	~T	High-medium (0.70)	Neutral (0.05)	Neutral (-0.02)	0.44	
20	Following the resumption of legal trade, demand and prices for saiga horn fluctuate unpredictably, triggering increased poaching and illegal trade.	Trade, demand, and markets	~T	Neutral (-0.24)	Neutral (0.05)	Neutral (0.38)	0.44	
21 (saved)	Earlier and more variable spring green-up disrupts the timing of calving leading to reduced calf survival which increases vulnerability to population crashes and extinction.	Climate and environmental change	~T	Neutral (-0.30)	High (1.15)	Neutral (-0.19)	0.39	
22	Improper implementation of sustainable use, including excessive harvesting or skewed sex and age structure in offtake, leads to major saiga population declines.	Population dynamics and management	~T	Neutral (0.31)	Low-medium (-0.92)	High-medium (0.58)	0.35	
23	Abundance management decisions, such as zoning, population control, and controlled use, prove socially and politically sensitive, while the institutional arrangements needed to support them - including trust, transparency, benefit-sharing, legal frameworks, coordination, and compensation - lag behind biological recovery.	Population dynamics and management	~T	Neutral (0.27)	Neutral (0.36)	Neutral (-0.24)	0.35	
24 (saved)	Large saiga populations begin to regulate themselves from mass die-offs, other disease, or resource depletion, leading to benefits for vegetation.	Population dynamics and management	~O	Neutral (-0.08)	High-medium (0.83)	Low-medium (-0.93)	0.28	

* Issues rank 3 and 6 were merged following SR1. † Issues rank 7 and 13 were merged following SR1.

Bold = issues progressing from SR1; ranks based on Total. T/O = Threat/Opportunity where T = Threat, ~T = Leaning Threat, C = Contested, ~O = Leaning Opportunity, O = Opportunity. Novelty, Likelihood, and Impact are median z-scores.

3.2.2 SR2: refined issue landscape

Seventeen issues, refined following the ENGAGE phase, were scored in SR2 (**Table 3**). Again, most issues (13/17) were classified as threats, while only one (a 38% decrease from SR1) was an opportunity. Three were entirely contested in impact direction. The range of Total scores decreased by 16.25% between scoring rounds, indicating convergence. The top six issues (**Table 3**, bold) progressed to the final shortlist based on a natural break in scores. These issues showed a similar scoring pattern to the high scorers from SR1: high-medium Likelihood and Impact scores, but generally neutral Novelty - except for the top-ranking issue, which received a remarkably high Novelty score relative to other issues. Rank 12 also showed high Novelty, but its low Likelihood and neutral Impact limited its overall ranking.

Table 3. The 17 Scoring Round 2 issues, with their Drivers, Impact Directions, and scores.

Scoring Round 2 Issues							
Rank	Issue wording	Driver	T/O	Likelihood	Novelty	Impact	Total
1	Interacting pressures create cumulative stress, with effects that undermine population resilience.	Wildlife health and disease	T	High-medium (0.50)	High (1.08)	High-medium (0.93)	2.00
2	Rapid expansion of linear infrastructure creates barriers that fragment habitats and restrict movement between key areas.	Development and infrastructure	T	High-medium (0.92)	Neutral (-0.35)	High-medium (0.65)	1.08
3	Anthropogenic activities degrade and fragment the steppe, reducing the quality and extent of suitable saiga range.	Development and infrastructure	T	High-medium (0.74)	Neutral (-0.12)	Neutral (0.27)	1.01
4	Current large population sizes create a false sense of security, lowering preparedness for mass mortality events.	Population dynamics and management	T	Neutral (0.35)	Neutral (-0.08)	High-medium (0.56)	0.71
5	Disease outbreaks, including emerging or previously absent pathogens, trigger mass mortality events, particularly in large or naïve herds and where wildlife disease surveillance is limited.	Wildlife health and disease	T	Neutral (0.26)	Neutral (-0.47)	High-medium (0.65)	0.71
6	Climate-driven resource scarcity shifts saiga distributions and movement pathways into human-dominated landscapes, increasing overlap with livestock, infrastructure, and people.	Climate and environmental change	~T	High-medium (0.83)	Neutral (-0.24)	Neutral (0.11)	0.68
7	Climate change drives large-scale ecosystem change, altering the distribution and quality of suitable saiga habitat.	Climate and environmental change	~T	Neutral (0.24)	Neutral (-0.08)	Neutral (-0.05)	0.03
8	Increasing impacts from growing saiga populations and an absence of local benefits cause saiga to be seen as a burden by local communities, reducing support for their conservation.	Human-saiga interactions and social acceptance	~T	Neutral (0.24)	Low-medium (-0.52)	Neutral (0.27)	-0.04
9	Coexistence between local communities and saiga is not prioritised, leading to political pressure driving management decisions.	Human-saiga interactions and social acceptance	T	Neutral (0.37)	Neutral (-0.47)	Neutral (0.05)	-0.11
10	The expansion of road networks into previously isolated saiga habitat facilitates poaching, disease spillover, and collisions with vehicles.	Development and infrastructure	~T	Neutral (0.35)	Neutral (0.00)	Low-medium (-0.58)	-0.26
11	A craze or a novel use for saiga horn emerges.	Trade, demand, and markets	~T	Low (-1.05)	High-medium (0.80)	Neutral (-0.18)	-0.36
12	Armed conflict and/or economic collapse weakens governance, limits enforcement, and hinders effective wildlife management.	Political instability and geopolitical change	~T	Low (-1.13)	High (1.07)	Neutral (0.40)	-0.41
13	As saiga populations grow, density-dependent processes lead to self-regulation of population size.	Population dynamics and management	C	High-medium (0.56)	Neutral (-0.35)	Low-medium (-0.78)	-0.46
14	Integration of research across disciplines improves understanding of drivers of saiga mass mortality events.	Conservation action and knowledge systems	~O	Neutral (-0.32)	Neutral (-0.33)	Neutral (0.16)	-0.63
15	Large saiga populations increase carcass availability, influencing nutrient cycling and scavenger dynamics in steppe ecosystems.	Population dynamics and management	C	Neutral (-0.32)	High-medium (0.75)	Low (-1.27)	-0.71
16	Effective measures are implemented to reduce human-saiga conflict.	Conservation action and knowledge systems	C	Low-medium (-0.75)	Low-medium (-0.53)	Neutral (0.25)	-0.94
17	Changes in seasonal timing shift calving periods and affect calf survival.	Climate and environmental change	~T	Low (-1.13)	High-medium (0.90)	Low (-1.02)	-1.71

Bold = final shortlist; ranks based on Total. T/O = Threat/Opportunity where T = Threat, ~T = Leaning Threat, C = Contested, ~O = Leaning Opportunity, O = Opportunity. Novelty, Likelihood, and Impact are median z-scores.

3.3 AIM B: trends in prioritisation

3.3.1 Influence of participant background on Driver prioritisation

Ten driver themes emerged from SR1 issues, eight of which were also present in SR2 (**Figure 7**). There was a notable gap between the two highest-ranking Drivers (Wildlife health and disease and Development and infrastructure) and the third-ranked Driver (*Climate and environmental change*), indicating these two were of particular high priority.

Final Driver Ranking (SR2)		
1	Wildlife health and disease (disease, stress, and One Health approaches for saiga)	Dt = 1.36 ★ = 2
2	Development and infrastructure (roads, railways, fences, and other developments in the saiga range)	Dt = 1.01 ★ = 3
3	Climate and environmental change (extreme weather, ecosystem change, and phenology shifts in the saiga range)	Dt = 0.03 ★ = 3
4	Human-saiga interactions and social acceptance (human-wildlife conflict challenges and perceptions of saiga)	Dt = -0.08 ★ = 2
5	Trade, demand, and markets (legal and illegal trade of saiga products, sustainable use, regulation, and ecotourism)	Dt = -0.36 ★ = 1
6	Political instability and geopolitical change (geopolitics, international borders, and conflict)	Dt = -0.41 ★ = 1
7	Population dynamics and management (saiga population size and management responses)	Dt = -0.46 ★ = 3
8	Conservation action and knowledge systems (research, monitoring, collaboration, and conservation action for saiga)	Dt = -0.79 ★ = 2
–	Governance and institutions (policy, funding, coordination, and institutional capacity for saiga conservation)	
–	Land-use practices and resource systems (land-use change and planning, and resource scarcity)	

Figure 7. Drivers identified through inductive thematic analysis and their descriptions, ordered by SR2 Driver Total. Governance and institutions, and Land-use practices and resource systems are unranked because no SR2 issues fell under these drivers. Dt = SR2 Driver Total (median Issue Total across issues within a driver); ★ = number of SR2 issues within that Driver.

Driver prioritisation was broadly consistent across background groups, made clear by horizontal banding in **Figure 8** below. *Political instability and geopolitical change*, and *Demand, trade, and markets* showed greater variation, but this should be interpreted with caution as these Drivers represent only one SR2 issue each. Differences in vertical patterns between background groups indicate differing prioritisation of the Driver set, though sample sizes were often small. The most distinct pattern was observed for those using Media/Public Reporting as a source of saiga information, with higher scores relative to other information sources for *Trade demand and markets*, and *Conservation and knowledge systems*, but lower scores for *Wildlife health and disease*, *Development and infrastructure*, and *Political instability and geopolitical change*.

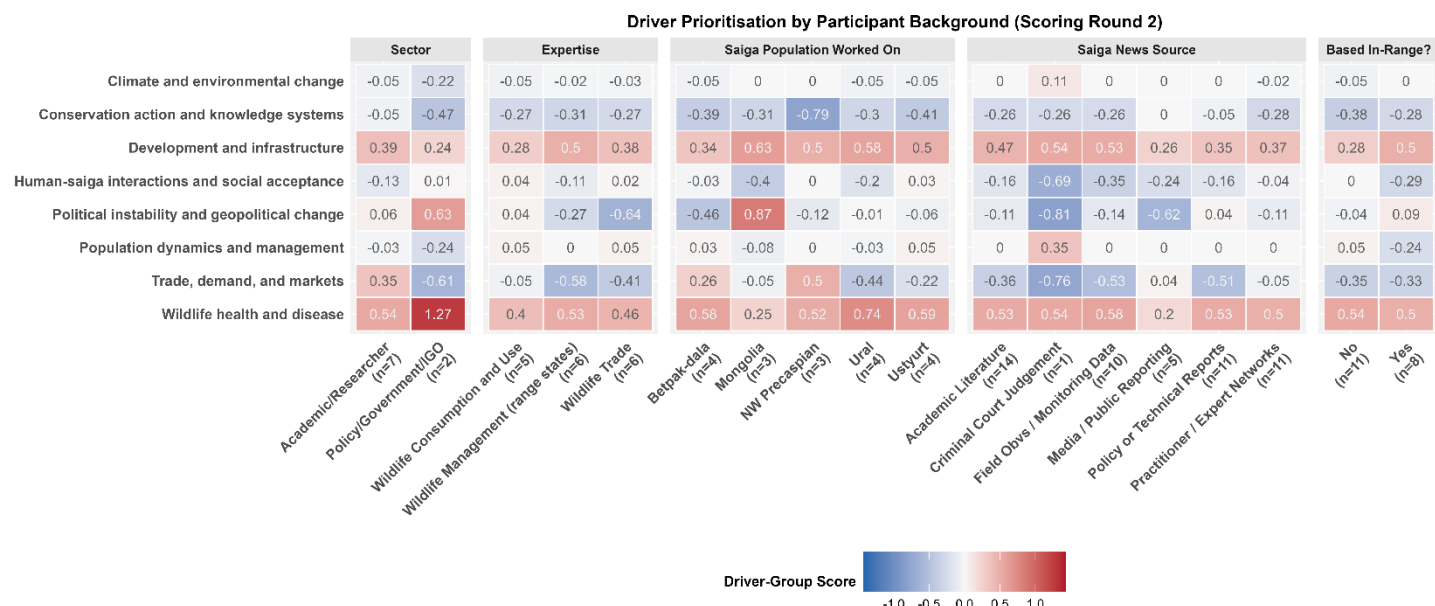


Figure 8. Heat map of median SR2 driver scores by driver and background group. Horizontal patterns show how each driver was prioritised across groups; vertical patterns show how each group prioritised the driver set. Higher scores (red) indicate higher priority.

I used LMERS to test focal groups (**Table 4**) relating to my three hypotheses, with **Table 5** indicating whether the focal group for each hypothesis, or all other participants, prioritised each Driver more highly.

Table 4. The study's three hypotheses, and the extent to which they were supported.

Hypothesis	Supported?
H1: Participants who are based in range states and/or have experience working on abundant saiga populations (Ural/Betpak-Dala) will assign greater importance to overabundance-related drivers than participants working on other populations or non-range-state contexts.	Weakly supported
H2: Participants who use media/public reporting as sources of information about saigas will prioritise drivers differently from participants who do not use these information sources.	Supported
H3: Participants with wildlife trade expertise will assign greater importance to trade-related drivers than participants without trade expertise.	Partially Supported

Table 5. Directional differences in driver prioritisation by hypothesis focal group versus all others.

Directional Differences in Driver Prioritisation Between Participant Groups (Scoring Round 2)				
	Based in Range State (n=8) vs Others (n=11)	Ural/Betpak-Dala Experience (n=5) vs Others (n=14)	Media/Public Reporting Users (n=5) vs Others (n=14)	Wildlife Trade Expertise (n=6) vs Others (n=13)
Climate and environmental change	↑	↑	↓	↓
Conservation action and knowledge systems	↓	↓**	↑***	↑
Development and infrastructure	↑	↓	↓*	↓
Human-saiga interactions and social acceptance	↓*	↓	↑	↑*
Political instability and geopolitical change	↑	↑	↓	↓*
Population dynamics and management	↓	↓	↑	↑
Trade, demand, and markets	↑	↑*	↑*	↑
Wildlife health and disease	↓	↑**	↓***	↓*

Arrows indicate which group scored each Driver more highly (↑ = Focal Group; ↓ = Others), based on estimated marginal means (EMMs) from linear mixed effects model (LMER). Asterisks denote statistical significance after Benjamini-Hochberg adjustment (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). The full EMM and adjusted p -value table is available in Appendix J.

H1: Participants based in range states assigned significantly lower priority to *Human-saiga interactions and social acceptance* ($\Delta\text{EMM}=-0.15$, $n=19$, $p=0.045$), but scored *Population dynamics and management* and *Wildlife health and disease* similarly to others, with small non-significant differences ($\Delta\text{EMM}=0.04$, $n=19$, $p=0.648$; $\Delta\text{EMM}=-0.01$, $n=19$, $p=0.924$). Similarly, participants experienced with the Ural/Betpak-Dala populations perceived *Human-saiga interactions* and *Population dynamics and management* almost identically to others, with small, non-significant reductions ($\Delta\text{EMM}=-0.08$, $n=19$, $p=0.274$; $\Delta\text{EMM}=-0.01$, $n=19$, $p=0.866$). They significantly deprioritised *Conservation action and knowledge systems* ($\Delta\text{EMM}=-0.20$, $n=19$, $p=0.010$), but significantly prioritised *Wildlife health and disease* ($\Delta\text{EMM}=+0.23$, $n=19$, $p=0.003$) and *Trade, demand and markets* ($\Delta\text{EMM}=+0.21$, $n=19$, $p=0.046$).

H2: Participants using Media/Public Reporting as a source of saiga information assigned significantly higher priority to *Conservation action and knowledge systems* ($\Delta\text{EMM}=+0.47$, $n=19$, $p<0.001$). They also significantly prioritised *Trade, demand and markets* ($\Delta\text{EMM}=+0.27$, $n=19$, $p=0.014$), while assigning significantly lower priority to *Wildlife health and disease* ($\Delta\text{EMM}=-0.33$, $n=19$, $p<0.001$) and *Development and infrastructure* ($\Delta\text{EMM}=-0.16$, $n=19$, $p=0.011$) than those who did not use this source.

H3: Participants with wildlife trade expertise assigned higher priority to *Trade, demand and markets* than non-wildlife trade experts, although this difference was small and non-significant ($\Delta\text{EMM}=+0.08$, $n=19$, $p=0.462$). They significantly prioritised *Human-saiga interactions and social acceptance* ($\Delta\text{EMM}=+0.18$, $n=19$, $p=0.015$), while significantly deprioritising *Political instability and geopolitical change* ($\Delta\text{EMM}=-0.22$, $n=19$, $p=0.029$) and *Wildlife health and disease* ($\Delta\text{EMM}=-0.16$, $n=19$, $p=0.040$).

3.3.2 Changes in Driver prioritisation between rounds

I compared Driver ranks for SR1 and SR2 to identify potential shifts in prioritisation that may have occurred due to the evidence summaries provided and discussions during the ENGAGE phase (**Figure 9**). There was an apparent shift in prioritisation between rounds, with only *Conservation action and knowledge systems* maintaining its rank (eighth). *Trade, demand and markets* rose by three ranks, while all other issues shifted up or down one rank.

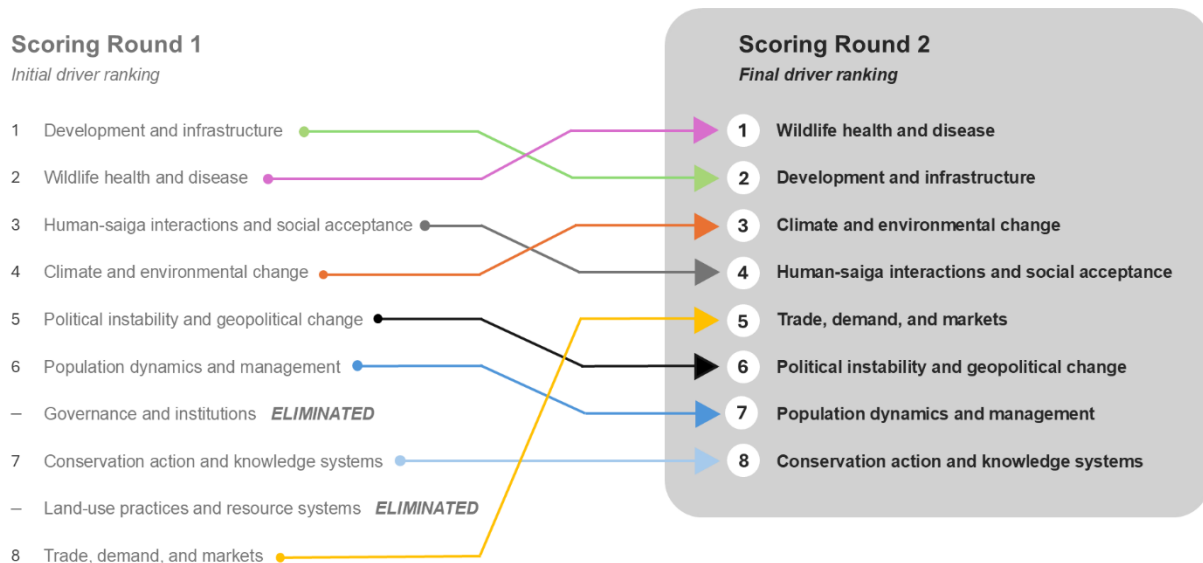


Figure 9. Rank changes in driver prioritisation between Scoring Rounds 1 and 2. Governance and institutions, and Land-use practices and resource systems were only present in SR1.

Exploring these shifts further, **Figure 10** shows changes in scoring between rounds for participants who scored in both rounds. *Human-saiga interactions and social acceptance* exhibited declines across the board, including a significant decline for Total ($\text{Total}\Delta\text{EMM} = -0.88$, $n=13$, $p=0.032$), the overall score for that Driver, indicating deprioritisation between rounds. *Trade, demand, and markets* had interestingly only increased in Novelty, and very slightly in Impact, suggesting its three-rank jump between rounds was driven by these criteria, though neither of these changes was significant ($\text{Novelty}\Delta\text{EMM} = +0.27$, $n=13$, $p=0.338$; $\text{Impact}\Delta\text{EMM} = +0.01$, $n=13$, $p=0.969$). *Political instability and geopolitical change* showed an increase in Novelty despite decreases in the other criteria, implying that participants increasingly viewed it as a more emerging issue in the saiga context. However, this change was non-significant ($\text{Novelty}\Delta\text{EMM} = +0.45$, $n=13$, $p=0.171$). Although *Conservation action and knowledge systems* showed very little change overall ($\text{Total}\Delta\text{EMM} = +0.01$, $n=13$, $p=0.979$), it showed a significant increase in Impact ($\text{Impact}\Delta\text{EMM} = +0.50$, $n=13$, $p=0.024$), suggesting that participants viewed this Driver as more influential on saiga populations in SR2.

Driver Prioritisation and Changes Between Scoring Rounds (PAIRED)

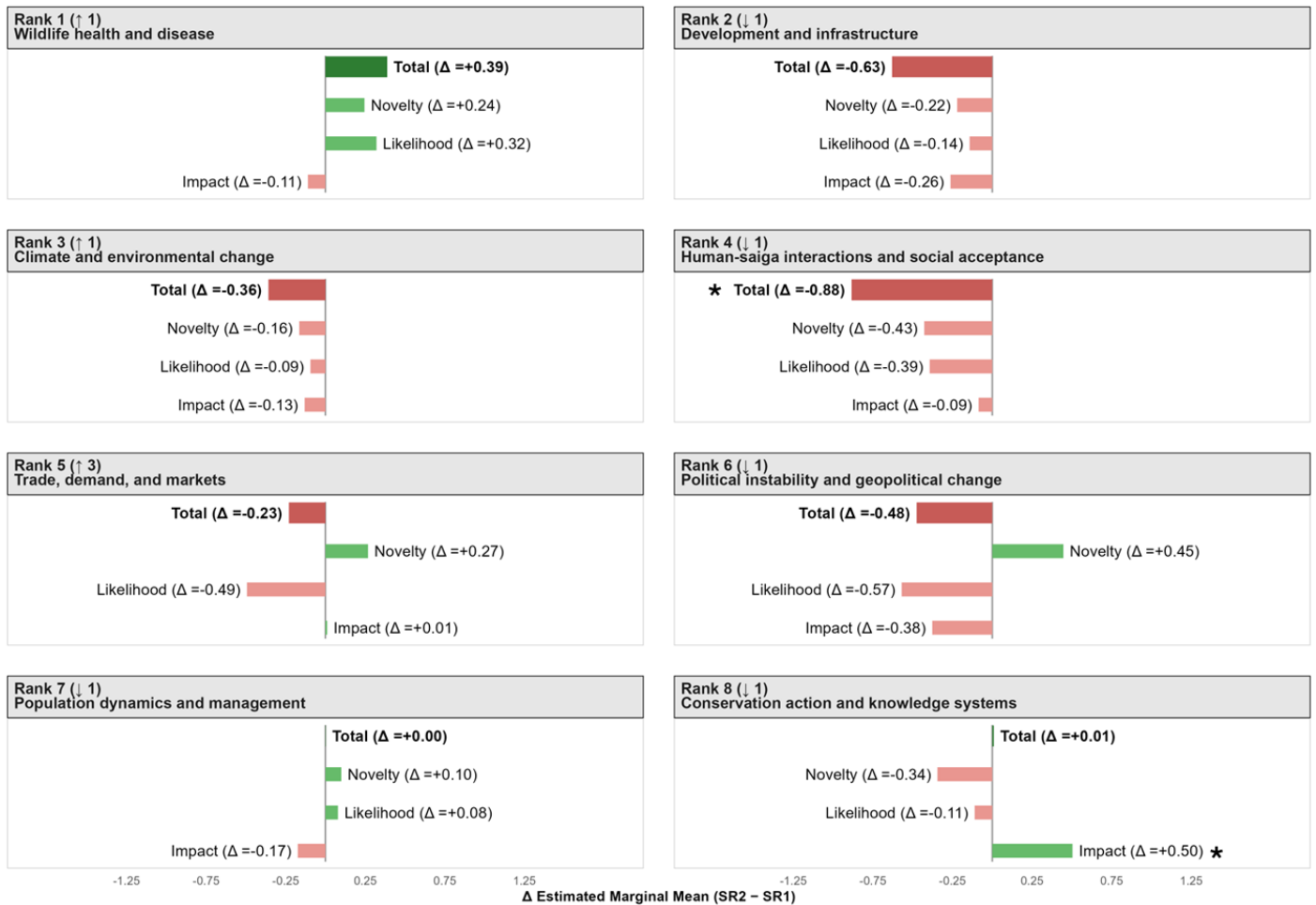


Figure 10. Changes in driver scores between scoring rounds. Green bars to the right of the midline ($\Delta EMM = 0$) indicate higher scores in SR2, while red bars to the left indicate higher scores in SR1. Rank numbers indicate the SR2 ranking for each driver, and arrows show the direction and magnitude of rank change between scoring rounds. Asterisks denote statistical significance in the paired model after Benjamini-Hochberg correction (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Values are estimated marginal mean differences from the paired model; the full EMM and adjusted p -value table are available in Appendix L.

I also examined change between rounds in an unpaired analysis across all participants. The paired analysis is the main result because it captures within-participant judgement refinement. However, the unpaired analysis can reveal whether changes in group composition may have influenced the final shortlist. Although directional changes were similar (see **Appendix K**), the unpaired model produced an entirely different set of significant changes. In the paired model, the declines in Total for *Climate and environmental change* (Total $\Delta EMM = -0.52$, $n = 24$, $p = 0.045$), and *Development and infrastructure* were significant (Total $\Delta EMM = -0.61$, $n = 24$, $p = 0.033$), as were the declines in Likelihood for *Trade, demand, and markets* (Likelihood $\Delta EMM = -0.58$, $n = 24$, $p = 0.015$) and *Political instability and geopolitical change* (Likelihood $\Delta EMM = -0.64$, $n = 24$, $p = 0.019$), the latter also showing a significant increase in Novelty (Novelty $\Delta EMM = +0.57$, $n = 24$, $p = 0.049$). Additionally, *Human-saiga interactions and social acceptance* showed a significant decline in Novelty (Novelty $\Delta EMM = -0.41$, $n = 24$, $p = 0.045$).

4. Discussion

4.1 Priority issues for saiga conservation

This Delphi-like horizon scan identified six priority issues for saiga conservation, all perceived as threats (**Figure 11**).

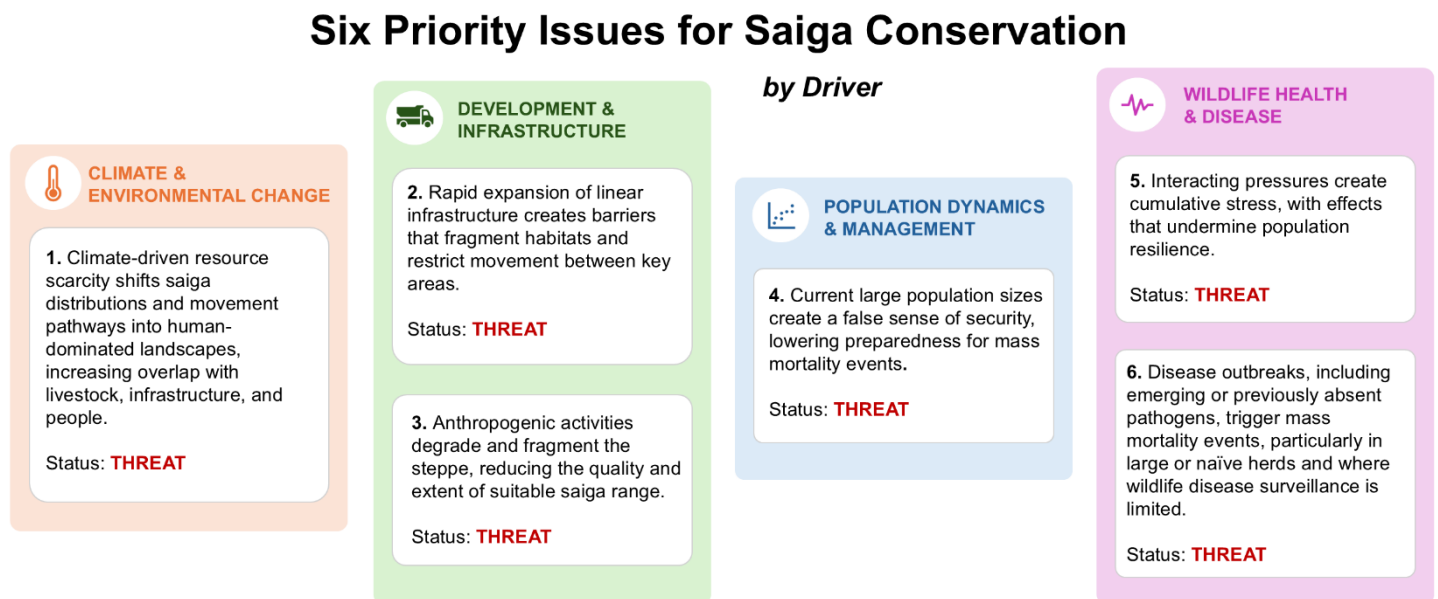


Figure 11. The six final high-priority issues for saiga conservation, grouped by driver. Panels show each driver category and its associated issues, with no priority order within or among panels.

This shortlist could support decision-making, as horizon scans are most useful when organisations compare identified issues against current priorities to determine where action, monitoring, or further research may be needed (Sutherland et al., 2012). Potential impact pathways and mitigation steps are outlined in **Figure 12**, including key uncertainties that could be addressed in further research. Although the six prioritised threats share cross-cutting risks, they differ in the mitigation strategies required. They should be treated as distinct but interacting pressures rather than problems to be addressed in isolation. As horizon scans are only the first stage of the strategic foresight cycle (Cuhls, 2020), this shortlist could be built upon by conducting scenario planning and analysis of past trends to improve understanding of these issues and guide intervention design (Cook et al., 2014).

Implications of the six priority issues for saiga conservation and strategies to mitigate them

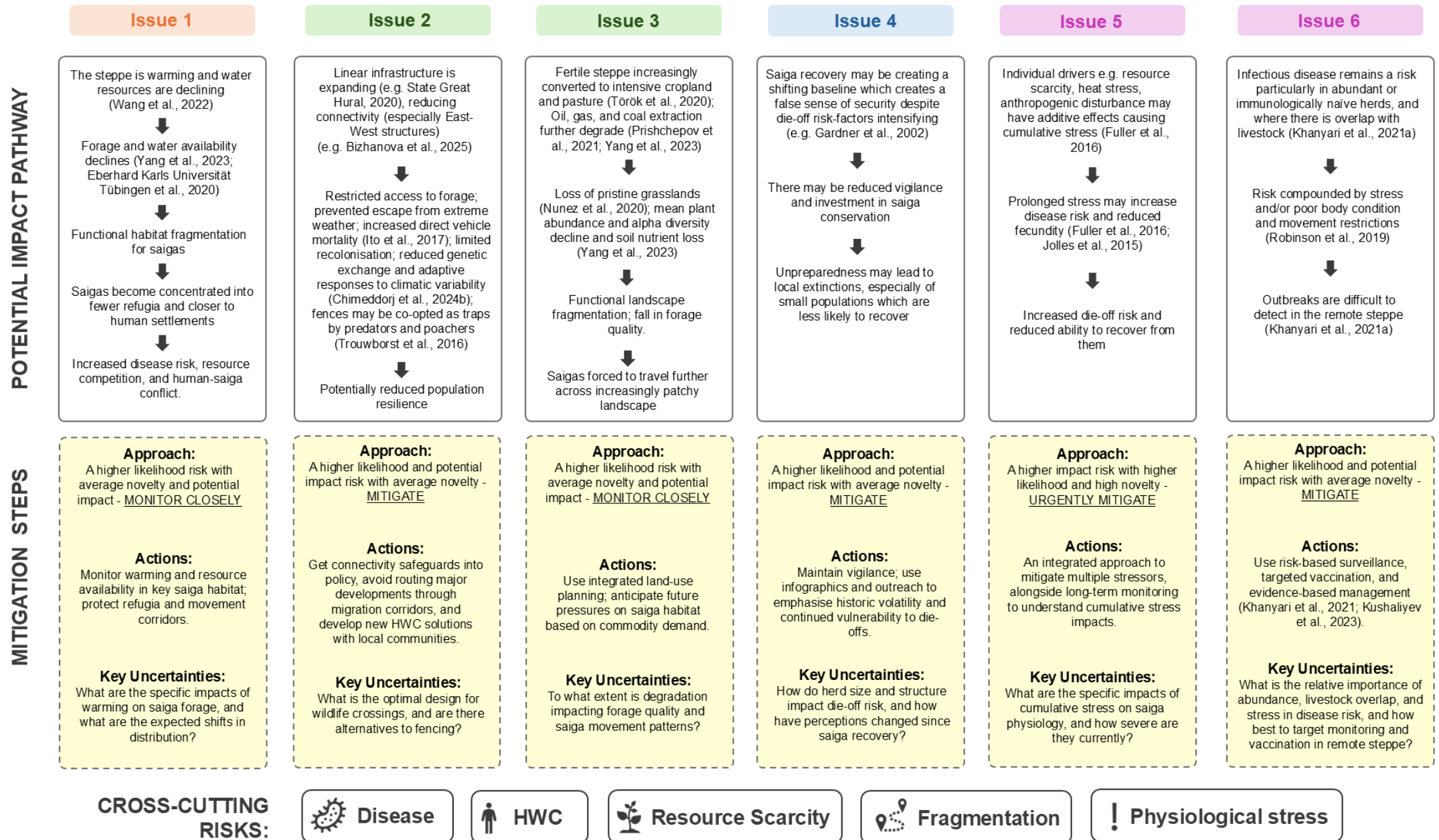


Figure 12. Potential impact pathways and mitigation steps for the six priority issues for saiga conservation. HWC = human-wildlife conflict.

4.2 What shaped prioritisation?

Understanding what shaped prioritisation helps determine whether the Delphi-like approach generated a robust collective judgement from diverse perspectives rather than simply aggregating disparate opinions.

4.2.1 Participant background

Although some differences were observed between background groups, Driver prioritisation was generally consistent across participants. This suggests successful integration of diverse perspectives to produce a shared view of the most important Drivers, with specific perspectives still retained. For example, the distinct scoring pattern for *Media/Public Reporting* users revealed their unique insights, but overall consistency across the cohort indicates that a shared judgement emerged regardless.

Hypothesis testing provided additional insights into background-specific prioritisation.

H1: Being based in a saiga range state was not a strong predictor of prioritisation: participants inside and outside range states prioritised *Wildlife health and disease*, *Trade, demand and markets*, and *Population dynamics and management* similarly, suggesting that range state affiliation is too broad a proxy for exposure to abundant populations. For example, participants in Mongolia may have little connection to the Ural/Betpak-Dala populations. In contrast, participants who had worked directly on the Ural/Betpak-Dala populations significantly prioritised *Wildlife health and disease* and *Trade, demand and markets* relative to other participants. This indicates that direct experience with large populations was a better predictor of a participant's priorities than their location. Overall, H1 was weakly supported.

H2: The marked difference in how Media/Public Reporting users prioritised the Driver set, compared with other information sources, provided early support for this hypothesis. These participants significantly prioritised *Trade, demand, and markets* compared to other participants, which may reflect the increased salience of trade issues in the media prior to and during the horizon scan, including CITES CoP20 decisions to reopen the international saiga horn trade partially (e.g. WCS, 2025; The Times of Central Asia, 2025). This contentious discourse may have influenced scoring to some extent. This focal group also significantly prioritised *Conservation action and knowledge systems*. This may reflect that media coverage has also highlighted conservation efforts underpinning saiga recovery, such as the Altyn Dala Conservation Initiative and its 2024 Earthshot Prize recognition (e.g., Fauna & Flora, 2024; RSPB, 2024). Media may influence perspectives on saiga conservation, consistent with findings that media portrayals shape

risk perceptions of sharks and support for their conservation (Le Busque et al., 2021). However, this focal group significantly deprioritised *Wildlife health and disease*, as well as *Development and infrastructure*. This was surprising as I noticed heavy media coverage of both during my evidence summary research, including reporting on disease outbreaks and barriers to migration (e.g. National Geographic, 2018; Saiga Conservation Alliance, 2024). The lower prioritisation of these Drivers may indicate that media/public reporting influences perspectives most strongly when coverage is recent or linked to policy decisions, as was the case for the CITES CoP20 decision.

H3: Participants with wildlife trade expertise did not score *Trade, demand, and markets* significantly differently from other participants, but they did show a distinct pattern across other Drivers linked to trade. They significantly deprioritised *Political instability and geopolitical change*, and *Wildlife health and disease*, despite both having knock-on effects for the saiga horn market, while significantly prioritising *Human-saiga interactions and social acceptance*, which included issues related to poaching and benefit-sharing from the horn trade. This suggests that trade expertise was reflected in prioritisation, but not in a straightforward way.

Overall, hypothesis tests indicate that some participant background variables shaped prioritisation, but not consistently. Differences emerged without preventing overall convergence, highlighting the main strength of the Delphi-like approach: bringing together diverse perspectives to identify shared priorities through collective judgement.

4.2.2 Shifts across scoring rounds

Shifts between scoring rounds can indicate judgement refinement during ENGAGE and the broader Delphi process.

Multiple between-round changes are supported by comments made during the ENGAGE workshops. For example, the deprioritisation of Novelty for *Human-saiga interactions and social acceptance* issues can be explained by comments from a participant with extensive saiga management experience, like: “We already see [HWC fencing solutions] happening”. The increase in Novelty and Impact for *Trade, demand, and markets* issues, though non-significant, could be explained by rich insights into potential new uses of saiga horn provided by trade experts that other participants were unaware of. The large and significant increase in Impact for *Conservation and knowledge systems issues* may have been shaped by a workshop realisation that the midlist issue ‘Practical measures are implemented to reduce human-saiga conflict’ could actually have detrimental impacts: “reducing conflict in the short term, but in the long term, you're only pushing those saigas somewhere in that landscape”. Such insights influenced other participants to reconsider their own perspectives, exemplified by one SR2 comment: “I have been guided in my

scoring to a considerable degree by the workshop discussion on this point”, an intended benefit of the Delphi-like approach.

External events and shifts in group composition could also have altered scoring patterns. For example, scoring may be impacted by conversations, global developments, or even changes in outlook between scoring rounds. The escalation of the 2026 Iran war might have been expected to make *Political instability and geopolitical change* seem less novel by bringing it onto people's radars, yet Novelty still increased. Workshop discussion may have encouraged participants to consider wider knock-on effects of geopolitical change, with one participant noting, “there are bigger pictures beyond just immediate local conflict as well, or economic collapse.” This suggests that the ENGAGE phase may have shaped perceptions more than external events did. Shifts in scoring may also reflect changes in group composition between rounds, as 6/19 SR2 scorers did not complete SR1. Although individual backgrounds did not strongly influence prioritisation, collective judgement depends on group composition, and the differing paired and unpaired results suggest it may have shaped the observed changes.

Overall, the observed changes in driver prioritisation between rounds appear to reflect judgement refinement but may also reflect external events and changes in group composition.

4.2.3 Overall confidence in the shortlist

The results provide confidence in the shortlist as a collective assessment of priorities for saiga conservation. Because Driver scores are aggregated from issue scores, the broad consistency in Driver prioritisation and evidence of judgement refinement suggest the shortlist was not shaped by random scoring variation or a few dominant voices. As with all horizon scans (e.g. Esmail et al., 2020; Sutherland et al., 2010), a different cohort of participants would likely have prioritised a different set of issues, but with 42 participants overall, I am confident that these priorities are representative of the saiga context.

While I have confidence that the shortlist represents priority issues for saiga conservation, I am not certain it entirely aligns with the aim of capturing priority *emerging* (high Novelty) issues. Applying equal weights to criteria when calculating totals meant that many high-ranking issues were driven more by elevated scores for Likelihood and Impact than by Novelty. If I were to repeat this exercise, I might place greater weight on issue Novelty to ensure the results align more closely with the exercise's goals. However, this would need to be supported by a very strong framing of what Novelty entails, as some participants found this criterion difficult to quantify, possibly due to a lack of horizon scanning or forward-looking experience. This challenge would likely ease if forward-looking exercises became more commonplace in species conservation and participants became

accustomed to thinking in this way. Further research could identify the optimal framing of Novelty to ensure any future species-level horizon scan can capture truly emerging issues. Despite the novelty concern, this horizon scan successfully identified threats for saiga conservation that are at least somewhat novel and likely to emerge with impacts on saiga in the next decade, thereby informing broader priority-setting.

4.3 Lessons for species-level horizon scanning

This exercise provided evidence that the Delphi-like horizon scanning can generate meaningful insights at the level of an individual species, not just in broader conservation contexts. However, I encountered various engagement challenges that future species-level horizon scans are likely to face as well. In **Figure 13** below, I outline these challenges, describe the criteria that a suitable species for horizon scanning should meet, and provide recommendations for future species-level horizon scans based on what worked in the saiga context.

Insights from the saiga case-study for species-level horizon scanning

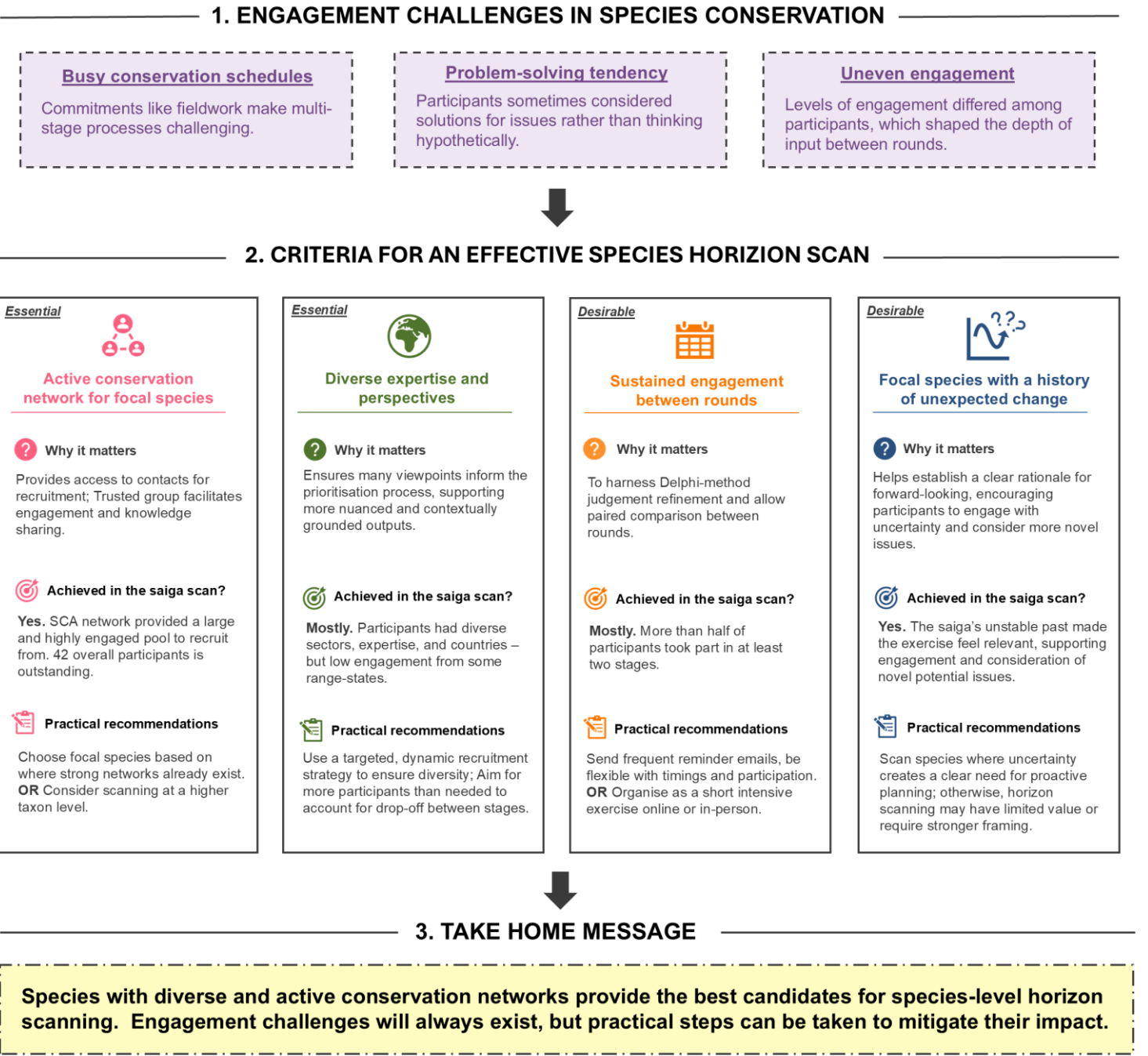


Figure 13. Criteria for species horizon scans to overcome engagement challenges in conservation, based on lessons from the saiga horizon scan.

5. Conclusion

Using a Delphi-like horizon scan, I collated rich insights from 42 participants to establish a set of priority emerging issues for saiga conservation over the next decade. This shortlist can inform conservation planning processes, including the next saiga MTIWP. It could also serve as a starting point for the broader strategic foresight process, bringing species conservation a step closer to the full integration of structured, forward-looking methods to help tackle the challenges of an increasingly uncertain world. In this first trial of species-level horizon scanning, I found that the method can effectively bring together scattered insights from a diverse group of participants to identify species priorities, with evidence of collective judgement emerging across the cohort. However, it needs to be carefully designed to address the challenges posed by the species conservation context. Going forward, species-level horizon scans are best suited for species with active, diverse, and engaged conservation networks, especially where past unpreparedness makes the need to identify and prioritise emerging issues very clear.

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7. Bibliography

- Abdelhady, A. A., Seuss, B., Jain, S., Abdel-Raheem, K. H. M., Elsheikh, A., Ahmed, M. S., Elewa, A. M. T., & Hussain, A. M. (2024). New and emerging technologies in paleontology and paleobiology: A horizon scanning review. *Journal of African Earth Sciences*, 210, 105155. <https://doi.org/10.1016/j.jafrearsci.2023.105155>
- Absatirov, G., Smagulov, D., Bozymov, K., Shalmenov, M., Nassambayev, Y., Yessengaliyev, K., Baitlessova, L., & Girisgin, A. O. (2025). Risks to the Growth, Conservation and Management of the Ural Saiga Population. *Diversity*, 17(9), 595. <https://doi.org/10.3390/d17090595>
- Abuduwalli, J., Issanova, G., & Saparov, G. (2019). Water Resources and Impact of Climate Change on Water Resources in Central Asia. In J. Abuduwalli, G. Issanova, & G. Saparov (Eds), *Hydrology and Limnology of Central Asia* (pp. 1–9). Springer. https://doi.org/10.1007/978-981-13-0929-8_1
- Aiesheva, G., Kazambayeva, A., Yessengaliyeva, S., & Nursapina, K. (2025). Assessment of the Economic Impact of the Saiga Population on Pasture Ecosystems and Agriculture. *Earth*, 6(4), 155. <https://doi.org/10.3390/earth6040155>
- Aikens, E. O., Monteith, K. L., Merkle, J. A., Dwinnell, S. P. H., Fralick, G. L., & Kauffman, M. J. (2020). Drought reshuffles plant phenology and reduces the foraging benefit of green-wave surfing for a migratory ungulate. *Global Change Biology*, 26(8), 4215–4225. <https://doi.org/10.1111/gcb.15169>
- Aikens, E. O., Wyckoff, T. B., Sawyer, H., & Kauffman, M. J. (2022). Industrial energy development decouples ungulate migration from the green wave. *Nature Ecology & Evolution*, 6(11), 1733–1741. <https://doi.org/10.1038/s41559-022-01887-9>
- Allepuz, A., Stevenson, M., Kivaria, F., Berkvens, D., Casal, J., & Picado, A. (2015). Risk Factors for Foot-and-Mouth Disease in Tanzania, 2001–2006. *Transboundary and Emerging Diseases*, 62(2), 127–136. <https://doi.org/10.1111/tbed.12087>
- Association for the Conservation of Biodiversity of Kazakhstan (ACBK). (2025, March 21). *Overview report on saiga conservation status and saiga MOU implementation* (UNEP/CMS/Saiga/MOS5/Doc.3/Rev.1). Convention on Migratory Species.
- Ancrenaz, M., Dabek, L., & O'Neil, S. (2007). The Costs of Exclusion: Recognizing a Role for Local Communities in Biodiversity Conservation. *PLOS Biology*, 5(11), e289. <https://doi.org/10.1371/journal.pbio.0050289>
- Anderson, K., Tooth, S., Kim, D., Resler, L. M., Schillereff, D., Williams, J. W., Rocchini, D., Ponette-González, A. G., Kuhn, N. J., & Brian, J. V. (2024). A horizon scan for novel and impactful areas of physical geography research in 2023 and beyond. *Progress in Physical Geography: Earth and Environment*, 48(1), 3–23. <https://doi.org/10.1177/03091333231217881>
- Arnold, R. (2024). Using novel approaches to better characterise wildlife supply chains: A case study of the saiga antelope [Undergraduate dissertation]. Interdisciplinary Centre for Conservation Science, University of Oxford.
- Barrett, C. B., Travis, A. J., & Dasgupta, P. (2011). On biodiversity conservation and poverty traps. *Proceedings of the National Academy of Sciences*, 108(34), 13907–13912. <https://doi.org/10.1073/pnas.1011521108>
- Barton, P. S., Reboldi, A., Bonat, S., Mateo-Tomás, P., & Newsome, T. M. (2023). Climate-driven animal mass mortality events: Is there a role for scavengers? *Environmental Conservation*, 50(1), 1–6. <https://doi.org/10.1017/S0376892922000388>
- Baruzzi, C., Barton, B. T., Cove, M. V., Strickland, B. K., & Lashley, M. A. (2023). Scavenger and herbivore functional role impairment modulates changes in plant communities following mass mortality events. *Functional Ecology*, 37(8), 2207–2216. <https://doi.org/10.1111/1365-2435.14376>

- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). *Fitting linear mixed-effects models using lme4*. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Begilov, T., Grachev, Y., & Eszhanov, B. (2024). A study into the current state of Saiga tatarica L. populations with the use of retrospective data. *Acta Scientiarum. Animal Sciences*, 46, e68717–e68717. <https://doi.org/10.4025/actascianimsci.v46i1.68717>
- Bengston, D. N., Westphal, L. M., Adelson, P., Crabtree, J., Dockry, M. J., Hines, A., Kubik, G. H., Romero, M., Van Stanley, Z., & Zimmerman, N. L. (2024). Emerging Signals of Change that Could Shape the Future of Forestry: A Horizon Scan. *Journal of Forestry*, 122(2), 152–158. <https://doi.org/10.1093/jofore/fvad046>
- Bengston, Dr.D. (2023). Wild Cards in Natural Resource Planning: High Impact Surprises that Shape the Future. *Natural Resources Journal*, 63(1), 70.
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, 57(1), 289–300.
- Bizhanova, N., Grachev, A., Rametov, N., Baidavletov, Y., Saparbayev, S., Bepalov, M., Bepalov, S., Kumayeva, I., Toishibekov, Y., Khamchukova, A., & Grachev, Y. (2025). Railway and Road Infrastructure in Saiga Antelope Range in Kazakhstan. *Diversity*, 17(6), 431. <https://doi.org/10.3390/d17060431>
- Bowyer, R. T., Bleich, V. C., Stewart, K. M., & St, V. (2014). *Concepts with some clarifications*. 100(3).
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Braun, V., & Clarke, V. (2021). Conceptual and design thinking for thematic analysis. *Qualitative Psychology*, 9(1). <https://doi.org/10.1037/qp0000196>
- Brown, M. J. F., Dicks, L. V., Paxton, R. J., Baldock, K. C. R., Barron, A. B., Chauzat, M.-P., Freitas, B. M., Goulson, D., Jepsen, S., Kremen, C., Li, J., Neumann, P., Pattemore, D. E., Potts, S. G., Schweiger, O., Seymour, C. L., & Stout, J. C. (2016). A horizon scan of future threats and opportunities for pollinators and pollination. *PeerJ*, 4, e2249. <https://doi.org/10.7717/peerj.2249>
- Burgman, M. A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., Rumpff, L., & Twardy, C. (2011). Expert Status and Performance. *PLOS ONE*, 6(7), e22998. <https://doi.org/10.1371/journal.pone.0022998>
- Buuveibaatar, B., Young, J. K., Berger, J., Fine, A. E., Lkhagvasuren, B., Zahler, P., & Fuller, T. K. (2013). Factors affecting survival and cause-specific mortality of saiga calves in Mongolia. *Journal of Mammalogy*, 94(1), 127–136. <https://doi.org/10.1644/11-MAMM-A-077.1>
- Challender, D. W. S., 't Sas-Rolfes, M., Broad, S., & Milner-Gulland, E. J. (2025). A theory of change to improve conservation outcomes through CITES. *Frontiers in Ecology and Evolution*, 13. <https://doi.org/10.3389/fevo.2025.1425267>
- Chan, S., Maksimuk, A. V. and Zhirnov, L. V. (eds). 1995. From steppe to store: the trade in saiga antelope horn. pp. 47 pp.. TRAFFIC International, Cambridge, UK.
- Chang, W. (2025). *webshot2: Take screenshots of web pages* (R package version 0.1.2.9000). <https://github.com/rstudio/webshot2>
- Cheng, J., Sievert, C., Schloerke, B., Chang, W., Xie, Y., & Allen, J. (2025). *htmltools: Tools for HTML* (R package version 0.5.9). <https://doi.org/10.32614/CRAN.package.htmltools>
- Chimeddorj, B., Bayartogtokh, B., Mallon, D., Bayarbaatar, B., Bayandonoi, G., Ochirjav, M., Erdenebaatar, S., & Gombobaatar, S. (2024a). Ecology and conservation of the endangered Mongolian saiga (Saiga tatarica mongolica). *Mong. Mongolian Journal of Biological Sciences*, 22, 21–32.
- Chimeddorj, B., Buuveibaatar, B., Galsandorj, N., Dolgorjav, S., Myanganbuu, N., Bayandonoi, G., & Gombobaatar, S. (2024b). From isolation to integration: Assessing habitat connectivity of the endangered

saiga antelope in Mongolia. *Mammalian Biology*, 104(3), 221–229. <https://doi.org/10.1007/s42991-023-00391-2>

Convention on Biological Diversity. (2022). *Kunming-Montreal Global Biodiversity framework* (CBD/COP/15/L.25). United Nations. <https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222>

Convention on International Trade in Endangered Species of Wild Fauna and Flora. (2025). *CoP20 Inf. 23*. CITES.

Convention on Migratory Species. (2006). *Medium-term international work programme for the Saiga antelope (2007–2011)*. CMS.

Cook, C. N., Wintle, B. C., Aldrich, S. C., & Wintle, B. A. (2014). Using strategic foresight to assess conservation opportunity. *Conservation Biology: The Journal of the Society for Conservation Biology*, 28(6), 1474–1483. <https://doi.org/10.1111/cobi.12404>

Cuhls, K. E. (2020). Horizon Scanning in Foresight – Why Horizon Scanning is only a part of the game. *FUTURES & FORESIGHT SCIENCE*, 2(1), e23. <https://doi.org/10.1002/ffo2.23>

Dawson, M. N., Algar, A. C., Antonelli, A., Dávalos, L. M., Davis, E., Early, R., Guisan, A., Jansson, R., Lessard, J.-P., Marske, K. A., McGuire, J. L., Stigall, A. L., Swenson, N. G., Zimmermann, N. E., & Gavin, D. G. (2013). An horizon scan of biogeography. *Frontiers of Biogeography*, 5(2), fb_18854.

Dickman, A. J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human–wildlife conflict. *Animal Conservation*, 13(5), 458–466. <https://doi.org/10.1111/j.1469-1795.2010.00368.x>

Doughty, H., Veríssimo, D., Tan, R. C. Q., Lee, J. S. H., Carrasco, L. R., Oliver, K., & Milner-Gulland, E. J. (2019). Saiga horn user characteristics, motivations, and purchasing behaviour in Singapore. *PLOS ONE*, 14(9), e0222038. <https://doi.org/10.1371/journal.pone.0222038>

Earthshot Prize. (2024). *The Earthshot Prize 2024 winners and finalists*. The Earthshot Prize.

Eberhard Karls Universität Tübingen, Tesch, N., Thevs, N., & World Agroforestry Centre (ICRAF) Central Asia Programme. (2020). Wetland Distribution Trends in Central Asia. *Central Asian Journal of Water Research*, 6(1), 39–54. <https://doi.org/10.29258/CAJWR/2020-R1.v6-1/39-65.eng>

Eldem, T. (2022). Russia's war on Ukraine and the rise of the Middle corridor as a third vector of Eurasian connectivity: Connecting Europe and Asia via Central Asia, the Caucasus, and Turkey. In *SWP Comment 64/2022* (Version 1). Stiftung Wissenschaft und Politik, German Institute for International and Security Affairs. <https://doi.org/10.18449/2022C64>

Eliciting Expert Knowledge in Conservation Science. (n.d.). Retrieved 14 May 2026, from <https://conbio.onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2011.01806.x>

Esmail, N., Wintle, B. C., t Sas-Rolfes, M., Athanas, A., Beale, C. M., Bending, Z., Dai, R., Fabinyi, M., Gluszek, S., Haenlein, C., Harrington, L. A., Hinsley, A., Kariuki, K., Lam, J., Markus, M., Paudel, K., Shukhova, S., Sutherland, W. J., Verissimo, D., ... Milner-Gulland, E. J. (2020). Emerging illegal wildlife trade issues: A global horizon scan. *Conservation Letters*, 13(4), e12715. <https://doi.org/10.1111/conl.12715>

Fallah, B., Didovets, I., Rostami, M., & Hamidi, M. (2024). Climate change impacts on Central Asia: Trends, extremes and future projections. *International Journal of Climatology*, 44(10), 3191–3213. <https://doi.org/10.1002/joc.8519>

Fauna & Flora. (2024). *Groundbreaking saiga conservation initiative wins The Earthshot Prize*. Fauna & Flora.

Fereidouni, S., Freimanis, G. L., Orynbayev, M., Ribeca, P., Flannery, J., King, D. P., Zuther, S., Beer, M., Höper, D., Kydyrmanov, A., Karamendin, K., & Kock, R. (2019). Mass Die-Off of Saiga Antelopes, Kazakhstan, 2015. *Emerging Infectious Diseases*, 25(6), 1169–1176. <https://doi.org/10.3201/eid2506.180990>

- Feuerbacher, A., Lippert, C., Kuenzang, J., & Subedi, K. (2021). Low-cost electric fencing for peaceful coexistence: An analysis of human-wildlife conflict mitigation strategies in smallholder agriculture. *Biological Conservation*, 255, 108919. <https://doi.org/10.1016/j.biocon.2020.108919>
- Fey, S. B., Gibert, J. P., & Siepielski, A. M. (2019). The consequences of mass mortality events for the structure and dynamics of biological communities. *Oikos*, 128(12), 1679–1690. <https://doi.org/10.1111/oik.06515>
- Fey, S. B., Siepielski, A. M., Nusslé, S., Cervantes-Yoshida, K., Hwan, J. L., Huber, E. R., Fey, M. J., Catenazzi, A., & Carlson, S. M. (2015). Recent shifts in the occurrence, cause, and magnitude of animal mass mortality events. *Proceedings of the National Academy of Sciences*, 112(4), 1083–1088. <https://doi.org/10.1073/pnas.1414894112>
- Fletcher, R., & Toncheva, S. (2021). The political economy of human-wildlife conflict and coexistence. *Biological Conservation*, 260, 109216. <https://doi.org/10.1016/j.biocon.2021.109216>
- Foresight approaches in global public health: A practical guide for WHO staff*. (n.d.). Retrieved 14 May 2026, from <https://www.who.int/publications/i/item/9789240048393>
- From Steppe to Store: The Trade in Saiga Antelope Horn | The Saiga Resource Centre*. (n.d.). Retrieved 9 May 2026, from <https://www.saigaresourcecentre.com/literature/steppe-store-trade-saiga-antelope-horn>
- Fuller, A., Mitchell, D., Maloney, S. K., & Hetem, R. S. (2016). Towards a mechanistic understanding of the responses of large terrestrial mammals to heat and aridity associated with climate change. *Climate Change Responses*, 3(1), 10. <https://doi.org/10.1186/s40665-016-0024-1>
- Fuller, A., Mitchell, D., Maloney, S. K., Hetem, R. S., Fonsêca, V. F. C., Meyer, L. C. R., van de Ven, T. M. F. N., & Snelling, E. P. (2021). How dryland mammals will respond to climate change: The effects of body size, heat load and a lack of food and water. *Journal of Experimental Biology*, 224(Suppl_1), jeb238113. <https://doi.org/10.1242/jeb.238113>
- Gardner, I. A., Willeberg, P., & Mousing, J. (2002). Empirical and theoretical evidence for herd size as a risk factor for swine diseases. *Animal Health Research Reviews*, 3(1), 43–55. <https://doi.org/10.1079/AHRR200239>
- Gaynor, K. M., Fiorella, K. J., Gregory, G. H., Kurz, D. J., Seto, K. L., Withey, L. S., & Brashares, J. S. (2016). War and wildlife: Linking armed conflict to conservation. *Frontiers in Ecology and the Environment*, 14(10), 533–542. <https://doi.org/10.1002/fee.1433>
- Gentsch, R. P., Kjellander, P., & Röken, B. O. (2018). Cortisol response of wild ungulates to trauma situations: Hunting is not necessarily the worst stressor. *European Journal of Wildlife Research*, 64(1), 11. <https://doi.org/10.1007/s10344-018-1171-4>
- Giljov, A., Karenina, K., Giljov, A., & Karenina, K. (2024). Social arenas in the open habitat: The social role of waterholes for saiga antelope. *Therya*, 15(2), 182–191. <https://doi.org/10.12933/therya-24-5908>
- Goddard, M. A., Davies, Z. G., Guenat, S., Ferguson, M. J., Fisher, J. C., Akanni, A., Ahjokoski, T., Anderson, P. M. L., Angeoletto, F., Antoniou, C., Bates, A. J., Barkwith, A., Berland, A., Bouch, C. J., Rega-Brodsky, C. C., Byrne, L. B., Cameron, D., Canavan, R., Chapman, T., ... Dallimer, M. (2021). A global horizon scan of the future impacts of robotics and autonomous systems on urban ecosystems. *Nature Ecology & Evolution*, 5(2), 219–230. <https://doi.org/10.1038/s41559-020-01358-z>
- Gonzalez-Moral, S. G., Fairweather, M., Khan, S., Fairbairn, R., & Norman, G. (2025). *How should horizon scanning studies be reported? Developing a checklist of standard items* (p. 2025.10.23.25338620). medRxiv. <https://doi.org/10.1101/2025.10.23.25338620>
- Goodwin, P., & Wright, G. (2010). The limits of forecasting methods in anticipating rare events. *Technological Forecasting and Social Change*, 77(3), 355–368. <https://doi.org/10.1016/j.techfore.2009.10.008>
- Google. (n.d.). *Gemini* [Large language model]. <https://gemini.google.com/>

- Gusha, N. M. C., Wilhelm, M. R., Bova, C. S., Engelhard, G. H., Hyder, K., & Potts, W. M. (2025). Horizon scan survey to identify key research questions to promote sustainability of the marine recreational fishery in Namibia. *Fisheries Management and Ecology*, 32(3), e12709. <https://doi.org/10.1111/fme.12709>
- Haines, A. M., Elledge, D., Wilsing, L. K., Grabe, M., Barske, M. D., Burke, N., & Webb, S. L. (2012). Spatially explicit analysis of poaching activity as a conservation management tool. *Wildlife Society Bulletin*, 36(4), 685–692. <https://doi.org/10.1002/wsb.194>
- Hamidov, A., Helming, K., & Balla, D. (2016). Impact of agricultural land use in Central Asia: A review. *Agronomy for Sustainable Development*, 36(1), 6. <https://doi.org/10.1007/s13593-015-0337-7>
- Hines, A., Bengston, D. N., Dockry, M. J., & Cowart, A. (2018). Setting Up a Horizon Scanning System: A U.S. Federal Agency Example. *World Futures Review*, 10(2), 136–151. <https://doi.org/10.1177/1946756717749613>
- Hines, P., Yu, L. H., Guy, R. H., Brand, A., & Papaluca-Amati, M. (2019). Scanning the horizon: A systematic literature review of methodologies. *BMJ Open*, 9(5), e026764. <https://doi.org/10.1136/bmjopen-2018-026764>
- Hinsley, A., Challender, D. W. S., Masters, S., Macdonald, D. W., Milner-Gulland, E. J., Fraser, J., & Wright, J. (2024). Early warning of trends in commercial wildlife trade through novel machine-learning analysis of patent filing. *Nature Communications*, 15(1), 6379. <https://doi.org/10.1038/s41467-024-49688-x>
- Holmes, G. (2007). Protection, Politics and Protest: Understanding Resistance to Conservation. *Conservation and Society*, 5(2), 184.
- Horgan, F. G., & Kudavidanage, E. P. (2021). Translating Research into Wildlife Conservation Actions Through Multi-sector Collaboration in Tropical Asia. In C. C. Ferreira & C. F. C. Klütsch (Eds), *Closing the Knowledge-Implementation Gap in Conservation Science: Interdisciplinary Evidence Transfer Across Sectors and Spatiotemporal Scales* (pp. 371–411). Springer International Publishing. https://doi.org/10.1007/978-3-030-81085-6_13
- Hughes, A. C., Lechner, A. M., Chitov, A., Horstmann, A., Hinsley, A., Tritto, A., Chariton, A., Li, B. V., Ganapin, D., Simonov, E., Morton, K., Toktomushev, K., Foggin, M., Tan-Mullins, M., Orr, M. C., Griffiths, R., Nash, R., Perkin, S., Glémet, R., ... Yu, D. W. (2020). Horizon Scan of the Belt and Road Initiative. *Trends in Ecology & Evolution*, 35(7), 583–593. <https://doi.org/10.1016/j.tree.2020.02.005>
- Iannone, R., Cheng, J., Schloerke, B., Haughton, S., Hughes, E., Lauer, A., François, R., Seo, J., Brevoort, K., & Roy, O. (2026). *gt: Easily create presentation-ready display tables* (R package version 1.3.0.9000) [Computer software]. <https://gt.rstudio.com>
- Ibraibekov, Z., Myrzabayev, A., Bodeyev, M., Gabdullin, Y., Zhumakhanova, R., Tulindinova, G., Korogod, N. P., Shaibek, A., Gulzhazira, T., & Nurushev, M. (2025). Influence of semi-voluntary conditions of detention on the behavior, adaptive reactions and reproductive activity of Saiga Antelope (*Saigatatarica*). *Caspian Journal of Environmental Sciences*, 23(3), 627–633. <https://doi.org/10.22124/cjes.2025.8918>
- Ishii, R., & Fujita, N. (2013). A Possible Future Picture of Mongolian Forest-Steppe Vegetation Under Climate Change and Increasing Livestock: Results from a New Vegetation Transition Model at the Topographic Scale. In N. Yamamura, N. Fujita, & A. Maekawa (Eds), *The Mongolian Ecosystem Network: Environmental Issues Under Climate and Social Changes* (pp. 65–82). Springer Japan. https://doi.org/10.1007/978-4-431-54052-6_6
- Ito, T. Y., Lhagvasuren, B., Tsunekawa, A., & Shinoda, M. (2017). Habitat Fragmentation by Railways as a Barrier to Great Migrations of Ungulates in Mongolia. In *Railway Ecology* (pp. 229–246). Springer, Cham. https://doi.org/10.1007/978-3-319-57496-7_14
- Ito, T. Y., Lhagvasuren, B., Tsunekawa, A., Shinoda, M., Takatsuki, S., Buuveibaatar, B., & Chimeddorj, B. (2013). Fragmentation of the Habitat of Wild Ungulates by Anthropogenic Barriers in Mongolia. *PLOS ONE*, 8(2), e56995. <https://doi.org/10.1371/journal.pone.0056995>
- International Union for Conservation of Nature. (2025). *IUCN Red List: 60 years of success* [Report].

International Union for Conservation of Nature. (2023). Saiga tatarica, Assessment by: IUCN SSC Antelope Specialist Group. 8235.

Jolles, A. E., Beechler, B. R., & Dolan, B. P. (2015). Beyond mice and men: Environmental change, immunity and infections in wild ungulates. *Parasite Immunology*, 37(5), 255–266. <https://doi.org/10.1111/pim.12153>

Jones, P. F., Jakes, A. F., Telander, A. C., Sawyer, H., Martin, B. H., & Hebblewhite, M. (2019). Fences reduce habitat for a partially migratory ungulate in the Northern Sagebrush Steppe. *Ecosphere*, 10(7), e02782. <https://doi.org/10.1002/ecs2.2782>

Juárez, E. I. A. y, Mace, G. M., Cowlshaw, G., & Pettorelli, N. (2012). Natural population die-offs: Causes and consequences for terrestrial mammals. *Trends in Ecology & Evolution*, 27(5), 272–277. <https://doi.org/10.1016/j.tree.2011.11.005>

Karimova, T. Yu., Lushchekina, A. A., & Neronov, V. M. (2021). Saiga Populations of Russia and Kazakhstan: Current Status and Retrospective Analysis of Some Biological Parameters. *Arid Ecosystems*, 11(2), 164–172. <https://doi.org/10.1134/S2079096121020074>

Karimova, T. Yu., Lushchekina, A. A., Neronov, V. M., Pyurvenova, N. Yu., & Arylov, Yu. N. (2020). Biological Features of the Northwest Pre-Caspian Saiga Population at Different Sizes. *Arid Ecosystems*, 10(4), 298–304. <https://doi.org/10.1134/S2079096120040113>

Kark, S., Sutherland, W. J., Shanas, U., Klass, K., Achisar, H., Dayan, T., Gavrieli, Y., Justo-Hanani, R., Mandelik, Y., Orion, N., Pargament, D., Portman, M., Reisman-Berman, O., Safriel, U. N., Schaffer, G., Steiner, N., Tauber, I., & Levin, N. (2016). Priority Questions and Horizon Scanning for Conservation: A Comparative Study. *PLOS ONE*, 11(1), e0145978. <https://doi.org/10.1371/journal.pone.0145978>

Kemp, L., Adam, L., Boehm, C. R., Breitling, R., Casagrande, R., Dando, M., Djikeng, A., Evans, N. G., Hammond, R., Hills, K., Holt, L. A., Kuiken, T., Markotić, A., Millett, P., Napier, J. A., Nelson, C., ÓhÉigeartaigh, S. S., Osbourn, A., Palmer, M. J., ... Sutherland, W. J. (2020). Bioengineering horizon scan 2020. *eLife*, 9, e54489. <https://doi.org/10.7554/eLife.54489>

Khanyari, M., Robinson, S., Morgan, E. R., Brown, T., Singh, N. J., Salemgareyev, A., Zuther, S., Kock, R., & Milner-Gulland, E. J. (2021a). Building an ecologically founded disease risk prioritization framework for migratory wildlife species based on contact with livestock. *Journal of Applied Ecology*, 58(9), 1838–1853. <https://doi.org/10.1111/1365-2664.13937>

Khanyari, M., Robinson, S., Morgan, E. R., Salemgareyev, A., & E.J. Milner-Gulland. (2021b). Identifying relationships between multi-scale social–ecological factors to explore ungulate health in a Western Kazakhstan rangeland. *People and Nature*, 4(2), 382–399. <https://doi.org/10.1002/pan3.10289>

Kirchherr, J., & Charles, K. (2018). Enhancing the sample diversity of snowball samples: Recommendations from a research project on anti-dam movements in Southeast Asia. *PLoS ONE*, 13(8), e0201710. <https://doi.org/10.1371/journal.pone.0201710>

Kock, R. A., Orynbayev, M., Robinson, S., Zuther, S., Singh, N. J., Beauvais, W., Morgan, E. R., Kerimbayev, A., Khomenko, S., Martineau, H. M., Rystaeva, R., Omarova, Z., Wolfs, S., Hawotte, F., Radoux, J., & Milner-Gulland, E. J. (2018). Saigas on the brink: Multidisciplinary analysis of the factors influencing mass mortality events. *Science Advances*, 4(1), eaao2314. <https://doi.org/10.1126/sciadv.aao2314>

Kock, R., Fine, A., Caron, A., Bataille, A., Willett, B. J., Keyyu, J., Misinzo, G., Mdetele, D., Gakuya, F., Feroudini, S., Benfield, C., Aguilar, X. F., Pruvot, M., Shiilegdamba, E., Shatar, M., Tully, M., Rossiter, P., Njeumi, F., & Parida, S. (2025). PPR Infection Crossing Between Domestic and Wild Hoofed Mammals: Does This Matter for Virus Eradication? In M. Munir & M. Abubakar (Eds), *Peste des Petits Ruminants Virus* (pp. 99–127). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-82214-8_6

Koshkina, A., Smelansky, I., Tabelinova, A., Stephens, G., Jones, S., Salemgareev, A., Bowe, M., & Devenish, A. (2026). Drivers of human-saiga antelope conflict in semi-arid rangelands of West Kazakhstan. *Biological Conservation*, 313, 111631. <https://doi.org/10.1016/j.biocon.2025.111631>

Kühl, A., Mysterud, A., Grachev, Iu. A., Bekenov, A. B., Ubushaev, B. S., Lushchekina, A. A., & Milner-Gulland, E. J. (2009). Monitoring population productivity in the saiga antelope. *Animal Conservation*, 12(4), 355–363. <https://doi.org/10.1111/j.1469-1795.2009.00260.x>

Kushaliyev, K., Ussenov, Z., Alimbekov, S., Millakaev, O., Kozhayeva, A., & Khairushev, A. (2023). Study of the saiga helminth fauna and Ural sheep in the western region of Kazakhstan. *Open Veterinary Journal*, 13(4), 485–494. <https://doi.org/10.5455/OVJ.2023.v13.i4.11>

Lavrakas, P.J. (2008). *Encyclopedia of Survey Research Methods*. Sage Publications, Inc. <https://doi.org/10.4135/9781412963947>

Le Busque, B., Dorrian, J., & Litchfield, C. (2021). The impact of news media portrayals of sharks on public perception of risk and support for shark conservation. *Marine Policy*, 124, 104341. <https://doi.org/10.1016/j.marpol.2020.104341>

Leclerc, C., Bellard, C., Luque, G. M., & Courchamp, F. (2015). Overcoming extinction: Understanding processes of recovery of the Tibetan antelope. *Ecosphere*, 6(9), art171. <https://doi.org/10.1890/ES15-00049.1>

Lenth, R. V., & Piaskowski, J. (2026). *emmeans: Estimated marginal means, aka least-squares means* (R package version 2.0.3) [Computer software]. <https://CRAN.R-project.org/package=emmeans>

Lucy, F. E., Davis, E., Anderson, R., Booy, O., Bradley, K., Britton, J. R., Byrne, C., Caffrey, J. M., Coughlan, N. E., Crane, K., Cuthbert, R. N., Dick, J. T. A., Dickey, J. W. E., Fisher, J., Gallagher, C., Harrison, S., Jebb, M., Johnson, M., Lawton, C., ... Trodd, W. (2020). Horizon scan of invasive alien species for the island of Ireland. *Management of Biological Invasions*, 11(2), 155–177. <https://doi.org/10.3391/mbi.2020.11.2.01>

Macinnis-Ng, C., Ziedins, I., Ajmal, H., Baisden, W. T., Hendy, S., McDonald, A., Priestley, R., Salmon, R. A., Sharp, E. L., Tonkin, J. D., Velarde, S., Watene (Ngāti Manu, T. H., Ngāti Whātua Ōrākei, Tonga), Krushil, & Godsoe, W. (2024). Climate change impacts on Aotearoa New Zealand: A horizon scan approach. *Journal of the Royal Society of New Zealand*, 54(4), 523–546. <https://doi.org/10.1080/03036758.2023.2267016>

Martin, M. A., Sendra, O. A., Bastos, A., Bauer, N., Bertram, C., Blenckner, T., Bowen, K., Brando, P. M., Rudolph, T. B., Büchs, M., Bustamante, M., Chen, D., Cleugh, H., Dasgupta, P., Denton, F., Donges, J. F., Donkor, F. K., Duan, H., Duarte, C. M., ... Woodcock, J. (2021). Ten new insights in climate science 2021: A horizon scan. *Global Sustainability*, 4, e25. <https://doi.org/10.1017/sus.2021.25>

Martín-López, B., Montes, C., Ramírez, L., & Benayas, J. (2009). What drives policy decision-making related to species conservation? *Biological Conservation*, 142(7), 1370–1380. <https://doi.org/10.1016/j.biocon.2009.01.030>

Mc Guinness, S. K. (2016). Perceptions of crop raiding: Effects of land tenure and agro-industry on human–wildlife conflict. *Animal Conservation*, 19(6), 578–587. <https://doi.org/10.1111/acv.12279>

Mekonen, S. (2020). Coexistence between human and wildlife: The nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. *BMC Ecology*, 20(1), 51. <https://doi.org/10.1186/s12898-020-00319-1>

Mendgen, P., Dejid, N., Olson, K., Buuveibaatar, B., Calabrese, J. M., Chimeddorj, B., Dalannast, M., Fagan, W. F., Leimgruber, P., & Müller, T. (2023). Nomadic ungulate movements under threat: Declining mobility of Mongolian gazelles in the Eastern Steppe of Mongolia. *Biological Conservation*, 286, 110271. <https://doi.org/10.1016/j.biocon.2023.110271>

Middleton, A. D., Merkle, J. A., McWhirter, D. E., Cook, J. G., Cook, R. C., White, P. J., & Kauffman, M. J. (2018). Green-wave surfing increases fat gain in a migratory ungulate. *Oikos*, 127(7), 1060–1068. <https://doi.org/10.1111/oik.05227>

Mikkelsen, G. M., Gonzalez, A., & Peterson, G. D. (2007). Economic Inequality Predicts Biodiversity Loss. *PLOS ONE*, 2(5), e444. <https://doi.org/10.1371/journal.pone.0000444>

Mjachina, K., Hu, Z., & Chibilyev, A. (2018). Detection of damaged areas caused by the oil extraction in a steppe region using winter landsat imagery. *Journal of Applied Remote Sensing*, 12(1), 016017. <https://doi.org/10.1117/1.JRS.12.016017>

Mills, J. A. (1999). *Tibetan antelope: Fashion statement spells death for Tibetan antelope* [Unpublished report]. TRAFFIC India.

Milner-Gulland, E. J., Kholodova, M. V., Bekenov, A., Bukreeva, O. M., Grachev, Iu. A., Amgalan, L., & Lushchekina, A. A. (2001). Dramatic declines in saiga antelope populations. *Oryx*, 35(4), 340–345. <https://doi.org/10.1046/j.1365-3008.2001.00202.x>

Milner-Gulland, E. & Mallon, D.P. 2024. *Saiga tatarica* (Green Status assessment). *The IUCN Red List of Threatened Species* 2024: e.T19832A1983220252. Accessed on 20 May 2026.

Monk, J. D., Smith, J. A., Donadio, E., Perrig, P. L., Crego, R. D., Fileni, M., Bidder, O., Lambertucci, S. A., Pauli, J. N., Schmitz, O. J., & Middleton, A. D. (2022). Cascading effects of a disease outbreak in a remote protected area. *Ecology Letters*, 25(5), 1152–1163. <https://doi.org/10.1111/ele.13983>

Moore, J. F., Mulindahabi, F., Masozera, M. K., Nichols, J. D., Hines, J. E., Turikunkiko, E., & Oli, M. K. (2018). Are ranger patrols effective in reducing poaching-related threats within protected areas? *Journal of Applied Ecology*, 55(1), 99–107. <https://doi.org/10.1111/1365-2664.12965>

Morgan, E. R., Lundervold, M., Medley, G. F., Shaikenov, B. S., Torgerson, P. R., & Milner-Gulland, E. J. (2006). Assessing risks of disease transmission between wildlife and livestock: The Saiga antelope as a case study. *Biological Conservation, Infectious Disease and Mammalian Conservation*, 131(2), 244–254. <https://doi.org/10.1016/j.biocon.2006.04.012>

Mukherjee, N., Hugé, J., Sutherland, W. J., McNeill, J., Van Opstal, M., Dahdouh-Guebas, F., & Koedam, N. (2015). The Delphi technique in ecology and biological conservation: Applications and guidelines. *Methods in Ecology and Evolution*, 6(9), 1097–1109. <https://doi.org/10.1111/2041-210X.12387>

Müller, K., & Wickham, H. (2026). *tibble: Simple data frames* (R package version 3.3.1). <https://tibble.tidyverse.org/>

National Geographic Staff. (2018, January 29). *Endangered Saiga Antelope Die-Off Caused by Nose Bacteria in Kazakhstan*. National Geographic.

Nemorin, S., Vlachidis, A., Ayerakwa, H. M., & Andriotis, P. (2023). AI hyped? A horizon scan of discourse on artificial intelligence in education (AIED) and development. *Learning, Media and Technology*, 48(1), 38–51. <https://doi.org/10.1080/17439884.2022.2095568>

Ngorima, A., Brown, A., Masunungure, C., & Biggs, D. (2020). Local community benefits from elephants: Can willingness to support anti-poaching efforts be strengthened? *Conservation Science and Practice*, 2(12), e303. <https://doi.org/10.1111/csp2.303>

Niedziałkowski, K., Paavola, J., & Jędrzejewska, B. (2012). Participation and Protected Areas Governance: The Impact of Changing Influence of Local Authorities on the Conservation of the Białowieża Primeval Forest, Poland. *Ecology and Society*, 17(1), art2. <https://doi.org/10.5751/ES-04461-170102>

Nowack, M., Endrikat, J., & Guenther, E. (2011). Review of Delphi-based scenario studies: Quality and design considerations. *Technological Forecasting and Social Change, The Delphi Technique: Past, Present, and Future Prospects*, 78(9), 1603–1615. <https://doi.org/10.1016/j.techfore.2011.03.006>

Nunez, S., Alkemade, R., Kok, K., & Leemans, R. (2020). Potential biodiversity change in Central Asian grasslands: Scenarios for the impact of climate and land-use change. *Regional Environmental Change*, 20(2), 39. <https://doi.org/10.1007/s10113-020-01619-4>

Nunn, C. L., Jordán, F., McCabe, C. M., Verdolin, J. L., & Fewell, J. H. (2015). Infectious disease and group size: More than just a numbers game. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1669), 20140111. <https://doi.org/10.1098/rstb.2014.0111>

O'Connor, N., Eastaugh, C., Lister, J., Mcdaid, C., Hewitt, C., Craig, D., & Norman, G. (2025). A scoping review of horizon scanning approaches used to identify emerging research methods. *NIHR Open Research*, 5, 86. <https://doi.org/10.3310/nihropenres.13981.1>

OpenAI. (2024). *ChatGPT Edu* [Large language model]. <https://openai.com/index/introducing-chatgpt-edu/>

Orynbayev, M. B., Beauvais, W., Sansyzbay, A. R., Rystaeva, R. A., Sultankulova, K. T., Kerimbaev, A. A., Kospanova, M. N., & Kock, R. A. (2016). Seroprevalence of infectious diseases in saiga antelope (*Saiga tatarica tatarica*) in Kazakhstan 2012–2014. *Preventive Veterinary Medicine*, 127, 100–104. <https://doi.org/10.1016/j.prevetmed.2016.03.016>

Parker, M., Acland, A., Armstrong, H. J., Bellingham, J. R., Bland, J., Bodmer, H. C., Burall, S., Castell, S., Chilvers, J., Cleevely, D. D., Cope, D., Costanzo, L., Dolan, J. A., Doubleday, R., Feng, W. Y., Godfray, H. C. J., Good, D. A., Grant, J., Green, N., ... Sutherland, W. J. (2014). Identifying the Science and Technology Dimensions of Emerging Public Policy Issues through Horizon Scanning. *PLOS ONE*, 9(5), e96480. <https://doi.org/10.1371/journal.pone.0096480>

Pedersen, T. L. (2025). *patchwork: The composer of plots* (R package version 1.3.2) [Computer software]. <https://CRAN.R-project.org/package=patchwork>

Pérez-Jvostov, F., Sutherland, W. J., Barrett, R. D. H., Brown, C. A., Cardille, J. A., Cooke, S. J., Cristescu, M. E., St-Gelais, N. F., Fussmann, G. F., Griffiths, K., Hendry, A. P., Lapointe, N. W. R., Nyboer, E. A., Pentland, R. L., Reid, A. J., Ricciardi, A., Sunday, J. M., & Gregory-Eaves, I. (2020). Horizon scan of conservation issues for inland waters in Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 77(5), 869–881. <https://doi.org/10.1139/cjfas-2019-0105>

Prishchepov, A. V., Myachina, K. V., Kamp, J., Smelansky, I., Dubrovskaya, S., Ryakhov, R., Grudin, D., Yakovlev, I., & Urazaliyev, R. (2021). Multiple trajectories of grassland fragmentation, degradation, and recovery in Russia's steppes. *Land Degradation & Development*, 32(11), 3220–3235. <https://doi.org/10.1002/ldr.3976>

Pruvot, M., Fine, A. E., Hollinger, C., Strindberg, S., Damdinjav, B., Buuveibaatar, B., Chimeddorj, B., Bayandonoi, G., Khishgee, B., Sandag, B., Narmandakh, J., Jargalsaikhan, T., Bataa, B., McAloose, D., Shatar, M., Basan, G., Mahapatra, M., Selvaraj, M., Parida, S., ... Shiilegdamba, E. (2020). Outbreak of Peste des Petits Ruminants among Critically Endangered Mongolian Saiga and Other Wild Ungulates, Mongolia, 2016–2017. *Emerging Infectious Diseases*, 26(1), 51–62. <https://doi.org/10.3201/eid2601.181998>

Reimoser, F., & Putman, R. (2011). Impacts of wild ungulates on vegetation: Costs and benefits. In R. Putman, M. Apollonio, & R. Andersen (Eds), *Ungulate Management in Europe* (1st edn, pp. 144–191). Cambridge University Press. <https://doi.org/10.1017/CBO9780511974137.007>

Robinson, S., Milner-Gulland, E. J., Grachev, Y., Salemgareyev, A., Orynbayev, M., Lushchekina, A., Morgan, E., Beauvais, W., Singh, N., Khomenko, S., Cammack, R., & Kock, R. (2019). Opportunistic bacteria and mass mortality in ungulates: Lessons from an extreme event. *Ecosphere*, 10(6), e02671. <https://doi.org/10.1002/ecs2.2671>

Rondeau, D., Perry, B., & Grimard, F. (2020). The Consequences of COVID-19 and Other Disasters for Wildlife and Biodiversity. *Environmental & Resource Economics*, 76(4), 945–961. <https://doi.org/10.1007/s10640-020-00480-7>

RSPB. (2024). *Altyn Dala Conservation Initiative wins The Earthshot Prize 2024*. Royal Society for the Protection of Birds.

Saiga Conservation Alliance. (2024). *Celebrating Mongolia's new standard for linear infrastructure fencing: A win for migratory species*. Saiga Conservation Alliance.

Schaller, G. B. (1998). *Wildlife of the Tibetan steppe*. University of Chicago Press.

Schweiger, D. M., Sandberg, W. R., & Rechner, P. L. (1989). Experiential Effects of Dialectical Inquiry, Devil's Advocacy, and Consensus Approaches to Strategic Decision Making. *The Academy of Management Journal*, 32(4), 745–772. <https://doi.org/10.2307/256567>

Seymour, C. L., Gillson, L., Child, M. F., Tolley, K. A., Curie, J. C., da Silva, J. M., Alexander, G. J., Anderson, P., Downs, C. T., Egoh, B. N., Ehlers Smith, D. A., Ehlers Smith, Y. C., Esler, K. J., O'Farrell, P. J., Skowno, A. L., Suleman, E., & Veldtman, R. (2020). Horizon scanning for South African biodiversity: A need for social engagement as well as science. *Ambio*, 49(6), 1211–1221. <https://doi.org/10.1007/s13280-019-01252-4>

Shackleton, R. T., Angelstam, P., van der Waal, B., & Elbakidze, M. (2017). Progress made in managing and valuing ecosystem services: A horizon scan of gaps in research, management and governance. *Ecosystem*

Services, Investing in Ecological Infrastructure in South Africa, 27, 232–241.
<https://doi.org/10.1016/j.ecoser.2016.11.020>

Singh, N. J., Grachev, I. A., Bekenov, A. B., & Milner-Gulland, E. J. (2010). Tracking greenery across a latitudinal gradient in central Asia – the migration of the saiga antelope. *Diversity and Distributions*, 16(4), 663–675. <https://doi.org/10.1111/j.1472-4642.2010.00671.x>

Singh, N. J., & Milner-Gulland, E. J. (2011). Conserving a moving target: Planning protection for a migratory species as its distribution changes. *Journal of Applied Ecology*, 48(1), 35–46. <https://doi.org/10.1111/j.1365-2664.2010.01905.x>

Soga, M., & Gaston, K. J. (2018). Shifting baseline syndrome: Causes, consequences, and implications. *Frontiers in Ecology and the Environment*, 16(4), 222–230. <https://doi.org/10.1002/fee.1794>

Stanley, M. C., Beggs, J. R., Bassett, I. E., Burns, B. R., Dirks, K. N., Jones, D. N., Linklater, W. L., Macinnis-Ng, C., Simcock, R., Souter-Brown, G., Trowsdale, S. A., & Gaston, K. J. (2015). Emerging threats in urban ecosystems: A horizon scanning exercise. *Frontiers in Ecology and the Environment*, 13(10), 553–560. <https://doi.org/10.1890/150229>

State Great Hural of Mongolia. (2020). “Vision-2050” Long-Term Development Policy of Mongolia. Resolution adopted 13 May 2020.

Sutherland, W. J., Allison, H., Aveling, R., Bainbridge, I. P., Bennun, L., Bullock, D. J., Clements, A., Crick, H. Q. P., Gibbons, D. W., Smith, S., Rands, M. R. W., Rose, P., Scharlemann, J. P. W., & Warren, M. S. (2012). Enhancing the value of horizon scanning through collaborative review. *Oryx*, 46(3), 368–374. <https://doi.org/10.1017/S0030605311001724>

Sutherland, W. J., Bailey, M. J., Bainbridge, I. P., Brereton, T., Dick, J. T. A., Drewitt, J., Dulvy, N. K., Dusic, N. R., Freckleton, R. P., Gaston, K. J., Gilder, P. M., Green, R. E., Heathwaite, A. L., Johnson, S. M., Macdonald, D. W., Mitchell, R., Osborn, D., Owen, R. P., Pretty, J., ... Woodroof, H. J. (2008). Future novel threats and opportunities facing UK biodiversity identified by horizon scanning. *Journal of Applied Ecology*, 45(3), 821–833. <https://doi.org/10.1111/j.1365-2664.2008.01474.x>

Sutherland, W. J., Clout, M., Côté, I. M., Daszak, P., Depledge, M. H., Fellman, L., Fleishman, E., Garthwaite, R., Gibbons, D. W., De Lurio, J., Impey, A. J., Lickorish, F., Lindenmayer, D., Madgwick, J., Margerison, C., Maynard, T., Peck, L. S., Pretty, J., Prior, S., ... Watkinson, A. R. (2010). A horizon scan of global conservation issues for 2010. *Trends in Ecology & Evolution*, 25(1), 1–7. <https://doi.org/10.1016/j.tree.2009.10.003>

Sutherland, W. J., Fleishman, E., Clout, M., Gibbons, D. W., Lickorish, F., Peck, L. S., Pretty, J., Spalding, M., & Ockendon, N. (2019). Ten Years On: A Review of the First Global Conservation Horizon Scan. *Trends in Ecology & Evolution*, 34(2), 139–153. <https://doi.org/10.1016/j.tree.2018.12.003>

Sutherland, W. J., & Woodroof, H. J. (2009). The need for environmental horizon scanning. *Trends in Ecology & Evolution*, 24(10), 523–527. <https://doi.org/10.1016/j.tree.2009.04.008>

Tacconi, L., & Williams, D. A. (2020). Corruption and Anti-Corruption in Environmental and Resource Management. *Annual Review of Environment and Resources*, 45(Volume 45, 2020), 305–329. <https://doi.org/10.1146/annurev-environ-012320-083949>

Tew, E. R., Ambrose-Oji, B., Beatty, M., Büntgen, U., Butterworth, H., Clover, G., Cook, D., Dauksta, D., Day, W., Deakin, J., Field, A., Gardiner, B., Harrop, P., Healey, J. R., Heaton, R., Hemery, G., Hill, L., Hughes, O., Khaira-Creswell, P. K., ... Sutherland, W. J. (2024). A horizon scan of issues affecting UK forest management within 50 years. *Forestry: An International Journal of Forest Research*, 97(3), 349–362. <https://doi.org/10.1093/forestry/cpad047>

The Times of Central Asia. (2025). *Kazakhstan to permit limited saiga horn exports under strict controls*. The Times of Central Asia.

Theng, M., Glikman, J. A., & Milner-Gulland, E. J. (2018). Exploring saiga horn consumption in Singapore. *Oryx*, 52(4), 736–743. <https://doi.org/10.1017/S0030605317001624>

- Thomas-Walters, L., Hinsley, A., Bergin, D., Burgess, G., Doughty, H., Eppel, S., MacFarlane, D., Meijer, W., Lee, T. M., Phelps, J., Smith, R. J., Wan, A. K. Y., & Veríssimo, D. (2021). Motivations for the use and consumption of wildlife products. *Conservation Biology*, 35(2), 483–491. <https://doi.org/10.1111/cobi.13578>
- Thyrring, J., Archambault, P., Burrows, M., Iken, K., Lima, F. P., Micael, J., Molis, M., Monteiro, C., Olenin, S., Renaud, P. E., Scrosati, R. A., Seabra, R., Sukhotin, A. A., Węśławski, J.-M., Zwerschke, N., & Sejr, M. K. (2025). A horizon scan for Arctic coastal biodiversity research: Understanding changes requires international collaboration. *Trends in Ecology & Evolution*, 40(5), 460–467. <https://doi.org/10.1016/j.tree.2025.02.008>
- Török, P., Neuffer, B., Heilmeyer, H., Bernhardt, K.-G., & Wesche, K. (2020). Climate, landscape history and management drive Eurasian steppe biodiversity. *Flora*, 271, 151685. <https://doi.org/10.1016/j.flora.2020.151685>
- Travis, D., WATSON, R. P., & Tauer, A. (2011). The spread of pathogens through trade in wildlife. *Revue Scientifique et Technique (International Office of Epizootics)*, 30, 219–239. <https://doi.org/10.20506/rst.30.1.2035>
- Trevathan-Tackett, S. M., Sherman, C. D. H., Huggett, M. J., Campbell, A. H., Laverock, B., Hurtado-McCormick, V., Seymour, J. R., Firl, A., Messer, L. F., Ainsworth, T. D., Negandhi, K. L., Daffonchio, D., Egan, S., Engelen, A. H., Fusi, M., Thomas, T., Vann, L., Hernandez-Agreda, A., Gan, H. M., ... Macreadie, P. I. (2019). A horizon scan of priorities for coastal marine microbiome research. *Nature Ecology & Evolution*, 3(11), 1509–1520. <https://doi.org/10.1038/s41559-019-0999-7>
- Trouwborst, A., Fleurke, F., & Dubrulle, J. (2016). Border Fences and their Impacts on Large Carnivores, Large Herbivores and Biodiversity: An International Wildlife Law Perspective. *Review of European, Comparative & International Environmental Law*, 25(3), 291–306. <https://doi.org/10.1111/reel.12169>
- Tsakalidis, A., Boelman, E., Marmier, A., Gkoumas, K., & Pekar, F. (2021). Horizon scanning for transport research and innovation governance: A European perspective. *Transportation Research Interdisciplinary Perspectives*, 11, 100424. <https://doi.org/10.1016/j.trip.2021.100424>
- United Nations Office for Disaster Risk Reduction (UNDRR), & International Science Council (ISC). (2025). UNDRR–ISC Hazard Information Profiles – 2025 Update: MH0503 Dzuud United Nations Office for Disaster Risk Reduction; International Science Council. <https://www.undrr.org/terms/hips/MH0503>
- Valente, A. M., Acevedo, P., Figueiredo, A. M., Fonseca, C., & Torres, R. T. (2020). Overabundant wild ungulate populations in Europe: Management with consideration of socio-ecological consequences. *Mammal Review*, 50(4), 353–366. <https://doi.org/10.1111/mam.12202>
- Van Woensel, L. (2024). Foresight in EU policy-making: Purpose, mindsets and methods. *European Law Journal*, 30(3), 361–381. <https://doi.org/10.1111/eulj.12522>
- Verrelli, B. C., Alberti, M., Des Roches, S., Harris, N. C., Hendry, A. P., Johnson, M. T. J., Savage, A. M., Charmantier, A., Gotanda, K. M., Govaert, L., Miles, L. S., Rivkin, L. R., Winchell, K. M., Brans, K. I., Correa, C., Diamond, S. E., Fitzhugh, B., Grimm, N. B., Hughes, S., ... Ziter, C. (2022). A global horizon scan for urban evolutionary ecology. *Trends in Ecology & Evolution*, 37(11), 1006–1019. <https://doi.org/10.1016/j.tree.2022.07.012>
- Vuola, M., & Pyhälä, A. (2016). Local community perceptions of conservation policy: Rights, recognition and reactions. *Madagascar Conservation & Development*, 11(2), 77–86. <https://doi.org/10.4314/mcd.v11i2.6>
- Wang, Q., Okadera, T., Watanabe, M., Wu, T., & Ochirbat, B. (2022). Ground warming and permafrost degradation in various terrestrial ecosystems in northcentral Mongolia. *Permafrost and Periglacial Processes*, 33(4), 406–424. <https://doi.org/10.1002/ppp.2161>
- Wildlife Conservation Society. (2025). *CITES CoP20 decision allows international trade in saiga horn, strongly opposed by WCS*. WCS Newsroom.
- World Health Organisation (2022). *Foresight approaches in global public health: A practical guide for WHO staff*. Retrieved 19 May 2026, from <https://www.who.int/publications/i/item/9789240048393>
- Wickham, H., François, R., Henry, L., Müller, K., & Vaughan, D. (2026). *dplyr: A grammar of data manipulation* (R package version 1.2.1) [Computer software]. <https://dplyr.tidyverse.org>

- Wickham, H., Vaughan, D., & Girlich, M. (2026). *tidyr: Tidy messy data* (R package version 1.3.2) [Computer software]. <https://tidyr.tidyverse.org>
- Wickham, H. (2025). *stringr: Simple, consistent wrappers for common string operations* (R package version 1.6.0) [Computer software]. <https://stringr.tidyverse.org>
- Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York. <https://ggplot2.tidyverse.org>
- Wilcove, D. S., & Wikelski, M. (2008). Going, Going, Gone: Is Animal Migration Disappearing. *PLOS Biology*, 6(7), e188. <https://doi.org/10.1371/journal.pbio.0060188>
- Wilke, C. O., & Wiernik, B. M. (2022). *ggtext: Improved text rendering support for ggplot2* (R package version 0.1.2). <https://github.com/wilkelab/ggtext>
- Willcox, B. K., Potts, S. G., Brown, M. J. F., Alix, A., Al Naggar, Y., Chauzat, M.-P., Costa, C., Gekière, A., Hartfield, C., Hatjina, F., Knapp, J. L., Martínez-López, V., Maus, C., Metodiev, T., Nazzi, F., Osterman, J., Raimets, R., Strobl, V., Van Oystaeyen, A., ... Senapathi, D. (2023). Emerging threats and opportunities to managed bee species in European agricultural systems: A horizon scan. *Scientific Reports*, 13(1), 18099. <https://doi.org/10.1038/s41598-023-45279-w>
- Wintle, B. C., Boehm, C. R., Rhodes, C., Molloy, J. C., Millett, P., Adam, L., Breitling, R., Carlson, R., Casagrande, R., Dando, M., Doubleday, R., Drexler, E., Edwards, B., Ellis, T., Evans, N. G., Hammond, R., Haseloff, J., Kahl, L., Kuiken, T., ... Sutherland, W. J. (2017). A transatlantic perspective on 20 emerging issues in biological engineering. *eLife*, 6, e30247. <https://doi.org/10.7554/eLife.30247>
- Wintle, B. C., Kennicutt II, M. C., & Sutherland, W. J. (2020). Scanning horizons in research, policy and practice. In J. A. Vickery, N. Ockendon, N. Pettorelli, P. N. M. Brotherton, W. J. Sutherland, & Z. G. Davies (Eds), *Conservation Research, Policy and Practice* (pp. 29–47). Cambridge University Press. <https://doi.org/10.1017/9781108638210.003>
- Wu, X., Liu, Y., Yan, X., Wei, X., Fan, X., Wang, D., Wu, T., Li, R., Hu, G., Zou, D., Bai, K., Dashtseren, A., & Adiya, S. (2025). Characteristics, impacts, and future research directions of Mongolian peatlands. *Environmental Reviews*, 33, 1–15. <https://doi.org/10.1139/er-2024-0070>
- Xiao, W., Zhang, W., Ye, Y., Lv, X., & Yang, W. (2020). Is underground coal mining causing land degradation and significantly damaging ecosystems in semi-arid areas? A study from an Ecological Capital perspective. *Land Degradation & Development*, 31(15), 1969–1989. <https://doi.org/10.1002/ldr.3570>
- Yang, H., Wu, M., Liu, W., Zhang, Z., Zhang, N., & Wan, S. (2011). Community structure and composition in response to climate change in a temperate steppe. *Global Change Biology*, 17(1), 452–465. <https://doi.org/10.1111/j.1365-2486.2010.02253.x>
- Yang, L. H., Postema, E. G., Hayes, T. E., Lippey, M. K., & MacArthur-Waltz, D. J. (2021). The complexity of global change and its effects on insects. *Current Opinion in Insect Science, Global Change Biology. Molecular Physiology. October (2021)*, 47, 90–102. <https://doi.org/10.1016/j.cois.2021.05.001>
- Yang, X., Lei, S., Shi, Y., Gong, C., Xu, J., & Wang, W. (2023). Impacts of open-pit coal mining and livestock grazing on plant diversity in a steppe: From the perspective of remote sensing. *Land Degradation & Development*, 34(16), 5122–5134. <https://doi.org/10.1002/ldr.4834>
- Yannelli, F. A., Bazzichetto, M., Conradi, T., Pattison, Z., Andrade, B. O., Anibaba, Q. A., Bonari, G., Chelli, S., Čuk, M., Damasceno, G., Fantinato, E., Geange, S. R., Guuroh, R. T., Holle, M. J. M., Kuzmič, F., Lembrechts, J. J., Mosyafiani, A., Šikuljak, T., Teixeira, J., ... Sperandii, M. G. (2022). Fifteen emerging challenges and opportunities for vegetation science: A horizon scan by early career researchers. *Journal of Vegetation Science*, 33(1), e13119. <https://doi.org/10.1111/jvs.13119>
- Zbyryt, A., Bubnicki, J. W., Kuijper, D. P. J., Dehnhard, M., Churski, M., & Schmidt, K. (2018). Do wild ungulates experience higher stress with humans than with large carnivores? *Behavioral Ecology*, 29(1), 19–30. <https://doi.org/10.1093/beheco/arx142>

Zhang, H.-X., Zhang, M.-L., & Sanderson, S. C. (2013). Retreating or Standing: Responses of Forest Species and Steppe Species to Climate Change in Arid Eastern Central Asia. *PLOS ONE*, 8(4), e61954. <https://doi.org/10.1371/journal.pone.0061954>

8. Management Report

Throughout my project, I generally had fortnightly meetings with my supervisor and Peter Damerell. While my supervisor was away on sabbatical (mid-Feb to mid-April), I had meetings with Peter as and when challenges arose.

Task	Oct 25	Nov 25	Dec 25	Jan 26	Feb 26	Mar 26	Apr 26	May 26
Questionnaire design & preparation of recruitment materials								
Horizon scanning reading/lit review								
Ethics application								
COLLECT stage								
FILTER stage (including SR1)								
Research for evidence summaries								
ENGAGE phase								
REASSESS phase (SR2)								
Intro write-up								
Analysis (ppt background and between round changes)								
Write-up								

Ethical approval

I experienced a major delay in obtaining ethical approval. I submitted my application to WorkTribe on October 28th, received a request for additional information on February 25th (which I responded to that day), and received a favourable opinion on February 26th. It was critical for me to launch my project at CITES CoP20 in early December, as a very large pool of potential participants was attending. This meant I had to collect participant data without approval, though I later received it. If I had waited until I had approval, I would have had to recruit online only, which likely would not have attracted enough participants to be able to proceed. There also would not have been enough time to run the methodology if I had started in late February.

COLLECT phase

The COLLECT stage took longer than anticipated due to a low response rate to the questionnaire during the busy Christmas and New Year's period, so I extended the deadline and sent multiple rounds of follow-up emails. The questionnaire was open between 3 Dec and 17 Jan (45 days), whereas I had intended it to be open for only ~14 days, resulting in a substantial delay.

FILTER phase

I then experienced a long delay while Scoring Round 1 was being translated, which meant I needed to quickly find another translator. Scoring Round 1 was open between 2 Feb and 13 Feb (11 days), and I was aggregating and circulating results, then waiting for participants to “save” issues until 24 Feb.

ENGAGE phase

I researched and wrote seventeen ~400-word evidence summaries between 13 Feb and 26 Feb (researching the additional saved issues once the “saving” deadline had passed), and I circulated these along with workshop invitations on 5 March. The workshops were held in two one-hour sessions on 7 and 9 March. Time was getting tight at this point, and I needed to write up Scoring Round 2 and leave enough time for translation, so I was only able to give participants who could not attend the workshops four additional days to send me their thoughts for inclusion.

REASSESS phase

Scoring Round 2 was open for 23 days between 1 and 23 April. I had planned to keep this open for ~14 days, but I had to extend the deadline due to a low response rate. While this stage was open, I wrote a draft of my introduction and began aggregating and analysing my data, as I could rerun my code with updated data once SR2 had closed.

Write-up

After analysing my data, I wrote up the first draft of my dissertation between April 30 and 15 May, then refined this over the next week to submit on 22 May, having received a self-certified extension.

9. Appendices

Appendix A: Glossary of acronyms

Appendix B: Deviations from reference study (Esmail et al., 2020)

Appendix C: Initial idea-gathering questionnaire (COLLECT)

Appendix D: Scoring Scales in SR1 and SR2

Appendix E: Background questions

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Appendix G: List of workshop prompt questions

Appendix H: Analytical Pipeline Overview

Appendix I: All Scoring Round 1 Issues

Appendix J: Hypothesis testing full table

Appendix K: Between-round changes paired vs unpaired figures

Appendix L: Between-round changes full tables

Appendix M: Repository of participant-facing materials

Appendix A: Glossary of acronyms

CITES = Convention on the International Trade of Endangered Species of Wild Fauna and Flora

CMS = Convention on Migratory Species

CoP20 = 20th meeting of the Conference of the Parties (to CITES)

EMM = Estimated Marginal Mean

GBF = (Kunming-Montreal) Global Biodiversity Framework

HWC = Human-Wildlife Conflict

IUCN-SSC = International Union for Conservation of Nature Species Survival Commission

IWT = Illegal Wildlife Trade

LMER = Linear Mixed-Effects Regression (Model)

SCA = Saiga Conservation Alliance

SR1 = Scoring Round 1

SR2 = Scoring Round 2

TCM = Traditional Chinese Medicine

Appendix B: Deviations from reference study (Esmail et al., 2020)

Stage	Reference study (Esmail et al., 2020)	My approach	Rationale for my approach
COLLECT	Asked participants to consult their networks and conduct their own research before submitting ideas.	I welcomed quick responses (~10-minute questionnaire)	As I was recruiting at events and on LinkedIn, keeping it as short as possible was important to maximise participation.
All stages after COLLECT	Selected a panel to take part in scoring, research, discussion, and rescoring. (participate)	I allowed anyone to participate in all stages and let people leave and rejoin.	The saiga community is smaller than the wildlife trade community and I had already experienced engagement challenges in the COLLECT stage. It would not have been feasible to maintain a consistent group throughout the process.
Scoring Rounds 1 & 2	Single 0-1000 composite score (0=low novelty, low plausibility, low potential future impact)	I had three separate scores	Kemp et al. (2020) state that “disaggregation in voting was likely to impose a greater burden on participants while providing little additional benefit”. However, I wanted to be able to report individual score breakdowns for each issue as a workshop discussion point and also to help inform recommended action points for the issue.
Scoring Rounds 1 & 2	Had a yes/no ‘have you heard of this issue before?’ question for each issue to calculate a ‘familiarity %’ as an additional measure of novelty.	I did not include this question.	I knew my cohort would be smaller than Esmail et al.’s, so I thought it better to ask participants how well-known the issues were to relevant stakeholders (via the novelty criterion), rather than whether they themselves had heard of them, as that would not be very representative.
Research phase	Cynics model (randomly assigned 4-5 issues to each assessor for them to research and had them discuss their findings in an online forum).	I was the cynic for all issues.	My supervisor advised that I do this to reduce the burden on participants and to provide a chance for me to learn more about the saiga context. It also ensured that all issues were investigated with equal rigour.
Thematic analysis	Quantitative topic modelling analysis (Latent Dirichlet Allocation)	I used an inductive qualitative thematic analysis.	I wanted to identify drivers, not count how often topics appeared. Also, participants often referred to the same driver but in a different way so I analysed the data manually to ensure this nuance was not lost.

Final shortlist	20 issues on the final shortlist	Six issues on the final shortlist	Esmail et al. started with a much larger number of issues (226) as they had 139 participants. I chose six rather than a round number due to a natural break in the rankings, as Brown et al. (2016) did in their horizon scan.
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Appendix C: Initial idea-gathering questionnaire (COLLECT)

- 1) In as much detail as you like, describe an issue that could affect saigas - positively or negatively - within the next 10 years. Explain what it is, why it matters, and include any examples that help to explain it.

- 2) I think this issue is most likely to be _____
 - A threat
 - An opportunity
 - Both / Uncertain

- 3) **WILD CARD:** Imagine it is the year 2035 - what has had a major impact on saigas that was not on most people's radar in 2025?

Appendix D: Scoring Scales Used in SR1 and SR2

Likelihood of emergence (how likely is it that this issue will occur in the next 10 years?)

Don't Know / Prefer Not to Score

1 = extremely unlikely to occur

2

3

4

5 = extremely likely to occur

Novelty (how well known is this issue among relevant stakeholders today?)

Don't Know / Prefer Not to Score

1 = very well known

2

3

4

5 = very poorly known / off the radar

Potential impact (if this issue were to occur, how large would its impact on saiga populations be, and would that impact be positive or negative?)

Don't Know / Prefer Not to Score

-5 = massive negative impact on saigas

-4

-3

-2

-1

0 = no significant impact on saigas

1

2

3

4

5 = massive positive impact on saigas

Appendix E: Participant background questions

1) Full Name: _____

2) How familiar are you with the saiga antelope or saiga conservation?

1 = no knowledge

2 = limited knowledge

3 = moderate knowledge

4 = good knowledge

5 = expert knowledge

3) Which of the following best describes your background or area of work?

- Academic or researcher
- Conservation practitioner (e.g. NGO, fieldwork, or management)
- Policy, government, or intergovernmental organisation
- Other (please specify)

4) What is your area of expertise?

- Wildlife trade
- Wildlife management within range states
- Wildlife consumption and use
- Other (please specify)

5) Do you currently work on, or have you previously worked on, saiga antelope?

- Yes
- No

6) Which information sources do you rely on **most** when engaging with wildlife-related issues?

(select all that apply)

- Academic literature
- Policy or technical reports
- Field observations / monitoring data
- Practitioner / expert networks
- Media or public reporting
- Other (please specify)

7) Which saiga population(s) or range state(s) do you have direct experience with? (select all that apply)

- Betpak-Dala (Kazakhstan)
- Ustyurt (Kazakhstan / Uzbekistan)
- Ural (Kazakhstan / Russia)
- Northwest Pre-Caspian (Russia)
- Mongolia
- Saiga-related work not tied to a specific population (please specify)
- Other (please specify)

Appendix F: Z-score bands and perceived impact direction metric

Z-score bands used:

Extremely low: $z \leq -2$

Low: $-2 < z \leq -1$

Low-medium: $-1 < z \leq -0.5$

Neutral: $-0.5 < z \leq 0.5$

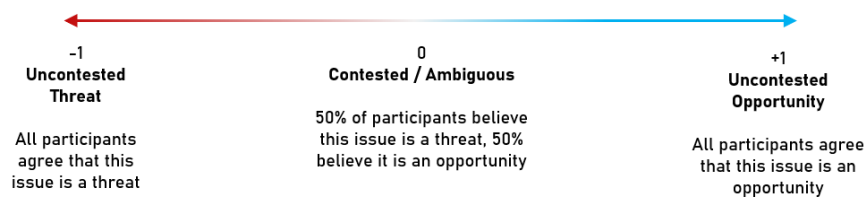
High-medium: $0.5 < z \leq 1$

High: $1 < z \leq 2$

Extremely high: $z > 2$

Perceived impact direction:

$$\text{Perceived Impact Direction} = \frac{(\# \text{ of positive impact scores}) - (\# \text{ of negative impact scores})}{\text{total \# of impact scores}}$$

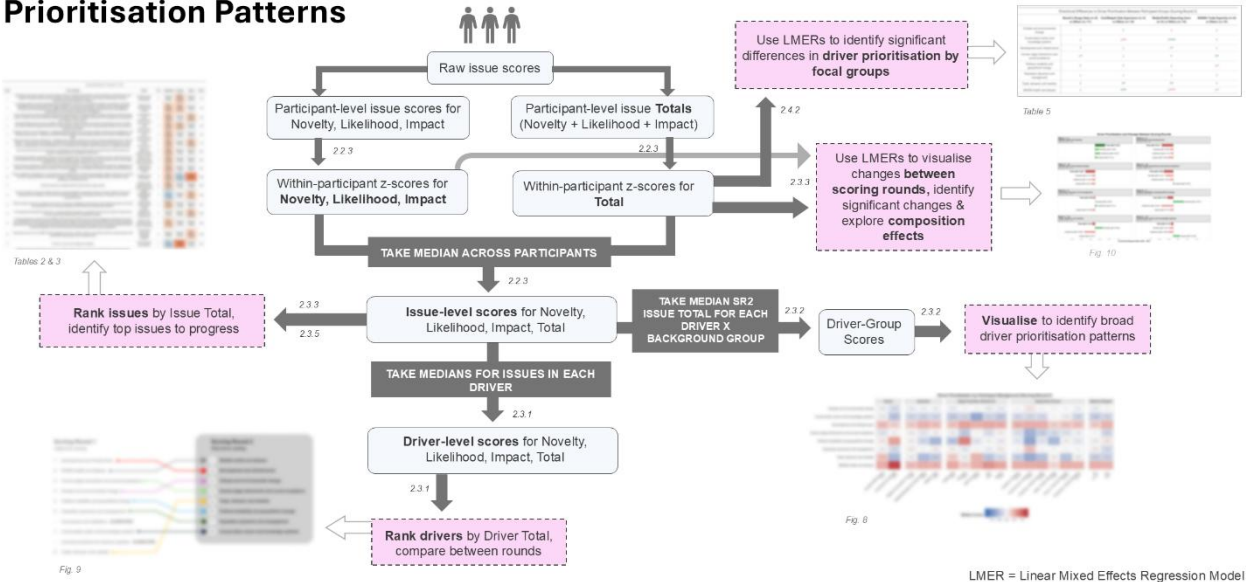


Appendix G: List of workshop prompt questions

- Do I agree that this issue has a low/average/high likelihood of occurring in the next 10 years? If not, why?
- Do I agree that this issue has low/average/high novelty (low level of awareness among relevant stakeholders currently)? If not, why?
- Do I agree that if this issue were to occur, it would have a low/average/high magnitude of impact on saigas? If not, why?
- Do I agree that this issue is a threat/opportunity? If not, why?
- Do I disagree with any of the information relating to this issue in the research document?
- Are there any important points relating to this issue that I believe others should be aware of when thinking about/scoring this issue, and are not mentioned in the research document?

Appendix H: Analytical Pipeline Overview

Summary: Analytical Pipeline for Issue Ranking and Modelling Prioritisation Patterns



Appendix I: All Scoring Round 1 Issues

Scoring Round 1 Issues								
Rank	Issue wording	Driver	T/O	Likelihood	Novelty	Impact	Total	
1	Cumulative stress from resource scarcity, climatic extremes, habitat fragmentation, human disturbance, infrastructure, and regional instability weakens immune function, reduces reproductive success, and increases vulnerability to disease, undermining overall population resilience.	Wildlife health and disease	-T	Neutral (0.05)	High-medium (0.95)	Neutral (0.23)	1.54	
2	Increasing aridity and poorly anticipated climate-adaptation responses (e.g. expanded irrigation, groundwater extraction, intensified livestock production) shift saiga distributions and movement pathways, increasing contact with people and infrastructure and elevating human-wildlife conflict, while limited understanding of these pressures and insufficient monitoring constrain effective anticipation and mitigation.	Climate and environmental change	T	High-medium (0.60)	High-medium (0.73)	Neutral (0.10)	1.45	
3	Linear infrastructure and hard borders isolate saiga subpopulations and reduce genetic exchange, limiting movement during extreme weather events and weakening adaptive capacity to climatic variability, with long-term consequences for population size, resilience, and recovery.*	Development and infrastructure	T	High-medium (0.88)	Neutral (-0.39)	High-medium (0.78)	1.42	
4	Expanded traffic networks increase wildlife-vehicle collisions, hinder effective enforcement, and improve access to remote areas which facilitates targeted poaching and enables greater livestock movement risking pathogen spillover into previously isolated saiga habitats.	Development and infrastructure	-T	High-medium (0.57)	High-medium (0.73)	Neutral (-0.02)	1.35	
5	Changes in land use and management - including agricultural expansion, extractive activities, infrastructure development, and altered grazing pressure - degrade and fragment steppe habitats, reducing habitat quality and the extent of suitable saiga range.	Development and infrastructure	-T	High-medium (0.82)	Neutral (-0.07)	Neutral (0.26)	1.35	
6	Rapid expansion of linear infrastructure - including roads, railways, mining access routes, fencing, agricultural lands, and hard borders - creates physical and functional barriers that fragment habitat and restrict saiga access to key forage areas, water sources, calving grounds, and recolonisation areas, increasing human-wildlife conflict and exposure to targeted poaching.*	Development and infrastructure	T	High-medium (0.68)	Neutral (0.10)	High-medium (0.96)	1.15	
7	Scarce food and water forces saigas closer to settlements and shared water points, increasing contact with livestock and people, creating pathways for pathogen transmission.†	Land-use practices and resource systems	-T	High-medium (0.70)	Neutral (0.14)	Neutral (0.47)	0.97	
8	Growing saiga numbers, agricultural impacts, mass die-offs that leave communities to manage carcasses, and the absence of local benefits shift perceptions of saigas from valued wildlife to pests, reducing tolerance for coexistence with a large, highly mobile herbivore and weakening public support for conservation.	Human-saiga interactions and social acceptance	-T	High-medium (0.70)	Neutral (-0.34)	Neutral (0.42)	0.92	
9	Climate change contributes to slow yet irreversible ecosystem changes - including shifting natural boundaries, degradation of permafrost, shrinkage of peatlands, wetlands, and natural springs - which degrade and fragment habitat, undermining saiga survival.	Climate and environmental change	-T	High-medium (0.57)	Neutral (-0.02)	Neutral (0.47)	0.91	
10	Disease outbreaks, including new or previously absent pathogens such as PPR and pasteurellosis, trigger rapid, large-scale mass die-offs in saiga populations, particularly in large or naïve herds and where limited wildlife disease surveillance means outbreaks are detected too late.	Wildlife health and disease	-T	High-medium (0.53)	Low-medium (-0.55)	High (1.11)	0.86	
11	Practical measures are implemented to reduce human-saiga conflict.	Human-saiga interactions and social acceptance	O	High-medium (0.56)	Neutral (-0.26)	Neutral (-0.08)	0.70	
12	Economic collapse and armed conflict undermine regulated wildlife management, disrupt or destroy habitat, and increase poaching and mass killing, as enforcement weakens and saigas are increasingly perceived as "fair game" due to their commercial value.	Political instability and geopolitical change	-T	Low-medium (-0.85)	Neutral (0.50)	High-medium (0.67)	0.65	
13	Climate change and land-use change reduce water and pasture availability, forcing saigas to alter migration patterns and move into agricultural areas, increasing competition with livestock and conflict with farmers.†	Climate and environmental change	-T	High-medium (0.57)	Neutral (-0.44)	Neutral (0.07)	0.61	
14	An unexpected catastrophic die off occurs, as people made the dangerous assumption that the sheer number of saiga meant die offs would have limited impacts on population numbers.	Population dynamics and management	-T	Neutral (0.49)	Neutral (0.35)	High-medium (0.67)	0.60	
15	As saiga populations expand, human-wildlife conflict generates political pressure where management prioritises horn value over coexistence and lacks compensation, dialogue, local incentives, and transparent benefit-sharing. Pressure from influential agricultural producers and legal trade without community-sensitive frameworks increases the risk of poorly justified decisions, weakened regulation, and renewed poaching, undermining sustainable saiga management.	Human-saiga interactions and social acceptance	T	High-medium (0.59)	Neutral (-0.05)	Neutral (0.20)	0.59	
16	Integrating research across wildlife health, pathogens, parasites, nutrition, climate, and weather improves understanding of the mechanisms driving saiga mass mortality events.	Conservation action and knowledge systems	O	Neutral (0.09)	Neutral (0.25)	High-medium (0.57)	0.49	
17	A craze or a new use for saiga horn emerges.	Trade, demand, and markets	-T	Low-medium (-0.59)	High (1.59)	Neutral (-0.02)	0.47	
18	Increasing frequency and intensity of dzuds due to climate change leads to reduced access to winter forage, starvation, reduced reproduction, increased vulnerability to disease and predation, and episodic mass mortality in saiga populations (the scale of which may be currently under-assessed), particularly where movement is restricted. These events also cause widespread livestock losses and broader wildlife declines.	Climate and environmental change	T	Neutral (0.22)	Neutral (0.14)	Neutral (0.10)	0.47	
19	Policy and management systems designed for scarcity are not prepared for the shift from emergency protection to routine abundance management, as large herds increasingly interact with agriculture, infrastructure, and grazing systems and require active, day-to-day land-use coordination.	Population dynamics and management	-T	High-medium (0.70)	Neutral (0.05)	Neutral (-0.02)	0.44	
20	Following the resumption of legal trade, demand and prices for saiga horn fluctuate unpredictably, triggering increased poaching and illegal trade.	Trade, demand, and markets	-T	Neutral (-0.24)	Neutral (0.05)	Neutral (0.38)	0.44	
21 (saved)	Earlier and more variable spring green-up disrupts the timing of calving leading to reduced calf survival which increases vulnerability to population crashes and extinction.	Climate and environmental change	-T	Neutral (-0.30)	High (1.15)	Neutral (-0.19)	0.39	
22	Improper implementation of sustainable use, including excessive harvesting or skewed sex and age structure in offtake, leads to major saiga population declines.	Population dynamics and management	-T	Neutral (0.31)	Low-medium (-0.92)	High-medium (0.58)	0.35	
23	Abundance management decisions, such as zoning, population control, and controlled use, prove socially and politically sensitive, while the institutional arrangements needed to support them - including trust, transparency, benefit-sharing, legal frameworks, coordination, and compensation - lag behind biological recovery.	Population dynamics and management	-T	Neutral (0.27)	Neutral (0.36)	Neutral (-0.24)	0.35	
24 (saved)	Large saiga populations begin to regulate themselves from mass die-offs, other disease, or resource depletion, leading to benefits for vegetation.	Population dynamics and management	-O	Neutral (-0.08)	High-medium (0.83)	Low-medium (-0.93)	0.28	
25	Weak traceability systems, limited transparency around stockpiles, governance gaps, and uneven international cooperation undermine the effectiveness of trade controls and allow illegal horn to enter legal supply chains.	Governance and institutions	-T	High-medium (0.53)	Low-medium (-0.89)	Neutral (0.39)	0.28	
26	Unsustainable use, where regulation, monitoring, and enforcement are inadequate, leads to increased illegal hunting, overuse of saiga populations, and threatens long-term population viability.	Governance and institutions	-T	Neutral (-0.25)	Low (-1.03)	High (1.02)	0.27	
27	Well-designed, regulated, and monitored sustainable use generates local business opportunities, income, and employment, creating strong incentives for coexistence, increasing tolerance for saigas, reducing conflict and poaching, and supporting long-term conservation in partnership with local communities.	Trade, demand, and markets	-O	Neutral (-0.48)	Low-medium (-0.51)	Neutral (0.47)	0.23	
28	International support, cooperation programmes, and collaboration with local, regional, and community-based conservancies strengthen coordinated efforts to restore and conserve saiga populations.	Governance and institutions	O	Neutral (0.37)	Low-medium (-0.54)	High-medium (0.56)	0.18	
29	Cross-sector and transboundary coordination across agriculture, veterinary services, wildlife conservation, land-use planning, and national borders - supported by harmonised monitoring, shared data platforms, and One Health surveillance - shifts saiga management toward preventative action, reduces tensions, and strengthens long-term population resilience.	Governance and institutions	-O	Neutral (-0.30)	Neutral (-0.46)	High-medium (0.66)	0.12	
30	Trade in live saigas exacerbates disease risks.	Trade, demand, and markets	-T	Low-medium (-0.91)	High (1.15)	Neutral (-0.25)	0.10	

* Issues rank 3 and 6 were merged following SR1. † Issues rank 7 and 13 were merged following SR1.

Scoring Round 1 Issues								
Rank	Issue wording	Driver	T/O	Likelihood	Novelty	Impact	Total	
31	Corruption, weak transparency, and state capture divert revenues from sustainable use, allowing benefits to be diverted away from local communities, fuelling dissatisfaction.	Governance and institutions	~T	High-medium (0.54)	Neutral (-0.42)	Neutral (0.14)	0.07	
32	Reintroduction efforts restore saiga populations to parts of their historic range where the species has been extirpated (e.g. China, Ukraine).	Conservation action and knowledge systems	~O	Neutral (0.21)	Neutral (0.18)	Neutral (-0.24)	0.04	
33	Increasing availability of spatial data and advances in Earth observation improve our capacity to monitor saiga at ecologically relevant scales, quantify how their movements and grazing influence ecosystem structure and function, and clarify their contributions to people through ecosystem services, informing management decisions.	Conservation action and knowledge systems	O	High-medium (0.60)	Neutral (0.31)	Neutral (-0.22)	0.03	
34	Climate-driven displacement of herder communities into key wildlife habitats increases competition for pasture and water, intensifies human-saiga conflict, and raises the risk of disease transmission from livestock.	Climate and environmental change	~T	Neutral (0.27)	Neutral (0.44)	Neutral (-0.26)	-0.07	
35	Large-scale and transboundary protected areas, restoration of historic migration corridors, and wildlife-friendly infrastructure enable long-distance movements and population recovery.	Conservation action and knowledge systems	~O	Neutral (-0.46)	Low-medium (-0.53)	High-medium (0.99)	-0.07	
36	Adaptive land-use planning, water management, and cross-sectoral collaboration, together with a shift toward more sustainable land-use practices, help mitigate food and water scarcity and improve habitat quality.	Land-use practices and resource systems	O	Neutral (-0.34)	Neutral (0.19)	Neutral (0.31)	-0.10	
37	Culls and population control measures do not adequately account for large saiga populations beginning to regulate themselves through mass die-offs, disease, or resource depletion, leading to overuse.	Population dynamics and management	~T	Neutral (-0.24)	Neutral (0.18)	Neutral (-0.18)	-0.11	
38	Reduced international and national funding - driven by increased defence spending and low conservation commitment - limits investment in law enforcement, protected area management, and monitoring	Governance and institutions	~T	High-medium (0.56)	Neutral (-0.16)	Neutral (-0.04)	-0.12	
39	Reopening legal saiga horn trade elsewhere in the species' range, together with new markets and increased demand in consumer countries, leads to increased poaching to meet demand and generate revenue, as well as greater cross-border trafficking, laundering, and enforcement challenges, with even low levels of illegal offtake having disproportionate impacts on small, highly localised, or recovering populations.	Trade, demand, and markets	~T	Neutral (0.12)	Low-medium (-0.55)	Neutral (0.50)	-0.17	
40	Effective law enforcement leads to recovery of currently small populations.	Governance and institutions	O	Neutral (0.05)	Low (-1.12)	Neutral (0.44)	-0.23	
41	With a well-organised system and a scientifically sound approach, sustainable use maintains high saiga population numbers while allowing harvesting.	Population dynamics and management	~O	Neutral (-0.23)	Neutral (-0.50)	Neutral (-0.18)	-0.27	
42	Unforeseen geopolitical changes, including shifts in national borders, disrupt cross-border governance, leading to fencing and policy changes along migration routes, and impeding saiga mass movements across their range.	Political instability and geopolitical change	~T	Neutral (-0.48)	Neutral (0.36)	Neutral (-0.08)	-0.37	
43	Integrated One Health approaches - combining field investigations (e.g. necropsies), movement tracking, Earth observation, climate and weather indicators, outbreak investigation protocols, veterinary and wildlife health monitoring (particularly in high-density populations), and targeted livestock vaccination - enable anticipation of high-risk conditions and preventative management that prevents disease outbreaks before they escalate.	Wildlife health and disease	O	Neutral (-0.28)	Neutral (-0.46)	High-medium (0.78)	-0.39	
44	Current large population sizes lead to over-investment in sustainable use and elevated community expectations immediately before a population crash.	Population dynamics and management	~T	Neutral (-0.33)	Neutral (0.49)	Low-medium (-0.56)	-0.47	
45	Raising the national and international profile of the saiga, alongside education and attitude-change initiatives (particularly for young people), increases public awareness, supports fundraising for conservation activities, and builds long-term support for saiga conservation.	Conservation action and knowledge systems	O	Neutral (-0.14)	Low-medium (-0.72)	Neutral (0.10)	-0.50	
46	Rural outmigration (the long-term movement of people away from rural areas) and the collapse of traditional grazing systems lead to undergrazed steppe, altered vegetation structure, reduced plant diversity, and changes in forage quality.	Land-use practices and resource systems	C	Neutral (-0.50)	Neutral (-0.15)	Low-medium (-0.82)	-0.58	
47	Well-regulated legal trade, with safeguards to ensure sustainable offtake and prevent illegal trade, provides stable funding for conservation systems including protection, monitoring, habitat management, and enforcement.	Trade, demand, and markets	~O	Low-medium (-0.53)	Neutral (-0.42)	Neutral (0.04)	-0.73	
48	New ecotourism initiatives are established.	Trade, demand, and markets	~O	Neutral (0.07)	Neutral (0.40)	Low-medium (-0.63)	-0.82	
49	International anti-sustainable-use NGOs lobby against regulated saiga trade, contributing to the reversal of CITES decisions (e.g. CoP20), restricting range states' ability to manage recovering populations, undermining emerging and legitimate saiga conservation models in range countries, and polarising key stakeholders and decision-makers, making policy spaces challenging to navigate.	Governance and institutions	~T	Low (-1.10)	Neutral (0.30)	Neutral (-0.31)	-0.92	
50	Well-regulated and transparent legal trade, supported by strong enforcement, traceability, precautionary quotas, and international cooperation, provide a controlled mechanism to reduce black-market activity.	Trade, demand, and markets	O	Neutral (-0.49)	Low-medium (-0.55)	Neutral (0.23)	-0.94	
51	Drier, milder winters linked to climate change increase saiga survival by reducing heavy snow and dzuds, improving access to forage and facilitating escape from predators.	Climate and environmental change	C	Neutral (-0.26)	Neutral (0.18)	Low (-1.05)	-1.06	
52	Poaching persists in all populations, with negative effects on population size and structure, behavioural changes, health, and more.	Governance and institutions	~T	Neutral (-0.07)	Low (-1.14)	Neutral (-0.18)	-1.07	
53	Resident and nonresident hunting interest is renewed, leading to increased harvest.	Trade, demand, and markets	~T	Neutral (0.45)	Neutral (-0.25)	Low (-1.05)	-1.07	
54	Failure of rapidly growing populations to respond to control measures leads to numbers exceeding ecological and land-use capacity, increasing pressure on landscapes and human systems.	Population dynamics and management	~T	Neutral (-0.23)	Neutral (-0.21)	Low-medium (-0.94)	-1.33	
55	Large predators are restored across the Eurasian steppes, helping regulate saiga populations and maintain natural herd movement.	Conservation action and knowledge systems	~O	Low (-1.11)	Neutral (0.23)	Low-medium (-0.53)	-1.59	
56	Captive breeding programs establish ex situ assurance populations that reduce extinction risk.	Population dynamics and management	C	Low-medium (-0.83)	Neutral (-0.34)	Low (-1.49)	-1.98	
57	The Mongolian saiga is formally recognised as a distinct species.	Conservation action and knowledge systems	C	Low (-1.14)	Neutral (-0.50)	Low (-1.78)	-2.89	

* Issues rank 3 and 6 were merged following SR1. † Issues rank 7 and 13 were merged following SR1.

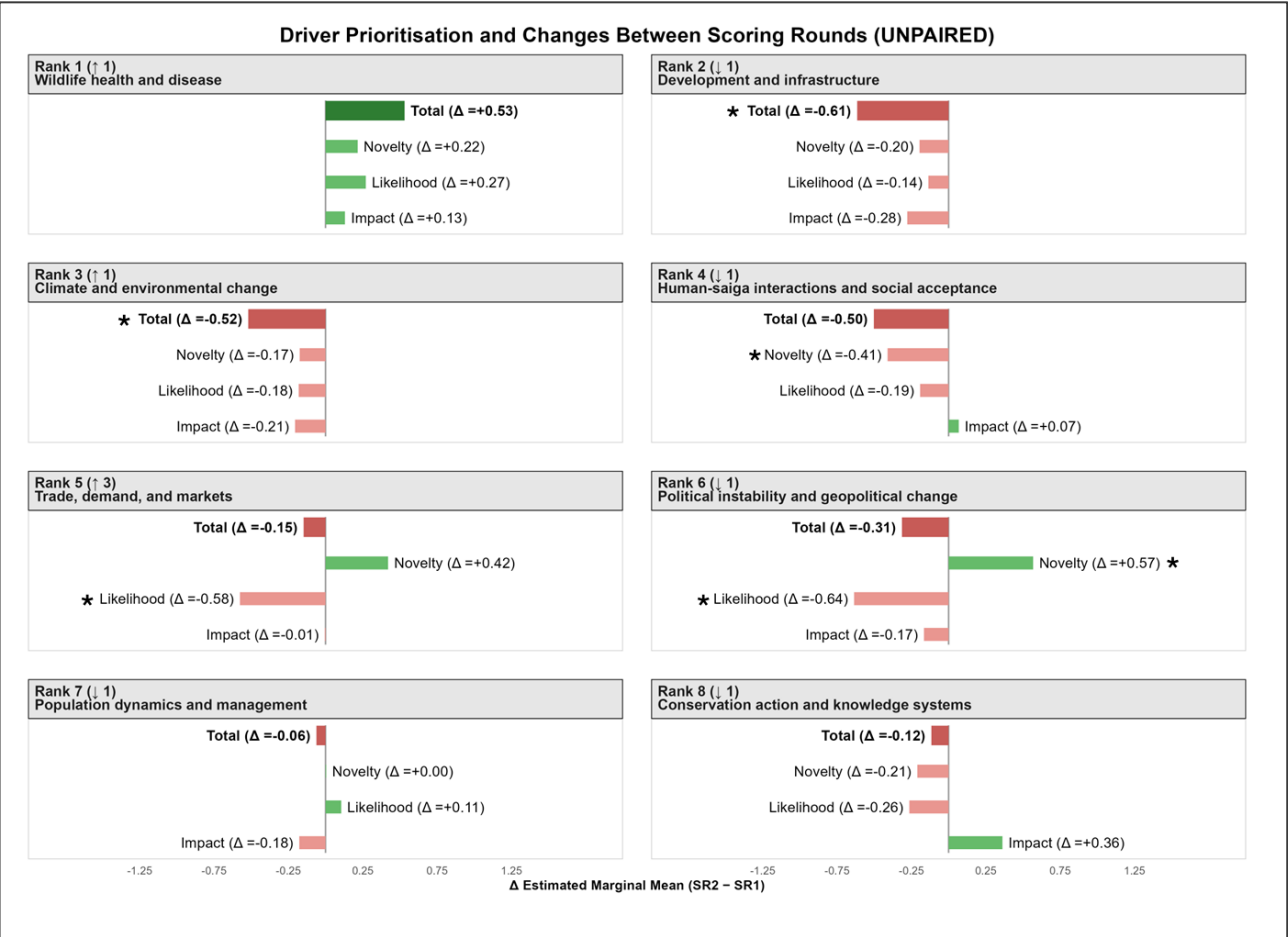
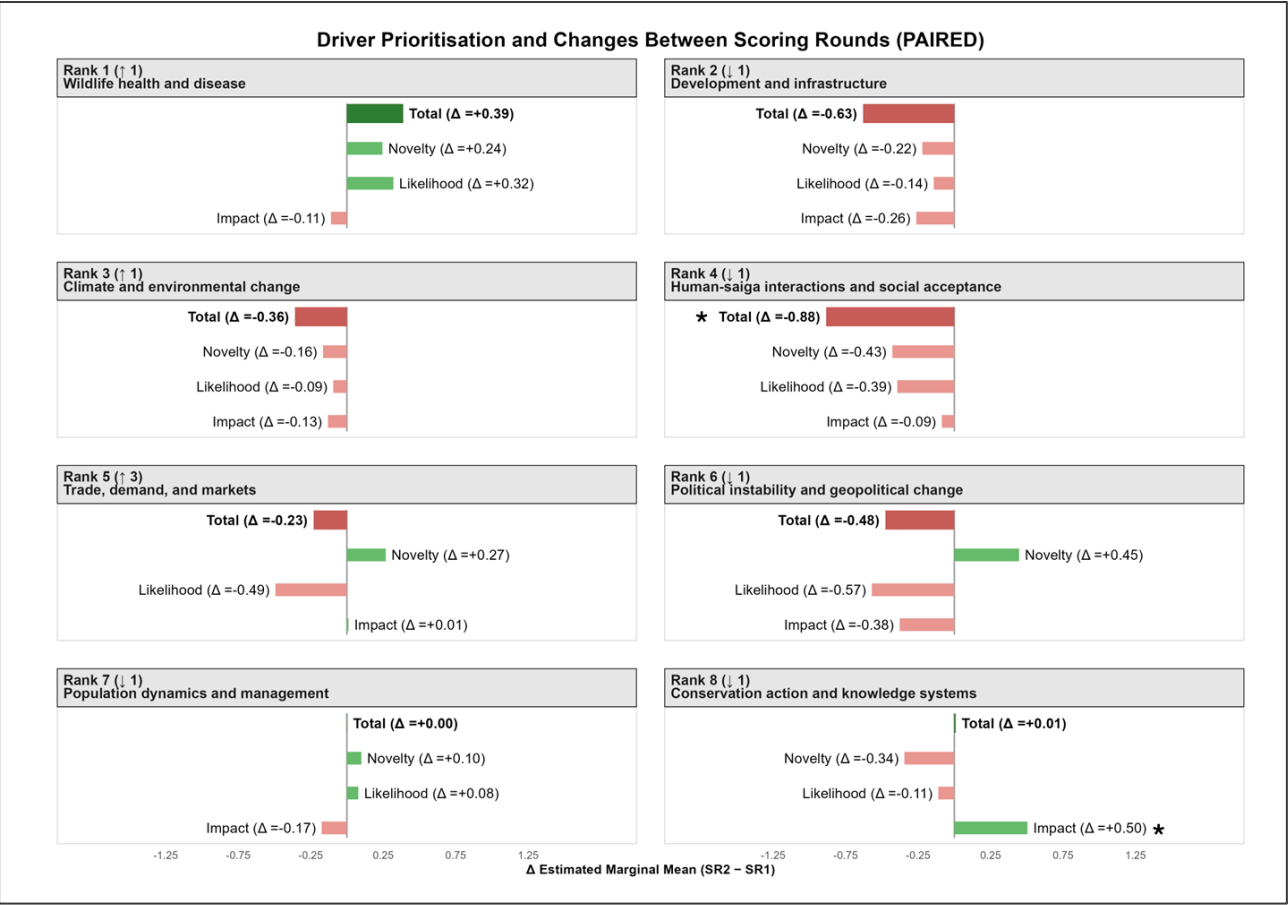
Bold = issues progressing from SR1; ranks based on Total. T/O = Threat/Opportunity where T = Threat, ~T = Leaning Threat, C = Contested, ~O = Leaning Opportunity, O = Opportunity. Novelty, Likelihood, and Impact are median z-scores.

Appendix J: Hypothesis testing full table

Estimated marginal mean differences (Δ EMM) and adjusted p-values				
	Based in Range State (n=8) vs Others (n=11)	Ural/Betpak-Dala Experience (n=5) vs Others (n=14)	Media/Public Reporting Users (n=5) vs Others (n=14)	Wildlife Trade Expertise (n=6) vs Others (n=13)
Climate and environmental change	0.01 (p=0.868)	0.03 (p=0.672)	-0.12 (p=0.075)	-0.01 (p=0.889)
Conservation action and knowledge systems	-0.02 (p=0.802)	-0.20 (p=0.010)**	0.47 (p<0.001)***	0.09 (p=0.210)
Development and infrastructure	0.10 (p=0.098)	-0.04 (p=0.559)	-0.16 (p=0.011)*	-0.04 (p=0.524)
Human-saiga interactions and social acceptance	-0.15 (p=0.045)*	-0.08 (p=0.274)	0.06 (p=0.444)	0.18 (p=0.015)*
Political instability and geopolitical change	0.06 (p=0.593)	0.06 (p=0.594)	-0.18 (p=0.095)	-0.22 (p=0.029)*
Population dynamics and management	-0.01 (p=0.924)	-0.01 (p=0.866)	0.11 (p=0.078)	0.02 (p=0.726)
Trade, demand, and markets	0.01 (p=0.948)	0.21 (p=0.046)*	0.27 (p=0.014)*	0.08 (p=0.462)
Wildlife health and disease	-0.04 (p=0.648)	0.23 (p=0.003)**	-0.33 (p<0.001)***	-0.16 (p=0.040)*

Estimated Marginal Mean differences with Benjamini-Hochberg adjusted p-values. Asterisks denote statistical significance (* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$).

Appendix K: Between-round changes paired vs unpaired figure



Changes in driver scores between scoring rounds. Green bars to the right of the midline ($\Delta\text{EMM} = 0$) indicate higher scores in SR2, while red bars to the left indicate higher scores in SR1. Rank numbers indicate the SR2 ranking for each driver, and arrows show the direction and magnitude of rank change between scoring rounds. Asterisks denote statistical significance in the paired model after Benjamini-Hochberg correction (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Values are estimated marginal mean differences from the paired model.

Appendix L: Between-round changes full tables

1. Paired (participants who scored in SR1 and SR2)

Round Differences in Driver Prioritisation - Paired				
	Novelty	Likelihood	Impact	Total
Climate and environmental change	-0.16 (p=0.387)	-0.09 (p=0.626)	-0.13 (p=0.491)	-0.36 (p=0.251)
Conservation action and knowledge systems	-0.34 (p=0.115)	-0.11 (p=0.612)	0.50 (p=0.024)*	0.01 (p=0.979)
Development and infrastructure	-0.22 (p=0.276)	-0.14 (p=0.483)	-0.26 (p=0.199)	-0.63 (p=0.068)
Human-saiga interactions and social acceptance	-0.43 (p=0.084)	-0.39 (p=0.110)	-0.09 (p=0.723)	-0.88 (p=0.032)*
Political instability and geopolitical change	0.45 (p=0.171)	-0.57 (p=0.079)	-0.38 (p=0.248)	-0.48 (p=0.390)
Population dynamics and management	0.10 (p=0.579)	0.08 (p=0.662)	-0.17 (p=0.333)	0.00 (p=0.994)
Trade, demand, and markets	0.27 (p=0.338)	-0.49 (p=0.078)	0.01 (p=0.969)	-0.23 (p=0.629)
Wildlife health and disease	0.24 (p=0.328)	0.32 (p=0.209)	-0.11 (p=0.666)	0.39 (p=0.346)

2. Unpaired (participants who scored in either or both of SR1 and SR2)

Round Differences in Driver Prioritisation - Unpaired				
	Novelty	Likelihood	Impact	Total
Climate and environmental change	-0.17 (p=0.270)	-0.18 (p=0.256)	-0.21 (p=0.192)	-0.52 (p=0.045)*
Conservation action and knowledge systems	-0.21 (p=0.248)	-0.26 (p=0.146)	0.36 (p=0.050)	-0.12 (p=0.700)
Development and infrastructure	-0.20 (p=0.253)	-0.14 (p=0.423)	-0.28 (p=0.105)	-0.61 (p=0.033)*
Human-saiga interactions and social acceptance	-0.41 (p=0.049)*	-0.19 (p=0.358)	0.07 (p=0.739)	-0.50 (p=0.144)
Political instability and geopolitical change	0.57 (p=0.045)*	-0.64 (p=0.019)*	-0.17 (p=0.542)	-0.31 (p=0.495)
Population dynamics and management	0.00 (p=0.977)	0.11 (p=0.476)	-0.18 (p=0.235)	-0.06 (p=0.804)
Trade, demand, and markets	0.42 (p=0.076)	-0.58 (p=0.015)*	-0.01 (p=0.982)	-0.15 (p=0.708)
Wildlife health and disease	0.22 (p=0.300)	0.27 (p=0.201)	0.13 (p=0.536)	0.53 (p=0.122)

Tables show estimated mean z-score SR2 - SR1 differences with Benjamini-Hochberg adjusted p-values. Asterisks denote statistical significance (* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$).

Appendix M: Repository of participant-facing materials

All participant-facing materials can be found in the following (fully anonymised) Dropbox:

<https://www.dropbox.com/sc/fo/je6mpf7swwgike1ftd801/AKvpLoL4rndwUAGIHxaEvGw?rlkey=b1za36tplvvis4a7ben16u4qe&st=kxm1a22p&dl=0>