Stakeholders from diverse backgrounds make similar judgments about ecological condition and collapse in Mongolian rangelands

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Abstract
Complex socio-ecological problems typically involve a variety of stakeholders, with viewpoints that may range between consensus and deep disagreement over values and judgments. Understanding this distribution of opinion is key to finding conservation solutions. We examine how stakeholders with widely different backgrounds vary in their judgments of rangeland degradation in Mongolia’s Gobi Desert, where grazing intensity is a contested issue. We gathered the judgments of 92 stakeholders from a highly diverse group including: (i) nomadic pastoralists (herders), (ii) experts in botany, (iii) experts in wildlife ecology, and (iv) conservation policy practitioners. These stakeholders considered degradation in five ecosystems including Desert shrublands, Steppe, and Siberian Elm riparian woodlands, using written site descriptions in a workshop context. Each stakeholder considered degradation using two conceptual frameworks: the notion of “ecosystem collapse” described by the IUCN Red List of Ecosystems and the concept of ecological condition. We used generalized additive models (GAMs) to examine the relationship between vegetation attributes and stakeholder judgments of condition. Although individual stakeholder varied in their judgments, we found only relatively small systematic variations between different types of stakeholders. Similarly, we found the degree of specialization of experts had little effect on the condition score. We also used GAMs to examine the relationship between vegetation attributes and stakeholder judgments of collapse, finding little variation between groups. We also explored the threshold of overall vegetation cover where stakeholders are likely to shift their judgment from collapsed to not collapsed, and while differences between ecosystems were observed, we found consensus between the different stakeholder groups within each ecosystem. Our results suggest that, at least in the context of the Southern Mongolia, diverse stakeholder groups have convergent views in respect to ecological degradation.
1 | INTRODUCTION

As anthropogenic impacts on natural systems intensify, there is a growing need for tools that characterize ecological change so that degradation can be recognized, actions can be prioritized, and management can be guided and assessed (Kukkala & Moilanen, 2013; Thomson et al., 2020). Such tools may take many forms, including condition metrics (Booth & Tueller, 2003; Davies et al., 2010; Sinclair et al., 2015; Smith et al., 2011) and ecological risk assessments (Allesina & Bondavalli, 2004; Murray et al., 2018), but they generally require human judgment in one way or another. For example, judgment may be required in the framing of goals (Campbell, 2001; Dale et al., 2008; Li et al., 2009), the selection of the key indicators of change (Niemeyer & de Groot, 2008; Suter, 2001), the selection of reference states (Bestelmeyer et al., 2009; Hobbs & Norton, 1996), the definition of thresholds used to categorize change (Bland et al., 2017), or in trading off the importance of one ecological value with others (e.g., species or places).

In most of these cases, empirical data cannot eliminate the need for judgments, which are an inherent component of the process of assessing ecological change.

In situations where judgments are required, questions arise about legitimacy: if something is merely an opinion, is it credible? There are many ways to provide reassurance about the credibility of human judgments, including peer review, feedback adjustment processes (e.g., Delphi, Dalkey, 1969), and the combination of many judgments into a group response that seeks to represent a consensus (e.g., Mendoza & Prabhu, 2006; Xu, 2009). While useful, consensus seeking may be problematic in cases where there are very divergent views, and a single consensus will inevitably ignore or disenfranchise those that disagree. This problem is often acute in the places where conservation is most urgent, such as situations where there are diverse stakeholder groups with divergent cultural viewpoints.

In this article, we examine judgments about ecological degradation by a very diverse stakeholder group. We aim to quantify the degree of consensus and divergence among these different groups, to gauge whether consensus-seeking approaches to ecological degradation are likely to lead to consensus solutions that satisfy most stakeholders, or to continued disagreement.

The socio-ecological context we examine is the rangelands of southern Mongolia, where an ancient tradition of nomadic pastoralism, an expanding mining industry, climate change and the habitats of numerous threatened species intersect (Farrington, 2005; Buuveibaatar et al., 2016). Nomadic pastoralism has been the dominant land use in Gobi Desert for millennia and continues despite the upheavals of collectivization under Soviet rule and then privatization of livestock after the Soviet Union collapsed. The recent intensification of livestock grazing has resulted in a decline of palatable species, increase in non-palatable species, and an overall decline in vegetation cover and increasing soil erosion. These changes are routinely perceived as degradation (Fernández-Giménez & Allen-Díaz, 1999; Zhou et al., 2011); however, the details are much debated. In this context, the stakeholders include nomadic pastoralists, government land use agencies, conservation organizations and the mining industry. Recently, there have been concerted efforts to include the voices of pastoralists alongside other stakeholders in ecological assessments and management decisions (Jamsranjav et al., 2019).

We examine stakeholder responses to two different degradation concepts, both with immediate practical applications and with subjective elements that require human judgment. The first is the notion of ecosystem collapse, as recently conceptualized by the IUCN Red List of Ecosystems (Bland et al., 2017). Under this framework, ecosystems may be assessed as collapsed, or at varying degrees of risk of collapse. This approach provides an ecologically informed and consistent logic and framework for making such assessments but requires a substantial degree of subjective judgment in selecting the essential ecosystem components that define collapse, and the tolerable degree of variation they can display until collapse is triggered. We explore how different stakeholders make judgments about collapse thresholds.

The second concept is the notion of ecological condition, which measures gradual ecosystem degradation via a continuous score that represents divergence from a reference state (Gibbons & Freudenberger, 2006). We use the condition metrics already developed for the rangelands of southern Mongolia by Sinclair et al. (2021). Here, the subjective elements are the formation of a reference state against which degradation is measured, and the judgment of how different degrees of change across multiple ecosystem attributes contribute to degradation.

We may expect stakeholders with different cultural backgrounds, values, affiliations, or experiences to make different judgments regarding the level of degradation at...
Further, differences in judgment may lead to disagreement in practical terms, if, for example, different stakeholders disagree about whether the degree of degradation or the risk of collapse is sufficient to warrant land use change. The effects of disagreement have indeed been documented in some cases. For example, Brown and Donovan (2013) describe how divergent views about forest degradation can fuel disagreements over forest management. Where views are divergent, it is important to understand and acknowledge this, and to be explicit about which views, or whose interests, are represented in any resultant judgment or decision. Alternatively, where views are similar among stakeholders, a detailed understanding of this convergence can provide more confidence when asserting the validity of consensus judgments and decisions. Documentation of a firm consensus can also build trust between stakeholders. Either way, a good understanding of the divergence or consensus among stakeholders is valuable.

2 | METHODS

2.1 | Study location and ecosystems

The Gobi Desert in central Asia is a vast arid region that lies in the rain-shadow of the Himalaya, in southern Mongolia and northern China. The ecosystems have been shaped by an extreme continental climate, with summer and winter temperature ranging between ±40°C and protracted periods with low rainfall; annual rainfall is frequently less than 100 mm (Sternberg et al., 2011).

Our study covered five widespread ecosystems of this region: Desert Steppe, Semi desert, True desert, Saxaul shrubland, and Elm forest (Table 1; Jambal and OIson 2016; Radnaakhand, 2016). All five ecosystems are grazed by a range of livestock species (Bedunah & Schmidt, 2004; Khishigbayar et al., 2015) and wild ungulates. Climate change is another major threat to these ecosystems in the Gobi (Vova et al., 2020).

2.2 | Stakeholder workshops

Consultations consisted of four face-to-face workshops: two in Ulaanbaatar (11 and 21 stakeholders, respectively), one in the southern Gobi hub of Khanbogd to accommodate nomadic pastoralists (35 stakeholders), and in an online assessment designed to accommodate international ecological and policy stakeholders (27 stakeholders). The workshops were facilitated in both Mongolian and English and the online assessments in English. No communication was permitted between stakeholders during the exercises, ensuring the independence of each stakeholder’s judgments.

All stakeholders were selected and contacted via the Wildlife Conservation Society Mongolia (WCS) and, based on prior relationships, were judged as having sufficient knowledge of the Gobi ecosystems to enable them to conduct evaluations based on simple vegetation data. All pastoralists involved in our study have a long-standing relationship with the WCS through the organizations South Gobi Cashmere program, which is designed to deliver benefits through improved rangeland management. In recognition of the long distances traveled away from their families and livestock, all pastoralists were “paid” via the provision of first aid supplies. The other stakeholders were not paid. Four of the authors participated as stakeholders.

All participants were informed of the purposes of the research, the nature of the data that would be collected and that it would be analyzed and displayed anonymously. Participation was entirely voluntary, and each participant was told they could contribute partial information if they felt uncomfortable providing certain information. Nine stakeholders declined to provide any personal information and therefore were unable to be used in the analysis.

We asked all participants three sets of questions, as described below: i) information about themselves to allow us to analyze differences among expertise and
background, ii) questions about ecosystem condition, and iii) questions about ecosystem collapse.

### 2.3 Description of expertise groups

Information about stakeholders was collected via a short questionnaire (Appendix S1), covering age, gender, nationality, professional affiliations, and sources of livelihood, followed by 25 topic questions relating to expertise in a range of fields. For each of the topic questions, stakeholders self-rated their level of expertise in that field by providing a score of 0 (no knowledge), 1 (some knowledge), or 2 (an expert in the relevant field). Some stakeholders provided many expertise scores of 2, others none, such that the quantum of expertise varied significantly between individuals. We decided to assume that each stakeholder had an equal total quantum of expertise, so we standardized the self-assessment data before proceeding further.

We classified the 25 topic questions into four categories in those related to (a) pastoralism \( (n = 8) \); (b) plant ecology \( (n = 5) \); (c) wildlife ecology \( (n = 5) \); (d) the general field of conservation biology, policy, and practice \( (n = 7; \) Table 2). The responses to these questions (equally weighted) were used to assign each person a relative degree of expertise in each of the four topic areas (i.e., representing their personal mix of topic knowledge and their degree of specialization in each topic); and from this, we allocated each person to their predominant category of expertise: (a) conservation policy and practice; (b) wildlife ecology; (c) botany; or (d) pastoralism.

No individual was completely specialized; every stakeholder had some expertise in at least three topic areas. Consequently, each of the four topic areas contains a mixture of expertise types, as shown in Figure 1. The pastoralist group was the most “pure” in expertise terms (i.e., many pastoralists are highly specialized in the questions about pastoralism), whereas the group that is predominantly conservation policy and planning consisted of individuals with an admixture of expertise types (Figure 1).

### 2.4 The assessment sites

Stakeholders evaluated a range of sites for each ecosystem, represented by simple descriptions on paper cards. The ecosystems were described using a set of variables specific to each ecosystem, including the cover and richness of various plant species groups (Appendix S2).

Each ecosystem was represented by between 125 and 128 site cards in total. Some cards represented real field sites, where appropriate data were available (only available after dedicated field sampling for True desert, Semi-desert and Desert Steppe, and these sites were not used in the first Ulaanbaatar workshop \( [n = 11] \) which was undertaken prior to the targeted fieldwork), but the majority were fictional sites, carefully created to span a very wide range of possible conditions for each ecosystem; wider than could be easily sampled in the field. Each site card described a single site (30 m × 30 m plot) for a single ecosystem, using variables that described important aspects of each system. All cards were

| Table 2 | The self-assessed topic questions used to characterize stakeholders |
|---------|---------------------------------------------------------------|
| **Category** | **(not apparent to stakeholders)** | **Questions** |
| Pastoralism | Raising sheep | Raising goats |
| | | Raising cattle |
| | | Raising camels |
| | | Hunting wild game |
| | | Horse husbandry |
| | | Animal illness and veterinary care |
| | | Management of vegetation with grazing |
| Specialist—Botany | The ecology or natural history of vascular plants | The ecology or natural history of nonvascular plants |
| | Scientific sampling of vegetation | Invasive / pest plant species |
| | The use of plants for medicine | |
| Specialist—Wildlife | Ecology or natural history of Birds | Ecology or natural history of Mammals |
| | Ecology or natural history of Reptiles & amphibians | Ecology or natural history of Invertebrates |
| | Invasive / pest animal species | |
| Conservation policy and practice | Environmental policy | Long term environmental change (1000s of years) |
| | | Mathematics and statistics |
| | | Management of vegetation with fire |
| | | Geological processes |
| | | Soil processes (including erosion) |
| | | Navigation across the landscape |
available in English and Mongolian. Visual aids (diagrams in Appendix S3) were included on the cards to assist stakeholders to visualize vegetation cover values.

Stakeholders were told that the site measurements represent August in a year of average rainfall. We did not specify the spatial location or context of the sites. We did not specify whether the site measurements were before or after a grazing event.

Each stakeholder received a subset of cards drawn at random from the full set without replacement (\( n = 15 \) in most cases; 17 for True desert, Desert Steppe, and Semi desert in the workshops and online evaluation where field data were available).

### 2.5 Elicitation of ecosystem condition and collapse

We required stakeholders to have a shared concept of condition. Our participants were given the following definition: *Ecological condition measures the retention (or loss) of the ecological attributes that characterize an ecosystem in its desired state.* We did not define the “desired state.” Rather, each stakeholder was asked to imagine their own “desired state.” Stakeholders were instructed on which factors they could consider when assessing condition and which were excluded from consideration. These were identical to the instructions provided by Sinclair et al. (2021) (Appendix S6). Importantly, the stakeholders were instructed not to consider ecosystem services to humans (e.g. personal income that could be derived from the site in livestock or money), and that they should only focus on natural or biodiversity values.

Stakeholders were required to consider the condition of each site in their card set, physically arrange them in order from worst to best, then provide numerical scores representing their condition on an intuitive and personal scale ranging from 0 (no value as an example of the ecosystem) and 100 (an example of a desired state) (sensu Sinclair et al., 2015, 2021). Tied ranks and scores were permitted. If any of the participants felt that their concept of 0 or 100 was not represented in their card, they were allowed to come up with their own set of values for the variables that resembled the upper and lower end of the condition spectrum. No stakeholder chose this option.

Stakeholders used the same ranked card sets to evaluate collapse. They were instructed to assess whether each site had suffered collapse (yes or no), using the collapse definition provided by the IUCN assessment criteria (Bland et al., 2017): *An ecosystem has collapsed when it has lost its defining features and transformed into a different system.*

Under the IUCN guidelines, the defining features may be subjectively selected for each ecosystem assessment. We chose to confine the selection of these features to only include considerations relevant to the information on the cards, but still allow the stakeholders leeway in their assessment of how these features should be defined or thresholded. We stated that the defining features of the five Gobi ecosystems are:

- Perennial grass/sedge cover within an appropriate range for the system,
- Shrub cover within an appropriate range for the system,
- Tree cover within an appropriate range for the system, and/or
- Soil surface appropriate to support the system (quantified by root exposure).

If ANY of these features are NOT present, the ecosystem has collapsed. Stakeholders only assessed whether each site had collapsed or not, they were not asked to assess the risk of future collapse at the site.

Even though the concepts of collapse and condition are both designed for evaluating ecological condition, they have several contrasting characteristics that may
be relevant to how people make judgments about them. Both concepts rely on a set of variables which are selected to capture the characteristics of an ecosystem relevant to degradation. In the case of condition, these variables are set, and stakeholders must make the following judgments:

![Graph showing predicted ecosystem condition score in two example Gobi ecosystems using two types of GAM with flexible non-linear function fit to each group. Blue lines and hue (95% confidence interval) represent a simple GAM with a single global smooth function and random effects of expert IDs, with the same line plotted for each expert group for each ecosystem. Red lines and hue (95% confidence interval) represent prediction of a GAM that allows for different smooth functions between groups. Gray points represent individual condition evaluations that the models used to make predictions. Dashed lines are predictions of condition score using data from only three group's data to predict the response of the remaining fourth expert group.](image)

**Figure 2** Predicted ecosystem condition score in two example Gobi ecosystems using two types of GAM with flexible non-linear function fit to each group. Blue lines and hue (95% confidence interval) represent a simple GAM with a single global smooth function and random effects of expert IDs, with the same line plotted for each expert group for each ecosystem. Red lines and hue (95% confidence interval) represent prediction of a GAM that allows for different smooth functions between groups. Gray points represent individual condition evaluations that the models used to make predictions. Dashed lines are predictions of condition score using data from only three group's data to predict the response of the remaining fourth expert group.
1. What is the desirable state for this ecosystem, and how would this manifest in the variables at hand? (Implicitly elicited)

2. How much does this site fall short of the desirable state? (Explicitly elicited, on a scale from 0 to 100)?

FIGURE 3  Probability of ecosystem collapse in two example Gobi ecosystems using two types of binomial GAMs with flexible non-linear functions fit to each group. Blue lines and hue (95% confidence interval) represent a simple GAM with a global smooth function and a random effect of expert IDs. Red lines and hue (95% confidence interval) represent prediction of a GAM that allows the smooth function to vary between expert groups. Dark gray dots represent data points (individual expert judgments as to whether the exemplar ecosystem was collapsed). Dashed lines are predictions of collapse using data from only three group’s data to predict the response of the remaining fourth expert group.
In the case of collapse, stakeholders must make the following judgments:

1. Which variables represent characteristics of the ecosystem which are essential? (Implicit).
2. What are the tolerance limits for those variables? (Implicit).
3. Does this site have variables that are all within the acceptable range? (Explicitly elicited, collapsed or not).

## 2.6 Modeling methods

### 2.6.1 Ecosystem condition

To test how the relationship between site variables and condition score varies between stakeholder groups and whether there is a common relationship that is held across groups, we fitted two types of Generalized Additive Models (GAMs) to predict ecosystem condition, in each of the five Gobi ecosystems. The rationale behind comparing two types of models was to see if the added stakeholder group-level term in the model helped explain the variation among groups and whether there is much difference between the prediction curves (Figures 2 and 3) for each stakeholder group.

We sought a single axis to express site variation. We performed principal component analysis (PCA) on the site variables and found that the first principal component (explaining 62.31% of variation) is very closely aligned with total vegetation cover (Appendix S4). This accords with the findings of Sinclair et al. (2021), who found that total vegetation cover captured most of the information necessary for the prediction of a condition score ($R^2$ of .73–.87 for different ecosystems). Using total vegetation cover also provides an intuitively sensible and objective reference point that can be accurately measured in the field.

The first type of model (Figures 2 and 3) is a simple GAM with a common global smooth function for all experts and a random effect of expert ID (Pedersen et al., 2019).

$$\log(C) = s(veg) + \zeta_{\text{expert}} + \epsilon$$

where $C$ is the expected value of ecosystem condition, $s$ is a smooth function (thin plate splines) of the covariate total vegetation cover ($veg$), $\zeta_{\text{expert}}$ is the random effect for expert identification, and $\epsilon$ is a Gaussian error term.

The second type of model (Figures 2 and 3) is similar to the first model but allows the shape of the smooth function relating vegetation condition to vegetation cover to differ between stakeholder groups. This allows the model to take account of intergroup variation in responses by allowing each group to have its own functional response, but penalizing functions that are too far from the average across all groups (Pedersen et al., 2019).

$$\log(C) = s(veg,\text{group}) + \zeta_{\text{expert}} + \epsilon$$

where, the added “group” variable describes intergroup variation in responses.

Models were then used to generate a prediction curve for each expertise group predicting the expected ecosystem condition across the range of total vegetation cover values.

We also ran the above two GAMs with added vegetation variables (the second and third PCs—Appendix S4) to investigate if these added co-variates also contribute to explain the variance in score.

### 2.6.2 Ecosystem collapse

To test if there is significant variation among the four expert groups’ judgments of thresholds for ecological collapse, a binary variable “collapse” was regressed against total vegetation cover for all five ecosystems. Again, we compared two types of GAMs to see if the addition of a group-level smoother improved the model performance compared to a base model with a common smooth function for all four expert groups. The model structures are a close analogue to those described above for ecosystem condition. Since ecosystem collapse is a binary outcome, we used a logit link function and Bernoulli error distribution. Rather than using tests of significance of hypothesized effects we used AIC to seek parsimony of prediction.

We explicitly investigated the threshold value of vegetation cover where the maximum value of probability of collapse is halved. We estimated this quantity and associated measures of uncertainty (SE and 95% confidence interval) by using a simulation approach (1000 bootstrap samples). The estimated parameter values for the smoothing spline of the GAM, and the associated variance–covariance matrix derived from the fitted model, were used to generate a large sample of parameter values, which can be assumed to approximate the joint sampling distribution of the model parameters. The resulting distribution of threshold values was assumed to approximate our uncertainty regarding the threshold, conditional on the assumed model structure, summarized by taking a sample mean and 95% confidence interval (Figure 4).

GAMs were fitted to the data using the R package mgcv (Wood, 2017). The estimation of thresholds for ecosystem collapse was carried out using a custom R script, relying on the MASS package in R (Venables & Ripley, 2002) to generate random samples from the multivariate normal parameter estimates.
3 | RESULTS

3.1 | Judgments of site condition

The condition scores provided by individual stakeholders varied substantially for most sites, but this variation was not associated with stakeholder group. This was true for all five ecosystems we investigated. We demonstrate this in three ways. First, when the four groups of stakeholders are compared against the consensus of all groups combined (represented by the condition metric of Sinclair et al., 2021), there is relatively little difference among stakeholder groups across all ecosystems, and the all-group consensus is close to the group mean for all groups.
(Figure 5). Stakeholders categorized as belonging to the conservation policy and practice group tended to make judgments that most closely resemble the consensus. This may reflect that fact that the conservation policy and practice group was the largest group and contained the broadest range of expertise fields (as shown in Figure 1).

Second, when we applied two types of GAMs which modeled the effect of vegetation cover on condition, the more complex model (which allowed for different smooth curves between stakeholder groups) did not substantially account for any additional variation for any ecosystem or any expertise group (Figure 2). Despite the site level variations, in all ecosystems, the 95% confidence intervals for both models overlap. We could also successfully predict the fourth group’s score response by only using data from the other three groups (dashed line Figure 2).

Third, when we investigated if condition assessment varied depending on experts’ breadth or narrowness of expertise (i.e., degree of specialization, not length of experience), we found very little effect (Figure 6). Across all areas of expertise, the regression slopes are generally flat (all $p$-values non-significant), suggesting that there is little effect of the breadth of stakeholders’ expertise on their judgment of ecosystem condition.

When we tested model performance with 10-fold cross validation (RMSE), the complex model had no advantage over the simpler model in terms of the mean RMSE. We also tested whether our assumption that total vegetation cover alone was sufficient to characterize the sites. Models that included additional vegetation variables (PC2 and PC3, Figure S7 from Appendix S4) did not significantly reduce the RMSE. However, additional vegetation variables did increase the variance explained by the model (Figure S8 from Appendix S5).

For all ecosystems but one (True desert), the stakeholders agreed that ecosystem condition increases steadily
with increased total vegetation cover. This accords with most of the literature describing vegetation dynamics in the Gobi Desert, where natural systems are characterized by rich and abundant flora, and degradation is associated with loss of cover and richness (Gao et al., 2015). In True desert however, expert opinion in all four expertise groups suggests that once total vegetation cover exceeds 75%, there are no further gains in condition. This makes intuitive sense in True desert, which is the most sparsely vegetated system, where even the most intact, rich and high-cover sites rarely exceed 75% total cover (evidenced by WCS monitoring data; Zhou et al., 2011). Indeed, cover above 75% may indicate an undesirable ecosystem shift (e.g. invasion of nutrient-loving annuals around wells or camps).

All stakeholder groups agreed on this relationship, providing reassurance that our results contain considered judgments, and are not merely inevitable or automatic responses by non-discriminating people.

### 3.2 Judgment of ecosystem collapse

We found consistent general relationships between vegetation cover and perceptions of ecosystem collapse: our GAMs clearly show that low vegetation cover always indicates increased likelihood that an ecosystem will be judged as collapsed. In all cases, the 95% confidence intervals for the model which treated the stakeholder groups as one overlapped with those from the model...
with an additional term for the stakeholder groups, confirming that there was a consensus among different stakeholder groups. The concordance among expert groups was supported by model comparison using AIC (all values provided in Appendix S5)—in all ecosystems the simpler model with a single global smooth function (blue on Figure 3) was preferred over the complex model with different smooth functions for each stakeholder group (red on Figure 3). Additionally, we could successfully predict the fourth group’s response on collapse by only using data from the other three groups (dashed line Figure 3).

The results (Figure 3) showed clear differences between ecosystems, confirming that similar ecosystem specific judgments are being made by diverse stakeholders across different ecosystems, not just generic or uninformed decisions. For example, all stakeholder groups agree that high cover virtually guarantees a judgment of “not collapsed” in Elm forest, whereas high cover (>75%) actually raises the probability that a site will be judged “collapsed” for True desert (Figure 3). This is consistent with the pattern noted above, where low cover is natural and expected in True desert, and exceptionally high cover may indicate an undesirable ecosystem shift.

When we performed 10-fold cross validation, the mean AUC did not improve with additional vegetation variables or added group-level function, indicating they do not improve model performance.

3.3 | Judgment of collapse threshold

We conducted threshold analyses to determine where on the total vegetation cover spectrum (0–100), the probability of collapse was reduced to 50% of its maximum. Figure 4 shows the results, by ecosystem and expertise group. There was more variation between ecosystems than between stakeholder groups, who again showed consistent judgments for a given ecosystem. In every ecosystem, the mean threshold value for each stakeholder group was within the 95% confidence intervals for all other groups. For most ecosystems, the probability of a “collapsed” judgment is halved when total vegetation cover is around 10%–13%, with the exception of True desert, where this threshold was clearly less than 10% (Figure 4). This is consistent with the results above, reflecting the natural sparseness of this ecosystem.

4 | DISCUSSION

Our results show that people with different cultural backgrounds and livelihoods can put their minds to the same ecological problems (here, evaluation of ecological condition and collapse thresholds) and come up with broadly similar judgments. This is striking given how diverse the stakeholder groups in our study are, and particularly since they may be perceived as having different values and material interests pertaining to the issue of overgrazing; herders make their livelihoods from grazing (Fernández-Giménez et al., 2018), and conservationists often decry the damage done by grazing (Berger et al., 2013). While we might have naively expected opposing viewpoints, we found that all groups had a similar appreciation of ecological condition and collapse. This is, of course, less surprising when we consider that our stakeholders, regardless of their backgrounds or interests, share a deep knowledge of and connection to the ecosystems, which underpins their judgments (Fernandez-Gimenez, 2000).

Specifically, our results suggest that the ecological condition metrics for the Gobi Desert previously devised by Sinclair et al. (2021), which claimed to represent a consensus view across all stakeholder groups, do successfully navigate the inherent variation between individuals, producing scores representative of a consensus shared by all stakeholder groups. Similarly, our results suggest that the degree of subjective variation involved in assessing ecosystem collapse under the IUCN Red List framework (Bland et al., 2017) is relatively low and does not cause large differences in the assessment of collapse at the site level.

While we found a general consensus across stakeholder groups, it is important to note that there was substantial variation in responses between individual experts. We interpret this variation as relatively minor in our socio-ecological context. The degree of measured variation suggests that some individuals will always disagree with the group consensus, and these individuals may occasionally be unrepresented or disenfranchised by a given assessment or decision. Importantly, however, our data show that this effect is not systematic in our context and should not lead to repeated or generalized biases against any particular group of people. This provides a sound background against which just decisions can be made.

The variation in the data also reminds us that our stakeholder set is not homogenous. Subtle differences may emerge to become important in other circumstances, such as when livelihoods are under more pressure (Lkhagvadorj et al., 2013), or where different questions are posed. In our study, we explicitly asked the stakeholders to evaluate ecosystem condition from the point of view of the persistence of the natural biota, and not in terms of livestock grazing potential or any profit that could be made from the land. Had we instead asked our stakeholders a different question, such as “how desirable is this site to you, for any purpose including livestock grazing,” it is possible that less consensus would have been found. It is important to remember that the context of the problem—and thus the framing of the question is
as much a part of the socio-ecological context as the stakeholder group or the ecosystem.

We do not claim that our results are generalizable to all ecosystems. However, they demonstrate methods for assessing where consensus is likely, and where conflict may be expected in other situations. Our approach focuses on the current state and does not stipulate on prospective changes in future.

We encourage others to adopt similar elicitation and modeling methods in other ecosystems to understand how stakeholders evaluate ecological degradation in different contexts.

ACKNOWLEDGMENTS
The work would not have been possible without the generosity of over 90 stakeholders, we greatly appreciate their efforts. We thank two anonymous reviewers for their contribution in improving this article. The data for this article derived from a project that was funded by Oyu Tolgoi, Mongolia (OT; Rio Tinto). We thank Samdanjigmed Tulganyam, Altantsetseg Balt, and James Hamilton (OT) for their engagement with the project and useful insights. The project was supported by Sustainability East Asia and Wildlife Conservation Society, Mongolia Country Program (WCS), and we especially thank Enkhtuvshin Shiilegdamba (Acting Director Zhou et al., WCS) for his support. This article was funded by the Arthur Rylah Institute (Department of Environment, Land, Water and Planning). The video used to facilitate international participation was filmed by Fern Hames (ARI). We would also like thank Graeme Newell and Tim O’Brien of ARI for their support of this work. Ashley Sparrow and Lily Van Eeden provided valuable feedback through internal review. We thank Emily Nicholson (Deakin University) and David Keith (University of New South Wales) for useful discussions about the IUCN Red List of Ecosystems.

CONFLICT OF INTEREST
The authors declare no competing financial interests or personal relationships that could have appeared to influence the work described in this article.

DATA AVAILABILITY STATEMENT
Once accepted, all data and analysis code will be uploaded to Zenodo and will be to public.

ETHICS STATEMENT
All participants were informed of the purposes of the research, the nature of the data that would be collected and that it would be analyzed and displayed anonymously. Participation was entirely voluntary, and each participant was told they could contribute partial information if they felt uncomfortable providing certain information.

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REFERENCES
Allesina, S., & Bondavalli, C. (2004). WAND: An ecological network analysis user-friendly tool. Environmental Modelling & Software, 19, 337–340. https://doi.org/10.1016/j.envsoft.2003.10.002
Bedunah, D. J., & Schmidt, S. M. (2004). Pastoralism and protected area Management in Mongolia’s Gobi Gurvansaikhan National Park. Development and Change, 35(1), 167–191. https://doi.org/10.1111/j.1467-7660.2004.00347.x
Berger, J., Buuveibaatar, B., & Mishra, C. (2013). Globalization of the cashmere market and the decline of large mammals in Central Asia. Conservation Biology, 27(4), 679–689.
Bestelmeyer, B. T., Tugel, A. J., Peacock, G. L., Robinett, D. G., Shaver, P. L., Brown, J. R., Herrick, J. E., Sanchez, H., & Havstad, K. M. (2009). State-and-transition models for heterogeneous landscapes: A strategy for development and application. Rangeland Ecology & Management, 62(1), 1–15. https://doi.org/10.1111/j.2011-08-146
Bland, L., Keith, D., Miller, R., Murray, N., & Rodriguez, J. (2017). Guidelines for the application of IUCN Red List of Ecosystems categories and criteria, version 1.1.Gland, Switzerland: IUCN.
Booth, D. T., & Tueller, P. T. (2003). Rangeland monitoring using remote sensing. Arid Land Research and Management, 17(4), 455–467. https://doi.org/10.1080/713936105
Brown, G. G., & Donovan, S. (2013). Escaping the national forest planning quagmire: using public participation GIS to assess acceptable national forest use. Journal of Forestry, 111, 115–125.
Buuveibaatar, B., Mueller, T., Strindberg, S., Leimgruber, P., Kaczensky, P., & Fuller, T. K. (2016). Human activities negatively impact distribution of ungulates in the Mongolian Gobi. Biological Conservation, 203, 168–175. https://doi.org/10.1016/j.biocon.2016.09.013
Campbell, D. E. (2001). Proposal for including what is valuable to ecosystems in environmental assessments. Environmental Science and Technology, 35(14), 2867–2873. https://doi.org/10.1021/es001818n
Dale, V. H., Biddinger, G. R., Newman, M. C., Oris, J. T., Suter, G. W., Thompson, T., Armitage, T. M., Meyer, J. L., Allen-King, R. M., Burton, G. A., Chapman, P. M., Conquest, L. L., Fernandez, I. J., Landis, W. G., Master, L. L., Mitsch, W. J., Mueller, T. C., Rabeni, C. F., Rodewald, A. D., ... van Heerden, I. L. (2008). Enhancing the ecological risk assessment process. Integrated Environmental Assessment and Management, 4(3), 306–313. https://doi.org/10.1897/IEAM_2007-066.1
Wesche, K., Walther, D., von Wehrden, H., & Hensen, I. (2011). Trees in the desert: Reproduction and genetic structure of fragmented Ulmus pumila forests in Mongolian drylands. *Flora—Morphology Distribution Functional Ecology of Plants*, 206, 91–99. https://doi.org/10.1016/j.flora.2010.01.012

Wood, S. (2017). *Generalized additive models: An introduction with R*. 2nd ed.

Xu, G., Yu, D., Xie, J., Tang, L., & Li, Y. (2014). What makes *Haloxylon persicum* grow on sand dunes while *H. ammodendron* grows on interdune lowlands: A proof from reciprocal transplant experiments. *Journal of Arid Land*, 6(5), 581–591. https://doi.org/10.1007/s40333-014-0029-1

Xu, Z. (2009). An automatic approach to reaching consensus in multiple attribute group decision making. *Computers & Industrial Engineering*, 56(4), 1369–1374. https://doi.org/10.1016/j.cie.2008.08.013

Zhou, Z.-Y., Li, F.-R., Chen, S.-K., Zhang, H.-R., & Li, G. (2011). Dynamics of vegetation and soil carbon and nitrogen accumulation over 26 years under controlled grazing in a desert shrubland. *Plant and Soil*, 341(1), 257–268. https://doi.org/10.1007/s11104-010-0641-6

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How to cite this article: Batpurev, K., Sinclair, S. J., Avirmed, O., Scroggie, M. P., Olson, K., & White, M. D. (2022). Stakeholders from diverse backgrounds make similar judgments about ecological condition and collapse in Mongolian rangelands. *Conservation Science and Practice*, 4(1), e574. https://doi.org/10.1111/csp2.574