OIL AND GAS DEVELOPMENT IN UZBEKISTAN: VEGETATION RESPONSES TO DISTURBANCE ON THE USTYURT PLATEAU

ABSTRACT

Habitat degradation through anthropogenic disturbance is one of the main drivers of global biodiversity loss. Resource extraction by the oil and gas industry is a large and growing component of this disturbance. This study quantifies the impacts of disturbance from oil and gas infrastructure on the semi-arid vegetation of the ecologically important Ustyurt Plateau, Uzbekistan. The footprint of oil and gas development on the Ustyurt is set to grow considerably in the future, so understanding the ecological consequences of infrastructure expansion will be vital, to mitigate negative impacts. The degree to which disturbed and undisturbed (control) sites differ in species abundance and vegetation cover, and how these metrics alter with distance from disturbance, were investigated using transects employing the line intercept method of data collection. Disturbed sites had significantly lower species abundance ($p<0.001$) and cover ($p<0.001$) compared to control sites, but this was only found at the site of disturbance itself (0 m), and not at further sampling points 25-500 m from disturbance; this indicates that the spatial extent of disturbance is limited. Other factors that could explain abundance and cover patterns, such as secondary disturbances and wind direction, were not significantly correlated to vegetation response variables. Disturbance was found to have a negative effect on species abundance and cover at the community, broad taxonomic group, and species levels; Alone among the vegetation groups, Poaceae showed an increase in species abundance at the site of the disturbance ($P < 0.05$). Because impacts can be seen at vegetation community level, impacts from infrastructure may affect other taxa and species relying upon this vegetation, such as the critically endangered saiga antelope. Future research should focus on the effects of disturbance on vegetation at finer spatial scales, and investigate disturbance effects on other taxa, completing the quantification of impacts from oil and gas development on the Ustyurt.

INTRODUCTION

Anthropogenic disturbance

Anthropogenic disturbance can affect all levels of biodiversity, from genetic diversity of species to whole ecosystem processes (Hooper et al., 2005). Land use change is the strongest driver of alterations in biodiversity, due to its impact on habitat availability and associated species extinctions

(Mace et al., 2005); when combined with the introduction of invasive species and climate change, anthropogenic disturbance has far-reaching spatio-temporal and socio-economic impacts (Sala, 2000).

Disturbance caused by human activity is different from the range of natural perturbations experienced by species on a regular basis, the latter of which can be beneficial to maintaining high levels of biodiversity (Connell, 1978). Large-scale agricultural practices and natural resource exploitation, are two of the most damaging anthropogenic disturbances to biodiversity (Baillie et al., 2004). The disturbance impacts of natural resource exploitation by the oil and gas industry, both social and ecological, have been well documented (E&P Forum/UNEP, 1997; IPIECA, 2011; Epstein & Selber, 2002; Kumpula et al., 2011). Social change from influxes of people following employment opportunities can put natural systems under additional pressure, for example by increasing water extraction, logging, and illegal poaching (Thibault & Blaney, 2003). Habitat disturbance from infrastructure affects wildlife both spatially and temporally, such as altering breeding patterns of birds (Walker et al. 2007) and the grazing pattern of herbivores, increasing the usage and pressure on surrounding undisturbed habitats (Vistnes & Nellemann, 2007). The spatial impacts of disturbance on biodiversity can extend at least 5 km from oil and gas infrastructure (Benítez-López et al., 2010), and persist for decades after disturbance has ceased, especially when a shift in community structure has altered successional trajectories (Kumpula et al., 2011; Kemper & Macdonald, 2009). It is important to study impacts of disturbance on vegetation because effects scale up from the individual to population, community, and functioning of the ecosystem (Grantz et al., 2003). Semi-arid vegetation may be particularly susceptible to disturbance due to the harsh environmental conditions associated with this habitat: extreme temperature ranges, intense UV, high winds, limited moisture, and low fertility of desert soils (Lovich & Bainbridge, 1999), resulting in semi-arid vegetation recovering poorly post-disturbance (Fiori & Martin, 2003) or not at all, with original communities persisting only in remnant patches (Rapport & Whitford, 1999).

Importance of semi-arid environments

Semi-arid biomes are globally important, covering 41 % of total land surface and supporting over 38 % of the human population (Millennium Ecosystem Assessment, 2005). Central Asian countries occupy a large proportion of this semi-arid biome and in Uzbekistan alone, semi-arid land covers over 99 % of the country (White & Nackoney, 2003). Uzbekistan is highly diverse in flora and fauna with an estimated 27,000 species (UNDP, 2010; USAID, 2001), stemming from the heterogeneity of the landscape and persistence of semi-arid habitats since the Jurassic period, and a complex evolutionary history (Kapustina, 2001). Within Uzbekistan, the Ustyurt Plateau is one such biodiverse region: covering 7 million hectares of north-western Uzbekistan it has 271 recorded vascular plant species (Gintzburger et al., 2011), and several IUCN Red Listed plant species (Esipov & Shomurodov, 2011;

IUCN, 2012). The Ustyurt is also home to the critically endangered saiga antelope (*Saiga tatarica tatarica*) (Mallon, 2008). The saiga antelope are keystone herbivores of the Ustyurt, and undertake extensive migrations following seasonal rainfall patterns and subsequent high-quality forage (Singh et al., 2010a). Populations have undergone severe declines in recent decades (Milner-Gulland et al., 2001), with habitat degradation and poaching being two of the main drivers of declines. A recent study (Singh et al., 2010b) has shown disturbance to affect the calving site selection of saiga, with avoidance of disturbance being preferential to selection of calving sites with optimal environmental conditions, indicating that anthropogenic disturbance is affecting the breeding pattern of this critically endangered species.

Oil and gas development

Juxtaposed to the ecological importance of Uzbekistan's semi-arid areas, is the fact that over 60 % of the country has potential oil and gas reserves. As energy is the most abundant and valuable natural resource in Central Asia, the potential of Uzbekistan's hydrocarbon reserves means it is poised for further economic growth in this sector (Dorian, 2006). Of global energy consumption, 26 % is from natural gas (Chow et al., 2003); Uzbekistan already exports more natural gas than any other former Soviet Central Asian country, and in 2004 alone produced over 63 billion cubic metres of gas. The Ustyurt Plateau is already receiving significant foreign investment for oil and gas projects, and development is set to continue in this region (Dorian, 2006).

Development of the Ustyurt Plateau since the 1960s for oil and gas production has resulted in extensive infrastructure growth, including exploration and extraction sites, pipelines, and roads (UNDP, 2010). Worldwide where these infrastructure types exist, there are impacts and disturbances caused by each: exploratory extraction sites denude land and are abandoned if oil or gas reserves are not found. Whilst drilling, a substantial amount of water is used lowering water tables, with discarded water containing varying amounts of heavy metals and other toxic compounds (Epstein & Selber, 2002). Noise produced by infrastructure disrupts habitat use by animals (Rabanal et al., 2010), and pipelines used to transport hydrocarbons can alter animal movement (Dyer et al., 2002; Curatolo & Murphy, 1986). But it is the ecological impacts of roads that have been particularly well studied (Coffin, 2007; Trombulak & Frissell, 2000; Forman & Alexander, 1998). On the Ustyurt Plateau, the majority of roads used by oil and gas industry vehicles are unpaved. Because roads are unpaved, vegetation is not only impacted by their physical presence, causing soil compaction and reduced plant growth (Adams et al., 1982), dust clouds are also produced with passing vehicles, with dust then settling on vegetation (Gintzburger et al., 2011). Dust adversely affects key processes within plants such as photosynthesis, respiration and transpiration (Farmer, 1993). In arid environments dust is particularly damaging, as abrasion from wind-driven particulates damages and coats leaf surfaces altering their radiation balance (Grantz et al., 2003). Dust deposition can also alter nutrient cycling, through effects on soil bacteria and fungi, which is potentially damaging in a nutrient-limited semi-arid environment (Forbes et al., 2001). Furthermore, plant communities can be impacted by the invasion of non-native species brought in via vehicles (Gelbard & Belnap, 2003), and the physical presence of roads can create barriers to dispersal and gene flow between sub-divided populations, altering population demographics and communities (Forman & Alexander, 1998). Not all ecological systems are equally affected by roads, but their presence is highly correlated with changes in species composition (Trombulak & Frissell, 2000).

Post-disturbance semi-arid plant communities tend to have lower species richness compared to undisturbed areas (Simmers & Galatowitsch, 2010). Even low-intensity and small-scale disturbances have immediate and persistent effects (Forbes et al., 2001), with significant amounts of time needed for species to be restored to pre-disturbance levels (Cui et al., 2009). The effects of disturbance with distance have also been well studied. Gelbard & Harrison (2003) found that plant cover was significantly lower within 10 m of roads, with native species richness highest over 1 km away. Lee (2012) also found species richness to be lower closer to roads, and Fiori & Martin (2003) found as distance from disturbance increased so did vegetation, with a decrease in bare soil. Other studies, however, have found species richness to increase with proximity to roads (Zeng et al., 2011), with off-road tracks providing favourable microsites for vegetation establishment (Brown & Schoknecht, 2001). Boeken & Shachak (1994) also found that man-made disturbance created seed traps and favourable establishment sites, resulting in higher species richness in disturbed areas compared to the surrounding un-disturbed landscape.

Quantifying disturbance on the Ustyurt Plateau

Impacts of disturbance on semi-arid vegetation on the Ustyurt Plateau have not been quantified. Due to the ecological importance of the Ustyurt, it is essential to understand how disturbance is currently affecting biodiversity, as the area becomes increasingly under pressure from oil and gas development (Osti et al., 2011). Oil and gas companies are attempting to balance the needs of development with those of conservation by implementing conservation mechanisms such as biodiversity offsetting: the theory being that negative environmental impacts associated with development are balanced with environmental gains, resulting in a neutral or positive outcome for biodiversity (Kiesecker et al., 2009). Biodiversity offsetting policies for the Ustyurt Plateau (Bull et al. in press) can be enhanced and influenced by the provision of sound scientific knowledge of the impacts of oil and gas activity on biodiversity, and subsequent conservation needs (ten Kate et al., 2004; UNDP, 2010).

A pilot study on the Ustyurt Plateau in 2011 (Gintzburger et al., 2011) showed potential negative impacts of oil and gas infrastructure on vegetation. The present study aims to quantify impacts on vegetation by investigating the effects of disturbance on species abundance and vegetation cover. These metrics were chosen because time in the field was expected to be limited: fast and reliable data collection was essential therefore, and these metrics have successfully been used in previous studies investigating the impacts of disturbance on vegetation (e.g. Simmers & Galatowitsch, 2010; Fiori & Martin, 2003; Gelbard & Harrison, 2003; Lee et al., 2012), and provide solid understanding of the state of plant communities.

To enable quantification of oil and gas infrastructure impacts on the vegetation of the Ustyurt, three key questions are asked:

1. Is there a measurable difference in species abundance and percentage cover in disturbed and undisturbed (control) sites?
2. Does species abundance and percentage cover increase with distance from disturbance, and at what point does abundance and cover in disturbed sites reach that of un-disturbed sites?
3. Which other factors aside from disturbance, such as dominant wind direction and presence of secondary disturbances, drive patterns in observed species abundance and cover?

Within these questions, responses of different levels of the plant community will be explored: that of the community (when all species data are combined), broad taxonomic groups of species, and single species. Species abundance and cover levels are expected to increase with distance from disturbance, with the main effects of disturbance on vegetation seen within 500 m, and especially within 100 m (Angold, 1997; Lee et al., 2012; Zeng et al., 2011). Responses are expected to vary between groups and between species (Buonopane et al., 2005). Dominant wind direction is also thought to be influential on abundance and cover patterns due to its directional effects on dust deposition (Gintzburger et al., 2003; Gintzburger et al., 2011; Forman et al., 1997), as is the presence of secondary disturbances. The size of disturbance could affect patterns in species abundance and cover due to differential effects of large disturbances compared to smaller ones; the type of disturbance may also be influential. It is hoped that by quantifying impacts of disturbance in this way, and understanding the other drivers of species abundance and cover patterns, negative impacts of oil and gas infrastructure on the vegetation of the Ustyurt Plateau, and the associated biodiversity relying on it, can be mitigated.

METHODS

Data were collected during an 18-day field expedition in May-June 2012, led by the United Nations Development Programme (UNDP) to the Ustyurt Plateau, Uzbekistan. Transects employing the line intercept method (Canfield, 1941) were used to gather data on species abundance and vegetation cover at both disturbed and control sites, with data analysed using linear mixed effects models.

Survey locations

Surveys were carried out in eight sites across the Ustyurt Plateau (Fig. 1), determined by the UNDP expedition itinerary, with sites selected by local experts to reflect the heterogeneous nature of biodiversity on the Ustyurt (Esipov & Shomurodov, 2011).

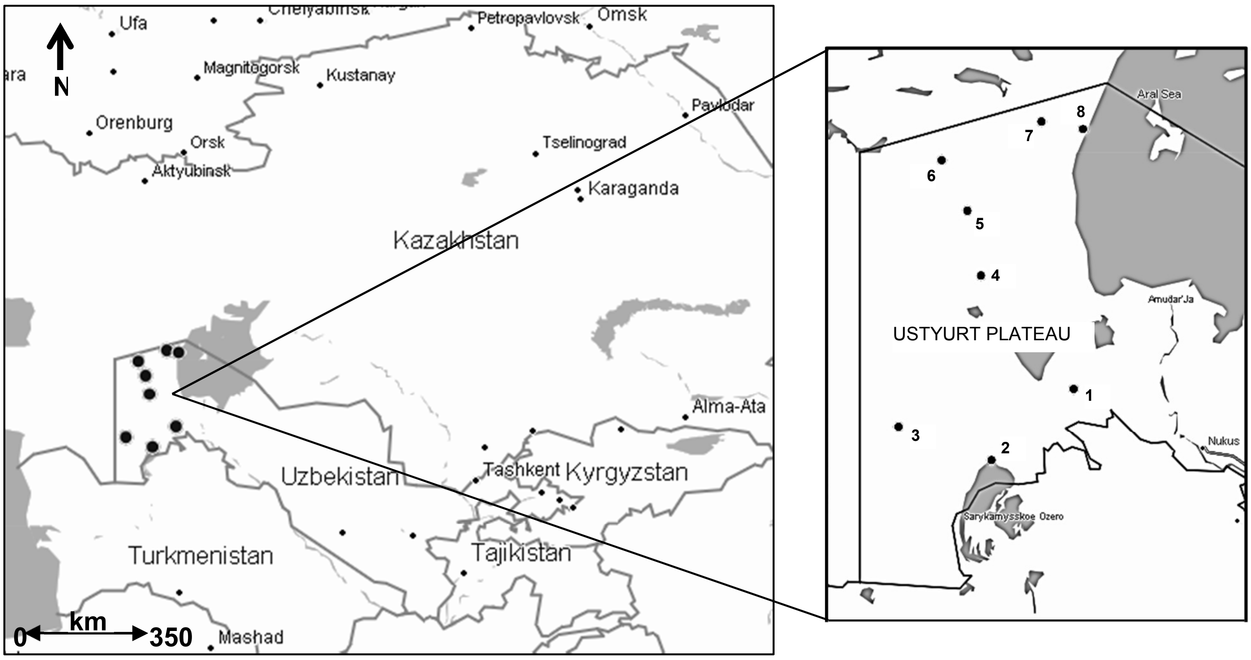

Fig.1: Geography of Central Asia, Uzbekistan, and the Ustyurt Plateau (detailed map section). Numbered points are survey site locations. Maps created using Garmin BaseCamp software (2012).

Disturbed and control sites

All well-developed anthropogenic disturbances encountered were sampled. These included unpaved roads (the majority of which are primarily used by oil and gas companies), one extraction site and one pipeline (Fig. 2), deemed 'primary disturbances.' Sites without primary disturbances were classed as controls. Disturbance on vegetation is not thought to extend past 500 m (e.g. Zeng et al., 2011), and so transects situated

Fig. 2: Overview of sites surveyed, with number of control and disturbed transects per site and type of disturbance surveyed.

Site	Number of replicate transects		Disturbance type	
	Control	Disturbed		
1	0	2	Road	
2	0	4	Road	
3	0	2	Road	
		1	Extraction site	
4	3	2	Road	
5	3	0	NA	
6	0	4	Road	
7	1	0	NA	
8	0	2	Pipeline	
Total	7	17	Road	n =14
			Pipeline	n = 2
			Extraction site	n = 1

>500 m from primary disturbances were also classed as controls. There is a network of less-developed (secondary) disturbances, such as small tracks, evident throughout the Ustyurt and present in both control and disturbed sites.

Transects

Disturbance type and transect orientation

Disturbance sources were either linear (road or pipeline) or point (gas extraction site) in nature. In each case, transects ran from the centre of the disturbance for 500 m, but the nature of the disturbance dictated the direction: for linear sources, transects ran perpendicular to the disturbance, and for point sources, transects ran on a bearing selected at random. This ensured that the primary disturbance being surveyed only exacted its effects on vegetation from the start of the transect. The size and type of primary disturbance was recorded.

Design

Transects were in a 'spine and rib' formation with the main 500 m 'spine' transect (hereon simply 'transect') following the transect bearing (see Fig. 3). Twenty metre 'rib' transects perpendicularly bisected the transect with increased sampling effort close to the disturbance source to detect any fine-scale effects of disturbance on vegetation (Angold, 1997; Lee et al., 2012). Replicate transects were situated a minimum of 500 m from one another to ensure independence.

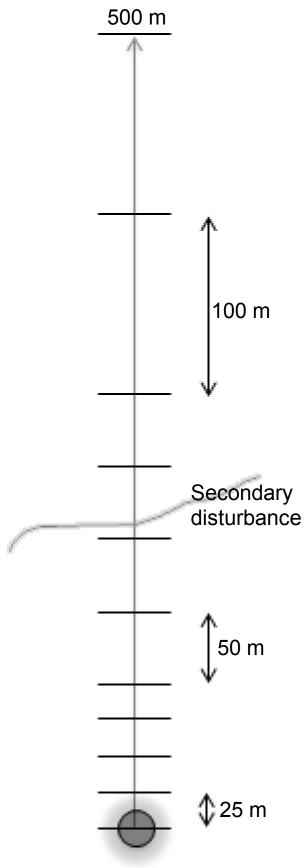

Fig. 3: Design of 'spine and rib' transects: the main 500 m 'spine' transect originates from the centre of disturbance with 20 m 'rib' transects bisecting it at set intervals: 25 m intervals between 0-100 m (where 0 m is the centre of disturbance), 50 m intervals between 100-300 m, and 100 m intervals between 300-500 m, giving increased sampling effort closer to the disturbance. The line intercept method was used to collect species abundance and vegetation cover data along each 'rib.' Secondary disturbances e.g. small tracks were also recorded.

Data collection

Species abundance and vegetation cover data were collected along each 'rib' transect using the line intercept method (Canfield, 1941): a 20 m line marked at 5 cm intervals was viewed from above, with all plants in contact with the line recorded, along with the length of line they were in contact with (the intercept). Vegetation observed on the 'rib' transects was identified to species level where possible. Where species could not be identified, they were grouped: Chenopodaceae, herbaceous flowering plants, Poaceae, non-woody succulents and woody shrubs (Fig. 4). The presence and width of secondary disturbances within 10 m and 50 m of 'ribs' was recorded.

Methodological considerations and compromises

This was a time-limited yet geographically extensive expedition. All terrain was off-road and covered in two 4x4 vehicles, which meant that travel times were long: it is approximately 350 km from the most southerly to northerly transect locations. The resulting logistical constraints necessitated methodological flexibility, for example it was not possible to carry out replicate disturbance or control surveys in all sites visited, limiting the dataset. Due to the relatively small dataset, it was important to ensure data were representative of the Ustyurt as a whole, to allow broad conclusions about the impact of oil and gas infrastructure to be drawn. Survey areas were chosen to keep transects within broad habitat types, for example *Anabasis sp. – Artemisia sp. – Salsola sp.* associations (Esipov & Shomurodov, 2011; Gintzburger et al., 2003; Gintzburger et al., 2011). Within these areas, transect location was selected at random by walking for an agreed time, using the stopping point as the transect start point. When surveying the extraction site, a random transect bearing could have taken the transect towards buildings and other major sources of disturbance. This would have severely impacted our ability to investigate the effects of disturbance with distance, and so the transect bearing was altered to achieve this.

Fig. 4: Overview of broad taxonomic groups and species surveyed. Because the relationship between distance and disturbance was one of the fundamental questions being investigated, species used in species-level analyses needed to occur at all distances surveyed: only two species fulfilled this criterion.

Broad taxonomic grouping	Number of species within group	Species within group used for species-level analysis
Chenopodaceae	9	*Anabasis salsa*
Poaceae	2	*Eremopyrum distans*
Herbaceous flowering plants	25	NA
Non-woody succulents	7	NA
Woody shrubs	4	NA
Total species	47	2

ANALYSIS

All statistical analyses were conducting using 'R' (R Development Core Team, 2011), using linear mixed effects models (Bates et al., 2012).

Species abundance and vegetation cover

Species abundance and vegetation cover were the response variables in all models. Species abundance data were in the form of counts, necessitating the use of the Poisson error family in models. Vegetation percentage cover data required arcsine square root transformation; transformation of data negates the need to specify an error family.

Explanatory variables

Several explanatory variables could explain patterns in species abundance and cover: whether sites were control or disturbed, distance from disturbance, disturbance width, presence of secondary disturbances, and transect direction (indicating effects of dominant wind direction). Wind direction data were obtained for 2009 and 2010 from the hydro-meteorological station in Jaslyk (central Ustyurt). Distance was fitted as an interaction term with control and disturbed sites, to test the relationship between species abundance and cover with distance, in both control and disturbed sites. Fitting an interaction between control and distance tested surveyor consistency along transects, and provided accurate baselines for species abundance and cover.

All explanatory variables were fitted in maximal models using community-level data (where all species data were combined). In models for broad taxonomic groups and single species, data were not sufficient to permit this: only whether sites were control or disturbed, with distance as an interaction term were fitted to avoid overparameterisation of models. Maximal models were simplified through stepwise deletion of highest order non-significant terms (Crawley, 2007); minimum adequate models and model output summaries can be found in the Appendix.

Statistical considerations

The transect design resulted in 'ribs' being pseudoreplicated and nested within 'transect.' To account for this, 'transect' was fitted as a random effect within all linear mixed effects models; this also accounted for spatial autocorrelation of data identified by the Moran's I test (Crawley, 2005). It is not possible to use quasi- error families, nor is it clear how to test and account for overdispersion within linear mixed effects models. Due to the limited number of data used, overdispersion was not considered to be a likely problem, and so testing for it was not attempted.

Analysis involving multiple comparisons within a single dataset can be accounted for by using the sequential Bonferroni adjustment of p-values. There are arguments against this (Moran, 2003), and no clear solution, thus p-values in this study have not been altered. P-values for all general linear mixed effects models were produced using Markov Chain Monte Carlo sampling with 10,000 iterations (Baayen, 2011).

RESULTS

Is there a measurable difference in species abundance and percentage cover of vegetation in disturbed and undisturbed (control) sites?

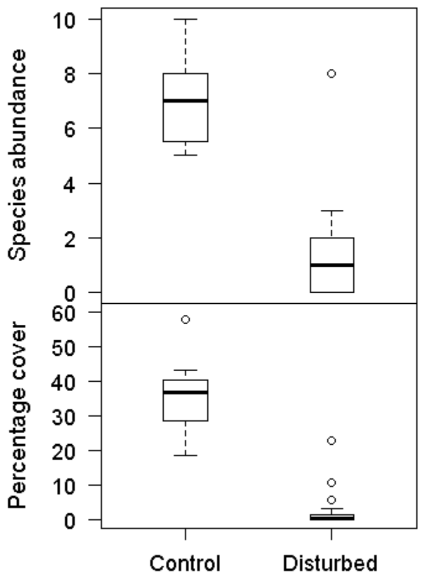

Fig. 5: Boxplots showing differences in vegetation responses at the 0 m 'rib' transect of control and disturbed sites. Differences in both species abundance and cover are significant ($P < 0.001$), tested using the non-parametric Wilcoxon Rank test.

Disturbance has an overall negative effect on community species abundance (z = -6.2, $P < 0.001$) and vegetation cover (t = -4.7, $P < 0.001$) compared to control sites (Fig. 5 & 6).

The species abundance and percentage cover of three broad taxonomic groups - Chenopodaceae, herbaceous flowering plants, and woody shrubs - are also negatively affected by disturbance compared to control sites (Fig. 7). The species abundance of Poaceae is positively affected by disturbance (t = 3.7, $P < 0.001$), yet percentage cover is negatively affected (t = -2.7, $P < 0.01$). Non-woody succulents show no difference in species abundance or cover between control and disturbed sites ($P > 0.05$).

At species level the percentage cover of *Anabasis salsa* (Chenopodaceae) and *Eremopyrum distans* (Poaceae) was negatively affected by disturbance (t = -2.4, $P < 0.05$; t = -4.1, $P < 0.001$ respectively) compared to control sites.

Does species abundance and vegetation cover increase with distance from disturbance, and at what point does vegetation in disturbed sites reach that of un-disturbed sites?

Overall species abundance and cover increases with distance from disturbance, until it asymptotes to the baseline levels in control sites (Fig. 6). In general, species abundance and cover are only significantly different to baseline levels (those at 500 m) at the site of disturbance itself (0 m); between 25-500 m from disturbance, species abundance and cover are not significantly different to baseline levels. This is the case for species abundance at community level (z = -4.7, $P < 0.001$), and at broad taxonomic group level: Chenopodaceae (t = -3.1, $P < 0.001$), herbaceous flowering plants (z = -3.1, $P < 0.01$) and woody shrubs (t = -2.4, $P < 0.01$). Non-woody succulents show no relationship between species abundance and distance ($P > 0.05$). Poaceae are the only group to show a decline in species abundance with distance from disturbance, with more species at the site of disturbance compared to baseline levels (t = 2.1, $P < 0.001$) (Fig. 7).

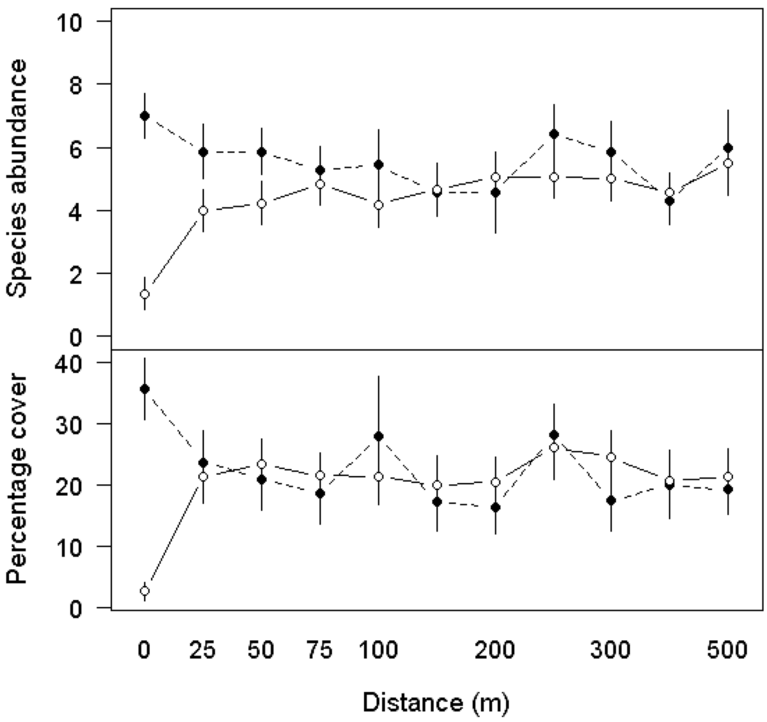

Fig. 6: Interaction plots for abundance and cover with distance. Hollow points represent disturbed sites, solid points represent controls. Graphs produced using "Sciplot" with 95 % confidence intervals displayed (Morales, 2011).

Vegetation cover is also only significantly different at the site of disturbance to baseline levels at community level (t = -5.2, $P < 0.001$), and broad taxonomic group level: Chenopodaceae (t = -4.1, $P < 0.001$), herbaceous flowering plants (t = -3.1, $P < 0.01$), Poaceae (t = -2.1, $P < 0.01$) and woody shrubs (t = -2.9, $P < 0.05$). Non-woody succulents show no relationship between vegetation cover and distance from disturbance ($P > 0.05$). At species level, the percentage cover of *A. salsa* and *E. distans* are also only significantly different to baseline levels at 0 m (t=-2.5, $P < 0.05$ and t=-3.2, $P < 0.01$ respectively).

Which other factors aside from disturbance itself, such as dominant wind direction and presence of secondary disturbances, drive patterns in observed species abundance and cover?

There was a positive effect on species abundance when disturbances were under 3 m in width and over 10 m in width (z = 2.4, $P < 0.05$ and z = 2.8, $P < 0.01$ respectively); vegetation cover was not significantly affected. There were no significant negative effects of disturbance width on vegetation. There were no significant effects on either abundance or cover from other variables such as secondary disturbances and compass quadrant occupied by transects (used to investigate the effects of dominant wind direction) (Fig. 8).

Fig. 7: Overview of vegetation response to disturbance at community, broad taxonomic group, and species levels. Negative responses are denoted by '-' and positive by '+.' Non-significance is taken to be $p > 0.05$ and is indicated by 'NS.' The distance at which vegetation is significantly different to baseline levels (values at 500 m) is shown.

Variable	Effect of disturbance		Distance at which vegetation is significantly different to baseline levels (m)	
	Species abundance	Percentage cover	Species abundance	Percentage cover
Combined species	- ($z = -6.2$, $p < 0.001$)	- ($t = -4.68$, $p < 0.001$)	0 - ($z = -4.7$, $p < 0.001$)	0 - ($t = -5.2$, $p < 0.001$)
Chenopodaceae	- ($t = -5.1$, $p < 0.001$)	- ($t = -5.4$, $p < 0.001$)	0 - ($t = -3.1$, $p < 0.001$)	0 - ($t = -4.1$, $p < 0.001$)
Poaceae	+ ($t = 3.7$, $p < 0.01$)	- ($t = -2.7$, $p < 0.01$)	0 + ($t = 2.1$, $p < 0.05$)	0 - ($t = -2.1$, $p < 0.05$)
Herbaceous flowering plants	- ($z = -3.1$, $p < 0.01$)	- ($t = -2.8$, $p < 0.01$)	0 - ($z = -3.1$, $p <0.01$)	0 - ($t = -3.1$, $p < 0.001$)
Non-woody succulents	NS	NS	NS	NS
Woody shrubs	- ($t = -3.0$, $p < 0.01$)	- ($t = -2.2$, $p < 0.05$)	0 - ($t = -2.4$, $p < 0.05$	0 - ($t = -2.9$, $p < 0.01$)
Anabasis salsa	NA	- ($t = -2.4$, $p < 0.05$)	NA	0 - ($t = -2.5$, $p < 0.05$)
Eremopyrum distans	NA	- ($t = -4.1$, $p < 0.001$)	NA	0 - ($t = 3.2$, $p <0.01$)

Fig. 8: Overview of explanatory variables used in maximal models for community-level analyses. Whether explanatory variables had a significant effect on vegetation response is indicated, as is the direction of response ('+' indicating a positive response and '-' indicating a negative response). There were not sufficient replicates of disturbance type to allow this analysis. Maximal models with all explanatory variables were only fitted with data involving community data (all species data combined), not for broad taxonomic groups or single species due to insufficient data.

Explanatory variables	Significant		Vegetation response	
	Species abundance	Percentage cover	Species abundance	Percentage cover
Disturbed site	✓	✓	-	-
Disturbance <3 m wide	✓	x	+	NA
Disturbance >10 m wide	✓	x	+	NA
Proximity to disturbance	✓	✓	-	-
Secondary disturbance within 10 m of 'rib'	x	x	NA	NA
Secondary disturbance within 50 m of 'rib'	x	x	NA	NA
Secondary disturbance crossing 'rib'	x	x	NA	NA
Compass quadrant	x	x	NA	NA

DISCUSSION

This study has shown that oil and gas infrastructure, in an ecologically important semi-arid region, has a negative effect on species abundance and cover of vegetation. Species abundance and cover is however only significantly affected at the point of disturbance itself, with no significant differences detected at other sampled distances. One would expect species abundance and cover to be lower at the point of disturbance, due to the physical disturbance caused by the construction of pipelines, extraction sites and regular passage of vehicles. However it is unexpected to find no significant effects on vegetation at greater distances, indicating that the spatial extent of disturbance is limited to within the first 25 m of disturbance on the Ustyurt Plateau.

Disturbance has a negative impact on species abundance and cover at the community level, the broad taxonomic group level, and at species level. Poaceae are the only group to show a positive interaction with disturbance, with an increase in species abundance at the site of disturbance and a decrease in abundance with distance. The percentage cover of Poaceae was however negatively affected by disturbance. Poaceae are excellent colonists and have previously been found to increase in abundance near disturbance, and so this differential response between groups and species was expected (e.g. Buonopane et al., 2005; Yorks et al., 1997). However, even though there is evidence of a positive effect of disturbance on Poaceae species abundance, the total species abundance of Poaceae in this study was two: a small sample size that could produce misleading results. By looking at vegetation responses at different taxonomic hierarchies, this study shows that disturbance effects scale up from the individual, to population and community levels. Such alterations in plant community composition could affect ecosystem functioning, for example by disrupting nutrient cycling and reducing habitat quality, potentially leading to desertification of the region (Belnap, 1995). Further work would allow investigation into whether disturbance effects can be seen in other taxonomic groups on the Ustyurt such as invertebrates, reptiles, mammals and birds, and whether the spatial scale of responses differ (Benítez-López et al., 2010).

Other factors that may have explained vegetation responses to disturbance were also investigated, such as the presence of secondary disturbances and wind direction, as they were thought to be influential on the Ustyurt (Esipov & Shomurodov, 2011). These factors did not explain any patterns in vegetation response to disturbance. This is understandable in the case of secondary disturbances, if the spatial effects from primary disturbances are themselves limited. Even though small disturbances can have detrimental effects on vegetation (Forbes et al., 2001), the limited dataset of this study may have prevented the negative effects of secondary disturbances from being detected. Wind direction was thought to be particularly important on the Ustyurt as strong winds are characteristic of this continental landmass (Gintzburger et al., 2003). Given that there is substantial bare ground exposed by infrastructure, dust produced by wind erosion of bare soil and vehicle movement, with subsequent deposition away from the dominant wind direction, could affect vegetation growth. Annual wind direction data obtained showed wind directions to be relatively well spread. If there is no dominant wind direction dust deposition is likely to be balanced in all directions, which would explain why no directional effect from dust deposition was detected. However, the wind data obtained was only for 2009 and 2010: data over a greater time scale may show dominance of a particular wind direction more accurately. Future work could explore this area further by focussing on quantifying aeolian dust deposition (Goossens & Rajot, 2008), and investigate whether effects on vegetation from wind vary spatially across the Ustyurt.

Interestingly, the size of disturbance has significant positive effects on species abundance, but no significant negative effects: if the disturbance was less than 3 m wide a positive effect on species abundance was observed, but no significant effects on percentage cover. This may be because a disturbance less than 3 m wide is likely to be a small infrequently used single-track road. If roads are not used often, then the low intensity disturbance may be providing establishment opportunities for species, as discussed in the intermediate disturbance hypothesis (Connell, 1978). Disturbances over 10 m wide may also increase the availability of establishment sites for species because the intensity of road use could be more diffuse over a larger area. Transects could fall on the relatively undisturbed 'hump' between tyre ruts, which may have led to higher species abundance records at the site of disturbance. Water pooling in tyre ruts may also create favourable establishment sites for plants (Briones et al., 1998; Brooks & Lair, 2005; Boeken & Shachak, 1994).

This study is relatively data-limited, and therefore provides a robust initial study forming the basis for future work. As no significant effects on vegetation from infrastructure were detected at 25 m from disturbance and beyond, future work should increase sampling effort within the first 25 m from disturbance. This would provide a more accurate idea of whether disturbance effects are limited to the area covered by the disturbance itself, or whether they extend further. More replicate extraction and pipeline sites should be surveyed, to find out whether vegetation responses differ between disturbance types. Increasing the amount of data would mean that maximal models with all explanatory variables could be fitted with broad taxonomic group and single species data, as well as community-level data. This would help highlight more of the potential differential responses to disturbance within this taxonomic hierarchy. It would also be beneficial to focus single species studies on those that are of greatest fodder benefit for ungulates, both wild and domestic, as there are potentially impacts from industry on the quality of grazing land available. This is particularly important given that the critically endangered saiga antelope relies on the Ustyurt Plateau for grazing and is already undergoing severe population declines (Singh et al., 2010b; Milner-Gulland et al., 2001). The sampling method itself could also be modified to include cover of lichens growing on the soil surface: because non-vascular plants were not included in this study, the actual percentage cover of plant biomass present is likely to be underestimated.

Being able to quantify the impacts of oil and gas infrastructure on the vegetation of the Ustyurt Plateau will help inform biodiversity offsetting policies for companies working in the region: once the spatial extent of vegetation effects has been found, it can be summed for the Ustyurt as a whole by using satellite imagery of the infrastructure network, to calculate the total area of disturbed habitat. The Ustyurt is going to be developed for oil and gas extraction, and so biodiversity offsetting will aim to mitigate the negative impacts associated with infrastructure development (UNDP, 2010). However other potential threats associated with increased amounts of infrastructure must also be considered, such as influxes of people increasing pressure on natural resources.

Whilst this study could not assess all impacts associated with oil and gas development, it does quantify some of the effects of oil and gas infrastructure on the vegetation of the ecologically important Ustyurt Plateau. This bolsters current knowledge of the effects of infrastructure disturbance on simple plant communities in nutrient-poor areas such as Arctic tundra (Kemper & Macdonald, 2009), steppe environments (Fiori & Martin, 2003) and other semi-arid desert regions (Simmers & Galatowitsch, 2010). Oil and gas exploration is burgeoning in these habitat types: providing accurate assessments of the spatial scale of disturbance by infrastructure is essential, if we are to mitigate any negative ecological impacts associated with the oil and gas industry in terrestrial environments.

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REFERENCES

Adams, J.A., Endo, A.S., Stolzy, L.H., Rowlands, P.G. & Hyrum, B.J., 1982. Controlled Experiments on Soil Compaction Produced by Off-Road Vehicles in the Mojave Desert, California. Journal of Applied Ecology, 19(1), pp.167–175.

Angold, P.G., 1997. The impact of a road upon adjacent heathland vegetation: effects on plant species composition. Journal of Applied Ecology, 34(2), pp.409–417.

Baayen, R.H., 2011. languageR: Data sets and functions with “Analyzing Liguistic Data: A practical introduction to statistics.” <http://cran.r-project.org/package=languageR>

Baillie, J.E.M., Hilton-Taylor, C. & Stuart, S.N. (Editors) 2004. 2004 IUCN Red List of Threatened Species. A global Species assessment. Gland, Switzerland and Cambridge, UK.

Bates, D., Maechler, M. & Bolker, B., 2012. lme4: Linear mixed-effects models using S4 classes. <http://cran.r-project.org/package=lme4>

Belnap, J., 1995. Surface disturbances: their role in accelerating desertification. Environmental monitoring and assessment, 37, pp.39–57.

Benítez-López, A., Alkemade, R. & Verweij, P.A., 2010. The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. Biological Conservation, 143(6), pp.1307–1316.

Boeken, B. & Shachak, M., 1994. Desert Plant Communities in Human-Made Patches--Implications for Management. Ecological Applications, 4(4), pp.702–716.

Briones, O., Montana, C. & Ezcurra, E., 1998. Competition intensity as a function of resource availability in a semiarid ecosystem. Oecologia, 116(3), pp.365–372.

Brooks, M.L. & Lair, B., 2005. Ecological Effects of Vehicular Routes in a Desert Ecosystem. United States Geological Survey, Western Ecological Centre.

Brown, G. & Schoknecht, N., 2001. Off-road vehicles and vegetation patterning in a degraded desert ecosystem in Kuwait. Journal of Arid Environments, 49(2), pp.413–427.

Bull, J.W., Suttle, K.B., Singh, N.J., Milner-Gulland, E.J., in prep. Conservation when nothing stands still: moving targets and biodiversity offsets. Frontiers in Ecology and Conservation.

Buonopane, M., Huenneke, L.F. & Remmenga, M., 2005. Community response to removals of plant functional groups and species from a Chihuahuan Desert shrubland. Oikos, 110(1), pp.67–80.

Canfield, R.H., 1941. Application of the Line Interception Method in Sampling Range Vegetation. Journal of Forestry, pp.388–394.

Chow, J., Kopp, R.J. & Portney, P.R., 2003. Energy resources and global development. Science, 302(5650), pp.1528–31.

Coffin, A.W., 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography, 15(5), pp.396–406.

Connell, J.H., 1978. Diversity in Tropical Rain Forests and Coral Reefs. Science, 199(4335), pp.1302–1310.

Crawley, M.J., 2005. Statistics: an introduction using R. John Wiley & Sons Ltd., Chichester

Crawley, M.J., 2007. The R Book. John Wiley & Sons Ltd., Chichester

Cui, B., Zhao, S., Zhang, K., Li, S., Dong, S. & Bai, J., 2009. Disturbance of Dabao highway construction on plant species and soil nutrients in Longitudinal Range Gorge Region (LRGR) of Southwestern China. Environmental monitoring and assessment, 158(1-4), pp.545–59.

Curatolo, J.A. & Murphy, S.M., 1986. The effects of pipelines, roads, and traffic on the movements of Caribou, Rangifer tarandus. The Canadian field-naturalist, 100, pp.218–224.

Dorian, J.P., 2006. Central Asia: A major emerging energy player in the 21st century. Energy Policy, 34(5), pp.544–555.

Dyer, S.J., O’Neill, J.P., Wasel, S.M. & Boutin, S., 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. Canadian Journal of Zoology, 80, pp.839–845.

E&P Forum/UNEP, 1997. Technical Report. Environmental management in oil and gas exploration and production: an overview of issues and approaches.

Epstein, P.R. & Selber, J. eds., 2002. Oil: A life cycle analysis of its health and environmental impacts. The Centre for Health and the Global Environment, Harvard Medical School, Boston.

Esipov, A.V. & Shomurodov, H., 2011. Baseline research of biodiversity on Plateau Ustyurt and adjoining territories, establishment of the network of monitoring stations.

Farmer, A., 1993. The effects of dust on vegetation - a review. Environmental Pollution, 79, pp.63–75.

Fiori, S.M. & Martin, S., 2003. Potential impacts of petroleum exploration and exploitation on biodiversity in a Patagonian Nature Reserve , Argentina. Biodiversity and Conservation, 12, pp.1261–1270.

Forbes, B.C., Ebersole, J.J. & Strandberg, B., 2001. Anthropogenic Disturbance and Patch Dynamics in Circumpolar Arctic Ecosystems. Conservation Biology, 15(4), pp.954–969.

Forman, R.T.T. & Alexander, L.E., 1998. Roads and their major ecological effects. Annual Review of Ecology, Evolution, and Systematics, 29, pp.207–31.

Forman, R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S. & Alexander, L.E., 1997. Ecological effects of roads: Toward three summary indices and an overview for North America. Habitat fragmentation & infrastructure – proceedings, pp. 39-54
Garmin 2012 "BaseCamp" mapping software and basemaps <www.garmin.com>
Gelbard, J.L. & Belnap, J., 2003. Roads as Conduits for Exotic Plant Invasions in a Semiarid Landscape. Conservation Biology, 17(2), pp.420–432.
Gelbard, J.L. & Harrison, S., 2003. Roadless Habitats as Refuges for Native Grasslands: Interactions with Soil, Aspect, and Grazing. Ecological Applications, 13(2), pp.404–415.
Gintzburger, G., Toderich, K.N., Mardonov, B.K. & Mahmudov, M.M., 2003. Rangelands of the arid and semi-arid zones in Uzbekistan. CIRAD - ICARDA.
Gintzburger, G., Rajabov, T. & Bull, J., 2011. Ustyurt Rangelands Mission Report, USAID. Commissioned by Fauna and Flora International, Cambridge, UK.
Goossens, D. & Rajot, J.L., 2008. Techniques to measure the dry aeolian deposition of dust in arid and semi-arid landscapes : a comparative study in West Niger. Earth Surface Processes and Landforms, 33, pp.178–195.
Grantz, D. a, Garner, J.H.B. & Johnson, D.W., 2003. Ecological effects of particulate matter. Environment international, 29(2-3), pp.213–39.
Hooper, D.U., Chapin III, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A.J., Vandermeer, J. & Wardle, D.A., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs, 75(1), pp.3–35.
IPIECA, 2011. Ecosystem services guidance: Biodiversity and ecosystem services guide and checklists. London, UK.
IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <www.iucnredlist.org>
Kapustina, L.A., 2001. Biodiversity, Ecology, and Microelement Composition of Kyzylkum Desert Shrubs (Uzbekistan). In: McArthur, E.D. & Fairbanks, D.J. comps. 2001. Shrubland ecosystem genetics and biodiversity: proceedings, pp. 98–103.
Kemper, T.J. & Macdonald, E.S., 2009. Directional change in upland tundra plant communities 20-30 years after seismic exploration in the Canadian low-arctic. Journal of Vegetation Science, 20, pp.557–567.
Kiesecker, J.M., Copeland, H., Pocewicz, A., Nibbelink, N., McKenney, B., Dahlke, J., Holloran, M. & Stroud, D., 2009. A Framework for Implementing Biodiversity Offsets: Selecting Sites and Determining Scale. BioScience, 59(1), pp.77–84.
Kumpula, T., Pajunen, A., Kaarlejarvi, E. Forbes, B.C. & Stammler, F., 2011. Land use and land cover change in Arctic Russia: Ecological and social implications of industrial development. Global Environmental Change, 21(2), pp.550–562.
Lee, M. A., Davies, L. & Power, S. A., 2012. Effects of roads on adjacent plant community composition and ecosystem function: An example from three calcareous ecosystems. Environmental pollution, 163, pp.273–80.
Lovich, J. & Bainbridge, D., 1999. Anthropogenic Degradation of the Southern California Desert Ecosystem and Prospects for Natural Recovery and Restoration. Environmental management, 24(3), pp.309–326.
Mace, G., Masundire, H. & Baillie, J., 2005. Biodiversity. In Ceballos, G., Lavorel, S., Orians, G. & Pacala, S. eds. 2005. Ecosystems and Human Well-being: Current State and Trends.
Mallon, D.P. 2008. *Saiga tatarica ssp. tatarica*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <www.iucnredlist.org>
Manuel Morales, with code developed by the R Development Core Team, with general advice from the R-help listserv community and especially Duncan Murdoch. (2011). Sciplot: Scientific Graphing Functions for Factorial Designs. R package version 1.0-9. <http://CRAN.R-project.org/package=sciplot>
Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis, Washington, DC.
Milner-Gulland, E.J., Kholodova, M.V., Bekenov, A., Bukreeva, O.M., Grachev, I.A., Amgalan, L. & Lushchekina, A.A., 2001. Dramatic declines in saiga antelope populations. Oryx, 35(4), pp.340–345.
Moran, M.D., 2003. Arguments for rejecting the sequential Bonferroni in ecological. Oikos, 2(100), pp.403–405.
Osti, M., Coad, L., Fisher, J.B., Bomhard, B. & Hutton, J.M., 2011. Oil and gas development in the World Heritage and wider protected area network in sub-Saharan Africa. Biodiversity and Conservation, 20(9), pp.1863–1877.
R Development Core Team, 2011. R: A language and environment for statistical computing. <http://www.r-project.org/>
Rabanal, L.I., Kuehl, S., Mundry, R., Robbins, M.M. & Boesch, C., 2010. Oil prospecting and its impact on large rainforest mammals in Loango National Park, Gabon. Biological Conservation, 143(4), pp.1017–1024.

Rapport, D.J. & Whitford, W.G., 1999. How Ecosystems Respond to Stress: common properties of arid and aquatic systems. BioScience, 49(3), pp.193–203.
Sala, O.E., 2000. Global Biodiversity Scenarios for the Year 2100 . Science, 287(5459), pp.1770–1774.
Simmers, S.M. & Galatowitsch, S.M., 2010. Factors Affecting Revegetation of Oil Field Access Roads in Semiarid Grassland. Restoration Ecology, 18(September), pp.27–39.
Singh, N.J., Grachev, I.A., Bekenov, A.B. & Milner-Gulland, E.J., 2010a. Tracking greenery across a latitudinal gradient in central Asia - the migration of the saiga antelope. Diversity and Distributions, 16(4), pp.663–675.
Singh, N.J., Grachev, I.A., Bekenov, A.B. & Milner-Gulland, E.J., 2010b. Saiga antelope calving site selection is increasingly driven by human disturbance. Biological Conservation, 143(7), pp.1770–1779.
ten Kate, K., Bishop, J. & Bayon, R., 2004. Biodiversity offsets : Views, experience, and the business case. IUCN, Gland, Switzerland and Cambridge, UK, and Insight Investment, London, UK.
Thibault, M. & Blaney, S., 2003. The Oil Industry as an Underlying Factor in the Bushmeat Crisis in Central Africa. Conservation Biology, 17(6), pp.1807–1813.
Trombulak, S.C. & Frissell, C.A., 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology, 14(1), pp.18–30.
UNDP, 2010. Mainstreaming biodiversity into Uzbekistan's oil-and-gas sector policies and operations.
USAID, 2001. Biodiversity Assessment for Uzbekistan, Almaty, Kazakhstan.
Vistnes, I. & Nellemann, C., 2007. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology, 31(4), pp.399–407.
Walker, B.L., Naugle, D.E. & Doherty, K.E., 2007. Greater Sage-Grouse Population Response to Energy Development and Habitat Loss. Journal of Wildlife Management, 71(8), pp.2644–2654.
White, R.P. & Nackoney, J., 2003. Drylands, People, and Ecosystem Goods and Services: a web-based geospatial analysis, Washington, DC.
Yorks, T., West, N.E., Mueller, R.J. & Warren, S.D., 1997. Toleration of Traffic by Vegetation: Life Form Conclusions and Summary Extracts from a Comprehensive Data Base. Environmental management, 21(1), pp.121–31.
Zeng, S.-L., Zhang, T.-T., Gao, Y., Ouyang, Z.-T., Chen, J.-K., Li, B. & Zhao, B., 2011. Effects of road age and distance on plant biodiversity: a case study in the Yellow River Delta of China. Plant Ecology, 212(7), pp.1213–1229.

APPENDIX

MODEL OUTPUTS

Community-level analyses

Minimum adequate models for community data to investigate the overall patterns in response variables (species abundance and cover) between control and disturbed sites, with distance. Other significant explanatory variables are also present. All data are compared to those at 0 m in both control and disturbed sites. Binary data is used for disturbance width: 1 denotes disturbance is greater than the specified width, and 0 if not.

Species abundance

lmer (species abundance ~ control or disturbed sites * distance from disturbance + disturbance over 10 m wide + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: total_sp ~ C_D * DIST + Dist_width_over10m + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 275.5 359.7 -113.7    227.5
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.14574  0.38176
Number of obs: 247, groups: REP, 24

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          1.90462    0.20346   9.361  < 2e-16 ***
C_DD                -1.99024    0.32262  -6.169 6.87e-10 ***
DIST25              -0.17825    0.21174  -0.842  0.39988
DIST50              -0.17825    0.21174  -0.842  0.39989
DIST75              -0.28090    0.21788  -1.289  0.19732
DIST100             -0.25424    0.21624  -1.176  0.23971
DIST150             -0.42608    0.22737  -1.874  0.06094 .
DIST200             -0.42609    0.22737  -1.874  0.06094 .
DIST250             -0.08516    0.20655  -0.412  0.68013
DIST300             -0.17825    0.21174  -0.842  0.39989
DIST400             -0.49061    0.23191  -2.116  0.03439 *
DIST500             -0.15415    0.21036  -0.733  0.46369
Dist_width_over10m1  0.56598    0.20454   2.767  0.00566 **
C_DD:DIST25          1.26226    0.32116   3.930 8.48e-05 ***
C_DD:DIST50          1.31941    0.31988   4.125 3.71e-05 ***
C_DD:DIST75          1.55212    0.32135   4.830 1.36e-06 ***
C_DD:DIST100         1.37824    0.32471   4.245 2.19e-05 ***
C_DD:DIST150         1.63165    0.33137   4.924 8.48e-07 ***
C_DD:DIST200         1.71389    0.32966   5.199 2.00e-07 ***
C_DD:DIST250         1.33196    0.31719   4.199 2.68e-05 ***
C_DD:DIST300         1.41087    0.32091   4.396 1.10e-05 ***
C_DD:DIST400         1.63362    0.33656   4.854 1.21e-06 ***
C_DD:DIST500         1.48208    0.31796   4.661 3.14e-06 ***
```

lmer (species abundance ~ control or disturbed sites * distance from disturbance + disturbance over 3 m wide + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: total_sp ~ C_D * DIST + Dist_width_over3m + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 277.3 361.5 -114.6    229.3
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.15379  0.39216
Number of obs: 247, groups: REP, 24

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)        1.90413    0.20627   9.231  < 2e-16 ***
C_DD              -2.18127    0.36780  -5.931 3.02e-09 ***
DIST25            -0.17825    0.21173  -0.842   0.3999
DIST50            -0.17825    0.21173  -0.842   0.3999
DIST75            -0.28090    0.21788  -1.289   0.1973
DIST100           -0.25424    0.21624  -1.176   0.2397
DIST150           -0.42608    0.22737  -1.874   0.0609 .
```

```
DIST200            -0.42609    0.22737  -1.874   0.0609 .
DIST250            -0.08516    0.20655  -0.412   0.6801
DIST300            -0.17825    0.21174  -0.842   0.3999
DIST400            -0.49063    0.23191  -2.116   0.0344 *
DIST500            -0.15416    0.21036  -0.733   0.4637
Dist_width_over3m   0.60015    0.25484   2.355   0.0185 *
C_DD:DIST25         1.26226    0.32115   3.930 8.48e-05 ***
C_DD:DIST50         1.31942    0.31987   4.125 3.71e-05 ***
C_DD:DIST75         1.55213    0.32134   4.830 1.36e-06 ***
C_DD:DIST100        1.37506    0.32468   4.235 2.28e-05 ***
C_DD:DIST150        1.62557    0.33134   4.906 9.29e-07 ***
C_DD:DIST200        1.70783    0.32963   5.181 2.21e-07 ***
C_DD:DIST250        1.32959    0.31717   4.192 2.77e-05 ***
C_DD:DIST300        1.40850    0.32089   4.389 1.14e-05 ***
C_DD:DIST400        1.63126    0.33654   4.847 1.25e-06 ***
C_DD:DIST500        1.47971    0.31795   4.654 3.26e-06 ***
```

When ascertaining at what point vegetation becomes significantly different to baseline levels (taken to be those at 500 m, distances were reversed and all values compared to those at 500 m.

lmer (species abundance ~ control or disturbed * distance from baseline + disturbance width >10m + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: total_sp ~ C_D * DIST_rev + Dist_width_over10m + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 275.5 359.7 -113.7    227.5
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.14574  0.38176
Number of obs: 247, groups: REP, 24

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          1.75046    0.21166   8.270  < 2e-16 ***
C_DD                -0.50815    0.27849  -1.825  0.06805 .
DIST_revB_400m      -0.33646    0.23914  -1.407  0.15943
DIST_revC_300m      -0.02409    0.21963  -0.110  0.91265
DIST_revD_250m       0.06900    0.21463   0.321  0.74786
DIST_revE_200m      -0.27193    0.23474  -1.158  0.24669
DIST_revF_150m      -0.27193    0.23474  -1.158  0.24669
DIST_revG_100m      -0.10008    0.22397  -0.447  0.65500
DIST_revH_75m       -0.12675    0.22556  -0.562  0.57417
DIST_revI_50m       -0.02409    0.21963  -0.110  0.91265
DIST_revJ_25m       -0.02409    0.21963  -0.110  0.91265
DIST_revK_0m         0.15416    0.21036   0.733  0.46367
Dist_width_over10m1  0.56597    0.20454   2.767  0.00566 **
C_DD:DIST_revB_400m  0.15154    0.29297   0.517  0.60498
C_DD:DIST_revC_300m -0.07122    0.27485  -0.259  0.79555
C_DD:DIST_revD_250m -0.15012    0.27050  -0.555  0.57891
C_DD:DIST_revE_200m  0.23180    0.28517   0.813  0.41631
C_DD:DIST_revF_150m  0.14956    0.28714   0.521  0.60247
C_DD:DIST_revG_100m -0.10385    0.27972  -0.371  0.71044
C_DD:DIST_revH_75m   0.07003    0.27636   0.253  0.79996
C_DD:DIST_revI_50m  -0.16267    0.27465  -0.592  0.55365
C_DD:DIST_revJ_25m  -0.21983    0.27614  -0.796  0.42598
C_DD:DIST_revK_0m   -1.48218    0.31797  -4.661 3.14e-06 ***
```

lmer (species abundance ~ control or disturbed * distance from baseline + disturbance width >3m + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: total_sp ~ C_D * DIST_rev + Dist_width_over3m + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 277.3 361.5 -114.6    229.3
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.15379  0.39216
Number of obs: 247, groups: REP, 24

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          1.74998    0.21436   8.164 3.25e-16 ***
C_DD                -0.70156    0.33037  -2.124   0.0337 *
DIST_revB_400m      -0.33646    0.23913  -1.407   0.1594
DIST_revC_300m      -0.02409    0.21963  -0.110   0.9127
DIST_revD_250m       0.06900    0.21463   0.321   0.7479
DIST_revE_200m      -0.27193    0.23474  -1.158   0.2467
DIST_revF_150m      -0.27192    0.23473  -1.158   0.2467
DIST_revG_100m      -0.10008    0.22397  -0.447   0.6550
DIST_revH_75m       -0.12675    0.22555  -0.562   0.5742
DIST_revI_50m       -0.02409    0.21963  -0.110   0.9126
```

```
DIST_revJ_25m       -0.02409    0.21963  -0.110   0.9126
DIST_revK_0m         0.15415    0.21036   0.733   0.4637
Dist_width_over3m    0.60016    0.25484   2.355   0.0185 *
C_DD:DIST_revB_400m  0.15154    0.29297   0.517   0.6050
C_DD:DIST_revC_300m -0.07122    0.27484  -0.259   0.7955
C_DD:DIST_revD_250m -0.15012    0.27050  -0.555   0.5789
C_DD:DIST_revE_200m  0.22811    0.28518   0.800   0.4238
C_DD:DIST_revF_150m  0.14587    0.28715   0.508   0.6115
C_DD:DIST_revG_100m -0.10466    0.27972  -0.374   0.7083
C_DD:DIST_revH_75m   0.07242    0.27634   0.262   0.7933
C_DD:DIST_revI_50m  -0.16029    0.27463  -0.584   0.5595
C_DD:DIST_revJ_25m  -0.21745    0.27612  -0.788   0.4310
C_DD:DIST_revK_0m   -1.47980    0.31795  -4.654 3.25e-06 ***
```

Percentage cover

Percentage cover data is used in lmer following arcsine square root transformation, which negates the need for an error family to be specified. The percentage cover data were arcsine square root transformed prior to inclusion in models:

transformed percentage cover <- asin(sqrt(percent cover / 100))

Distance from disturbance (0 m):

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -229.8 -145.6  138.9   -384.7  -277.8
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.014249 0.11937
 Residual             0.010424 0.10210
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   0.35757    0.05937   6.023
C_DD         -0.33034    0.07054  -4.683
DIST25       -0.11986    0.05457  -2.196
DIST50       -0.14707    0.05457  -2.695
DIST75       -0.17064    0.05457  -3.127
DIST100      -0.07700    0.05457  -1.411
DIST150      -0.18429    0.05457  -3.377
DIST200      -0.19229    0.05457  -3.523
DIST250      -0.07557    0.05457  -1.385
DIST300      -0.18250    0.05457  -3.344
DIST400      -0.15636    0.05457  -2.865
DIST500      -0.16450    0.05457  -3.014
C_DD:DIST25   0.30727    0.06484   4.739
C_DD:DIST50   0.35428    0.06484   5.463
C_DD:DIST75   0.35914    0.06484   5.539
C_DD:DIST100  0.26427    0.06520   4.053
C_DD:DIST150  0.35259    0.06559   5.376
C_DD:DIST200  0.36559    0.06559   5.574
C_DD:DIST250  0.29913    0.06602   4.531
C_DD:DIST300  0.39113    0.06602   5.925
C_DD:DIST400  0.32609    0.06602   4.939
C_DD:DIST500  0.34141    0.06602   5.172
```

Distance from baseline (500 m):

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -229.8 -145.6  138.9   -384.7  -277.8
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.014249 0.11937
 Residual             0.010424 0.10210
Number of obs: 247, groups: REP, 24

Fixed effects:
                     Estimate Std. Error t value
```

```
(Intercept)           0.193071   0.059368   3.252
C_DD                  0.011078   0.071619   0.155
DIST_revB_400m        0.008143   0.054575   0.149
DIST_revC_300m       -0.018000   0.054575  -0.330
DIST_revD_250m        0.088929   0.054575   1.629
DIST_revE_200m       -0.027786   0.054575  -0.509
DIST_revF_150m       -0.019786   0.054575  -0.363
DIST_revG_100m        0.087500   0.054575   1.603
DIST_revH_75m        -0.006143   0.054575  -0.113
DIST_revI_50m         0.017429   0.054575   0.319
DIST_revJ_25m         0.044643   0.054575   0.818
DIST_revK_0m          0.164500   0.054575   3.014
C_DD:DIST_revB_400m -0.015321   0.066840  -0.229
C_DD:DIST_revC_300m  0.049714   0.066840   0.744
C_DD:DIST_revD_250m -0.042286   0.066840  -0.633
C_DD:DIST_revE_200m  0.024175   0.066516   0.363
C_DD:DIST_revF_150m  0.011175   0.066516   0.168
C_DD:DIST_revG_100m -0.077145   0.066246  -1.165
C_DD:DIST_revH_75m   0.017728   0.066017   0.269
C_DD:DIST_revI_50m   0.012863   0.066017   0.195
C_DD:DIST_revJ_25m  -0.034146   0.066017  -0.517
C_DD:DIST_revK_0m   -0.341415   0.066017  -5.172
```

Taxonomic group level analyses

Chenopodaceae

Species abundance

Chenopodaceae species abundance required square root transformation, therefore an error family is not specified in the models.

lmer (species abundance ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: sqrt(CH_total_sp + 1) ~ C_D * DIST + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance REMLdev
 191.9 276.1 -71.94    78.27   143.9
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.036926 0.19216
 Residual             0.074113 0.27224
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   1.95261    0.12595  15.504
C_DD         -0.76903    0.14965  -5.139
DIST25       -0.11741    0.14552  -0.807
DIST50       -0.01492    0.14552  -0.103
DIST75       -0.08368    0.14552  -0.575
DIST100      -0.09537    0.14552  -0.655
DIST150      -0.35678    0.14552  -2.452
DIST200      -0.14401    0.14552  -0.990
DIST250      -0.09081    0.14552  -0.624
DIST300      -0.09147    0.14552  -0.629
DIST400      -0.31137    0.14552  -2.140
DIST500      -0.07200    0.14552  -0.495
C_DD:DIST25   0.56508    0.17290   3.268
C_DD:DIST50   0.44014    0.17290   2.546
C_DD:DIST75   0.52381    0.17290   3.030
C_DD:DIST100  0.49990    0.17382   2.876
C_DD:DIST150  0.76613    0.17483   4.382
C_DD:DIST200  0.70532    0.17483   4.034
C_DD:DIST250  0.63263    0.17595   3.596
C_DD:DIST300  0.56186    0.17595   3.193
C_DD:DIST400  0.68478    0.17595   3.892
C_DD:DIST500  0.54088    0.17595   3.074
```

lmer (species abundance ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: sqrt(CH_total_sp + 1) ~ C_D * DIST_rev + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance REMLdev
 191.9 276.1 -71.94    78.27   143.9
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.036926 0.19216
 Residual             0.074113 0.27224
```

```
Number of obs: 247, groups: REP, 24

Fixed effects:
                    Estimate Std. Error t value
(Intercept)          1.88061    0.12595  14.932
C_DD                -0.22815    0.15316  -1.490
DIST_revB_400m      -0.23937    0.14552  -1.645
DIST_revC_300m      -0.01947    0.14552  -0.134
DIST_revD_250m      -0.01881    0.14552  -0.129
DIST_revE_200m      -0.07200    0.14552  -0.495
DIST_revF_150m      -0.28478    0.14552  -1.957
DIST_revG_100m      -0.02336    0.14552  -0.161
DIST_revH_75m       -0.01168    0.14552  -0.080
DIST_revI_50m        0.05709    0.14552   0.392
DIST_revJ_25m       -0.04541    0.14552  -0.312
DIST_revK_0m         0.07200    0.14552   0.495
C_DD:DIST_revB_400m  0.14390    0.17822   0.807
C_DD:DIST_revC_300m  0.02098    0.17822   0.118
C_DD:DIST_revD_250m  0.09175    0.17822   0.515
C_DD:DIST_revE_200m  0.16444    0.17734   0.927
C_DD:DIST_revF_150m  0.22526    0.17734   1.270
C_DD:DIST_revG_100m -0.04098    0.17659  -0.232
C_DD:DIST_revH_75m  -0.01707    0.17595  -0.097
C_DD:DIST_revI_50m  -0.10074    0.17595  -0.573
C_DD:DIST_revJ_25m   0.02420    0.17595   0.138
C_DD:DIST_revK_0m   -0.54088    0.17595  -3.074
```

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: CH_intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -104.6 -20.42  76.32   -247.3  -152.6
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.016385 0.12800
 Residual             0.018939 0.13762
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   0.52942    0.07104   7.453
C_DD         -0.45887    0.08440  -5.437
DIST25       -0.11901    0.07356  -1.618
DIST50       -0.14095    0.07356  -1.916
DIST75       -0.18048    0.07356  -2.453
DIST100      -0.13015    0.07356  -1.769
DIST150      -0.20031    0.07356  -2.723
DIST200      -0.17557    0.07356  -2.387
DIST250      -0.09416    0.07356  -1.280
DIST300      -0.20742    0.07356  -2.820
DIST400      -0.16719    0.07356  -2.273
DIST500      -0.14429    0.07356  -1.961
C_DD:DIST25   0.35619    0.08740   4.075
C_DD:DIST50   0.40975    0.08740   4.688
C_DD:DIST75   0.41109    0.08740   4.703
C_DD:DIST100  0.40343    0.08788   4.591
C_DD:DIST150  0.43888    0.08840   4.965
C_DD:DIST200  0.44690    0.08840   5.056
C_DD:DIST250  0.43701    0.08897   4.912
C_DD:DIST300  0.52306    0.08897   5.879
C_DD:DIST400  0.39978    0.08897   4.494
C_DD:DIST500  0.36319    0.08897   4.082
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: CH_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -104.6 -20.42  76.32   -247.3  -152.6
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.016385 0.12800
 Residual             0.018939 0.13762
Number of obs: 247, groups: REP, 24

Fixed effects:
                     Estimate Std. Error t value
(Intercept)          0.385137   0.071036   5.422
C_DD                -0.095682   0.086023  -1.112
DIST_revB_400m      -0.022901   0.073560  -0.311
```

```
DIST_revC_300m      -0.063137   0.073560  -0.858
DIST_revD_250m       0.050130   0.073560   0.681
DIST_revE_200m      -0.031283   0.073560  -0.425
DIST_revF_150m      -0.056019   0.073560  -0.762
DIST_revG_100m       0.014138   0.073560   0.192
DIST_revH_75m       -0.036190   0.073560  -0.492
DIST_revI_50m        0.003335   0.073560   0.045
DIST_revJ_25m        0.025276   0.073560   0.344
DIST_revK_0m         0.144287   0.073560   1.961
C_DD:DIST_revB_400m  0.036589   0.090092   0.406
C_DD:DIST_revC_300m  0.159873   0.090092   1.775
C_DD:DIST_revD_250m  0.073823   0.090092   0.819
C_DD:DIST_revE_200m  0.083714   0.089651   0.934
C_DD:DIST_revF_150m  0.075690   0.089651   0.844
C_DD:DIST_revG_100m  0.040237   0.089282   0.451
C_DD:DIST_revH_75m   0.047901   0.088967   0.538
C_DD:DIST_revI_50m   0.046560   0.088967   0.523
C_DD:DIST_revJ_25m  -0.007001   0.088967  -0.079
C_DD:DIST_revK_0m   -0.363189   0.088967  -4.082
```

Herbaceous flowering plants

Species abundance

lmer (species abundance ~ control or disturbed * distance from disturbance + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: Herbaceous_total_sp ~ C_D * DIST + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 257.1 337.8 -105.6    211.1
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.40678  0.63779
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    0.3841     0.3806   1.009  0.31289
C_DD          -2.0249     0.6508  -3.111  0.00186 **
DIST25        -0.4055     0.4581  -0.885  0.37605
DIST50        -0.6932     0.5018  -1.381  0.16716
DIST75        -0.4055     0.4581  -0.885  0.37605
DIST100       -0.5390     0.4773  -1.129  0.25877
DIST150       -0.6932     0.5018  -1.381  0.16716
DIST200       -1.0986     0.5794  -1.896  0.05794 .
DIST250       -0.1823     0.4297  -0.424  0.67133
DIST300       -0.5390     0.4773  -1.129  0.25877
DIST400       -1.0986     0.5794  -1.896  0.05794 .
DIST500       -0.6932     0.5018  -1.381  0.16716
C_DD:DIST25    1.4171     0.7450   1.902  0.05716 .
C_DD:DIST50    2.1401     0.7513   2.848  0.00439 **
C_DD:DIST75    2.0149     0.7167   2.812  0.00493 **
C_DD:DIST100   1.8490     0.7441   2.485  0.01296 *
C_DD:DIST150   1.9912     0.7641   2.606  0.00916 **
C_DD:DIST200   2.5398     0.8108   3.133  0.00173 **
C_DD:DIST250   1.5799     0.7150   2.210  0.02713 *
C_DD:DIST300   1.8624     0.7482   2.489  0.01281 *
C_DD:DIST400   2.5651     0.8108   3.164  0.00156 **
C_DD:DIST500   2.3419     0.7499   3.123  0.00179 **
```

lmer (species abundance ~ control or disturbed * distance from baseline + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: Herbaceous_total_sp ~ C_D * DIST_rev + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 257.1 337.8 -105.6    211.1
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 0.40678  0.63779
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)         -3.091e-01  4.783e-01  -0.646  0.51811
C_DD                 3.171e-01  5.590e-01   0.567  0.57045
DIST_revB_400m      -4.055e-01  6.478e-01  -0.626  0.53136
DIST_revC_300m       1.542e-01  5.583e-01   0.276  0.78247
DIST_revD_250m       5.108e-01  5.182e-01   0.986  0.32429
DIST_revE_200m      -4.055e-01  6.478e-01  -0.626  0.53137
```

```
DIST_revF_150m       1.874e-06  5.794e-01   0.000  1.00000
DIST_revG_100m       1.542e-01  5.583e-01   0.276  0.78247
DIST_revH_75m        2.877e-01  5.420e-01   0.531  0.59555
DIST_revI_50m        5.456e-06  5.794e-01   0.000  0.99999
DIST_revJ_25m        2.877e-01  5.420e-01   0.531  0.59555
DIST_revK_0m         6.932e-01  5.018e-01   1.381  0.16716
C_DD:DIST_revB_400m  2.231e-01  7.368e-01   0.303  0.76199
C_DD:DIST_revC_300m -4.796e-01  6.673e-01  -0.719  0.47234
C_DD:DIST_revD_250m -7.621e-01  6.298e-01  -1.210  0.22621
C_DD:DIST_revE_200m  1.978e-01  7.369e-01   0.268  0.78839
C_DD:DIST_revF_150m -3.508e-01  6.852e-01  -0.512  0.60870
C_DD:DIST_revG_100m -4.930e-01  6.638e-01  -0.743  0.45772
C_DD:DIST_revH_75m  -3.271e-01  6.338e-01  -0.516  0.60583
C_DD:DIST_revI_50m  -2.019e-01  6.728e-01  -0.300  0.76409
C_DD:DIST_revJ_25m  -9.249e-01  6.657e-01  -1.389  0.16472
C_DD:DIST_revK_0m   -2.342e+00  7.499e-01  -3.123  0.00179 **
```

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: HB_intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -150.5 -66.23  99.23   -297.6  -198.5
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.011110 0.10540
 Residual             0.015722 0.12539
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   0.21748    0.06191   3.513
C_DD         -0.20785    0.07356  -2.826
DIST25       -0.10069    0.06702  -1.502
DIST50       -0.11054    0.06702  -1.649
DIST75       -0.12450    0.06702  -1.858
DIST100      -0.02040    0.06702  -0.304
DIST150      -0.13894    0.06702  -2.073
DIST200      -0.17206    0.06702  -2.567
DIST250      -0.10124    0.06702  -1.511
DIST300      -0.06742    0.06702  -1.006
DIST400      -0.12787    0.06702  -1.908
DIST500      -0.10617    0.06702  -1.584
C_DD:DIST25   0.20002    0.07963   2.512
C_DD:DIST50   0.29163    0.07963   3.662
C_DD:DIST75   0.30633    0.07963   3.847
C_DD:DIST100  0.15297    0.08006   1.911
C_DD:DIST150  0.26233    0.08053   3.257
C_DD:DIST200  0.31351    0.08053   3.893
C_DD:DIST250  0.21119    0.08105   2.606
C_DD:DIST300  0.21235    0.08105   2.620
C_DD:DIST400  0.27437    0.08105   3.385
C_DD:DIST500  0.25470    0.08105   3.142
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: HB_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -150.5 -66.23  99.23   -297.6  -198.5
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.011110 0.10540
 Residual             0.015722 0.12539
Number of obs: 247, groups: REP, 24

Fixed effects:
                     Estimate Std. Error t value
(Intercept)          0.111313   0.061911   1.798
C_DD                 0.046844   0.075095   0.624
DIST_revB_400m      -0.021703   0.067021  -0.324
DIST_revC_300m       0.038755   0.067021   0.578
DIST_revD_250m       0.004931   0.067021   0.074
DIST_revE_200m      -0.065890   0.067021  -0.983
DIST_revF_150m      -0.032771   0.067021  -0.489
DIST_revG_100m       0.085769   0.067021   1.280
DIST_revH_75m       -0.018324   0.067021  -0.273
DIST_revI_50m       -0.004367   0.067021  -0.065
DIST_revJ_25m        0.005484   0.067021   0.082
DIST_revK_0m         0.106172   0.067021   1.584
C_DD:DIST_revB_400m  0.019670   0.082084   0.240
```

```
C_DD:DIST_revC_300m -0.042344   0.082084  -0.516
C_DD:DIST_revD_250m -0.043506   0.082084  -0.530
C_DD:DIST_revE_200m  0.058811   0.081681   0.720
C_DD:DIST_revF_150m  0.007636   0.081681   0.094
C_DD:DIST_revG_100m -0.101730   0.081342  -1.251
C_DD:DIST_revH_75m   0.051628   0.081052   0.637
C_DD:DIST_revI_50m   0.036936   0.081052   0.456
C_DD:DIST_revJ_25m  -0.054676   0.081052  -0.675
C_DD:DIST_revK_0m   -0.254699   0.081052  -3.142
```

Poaceae

Species abundance

Poaceae species abundance required transformation, hence an error family is not specified.

lmer (species abundance ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: (PO_total_sp + 1)^-1 ~ C_D * DIST + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance REMLdev
 39.46 123.7  4.272    -89.1  -8.543
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.029781 0.17257
 Residual             0.036080 0.18995
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   0.50000    0.09700   5.155
C_DD          0.43137    0.11525   3.743
DIST25        0.21429    0.10153   2.111
DIST50        0.21429    0.10153   2.111
DIST75        0.21429    0.10153   2.111
DIST100       0.21429    0.10153   2.111
DIST150       0.19048    0.10153   1.876
DIST200       0.26190    0.10153   2.580
DIST250       0.09524    0.10153   0.938
DIST300       0.11905    0.10153   1.173
DIST400       0.11905    0.10153   1.173
DIST500       0.09524    0.10153   0.938
C_DD:DIST25  -0.32213    0.12064  -2.670
C_DD:DIST50  -0.29272    0.12064  -2.426
C_DD:DIST75  -0.36134    0.12064  -2.995
C_DD:DIST100 -0.31545    0.12129  -2.601
C_DD:DIST150 -0.27239    0.12201  -2.233
C_DD:DIST200 -0.37716    0.12201  -3.091
C_DD:DIST250 -0.23776    0.12279  -1.936
C_DD:DIST300 -0.30919    0.12279  -2.518
C_DD:DIST400 -0.23776    0.12279  -1.936
C_DD:DIST500 -0.26157    0.12279  -2.130
```

lmer (species abundance ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: (PO_total_sp + 1)^-1 ~ C_D * DIST_rev + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance REMLdev
 39.46 123.7  4.272    -89.1  -8.543
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.029781 0.17257
 Residual             0.036080 0.18995
Number of obs: 247, groups: REP, 24

Fixed effects:
                     Estimate Std. Error t value
(Intercept)         5.952e-01  9.700e-02   6.137
C_DD                1.698e-01  1.175e-01   1.445
DIST_revB_400m      2.381e-02  1.015e-01   0.235
DIST_revC_300m      2.381e-02  1.015e-01   0.235
DIST_revD_250m      9.260e-16  1.015e-01   0.000
DIST_revE_200m      1.667e-01  1.015e-01   1.642
DIST_revF_150m      9.524e-02  1.015e-01   0.938
DIST_revG_100m      1.190e-01  1.015e-01   1.173
DIST_revH_75m       1.190e-01  1.015e-01   1.173
DIST_revI_50m       1.190e-01  1.015e-01   1.173
DIST_revJ_25m       1.190e-01  1.015e-01   1.173
DIST_revK_0m       -9.524e-02  1.015e-01  -0.938
C_DD:DIST_revB_400m  2.381e-02  1.243e-01   0.191
C_DD:DIST_revC_300m -4.762e-02  1.243e-01  -0.383
```

```
C_DD:DIST_revD_250m  2.381e-02  1.243e-01   0.191
C_DD:DIST_revE_200m -1.156e-01  1.237e-01  -0.934
C_DD:DIST_revF_150m -1.082e-02  1.237e-01  -0.087
C_DD:DIST_revG_100m -5.388e-02  1.232e-01  -0.437
C_DD:DIST_revH_75m  -9.978e-02  1.228e-01  -0.813
C_DD:DIST_revI_50m  -3.115e-02  1.228e-01  -0.254
C_DD:DIST_revJ_25m  -6.056e-02  1.228e-01  -0.493
C_DD:DIST_revK_0m    2.616e-01  1.228e-01   2.130
```

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: PO_intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -478.4 -394.2  263.2   -657.7  -526.4
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0045243 0.067263
 Residual             0.0034672 0.058883
Number of obs: 247, groups: REP, 24

Fixed effects:
              Estimate Std. Error t value
(Intercept)   0.113734   0.033787   3.366
C_DD         -0.107710   0.040145  -2.683
DIST25       -0.032854   0.031474  -1.044
DIST50       -0.047365   0.031474  -1.505
DIST75       -0.048881   0.031474  -1.553
DIST100      -0.055479   0.031474  -1.763
DIST150      -0.017995   0.031474  -0.572
DIST200      -0.051445   0.031474  -1.635
DIST250      -0.004413   0.031474  -0.140
DIST300      -0.031629   0.031474  -1.005
DIST400      -0.052682   0.031474  -1.674
DIST500      -0.022928   0.031474  -0.728
C_DD:DIST25   0.112216   0.037397   3.001
C_DD:DIST50   0.092638   0.037397   2.477
C_DD:DIST75   0.077819   0.037397   2.081
C_DD:DIST100  0.080369   0.037602   2.137
C_DD:DIST150  0.039795   0.037827   1.052
C_DD:DIST200  0.083128   0.037827   2.198
C_DD:DIST250  0.040034   0.038073   1.052
C_DD:DIST300  0.071034   0.038073   1.866
C_DD:DIST400  0.070560   0.038073   1.853
C_DD:DIST500  0.079630   0.038073   2.092
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: PO_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -478.4 -394.2  263.2   -657.7  -526.4
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0045243 0.067263
 Residual             0.0034672 0.058883
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error t value
(Intercept)          0.0908062  0.0337870   2.688
C_DD                -0.0280800  0.0407753  -0.689
DIST_revB_400m      -0.0297547  0.0314740  -0.945
DIST_revC_300m      -0.0087014  0.0314740  -0.276
DIST_revD_250m       0.0185146  0.0314740   0.588
DIST_revE_200m      -0.0285171  0.0314740  -0.906
DIST_revF_150m       0.0049331  0.0314740   0.157
DIST_revG_100m      -0.0325518  0.0314740  -1.034
DIST_revH_75m       -0.0259537  0.0314740  -0.825
DIST_revI_50m       -0.0244370  0.0314740  -0.776
DIST_revJ_25m       -0.0099266  0.0314740  -0.315
DIST_revK_0m         0.0229276  0.0314740   0.728
C_DD:DIST_revB_400m -0.0090707  0.0385477  -0.235
C_DD:DIST_revC_300m -0.0085968  0.0385477  -0.223
C_DD:DIST_revD_250m -0.0395962  0.0385477  -1.027
C_DD:DIST_revE_200m  0.0034975  0.0383606   0.091
C_DD:DIST_revF_150m -0.0398358  0.0383606  -1.038
C_DD:DIST_revG_100m  0.0007383  0.0382047   0.019
C_DD:DIST_revH_75m  -0.0018113  0.0380726  -0.048
C_DD:DIST_revI_50m   0.0130080  0.0380726   0.342
C_DD:DIST_revJ_25m   0.0325860  0.0380726   0.856
C_DD:DIST_revK_0m   -0.0796304  0.0380726  -2.091
```

Non-woody succulents

Species abundance

lmer (species abundance ~ control or disturbed * distance from disturbance + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: SU_total_sp ~ C_D * DIST + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 178.9 259.6 -66.46    132.9
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 1.6988   1.3034
Number of obs: 247, groups: REP, 24

Fixed effects:
               Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.328e+00  9.641e-01  -2.415   0.0157 *
C_DD          4.998e-01  1.121e+00   0.446   0.6557
DIST25        1.961e-06  1.035e+00   0.000   1.0000
DIST50       -1.394e-06  1.035e+00   0.000   1.0000
DIST75       -6.931e-01  1.268e+00  -0.547   0.5845
DIST100      -1.707e+01  3.721e+03  -0.005   0.9963
DIST150      -1.705e+01  3.680e+03  -0.005   0.9963
DIST200      -3.528e-07  1.035e+00   0.000   1.0000
DIST250      -1.707e+01  3.726e+03  -0.005   0.9963
DIST300      -6.931e-01  1.268e+00  -0.547   0.5845
DIST400      -1.707e+01  3.726e+03  -0.005   0.9963
DIST500      -6.931e-01  1.268e+00  -0.547   0.5845
C_DD:DIST25   3.365e-01  1.195e+00   0.282   0.7782
C_DD:DIST50  -9.163e-01  1.341e+00  -0.684   0.4943
C_DD:DIST75   6.931e-01  1.422e+00   0.488   0.6259
C_DD:DIST100  1.709e+01  3.721e+03   0.005   0.9963
C_DD:DIST150  1.736e+01  3.680e+03   0.005   0.9962
C_DD:DIST200  1.332e-01  1.220e+00   0.109   0.9131
C_DD:DIST250  1.631e+01  3.726e+03   0.004   0.9965
C_DD:DIST300 -7.021e-02  1.527e+00  -0.046   0.9633
C_DD:DIST400  1.700e+01  3.726e+03   0.005   0.9964
C_DD:DIST500  6.228e-01  1.441e+00   0.432   0.6655
```

lmer (species abundance ~ control or disturbed * distance from baseline + (1|transect), family = poisson)

```
Generalized linear mixed model fit by the Laplace approximation
Formula: SU_total_sp ~ C_D * DIST_rev + (1 | REP)
   Data: veg
   AIC   BIC logLik deviance
 178.9 259.6 -66.46    132.9
Random effects:
 Groups Name        Variance Std.Dev.
 REP    (Intercept) 1.6988   1.3034
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)         -3.021e+00  1.210e+00  -2.496   0.0126 *
C_DD                 1.123e+00  1.359e+00   0.826   0.4088
DIST_revB_400m      -1.636e+01  3.688e+03  -0.004   0.9965
DIST_revC_300m      -5.951e-06  1.464e+00   0.000   1.0000
DIST_revD_250m      -1.636e+01  3.688e+03  -0.004   0.9965
DIST_revE_200m       6.931e-01  1.268e+00   0.547   0.5845
DIST_revF_150m      -1.633e+01  3.643e+03  -0.004   0.9964
DIST_revG_100m      -1.635e+01  3.683e+03  -0.004   0.9965
DIST_revH_75m       -4.026e-06  1.464e+00   0.000   1.0000
DIST_revI_50m        6.931e-01  1.268e+00   0.547   0.5845
DIST_revJ_25m        6.931e-01  1.268e+00   0.547   0.5845
DIST_revK_0m         6.931e-01  1.268e+00   0.547   0.5845
C_DD:DIST_revB_400m  1.636e+01  3.688e+03   0.004   0.9965
C_DD:DIST_revC_300m -6.931e-01  1.707e+00  -0.406   0.6847
C_DD:DIST_revD_250m  1.566e+01  3.688e+03   0.004   0.9966
C_DD:DIST_revE_200m -4.897e-01  1.439e+00  -0.340   0.7336
C_DD:DIST_revF_150m  1.672e+01  3.643e+03   0.005   0.9963
C_DD:DIST_revG_100m  1.645e+01  3.683e+03   0.004   0.9964
C_DD:DIST_revH_75m   7.021e-02  1.616e+00   0.043   0.9653
C_DD:DIST_revI_50m  -1.539e+00  1.545e+00  -0.996   0.3191
C_DD:DIST_revJ_25m  -2.865e-01  1.420e+00  -0.202   0.8401
C_DD:DIST_revK_0m   -6.230e-01  1.441e+00  -0.432   0.6654
```

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: SU_intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -732.6 -648.4  390.3   -936.6  -780.6
Random effects:
 Groups   Name        Variance   Std.Dev.
 REP      (Intercept) 0.00041785 0.020441
 Residual             0.00125647 0.035447
Number of obs: 247, groups: REP, 24

Fixed effects:
               Estimate Std. Error t value
(Intercept)   0.0126801  0.0154654   0.820
C_DD          0.0196714  0.0183756   1.070
DIST25       -0.0011500  0.0189471  -0.061
DIST50        0.0188743  0.0189471   0.996
DIST75        0.0132155  0.0189471   0.698
DIST100      -0.0126801  0.0189471  -0.669
DIST150      -0.0126801  0.0189471  -0.669
DIST200      -0.0030945  0.0189471  -0.163
DIST250      -0.0126801  0.0189471  -0.669
DIST300       0.0019842  0.0189471   0.105
DIST400      -0.0126801  0.0189471  -0.669
DIST500      -0.0002927  0.0189471  -0.016
C_DD:DIST25  -0.0065834  0.0225125  -0.292
C_DD:DIST50  -0.0389485  0.0225125  -1.730
C_DD:DIST75  -0.0317864  0.0225125  -1.412
C_DD:DIST100  0.0040215  0.0226294   0.178
C_DD:DIST150  0.0009655  0.0227592   0.042
C_DD:DIST200 -0.0066480  0.0227592  -0.292
C_DD:DIST250 -0.0103085  0.0229033  -0.450
C_DD:DIST300 -0.0260328  0.0229033  -1.137
C_DD:DIST400 -0.0028494  0.0229033  -0.124
C_DD:DIST500  0.0010557  0.0229033   0.046
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: SU_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -732.6 -648.4  390.3   -936.6  -780.6
Random effects:
 Groups   Name        Variance   Std.Dev.
 REP      (Intercept) 0.00041785 0.020441
 Residual             0.00125647 0.035447
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error t value
(Intercept)          1.239e-02  1.547e-02   0.801
C_DD                 2.073e-02  1.885e-02   1.099
DIST_revB_400m      -1.239e-02  1.895e-02  -0.654
DIST_revC_300m       2.277e-03  1.895e-02   0.120
DIST_revD_250m      -1.239e-02  1.895e-02  -0.654
DIST_revE_200m      -2.802e-03  1.895e-02  -0.148
DIST_revF_150m      -1.239e-02  1.895e-02  -0.654
DIST_revG_100m      -1.239e-02  1.895e-02  -0.654
DIST_revH_75m        1.351e-02  1.895e-02   0.713
DIST_revI_50m        1.917e-02  1.895e-02   1.012
DIST_revJ_25m       -8.573e-04  1.895e-02  -0.045
DIST_revK_0m         2.927e-04  1.895e-02   0.016
C_DD:DIST_revB_400m -3.905e-03  2.321e-02  -0.168
C_DD:DIST_revC_300m -2.709e-02  2.321e-02  -1.167
C_DD:DIST_revD_250m -1.136e-02  2.321e-02  -0.490
C_DD:DIST_revE_200m -7.704e-03  2.309e-02  -0.334
C_DD:DIST_revF_150m -9.017e-05  2.309e-02  -0.004
C_DD:DIST_revG_100m  2.966e-03  2.299e-02   0.129
C_DD:DIST_revH_75m  -3.284e-02  2.290e-02  -1.434
C_DD:DIST_revI_50m  -4.000e-02  2.290e-02  -1.747
C_DD:DIST_revJ_25m  -7.639e-03  2.290e-02  -0.334
C_DD:DIST_revK_0m   -1.056e-03  2.290e-02  -0.046
```

Woody shrubs

Species abundance

Woody shrub species abundance required square root transformation, negating the need for inclusion of an error family within the model.

lmer(species abundance ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: sqrt(WS_total_sp + 1) ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC   BIC logLik deviance REMLdev
 -24.56 59.67  36.28   -159.4  -72.56
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.019473 0.13954
 Residual             0.027507 0.16585
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   1.34127    0.08192  16.373
C_DD         -0.29254    0.09734  -3.005
DIST25       -0.05917    0.08865  -0.667
DIST50        0.01377    0.08865   0.155
DIST75        0.01377    0.08865   0.155
DIST100       0.01377    0.08865   0.155
DIST150      -0.05917    0.08865  -0.667
DIST200      -0.22293    0.08865  -2.515
DIST250      -0.05917    0.08865  -0.667
DIST300      -0.10458    0.08865  -1.180
DIST400       0.07294    0.08865   0.823
DIST500      -0.05917    0.08865  -0.667
C_DD:DIST25   0.24843    0.10533   2.358
C_DD:DIST50   0.19985    0.10533   1.897
C_DD:DIST75   0.19985    0.10533   1.897
C_DD:DIST100  0.21290    0.10590   2.010
C_DD:DIST150  0.30582    0.10652   2.871
C_DD:DIST200  0.38673    0.10652   3.630
C_DD:DIST250  0.28043    0.10721   2.616
C_DD:DIST300  0.38501    0.10721   3.591
C_DD:DIST400  0.20749    0.10721   1.935
C_DD:DIST500  0.25773    0.10721   2.404
```

lmer (species abundance ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: sqrt(WS_total_sp + 1) ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC   BIC logLik deviance REMLdev
 -24.56 59.67  36.28   -159.4  -72.56
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.019473 0.13954
 Residual             0.027507 0.16585
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error t value
(Intercept)          1.282e+00  8.192e-02  15.650
C_DD                -3.481e-02  9.937e-02  -0.350
DIST_revB_400m       1.321e-01  8.865e-02   1.490
DIST_revC_300m      -4.541e-02  8.865e-02  -0.512
DIST_revD_250m      -1.438e-15  8.865e-02   0.000
DIST_revE_200m      -1.638e-01  8.865e-02  -1.847
DIST_revF_150m      -1.453e-15  8.865e-02   0.000
DIST_revG_100m       7.294e-02  8.865e-02   0.823
DIST_revH_75m        7.294e-02  8.865e-02   0.823
DIST_revI_50m        7.294e-02  8.865e-02   0.823
DIST_revJ_25m       -1.442e-15  8.865e-02   0.000
DIST_revK_0m         5.917e-02  8.865e-02   0.667
C_DD:DIST_revB_400m -5.024e-02  1.086e-01  -0.463
C_DD:DIST_revC_300m  1.273e-01  1.086e-01   1.172
C_DD:DIST_revD_250m  2.270e-02  1.086e-01   0.209
C_DD:DIST_revE_200m  1.290e-01  1.080e-01   1.194
C_DD:DIST_revF_150m  4.810e-02  1.080e-01   0.445
C_DD:DIST_revG_100m -4.482e-02  1.076e-01  -0.417
C_DD:DIST_revH_75m  -5.787e-02  1.072e-01  -0.540
C_DD:DIST_revI_50m  -5.787e-02  1.072e-01  -0.540
C_DD:DIST_revJ_25m  -9.299e-03  1.072e-01  -0.087
C_DD:DIST_revK_0m   -2.577e-01  1.072e-01  -2.404
```

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: WS_intercept ~ C_D * DIST + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -356.4 -272.1  202.2   -523.5  -404.4
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0024029 0.049020
 Residual             0.0066474 0.081531
Number of obs: 247, groups: REP, 24

Fixed effects:
              Estimate Std. Error t value
(Intercept)   0.099826   0.035956   2.776
C_DD         -0.095687   0.042722  -2.240
DIST25       -0.014209   0.043580  -0.326
DIST50       -0.045258   0.043580  -1.038
DIST75        0.003520   0.043580   0.081
DIST100       0.010632   0.043580   0.244
DIST150      -0.026440   0.043580  -0.607
DIST200      -0.053540   0.043580  -1.228
DIST250       0.036847   0.043580   0.846
DIST300      -0.058864   0.043580  -1.351
DIST400      -0.001082   0.043580  -0.025
DIST500      -0.061275   0.043580  -1.406
C_DD:DIST25   0.091864   0.051781   1.774
C_DD:DIST50   0.139248   0.051781   2.689
C_DD:DIST75   0.086633   0.051781   1.673
C_DD:DIST100  0.077831   0.052051   1.495
C_DD:DIST150  0.115465   0.052351   2.206
C_DD:DIST200  0.110845   0.052351   2.117
C_DD:DIST250  0.061900   0.052683   1.175
C_DD:DIST300  0.155561   0.052683   2.953
C_DD:DIST400  0.126100   0.052683   2.394
C_DD:DIST500  0.154822   0.052683   2.939
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: WS_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: veg
    AIC    BIC logLik deviance REMLdev
 -356.4 -272.1  202.2   -523.5  -404.4
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0024029 0.049020
 Residual             0.0066474 0.081531
Number of obs: 247, groups: REP, 24

Fixed effects:
                      Estimate Std. Error t value
(Intercept)          0.0385514  0.0359563   1.072
C_DD                 0.0591353  0.0438112   1.350
DIST_revB_400m       0.0601927  0.0435803   1.381
DIST_revC_300m       0.0024103  0.0435803   0.055
DIST_revD_250m       0.0981215  0.0435803   2.252
DIST_revE_200m       0.0077350  0.0435803   0.178
DIST_revF_150m       0.0348343  0.0435803   0.799
DIST_revG_100m       0.0719063  0.0435803   1.650
DIST_revH_75m        0.0647945  0.0435803   1.487
DIST_revI_50m        0.0160165  0.0435803   0.368
DIST_revJ_25m        0.0470652  0.0435803   1.080
DIST_revK_0m         0.0612747  0.0435803   1.406
C_DD:DIST_revB_400m -0.0287217  0.0533748  -0.538
C_DD:DIST_revC_300m  0.0007393  0.0533748   0.014
C_DD:DIST_revD_250m -0.0929221  0.0533748  -1.741
C_DD:DIST_revE_200m -0.0439768  0.0531080  -0.828
C_DD:DIST_revF_150m -0.0393567  0.0531080  -0.741
C_DD:DIST_revG_100m -0.0769914  0.0528803  -1.456
C_DD:DIST_revH_75m  -0.0681891  0.0526830  -1.294
C_DD:DIST_revI_50m  -0.0155742  0.0526830  -0.296
C_DD:DIST_revJ_25m  -0.0629578  0.0526830  -1.195
C_DD:DIST_revK_0m   -0.1548221  0.0526830  -2.939
```

Species-level analyses

Percentage cover data were arcsine square root transformed prior to inclusion in models.

Anabasis salsa

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
Formula: AS_intercept ~ C_D * DIST + (1 | REP)
   Data: species
    AIC    BIC logLik deviance REMLdev
 -258.6 -174.3  153.3   -416.3  -306.6
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0116074 0.107738
 Residual             0.0092442 0.096147
Number of obs: 247, groups: REP, 24

Fixed effects:
             Estimate Std. Error t value
(Intercept)   0.20941    0.05458   3.837
C_DD         -0.15787    0.06485  -2.435
DIST25       -0.08000    0.05139  -1.557
DIST50       -0.08129    0.05139  -1.582
DIST75       -0.07823    0.05139  -1.522
DIST100      -0.09956    0.05139  -1.937
DIST150      -0.16474    0.05139  -3.206
DIST200      -0.07668    0.05139  -1.492
DIST250      -0.11250    0.05139  -2.189
DIST300      -0.04983    0.05139  -0.970
DIST400      -0.07684    0.05139  -1.495
DIST500      -0.07118    0.05139  -1.385
C_DD:DIST25   0.14058    0.06106   2.302
C_DD:DIST50   0.11075    0.06106   1.814
C_DD:DIST75   0.12015    0.06106   1.968
C_DD:DIST100  0.18175    0.06140   2.960
C_DD:DIST150  0.20600    0.06177   3.335
C_DD:DIST200  0.15274    0.06177   2.473
C_DD:DIST250  0.14859    0.06217   2.390
C_DD:DIST300  0.15065    0.06217   2.423
C_DD:DIST400  0.12003    0.06217   1.931
C_DD:DIST500  0.15532    0.06217   2.498
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: AS_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: species
    AIC    BIC logLik deviance REMLdev
 -258.6 -174.3  153.3   -416.3  -306.6
Random effects:
 Groups   Name        Variance  Std.Dev.
 REP      (Intercept) 0.0116074 0.107738
 Residual             0.0092442 0.096147
Number of obs: 247, groups: REP, 24

Fixed effects:
                    Estimate Std. Error t value
(Intercept)         0.138230   0.054577   2.533
C_DD               -0.002554   0.065887  -0.039
DIST_revB_400      -0.005664   0.051392  -0.110
DIST_revC_300       0.021351   0.051392   0.415
DIST_revD_250      -0.041318   0.051392  -0.804
DIST_revE_200      -0.005497   0.051392  -0.107
DIST_revF_150      -0.093561   0.051392  -1.820
DIST_revG_100      -0.028376   0.051392  -0.552
DIST_revH_75m      -0.007045   0.051392  -0.137
DIST_revI_50m      -0.010111   0.051392  -0.197
DIST_revJ_25m      -0.008814   0.051392  -0.172
DIST_revK_0m        0.071181   0.051392   1.385
C_DD:DIST_revB_400 -0.035290   0.062943  -0.561
C_DD:DIST_revC_300 -0.004668   0.062943  -0.074
C_DD:DIST_revD_250 -0.006730   0.062943  -0.107
C_DD:DIST_revE_200 -0.002577   0.062637  -0.041
C_DD:DIST_revF_150  0.050681   0.062637   0.809
C_DD:DIST_revG_100  0.026429   0.062382   0.424
C_DD:DIST_revH_75m -0.035173   0.062166  -0.566
C_DD:DIST_revI_50m -0.044565   0.062166  -0.717
C_DD:DIST_revJ_25m -0.014734   0.062166  -0.237
C_DD:DIST_revK_0m  -0.155319   0.062166  -2.498
```

Eremopyrum distans

Percentage cover

lmer (percentage cover ~ control or disturbed * distance from disturbance + (1|transect))

```
Linear mixed model fit by REML
```

```
Formula: EP_intercept ~ C_D * DIST + (1 | REP)
   Data: species
   AIC   BIC logLik deviance REMLdev
 144.6 223.4 -48.31    34.51   96.62
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.043902 0.20953
 Residual             0.063096 0.25119
Number of obs: 197, groups: REP, 23

Fixed effects:
             Estimate Std. Error t value
(Intercept)    0.7203     0.1420   5.072
C_DD          -0.6611     0.1627  -4.064
DIST25        -0.4392     0.1732  -2.536
DIST50        -0.4626     0.1618  -2.858
DIST75        -0.4081     0.1618  -2.522
DIST100       -0.4354     0.1618  -2.690
DIST150       -0.4392     0.1732  -2.536
DIST200       -0.4271     0.1609  -2.655
DIST250       -0.5123     0.1896  -2.702
DIST300       -0.2933     0.1732  -1.694
DIST400       -0.3830     0.1618  -2.367
DIST500       -0.4692     0.1695  -2.768
C_DD:DIST25    0.6072     0.1958   3.100
C_DD:DIST50    0.6095     0.1850   3.294
C_DD:DIST75    0.5318     0.1850   2.874
C_DD:DIST100   0.5142     0.1850   2.780
C_DD:DIST150   0.4764     0.1969   2.419
C_DD:DIST200   0.5182     0.1874   2.765
C_DD:DIST250   0.6531     0.2125   3.073
C_DD:DIST300   0.5042     0.1994   2.529
C_DD:DIST400   0.5445     0.1870   2.912
C_DD:DIST500   0.6300     0.1962   3.211
```

lmer (percentage cover ~ control or disturbed * distance from baseline + (1|transect))

```
Linear mixed model fit by REML
Formula: EP_intercept ~ C_D * DIST_rev + (1 | REP)
   Data: species
   AIC   BIC logLik deviance REMLdev
 144.6 223.4 -48.31    34.51   96.62
Random effects:
 Groups   Name        Variance Std.Dev.
 REP      (Intercept) 0.043902 0.20953
 Residual             0.063096 0.25119
Number of obs: 197, groups: REP, 23

Fixed effects:
                    Estimate Std. Error t value
(Intercept)         0.251075   0.154033   1.630
C_DD               -0.031069   0.179886  -0.173
DIST_revB_400       0.086192   0.173399   0.497
DIST_revC_300       0.175943   0.184751   0.952
DIST_revD_250      -0.043109   0.198450  -0.217
DIST_revE_200       0.042136   0.172047   0.245
DIST_revF_150       0.030039   0.184751   0.163
DIST_revG_100       0.033826   0.173399   0.195
DIST_revH_75m       0.061123   0.173399   0.352
DIST_revI_50m       0.006652   0.173399   0.038
DIST_revJ_25m       0.030039   0.184751   0.163
DIST_revK_0m        0.469223   0.169530   2.768
C_DD:DIST_revB_400 -0.085523   0.201964  -0.423
C_DD:DIST_revC_300 -0.125822   0.213793  -0.589
C_DD:DIST_revD_250  0.023041   0.224897   0.102
C_DD:DIST_revE_200 -0.111862   0.201854  -0.554
C_DD:DIST_revF_150 -0.153652   0.211689  -0.726
C_DD:DIST_revG_100 -0.115851   0.200600  -0.578
C_DD:DIST_revH_75m -0.098268   0.200522  -0.490
C_DD:DIST_revI_50m -0.020482   0.200522  -0.102
C_DD:DIST_revJ_25m -0.022826   0.211264  -0.108
C_DD:DIST_revK_0m  -0.630024   0.196220  -3.211
```