

# Supporting information

Keith, D. A, Benson D. H., Baird, I. R.C., Watts, L., Simpson, C. C., Krogh, M., Gorissen, S., Ferrer-Paris, J. R. & Mason, T. J. (2022). Effects of interactions between anthropogenic stressors and recurring perturbations on ecosystem resilience and collapse. *Conservation Biology* (accepted 5/8/2022) [DOI:10.1111/cobi.13995]

## Appendix S5. Statistical models fitted to ecosystem drivers and state variables.

### Ecosystem drivers

#### Soil moisture

##### Linear mixed effects model

We modelled variation in Soil Moisture (volumetric %), in relation to three explanatory variables: log(Years since 2014); a factor with two levels for mined and unmined sites (using treatment contrasts), and rainfall in the three months over late spring - summer (November-January) just prior to sampling. We added one random effect of Site and a constant variance function with two different levels for mined and unmined sites. The variance is fixed to one for the control level (Unmined reference), and estimated for the treatment level (Mined). The model is:  
`mdl000 <- lme(SoilMoisture ~ logYears * Mine + Rain, random = ~ 1 | Site,  
 weights = varIdent(form= ~ 1 | Mine), data=newnsoil)`

##### Linear mixed-effects model fit by REML

AIC <dbl>	BIC <dbl>	logLik <dbl>
3402.231	3434.834	-1693.116

##### Random effects:

Formula: ~1 | Site

(Intercept) Residual

StdDev: 9.251101 8.303085

##### Variance function:

Structure: Different standard deviations per stratum

Formula: ~1 | Mine

##### Parameter estimates:

Unmined reference	Mined
1.000000	1.765437

##### Fixed effects: SoilMoisture ~ logYears \* Mine + Rain

	Value	Std.Error	DF	t-value	p-value
(Intercept)	86.39378	5.590549	431	15.453542	0.0000
logYears	-1.77496	0.917966	431	-1.933576	0.0538
MineMined	-20.43813	8.034454	4	-2.543811	0.0637
Rain	0.01962	0.003537	431	5.546988	0.0000
logYears:MineMined	-23.87648	1.779146	431	-13.420193	0.0000

Correlation:

	(Intr)	logYrs	MinMnd	Rain
logYears	-0.214			
MineMined	-0.680	0.163		
Rain	-0.146	-0.132	-0.004	
logYears:MineMined	0.119	-0.508	-0.311	0.009

Standardized Within-Group Residuals:

	Min	Q1	Med	Q3	Max
	-6.6708225	-0.5213518	0.1804146	0.5683773	2.4939164

Number of Observations: 440  
 Number of Groups: 6  
 Approximated 95% confidence intervals for the variance components:  
 Hide  
 intervals mdl201, which='var-cov'  
 Approximate 95% confidence intervals

Random Effects:

Level: Site			
	lower	est.	upper
sd((Intercept))	4.516312	9.251101	18.94973

Variance function:

	lower	est.	upper
Mined	1.539334	1.765437	2.02475

attr("label")  
 [1] "Variance function:"

within-group standard error:

	lower	est.	upper
	7.527907	8.303085	9.158087

### Fire severity

Fire severity was represented by diameter of the largest remaining twigs 1-2 m above ground (scorch height and % cover scorched/consumed were uninformative). We fitted a 2-factor model to examine the effect of mining treatment and landform (valley floor cf. valley side). We logged the twig diameter to improve homogeneity of variance.

Model:

`Logtwig~Mine*Val`

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Mine	1	0.2651	0.2651	0.963	0.349
Val	1	0.2340	0.2340	0.850	0.378
Mine:Val	1	0.4731	0.4731	1.719	0.219
Residuals	10	2.7518	0.2752		

## Ecosystem state variables

### Vegetation structure

We measured height and cover of woody and non-woody plant strata in March 2020 (10 weeks after fire) and November 2020 (11 months after fire), and fitted a 2-factor model to examine the effect of mining treatment and landform (valley floor cf. valley side).

#### Shrub cover

##### March 2020 survey

$\log(\text{Shbcov}+1) \sim \text{Mine} * \text{Val}$

Residuals:

Min	1Q	Median	3Q	Max
-0.94605	-0.19928	0.01589	0.32363	0.75870

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )	
(Intercept)	1.63919	0.26720	6.135	0.000111	***
Mineyes	-1.60742	0.40816	-3.938	0.002783	**
Valside	0.20789	0.37788	0.550	0.594297	
Mineyes:Valside	0.05493	0.57722	0.095	0.926063	

Simplified model:  $\text{LogShbcov} \sim \text{Mine}$

Residuals:

Min	1Q	Median	3Q	Max
-1.04999	-0.16318	-0.06787	0.30292	0.65476

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )	
(Intercept)	1.7431	0.1781	9.786	4.52e-07	***
Mineyes	-1.5800	0.2721	-5.807	8.38e-05	***

Random factor for swamps not important and omitted.

##### November 2020 survey

$\text{LogShbcovNov20} \sim \text{Mine} * \text{Val}$

Residuals:

Min	1Q	Median	3Q	Max
-1.15475	-0.71670	-0.03985	0.54838	1.48372

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )	
(Intercept)	1.8479	0.3616	5.110	0.000105	***
Mineyes	-1.0290	0.5114	-2.012	0.061358	.
Valside	0.3768	0.5114	0.737	0.471875	
Mineyes:Valside	-0.4790	0.7233	-0.662	0.517208	

Simplified model:  $\text{LogShbcovNov20} \sim \text{Mine}$

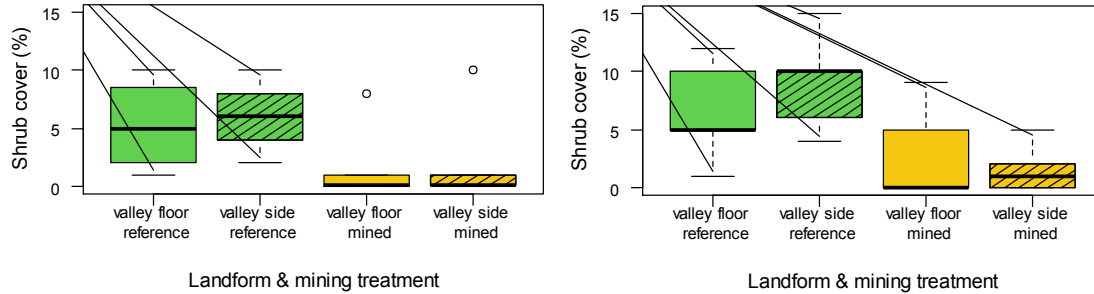
Residuals:

Min	1Q	Median	3Q	Max
-1.34318	-0.76779	-0.08253	0.40333	1.53480

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	2.0363	0.2454	8.297	1.45e-07 ***
Mineyes	-1.2685	0.3471	-3.655	0.00181 **

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**Figure S5.1.** Shrub cover in March 2020 (left) and November 2020 (right)

*Shrub height*

**March 2020 survey**

`LogShbhgt~Mine*Val`

Residuals:

Min	1Q	Median	3Q	Max
-0.62123	-0.32078	0.07192	0.33689	0.58585

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	-1.68136	0.22006	-7.640	1.76e-05 ***
Mineyes	-0.76482	0.33615	-2.275	0.0462 *
Valside	-0.29079	0.31121	-0.934	0.3721
Mineyes:valside	0.03306	0.47538	0.070	0.9459

Simplified model: `LogShbhgt~Mine`

Residuals:

Min	1Q	Median	3Q	Max
-0.47583	-0.42069	0.07347	0.27246	0.62278

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	-1.8268	0.1516	-12.051	4.61e-08 ***
Mineyes	-0.7483	0.2315	-3.232	0.0072 **

**November2020 survey**

`ShbhgtNov20 ~ Mine * Val`

Residuals:

Min	1Q	Median	3Q	Max
-0.130	-0.100	-0.015	0.100	0.220

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	0.30000	0.05303	5.657	3.57e-05 ***
Mineyes	-0.20000	0.07500	-2.667	0.0169 *
Valside	-0.02000	0.07500	-0.267	0.7931
Mineyes:valside	0.01000	0.10607	0.094	0.9261

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Simplified model: `ShbhgtNov20 ~ Mine`