Supporting Information

Demographic consequences of changing environmental periodicity, *Ecology*

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Appendix S2 - Vital-rate estimation and model selection for all three study species.

Data (Conquet et al. 2022a) are available in Dryad at https://doi.org/10.5061/dryad.hhmgqnkkc and code (Conquet et al. 2022b) is available in Zenodo at https://10.5281/zenodo.7078560.

For the seasonal vital rates for the marmot and meerkat populations, we first compared the possible random-effect structures (year random effect on the mean vital rate or on both the mean and the slope between seasons; see Table S1 for the marmots, and Table S2 for the meerkats; see also the R code). We did so by comparing the amount of variance explained by each structure (using the r.*squaredGLMM* function of the *MuMIn* R package; Bartoń 2020), and kept the one explaining the highest amount. We then selected the best fixed effects using the AICc (*AICctab* function of the *bbmle* R package; Bolker and R Development Core Team 2020). We took the most parsimonious model in the 2 dAICc range (i.e., the model with the fewest parameters), unless another model in that range fitted the data better or had a better biological justification (see Appendix S3: Fig. S1).

For the non-periodic vital rates of the marmot, we included a random effect of the year on the mean vital rate, after checking that the random effect did explain part of the variance (using the *r.squaredGLMM* function of the *MuMIn* R package; Bartoń 2020).

For the dewy pine, we fitted GLMs to estimate the vital rates in the deterministic states of the post-fire habitats sequence (TSF_0 to TSF_3; Table S3 and the R code), and GLMMs for the vital rates in the last stochastic state ($TSF_{>3}$; Table S4). We selected the

best random and fixed effects following the same approach as described above for the marmot and meerkat vital rates.

For Poisson GLMs, we controlled for under- and overdispersion by comparing the values of degrees of freedom and residual variance from the model summary and fitted under- and overdispersed Poisson GLMs using the quasi-Poisson distribution of the *glm* function from the *stats* R package (R Core Team 2020). For Poisson GLMMs, we tested for under/overdispersion using the *overdisp_fun* function from Prof. Ben Bolker's GLMM FAQ available at https://bbolker.github.io/mixedmodels-misc/glmmFAQ.html. We then fitted under- and overdispersed GLMMs using the *glmmPQL* function from the *MASS* R package (Venables and Ripley 2002).

Marmot vital rates

We fitted GLMMs to estimate the following vital rates: stage-specific survival, probability of transition to and stasis in the reproductive adult stage (binomial distribution), and reproductive adult recruitment (Poisson distribution). As prior evidence has determined that marmot population dynamics are density independent (Armitage 1973; Armitage et al. 2011; Paniw et al. 2020), we tested only for the fixed effect of season on the survival of yearlings, and reproductive and non-reproductive adults, and included year as a random effect in all models, either on the mean vital rate, or on both the mean and the slope of vital rates between seasons for seasonal vital rates (see R code).

Table S1 - Selection of the best model for seasonal vital rates. For the vital rates occurring in both winter and summer (i.e., stage-specific survival except for that of juveniles), we considered the random effect of the year on the mean vital rate, and both on the mean and the slope between seasons. We selected the best random effect by comparing the part of the variance explained by each structure. We then tested for the effect of season using the AICc to select the best model.

Best random effect selection
vital rate ~ season + (1|year)
vital rate ~ season + (1+season|year)
Best fixed effect selection *(with (1|year) as best random effect)*
vital rate ~ 1 + (1|year)
vital rate ~ season + (1|year)

Meerkat vital rates

We fitted GLMMs to model stage-specific survival, probability of transition from helper to dominant, and helper emigration (binomial distribution), as well as helper and dominant recruitment (Poisson distribution). We tested for the effects of season and population density on all vital rates (including a quadratic term, which has been shown to be biologically relevant; Paniw et al. 2019). We also used year as a random-effect variable, either on the mean vital rate or on both the mean and the slope of vital rates between seasons (see R code).

Table S2 - Selection of the best model for the meerkat vital rates. We considered the random effect of the year on the mean vital rate, and both on the mean and the slope between seasons. We selected the best random effect by comparing the part of the variance explained by each random effect structure. We tested for the effect of season, density and its quadratic term density^2, and the various combinations of these effects, including the interactions. We selected the best model using the AICc.

Best random effect selection
vital rate ~ season + (1|year)
vital rate ~ season + (1+season|year)
Best fixed effect selection   *with (1|year) as best random effect*
vital rate ~ 1 + (1|year)
vital rate ~ season + (1|year)
vital rate ~ density + (1|year)
vital rate ~ density + density^2 + (1|year)
vital rate ~ season + density + (1|year)
vital rate ~ season + density + season:density + (1|year)
vital rate ~ season + density + density^2 + (1|year)
vital rate ~ season + density + density^2 + season:density + (1|year)
vital rate ~ season + density + density^2 + season:density + season:density^2 + (1|year)

Dewy pine vital rates

After a fire, the dewy-pine population always transitions through a deterministic sequence of four post-fire (or time since fire, TSF) habitat states (TSF_0, TSF_1, TSF_2, and TSF_3). The vital rates in TSF_0 were considered constant. In order to model the vital rates associated with the three other habitat states, we fitted GLMs on demographic

data consisting of individuals continuously monitored from TSF_0 to TSF_3 at three sites. At each site, we used a binomial distribution to estimate the following vital rates: stage-specific survival, transition to and between the reproductive stages, and flowering probability. We used a Poisson distribution to model the reproductive stage-specific number of flowering stalks and number of flowers per stalk. We tested for the effects of TSF (categorical variable) and aboveground density of neighboring con-specifics (number of aboveground dewy pines per m^2), including a quadratic term, on vital rates (see R code). We did not consider a random year effect, as TSF was strongly correlated with year.

After three to four years after fire, when the habitat reaches a late post-fire state, dewy-pine populations do not change vital rates periodically anymore and continue to invest largely into a seed bank until a new fire occurs. In order to estimate the vital rates for this last post-fire stage ($TSF_{>3}$), we fitted GLMMs on the full dataset of individuals in that state censused in five populations of dewy pines characterized by high or low grazing (Paniw, Quintana-Ascencio et al. 2017). Here, we estimated vital rates testing for the effect of density and its quadratic term, and including year as a random effect on the mean vital rate (see R code).

Table S3 - Selection of the best model for the vital rates in the deterministic post-fire habitat states (TSF$_1$ to TSF$_3$). We tested for the effect of TSF, density and its quadratic term density^2, as well as the various combinations of these effects, including various interaction terms. We selected the best model using the AICc.

Best model selection
vital rate ~ 1
vital rate ~ TSF
vital rate ~ density
vital rate ~ density + density^2
vital rate ~ TSF + density
vital rate ~ TSF + density + density^2
vital rate ~ TSF + density + TSF:density
vital rate ~ TSF + density + density^2 + TSF:density
vital rate ~ TSF + density + density^2 + TSF:density + TSF:density^2

Table S4 - Selection of the best model for the vital rates of the stochastic post-fire habitat state (TSF$_{>3}$). We used a random effect of the year on the average vital rate if the random effect explained part of the variance. We then tested for the effect of density and its quadratic term density^2. We selected the best model using the AICc.

Best random effect selection
vital rate ~ 1 + (1|year)
Best fixed effect selection
with (1|year) as best random effect
vital rate ~ 1 + (1|year)
vital rate ~ density + (1|year)
vital rate ~ density + density^2 + (1|year)

For some dewy-pine vital rates, we could not fit any model due to a limited amount of data. We therefore used the observed data available to compute the average vital rate per TSF (see Table S5 for the deterministic post-fire states and Table S6 for the stochastic post-fire state). Moreover, we could not model some reproductive rates for 2016 because of a late flowering period with respect to the population census that year. In this case, we took the average of all the other years to estimate the missing parameters (Table S6).

Table S5 - Values taken for unmodeled vital rates for the deterministic post-fire habitat states (TSF$_1$ to TSF$_3$). Due to the scarcity of the data in some sites, we were not able to estimate some vital rates by fitting models. We estimated these parameters from the overall or TSF-specific mean of the observed data.

Vital rate	TSF$_1$	TSF$_2$	TSF$_3$
Human-disturbed site			
SD survival (σ_{SD})	modeled	0	0
J survival (σ_J)	modeled	0.33	0.33
J transition to LR (φ_J)	modeled	0.25	0
SR transition to LR (φ_{SR})	-	0.58	0.21
LR transition to SR (φ_{LR})	-	0	modeled
SR number of flowering stalks (fls$_{SR}$)	-	1.0	1.0
LR number of flowering stalks (fls$_{LR}$)	-	1.0	modeled
SR number of flowers per stalk (fps$_{SR}$)	-	5.0	4.0
LR number of flowers per stalk (fps$_{LR}$)	-	4.4	4.9
Naturally fire-disturbed site A			
SD survival (σ_{SD})	modeled	0.50	modeled
SR survival (σ_{SR})	-	1.0	modeled

LR survival (σ_{LR})	-	0.95	modeled
SR transition to LR (φ_{SR})	-	0.14	modeled
LR transition to SR (φ_{LR})	-	0.11	modeled
SR flowering probability ($p_{fl\,SR}$)	-	0.71	modeled
LR flowering probability ($p_{fl\,LR}$)	-	0.89	modeled
SR number of flowering stalks (fls$_{SR}$)	-	1.0	modeled
LR number of flowering stalks (fls$_{LR}$)	-	1.0	modeled
SR number of flowers per stalk (fps$_{SR}$)	-	2.9	modeled
LR number of flowers per stalk (fps$_{LR}$)	-	3.4	modeled
Naturally fire-disturbed site B			
SD survival (σ_{SD})	0.24	0	modeled
J survival (σ_{J})	modeled	0.43	modeled
SR survival (σ_{SR})	-	0.50	0.38
J transition to LR (φ_{J})	modeled	0	0.75
SR transition to LR (φ_{SR})	-	1.0	0.33
SR flowering probability ($p_{fl\,SR}$)	-	0.50	0.75
SR number of flowering stalks (fls$_{SR}$)	-	1.0	1.0

LR number of flowering stalks (fls$_{LR}$)	-	1.0	modeled
SR number of flowers per stalk (fps$_{SR}$)	-	8.5	3.8
LR number of flowers per stalk (fps$_{LR}$)	-	7.5	modeled

Table S6 - Values taken for unmodeled vital rates for the stochastic post-fire habitat state (TSF$_{>3}$). Due to the scarcity of the data, we were not able to estimate some vital rates by fitting models. We estimated these parameters from the overall mean of the observed data. Vital rates that could not be modeled for 2016 (*) were estimated by averaging the values across the other years.

Year	SR transition to LR (φ_{SR}) Low grazing	Number of flowering stalks SR (fls$_{SR}$) Low grazing	Number of flowering stalks SR (fls$_{SR}$) High grazing	Number of flowering stalks LR (fls$_{LR}$) Low grazing	Number of flowering stalks LR (fls$_{LR}$) High grazing	Number of flowers per stalk SR (fps$_{SR}$) Low grazing	Number of flowers per stalk LR (fps$_{LR}$) Low grazing
2011	modeled	1.2	1.0	modeled	1.4	2.1	modeled
2012	modeled	1.2	1.0	modeled	1.4	2.34	modeled
2013	modeled	1.0	1.0	modeled	1.3	2.3	modeled
2014	modeled	1.0	1.0	modeled	1.0	2.3	modeled
2015	modeled	1.2	1.0	modeled	1.3	3.2	modeled
2016	modeled	1.3 *	1.0	2.9 *	1.0	2.6 *	3.6 *
2017	0	1.3	1.2	modeled	1.6	3.0	modeled
2018	modeled	2.0	1.2	modeled	2.0	3.0	modeled

Parameters related to the seed bank were estimated from seed-burial and greenhouse experiments for naturally fire-disturbed and human-disturbed populations (Paniw et al. 2016; Paniw, Quintana-Ascencio et al. 2017), and only depended on TSF (Table S7). The number of seeds per flower was constant for every TSF (9.8 seeds per flower).

Table S7 - Seed-bank parameters for the human-disturbed site and the naturally fire-disturbed sites. The probabilities for a seed to germinate or not from the seed bank (outSB and staySB) and for a produced seed to germinate directly or contribute to the seed bank (goCont and goSB) depended on TSF and the type of site. From TSF_3 on, the seed bank parameters remained the same until the next fire.

Vital rate	TSF_0	TSF_1	TSF_2	$TSF_3/TSF_{>3}$
Human-disturbed site				
goSB	0	0	0.93	0.84
goCont	0	0	0.040	0.13
staySB	0.1	0.050	0.60	0.60
outSB	0.36	0.024	0.011	0.018
Naturally fire-disturbed sites A and B				
goSB	0	0	0.93	0.93
goCont	0	0	0.040	0.040
staySB	0.10	0.05	0.85	0.85
outSB	0.68	0.045	0.025	0.024

For TSF_0, where seeds can become seedlings but also juveniles in the same year, we determined the probability of these transitions as the proportion of seedling and juvenile individuals at TSF_1 (Table S8).

Table S8 - Probabilities of a germinated seed to transition to seedling (SD) or directly juvenile (J) in TSF_0. In TSF_0, the probability of a seed to transition to SD or J is determined from the proportion of SD and J individuals in each site the following year (i.e., in TSF_1).

Vital rate	Human-disturbed site	Naturally fire-disturbed site A	Naturally fire-disturbed site B
Seed transition to SD in TSF_0 (φ_{SB-SD})	0.17	0.97	0.22
Seed transition to J in TSF_0 (φ_{SB-J})	0.83	0.032	0.78

References – Appendix S2

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