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Data and R scripts to reproduce the analysis of the effect of changes in environmental periodicity on the dewy pine (*Drosophyllum lusitanicum*) population.

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File list

`DewyPinesTSF1_to_3_Data.csv`
`DewyPinesTSF3plus_Data.csv`
`01_DewyPines_VitalRatesEstimation_TSF1_to_3.R`
`02_DewyPines_VitalRatesEstimation_TSF3plus.R`
`03_DewyPines_Constants.R`
`04_DewyPines_MPMs.R`
`05_DewyPines_Simulations.R`
`06_DewyPines_Results.R`
`07_DewyPines_Sensitivities_Megamatrix_PostFireStates.R`

Description

`DewyPinesTSF1_to_3_Data.csv` – This dataset contains individual capture-recapture data collected on a population of dewy pines (*Drosophyllum lusitanicum*) at three sites (a human-disturbed site C and two naturally fire-disturbed sites E and F) between 2011 and 2019 in southern Spain. For each individual at each capture, the data contains information on the site, transect, and sub-quadrat where the individual was found (site, transect, and subQuadrat), the year and time since fire (TSF; one, two, and three corresponding to the first, second, and third and above years after a fire occurred, respectively) and the stage (stage; SD = seedling, J = juvenile, SR = small reproductive individual, LR = large reproductive individual). In addition, the data contains information on whether an individual survived to the next year (surv; 1 if it survived, 0 if not), whether a juvenile transitioned to large reproductive (transitionJ; 1 if it transitioned to LR, 0 if not),

whether a small and large reproductive individual grew or shrank, respectively (transitionSR and transitionLR; 1 if it transitioned to the other reproductive stage, 0 if not), whether an individual flowered (fl; 1 if it flowered, 0 if not), and the number of flowering stalks and flowers per stalk (fs and fps). The dataset also contains values for the above-ground density (density; in individuals/m^2) and its squared value (density2). This dataset is used to estimate vital rates in the dewy pine population in the deterministic post-fire habitat states TSF_1 (time since fire), TSF_2, and TSF_3, and assess the effect of changes in vital-rate periodicity on the dewy pine population dynamics.

`DewyPinesTSF3plus_Data.csv` – This dataset contains individual capture-recapture data collected on a population of dewy pines (*Drosophyllum lusitanicum*) at various little or highly grazed sites between 2011 and 2019 in southern Spain. For each individual at each capture, the data contains information on the site, transect and sub-quadrat where the individual was found (site, transect, and subQuadrat) and the type of grazing at that site (LS; LG = little grazed, HG = highly grazed), the year and time since fire (TSF; one, two, and three corresponding to the first, second, and third and above years after a fire occurred, respectively), and the stage (stage; SD = seedling, J = juvenile, SR = small reproductive individual, LR = large reproductive individual). In addition, the data contains information on whether an individual survived to the next year (surv; 1 if it survived, 0 if not), whether a juvenile transitioned to large reproductive (transitionJ; 1 if it transitioned to LR, 0 if not), whether a small and large reproductive individual grew or shrank, respectively (transitionSR and transitionLR; 1 if it transitioned to the other reproductive stage, 0 if not), whether an individual flowered (fl; 1 if it flowered, 0 if not), and the number of flowering stalks and flowers per stalk (fs and fps). The dataset also contains values for the above-ground density (density; in individuals/m^2) and its squared value (density2). This dataset is used to estimate vital rates in the dewy pine population in the last stochastic post-fire habitat state $TSF_{>3}$ (time since fire), and assess the effect of changes in vital-rate periodicity on the dewy pine population dynamics.

`01_DewyPines_VitalRatesEstimation_TSF1_to_3.R` – This script uses the individual capture-recapture data on the dewy pine population for TSF_1, TSF_2, and TSF_3 (`DewyPinesTSF1_to_3_Data.csv`) to estimate survival, transition, and reproductive rates (flowering probability, number of stalks, and number flower per stalk). We estimated vital rates using binomial (for survival, transition, and flowering probability rates) and Poisson generalized linear models (GLMs; for the number of flowering stalks and the number of flowers per stalk). We included time since fire, density, and squared density as fixed effects. We selected the best fixed effect using the AICc. We checked for over- and under-dispersion in the number of flowering stalks and the number of flowers per stalk models and fitted a quasi-Poisson model to account for it. At the end of the script, vital rates are stored in a data frame and all models are saved as `.RData` objects.

`02_DewyPines_VitalRatesEstimation_TSF3plus.R` – This script uses the individual capture-recapture data on the dewy pine population for $TSF_{>3}$ (`DewyPinesTSF3plus_Data.csv`) to estimate survival, transition, and reproductive rates (flowering probability, number of stalks, and number flower per stalk). We estimated vital rates using binomial (for survival, transition, and flowering probability rates) and

Poisson generalized linear mixed models (GLMMs; for the number of flowering stalks and the number of flowers per stalk). We included time since fire, density, and squared density as fixed effects, and year as a random effect on the intercept. We selected the best random effect by looking at the part of the variance explained by a year random effect compared to no random effect, using the *r.squaredGLMM* function of the *MuMIn* R package. We selected the best fixed effect using the AICc. We checked for over- and under-dispersion in the number of flowering stalks and the number of flowers per stalk models and fitted a quasi-Poisson model to account for it. At the end of the script, vital rates are stored in a data frame and all models are saved as `.RData` objects.

`03_DewyPines_Constants.R` – This script provides the values for constant vital rates for the seed bank dynamics in the human-disturbed (*seed.bankSiteC*) and naturally fire-disturbed sites (*seed.bankSitesEF*), the number of seeds per flower (*seeds.per.flower*), and the transition probability to seedling or juvenile from the seed bank in TSF_0 (*sb.transition.TSF0*). The constants are stored as `.csv` files or `.RData` objects.

`04_DewyPines_MPMs.R` – This script provides the functions to build periodic matrix population models (MPMs) for the dewy pine population, using vital rates estimated in `01_DewyPines_VitalRatesEstimation_TSF1_to_3.R` and `02_DewyPines_VitalRatesEstimation_TSF3plus.R`. The script contains one function for each post-fire habitat state (TSF_0 to $TSF_{>3}$) for the human-disturbed site (site C) and the naturally fire-disturbed sites (sites E and F). Depending on the TSF and site, the functions can take the density and the year as arguments and return the corresponding MPM.

`05_DewyPines_Simulations.R` – This script provides the *stoch.sim.droso* function to perform simulations under a control (no changes in vital-rate periodicity in the naturally fire-disturbed population), and a perturbed scenario where vital rates from the human-disturbed population are introduced in various combinations of the five post-fire habitat states, from the last one only ($TSF_{>3}$) and in earlier post-fire states until all are under a browsing perturbation. The function takes the number of simulations (nsimul; default is 500), the number of years in each simulation (nyears; default is 100, the initial population vector (n0), the type of disturbance (disturbance.type; “periodic” or “stochastic”, “stochastic” being the default), the fire-return probability (fire.prob; default is 1/30), or frequency (fire.freq; default is 15), the density scenario (density; TRUE if density dependence should be taken into account, FALSE if simulations should be performed at average population density). For each simulation, a sequence of post-fire habitats (*states*) is created. For stochastic fire, this is done using a Markov chain *envS* in which transitions from the first to the fifth state are deterministic and the transition between the fifth and the first state depends on the fire-return probability. For periodic fires, the population returns to TSF_0 once the number of years between two fires is reached. The function returns a list of annual growth rates for each simulation, a vector containing a 1 if the simulation led to population quasi-extinction, a vector with the timestep at which the population went extinct, a list of yearly population densities for each simulation, a list of post-fire habitat sequences, and a list of population vectors. The rest of the code performs all the simulations used in the manuscript and saves the results as a `.RData` object.

`06_DewyPines_Results.R` – This script processes the results of the vital-rate periodicity perturbation simulations for the dewy pine population. It computes and plots the mean stochastic log lambda, variance across 100 log lambda, and quasi-extinction probability in each scenario across 500 simulations. The results are saved as a `.csv` file.

`07_DewyPines_Elasticities_Megamatrix_PostFireStates.R` – This script computes and plots the elasticities of the population growth rate to each post-fire state using the megamatrix approach. We parameterized a 25 X 25 block-diagonal matrix **A** with each of five post-fire state-specific matrix population models on the diagonal and zeros elsewhere. We then built the megamatrix $\mathbf{M} = (\mathbf{C} \otimes \mathbf{I}) \times \mathbf{A}$, with **C** a matrix containing probabilities of transition between post-fire habitat states and **I** a 5 X 5 identity matrix. We then computed the elasticity of the population growth rate to each post-fire state using the *elasticity* function of the *popbio* package. The results are saved as a `.csv` file.