Delayed effects of climate on vital rates lead to demographic divergence in Amazon forest fragments

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Background

The Amazon is experiencing continuing deforestation resulting in fragmented forest habitat. In addition, changes in precipitation further threaten this region. The Biological Dynamics of Forest Fragments Project (BDFFP) created experimentally fragmented forest habitat (1 ha fragments) with matched continuous forest controls. In 1998, plots were established in BDFFP fragments and continuous forests to track demography of *Heliconia acuminata*, a long-lived understory plant.

Using a decade of demographic and climate data, we asked if drought had a (delayed) effect on survival, growth, and flowering and if its effects differed between forest fragments (FF) and continuous forest (CF).

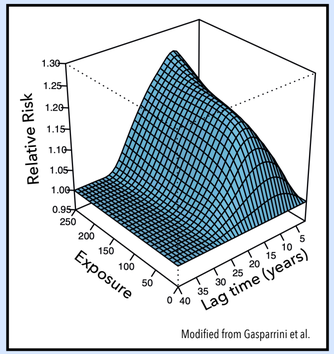
Standardized Precipitation Evapotranspiration Index

We quantified drought with the standardized precipitation evapotranspiration index (**SPEI**) on a 3 month scale. Negative values are dryer than rolling average conditions and positive values are wetter than rolling average. SPEI < -1 indicates drought, SPEI < -2 indicates severe drought.

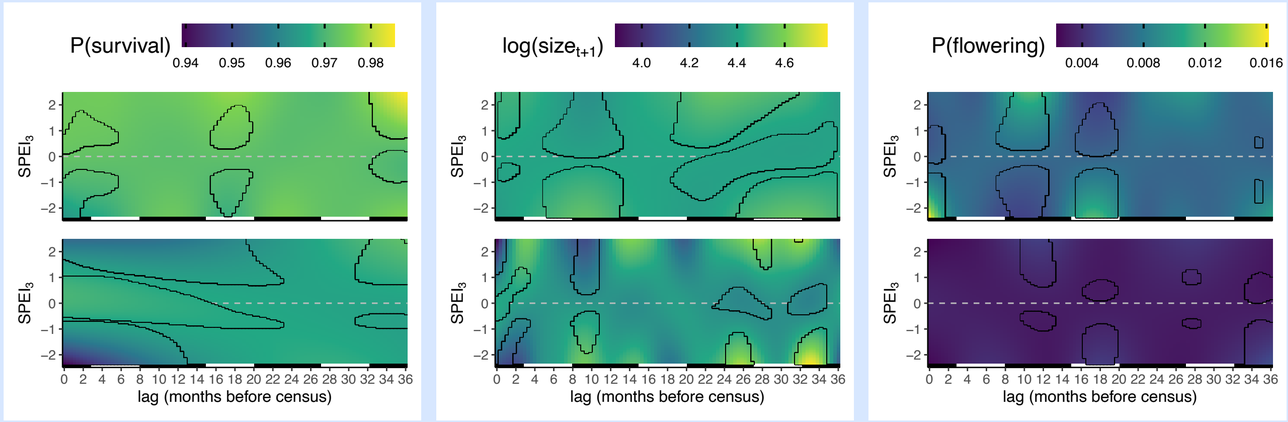
Distributed Lag Non-Linear Models

To model lagged effects of SPEI on *H. acuminata* vital rates, we used distributed lag non-linear models (**DLNMs**) implemented with a generalized additive model (GAM). The DLNMs modeled the effect of SPEI at different lag times up to 36 months using a penalized two dimensional smooth function. This allows for non-linear effects of SPEI and lag times, but constrains the shape of the function to vary smoothly across both dimensions. In addition, models included size as a covariate and plot as a random effect.

In an intuitive example DLNM to the right, risk of cancer increases roughly logarithmically with radiation exposure and risk is highest around 10 years after exposure.



Results



The x axis shows lag in months before the yearly February census. The bar at the bottom of each plot shows wet (black) and dry (white) seasons. Black outlines show regions where the effect of SPEI is significant (i.e. 95% CI does not overlap intercept).

- Plants in fragments are more sensitive to precipitation extremes than those in continuous forest
- Current vital rates were influenced by conditions up to 3 years in the past
- Direction and shape of response to SPEI varied by vital rate, season, and lag time.
- Survival, flowering, and size in year t+1 all increased significantly with plant size.

Our results demonstrate the importance of considering lagged effects in demography, especially for slow growing, long-lived plants. Unfortunately, the quantity of data (years / sites) to implement DLNMs is still rare for demographic experiments. Our results imply that plants in fragmented habitats may be less buffered from variable impacts of climate change. To investigate the consequences of fragmentation further, our future research will focus on using these vital rate models to model population growth under simulated future climate conditions.

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