Climate change & understory plant demography: Assessing the relative effects of forest fragmentation and drought frequency on population viability

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Climate change & understory plant demography: Assessing the relative effects of **forest fragmentation** and **drought** frequency on **population viability**

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Smithsonian

NSF

PDBFF INPA-SI

UF

2000

Fragmented tropical forests "are losing plant species through the disruption of key ecological processes such as pollination and seed dispersal."

Cardoso da Silva and Tabarelli 2000:72.

2022

Habitat loss disrupts species interactions… potentially orphaning species that depend on interacting partners…and increasing secondary extinction risk.

Sandor et al. 2022

Conventional Wisdom: Demographic Effects of Fragmentation

Reduced seed production

–

Reduced Seedling establishment

–

Reduced Population growth rate (λ)

Reduced recruitment reduces population viability

Plants in tropical landscapes are also influenced by the direct & indirect effects of climate change

Severe droughts:

Reduced tree growth, sharply elevated mortality in the following year

Conventional Wisdom: Demographic Effects of Drought

Elevated adult mortality

−

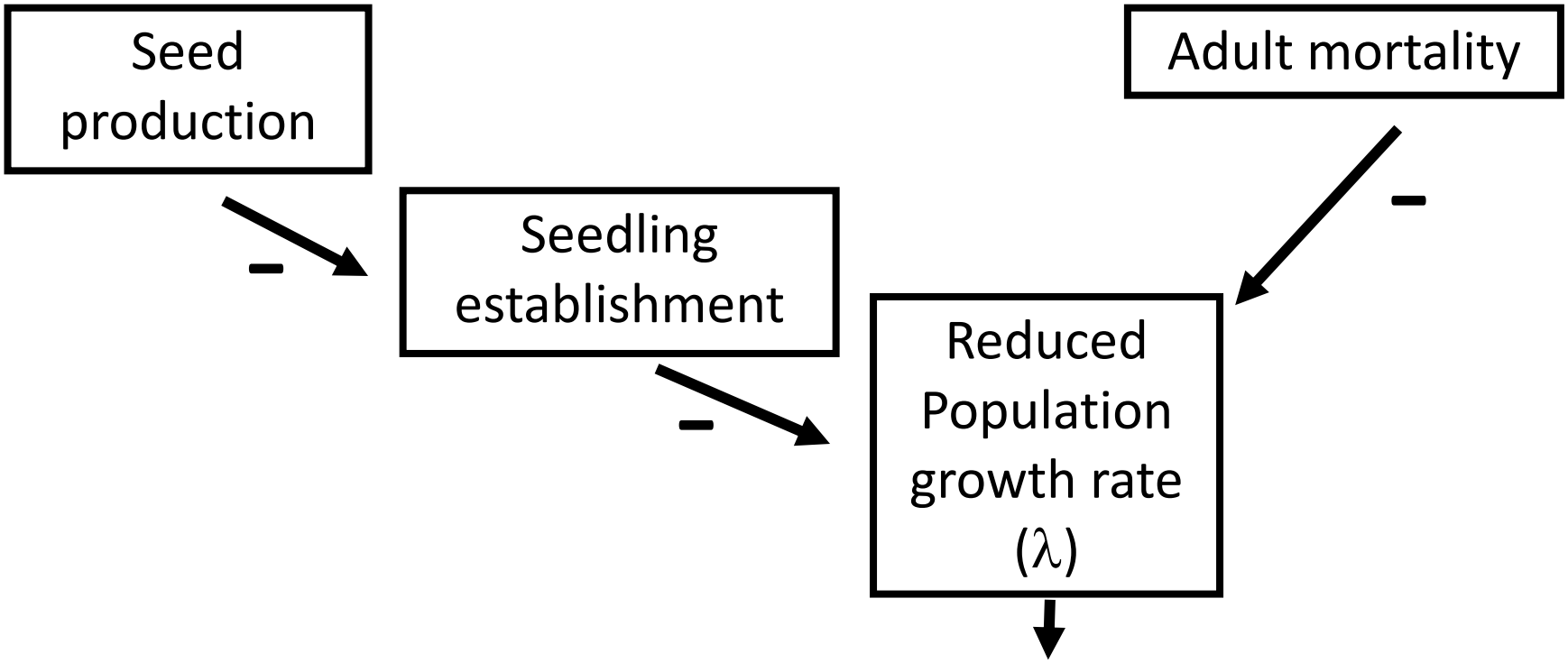
Reduced Population growth rate (λ)

Increases in drought frequency or intensity will reduce population viability

Hypothesis:

Fragmentation and drought could have strong and negative synergistic effects

Laurance & Williamson 2001, Opdam and Wascher 2004, Selwood et al. 2015



1) Droughts reduce population viability everywhere, but

2) Reductions in Fragments >> Continuous Forest

Problem #1:

Demographic responses are

(almost)

never linear.

The demographic impact on λ of **one** stage or ecological process depends on **all others** in the life cycle

The demographic impact on λ of **one** stage or ecological process depends on **all others** in the life cycle

Problem #2:

Quantifying the demographic effects of drought is a major technical (statistical) challenge.

Yr 1 Yr 2 Yr 3 Yr 3 Yr 4 Yr 5

For

Frag






$$n(y,t+1) = \int_{L}^{U} [p(x,y) + f(x,y)]n(x,t)dx.$$

or

$$\begin{pmatrix} 0 & F_2 & F_3 & F_4 & F_5 & F_6 \\ G_{21} & S_2 & R_{23} & R_{24} & R_{25} & R_{26} \\ 0 & G_{32} & S_3 & R_{34} & R_{35} & R_{36} \\ 0 & G_{42} & G_{43} & S_4 & R_{45} & R_{46} \\ 0 & G_{52} & G_{53} & G_{54} & S_5 & R_{56} \\ 0 & G_{62} & G_{63} & G_{64} & G_{65} & S_6 \end{pmatrix}$$

Davidson et al. 2010

λ_{For}

λ_{Frag}

ENSO 1 $_{t1}$

ENSO 1 $_{t1}$ + ENSO 1 $_{t2}$

ENSO 1 $_{t1}$ + ENSO 1 $_{t2}$ + ENSO 1 $_{t3}$

ENSO 1 $_{t1}$ + ENSO 1 $_{t2}$ + ENSO 1 $_{t3}$ + ENSO 1 $_{t4}$ + ENSO 2 $_{t1}$

A drought can have multi year or even delayed effects…

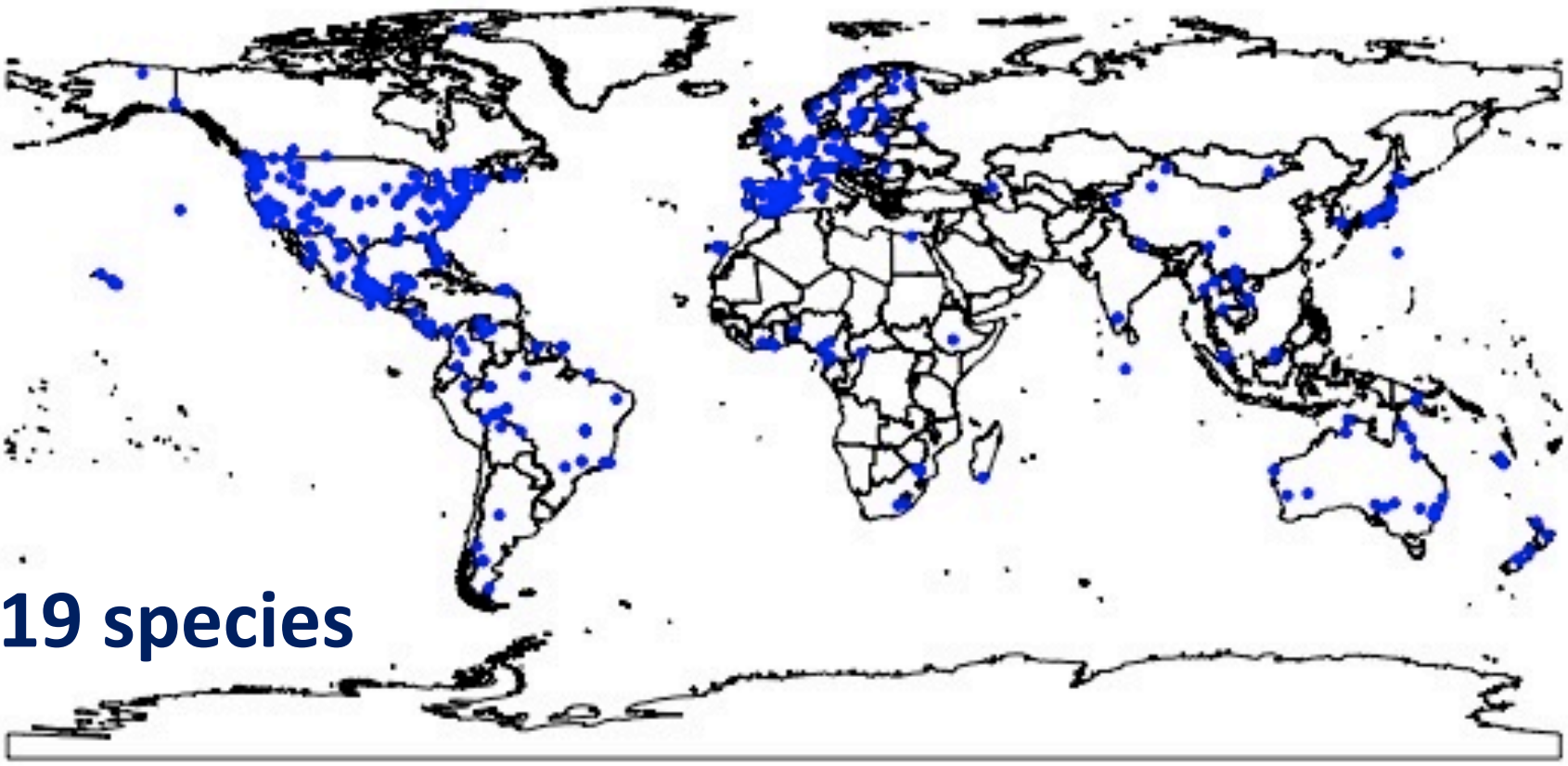
…that overlap with those of subsequent droughts.

Problem #3:

For tropical plant species, multi-year data spanning the *entire* life-cycle are very rare.

COMPADRE
Plant Matrix Database

Salguero-Gómez et al. (2015) The COMPADRE Plant Matrix Database: an online repository forplant population dynamics. *Journal of Ecology* 103, 202-218.



419 species

COMPADRE
Plant Matrix Database

Tropical Species: Fragments *AND* Continuous Forest

Heliconia Demography Project

Biological Dynamics of Forest Fragments Project (Manaus, Brazil)

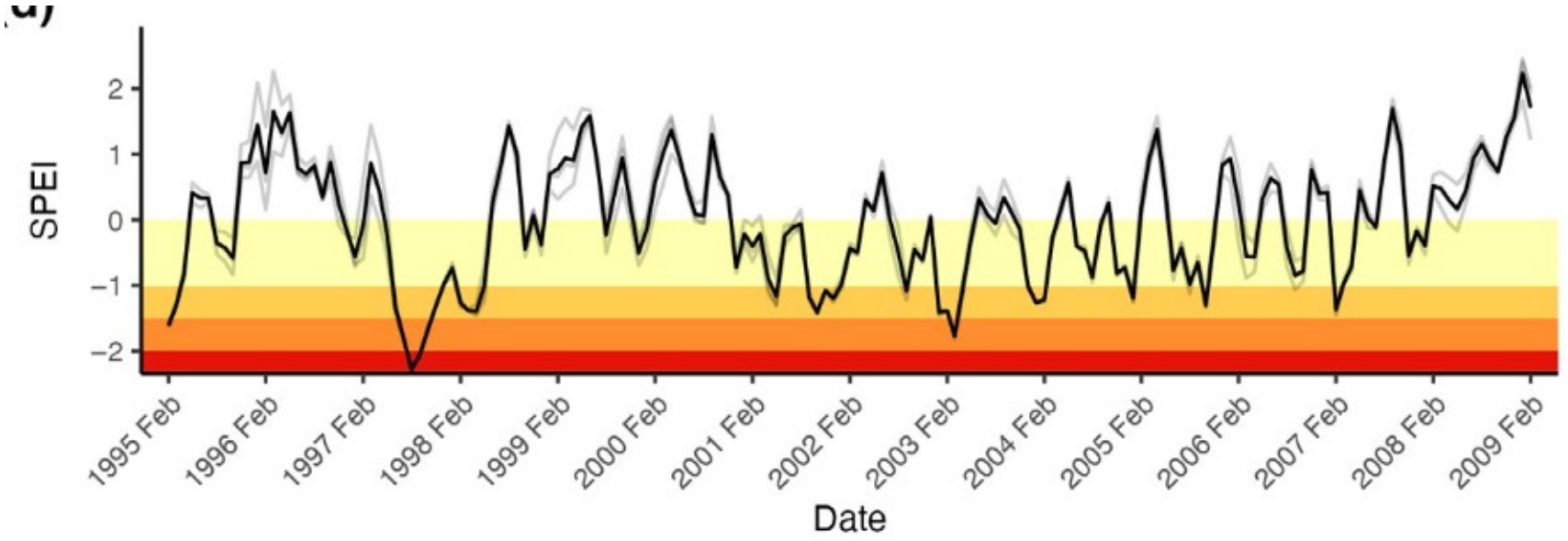
- Continuous Forest (CF): 6 plots
- 10-ha Fragments (10-ha): 3 plots
- 1-ha Fragments (1-ha): 4 plots
- Each plot=5000 m^2

- Plots up to 40 km apart
- Established 1998
- Annual census: 1999-2011
- >7000 plants

Step 1: Test for Delayed Effects of Droughts with:

Distributed Lag Nonlinear Models (DNLMs)

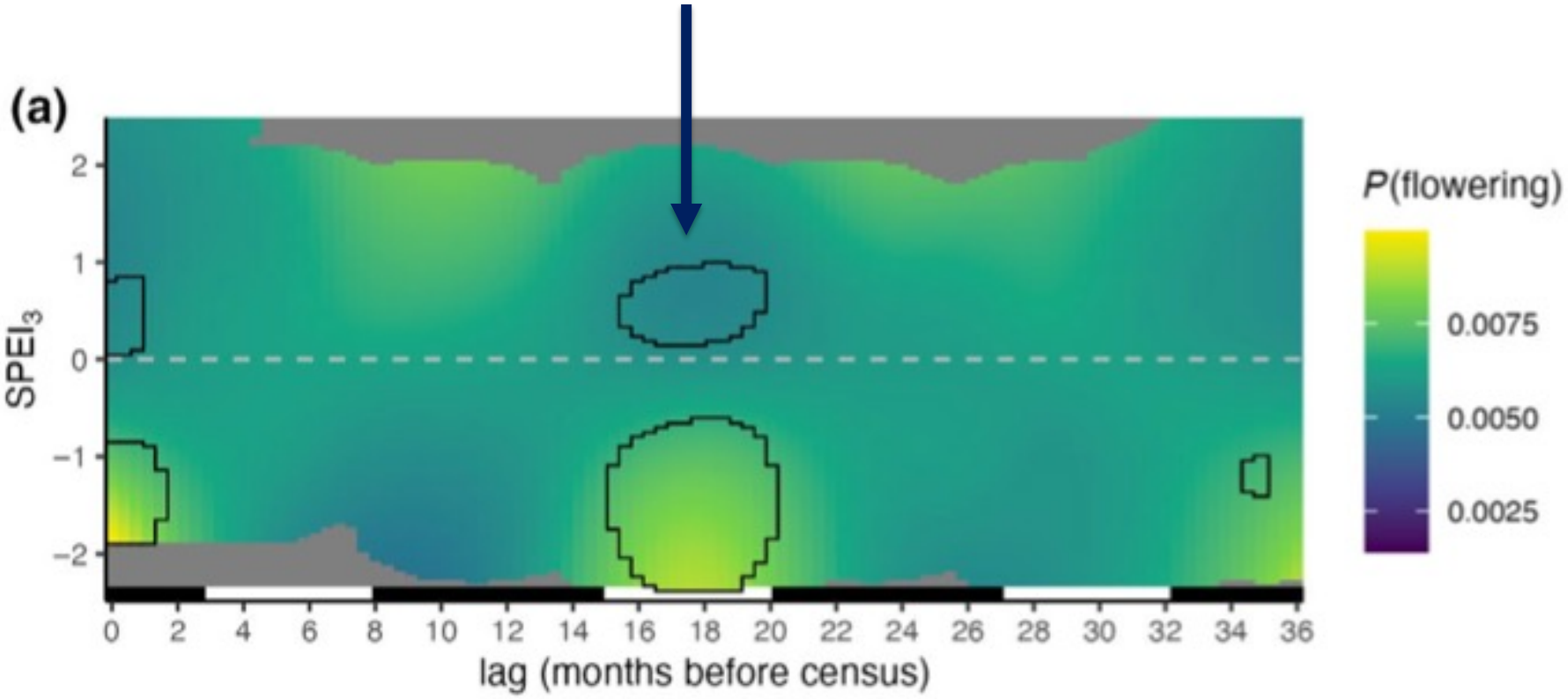
"DLNMs capture how potentially delayed effects of predictor variables affect an outcome by fitting a bidimensional predictor-lag response association spline"
(Gasparrini et al., 2017)



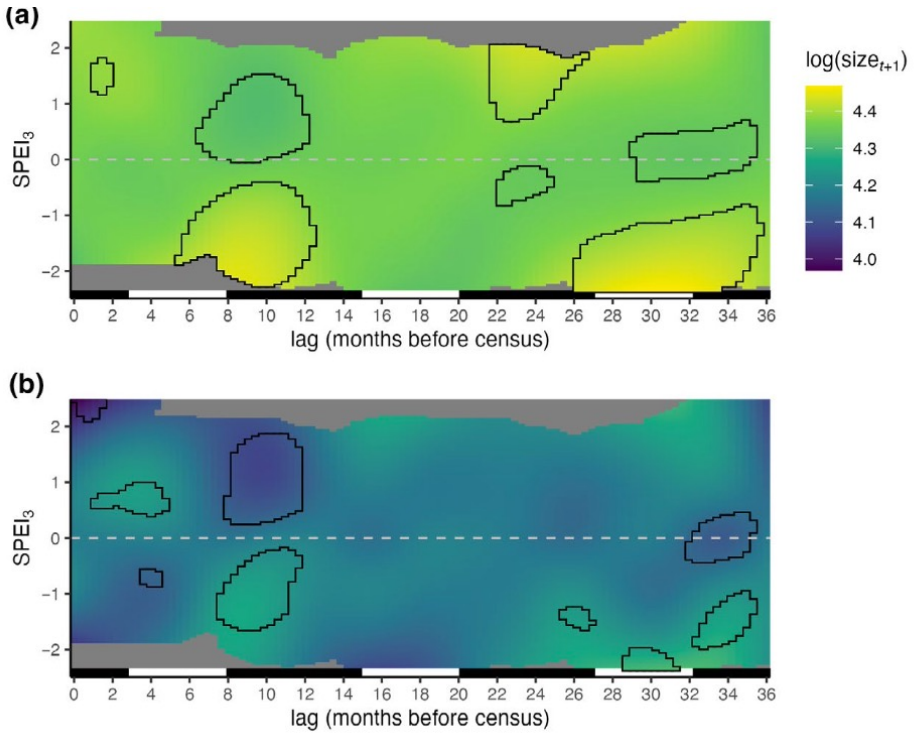
Predictor: SPEI (*standardized precipitation evapotranspiration index)*
Response: *Plant growth, survival, and flowering rates*

Warning: these models are complex, data-hungry, and computationally intensive.

Precipitation **2 dry seasons ago…**
…influences **flowering today**.



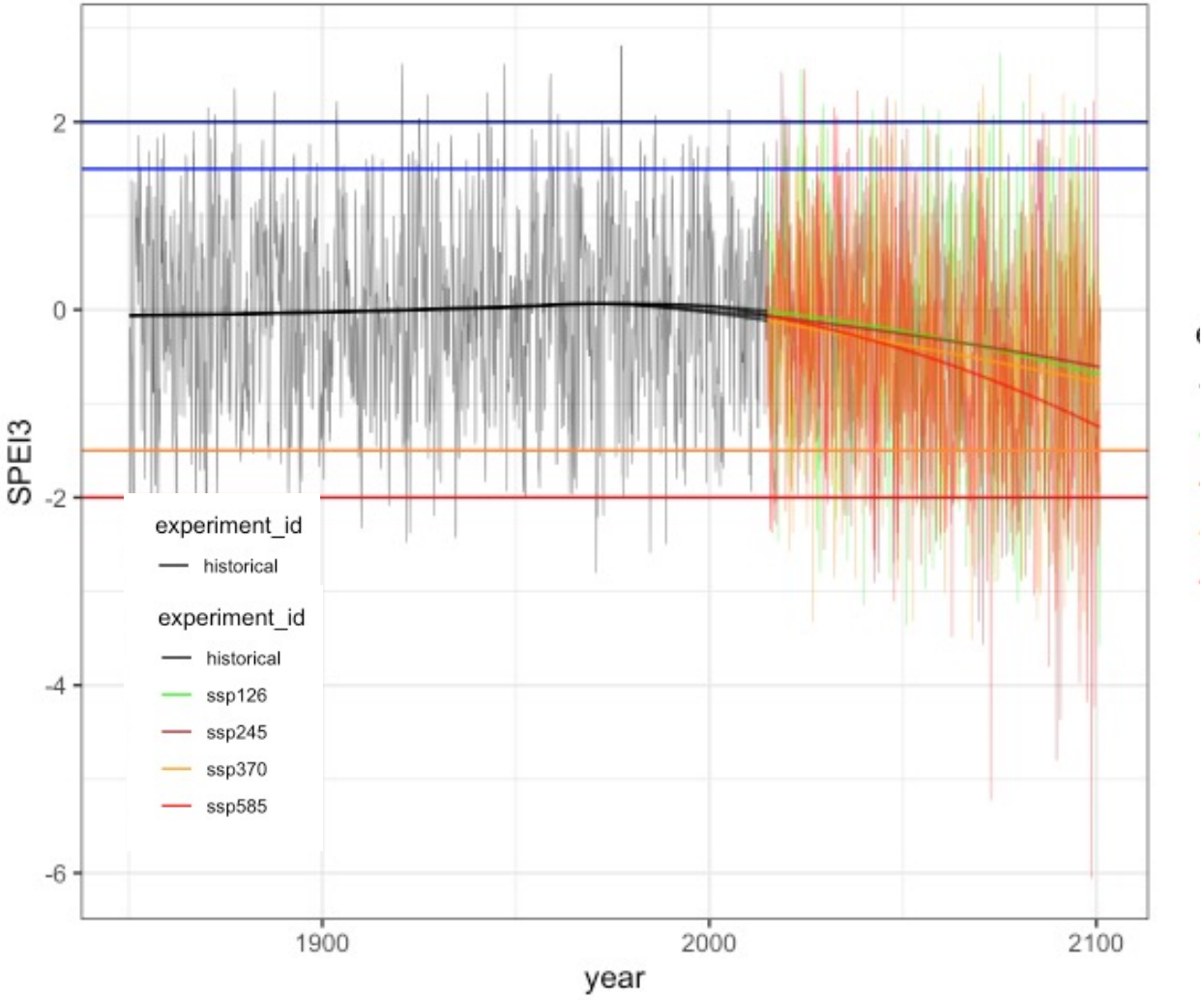
The effects of precipitation on demographic vial rates could be delayed up to 36 months



- Extremes in SPEI the previous year **reduce survival**
- A drought in the wet season 8–11 months prior to the census **increased growth**
- Drought two dry seasons prior **increased probability of flowering**.
- **Effects of precipitation extremes** on survival & growth were **more pronounced in forest fragments**

Scott, Uriarte, & Bruna (2022). Delayed effects of climate on vital rates lead to demographic divergence in Amazonian forest fragments. ***Global Change Biology***, 28, 463– 479. https://doi.org/10.1111/gcb.15900

Step 2: Assess viability of *H. acuminata* populations in FF and CF under different IPCC Scenarios

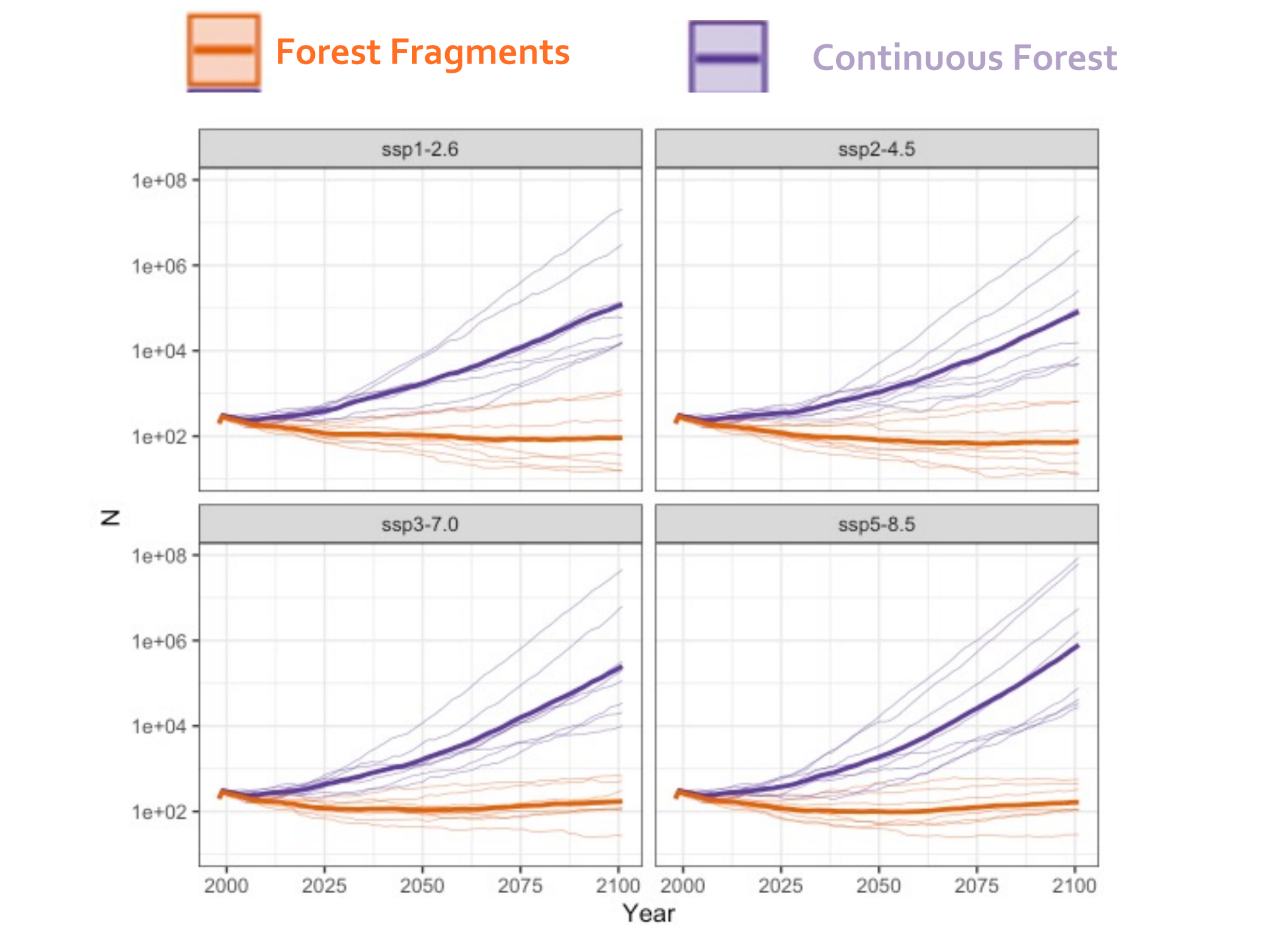


Start with identical populations in FF & CF:

1) Project 75 years into the future, using

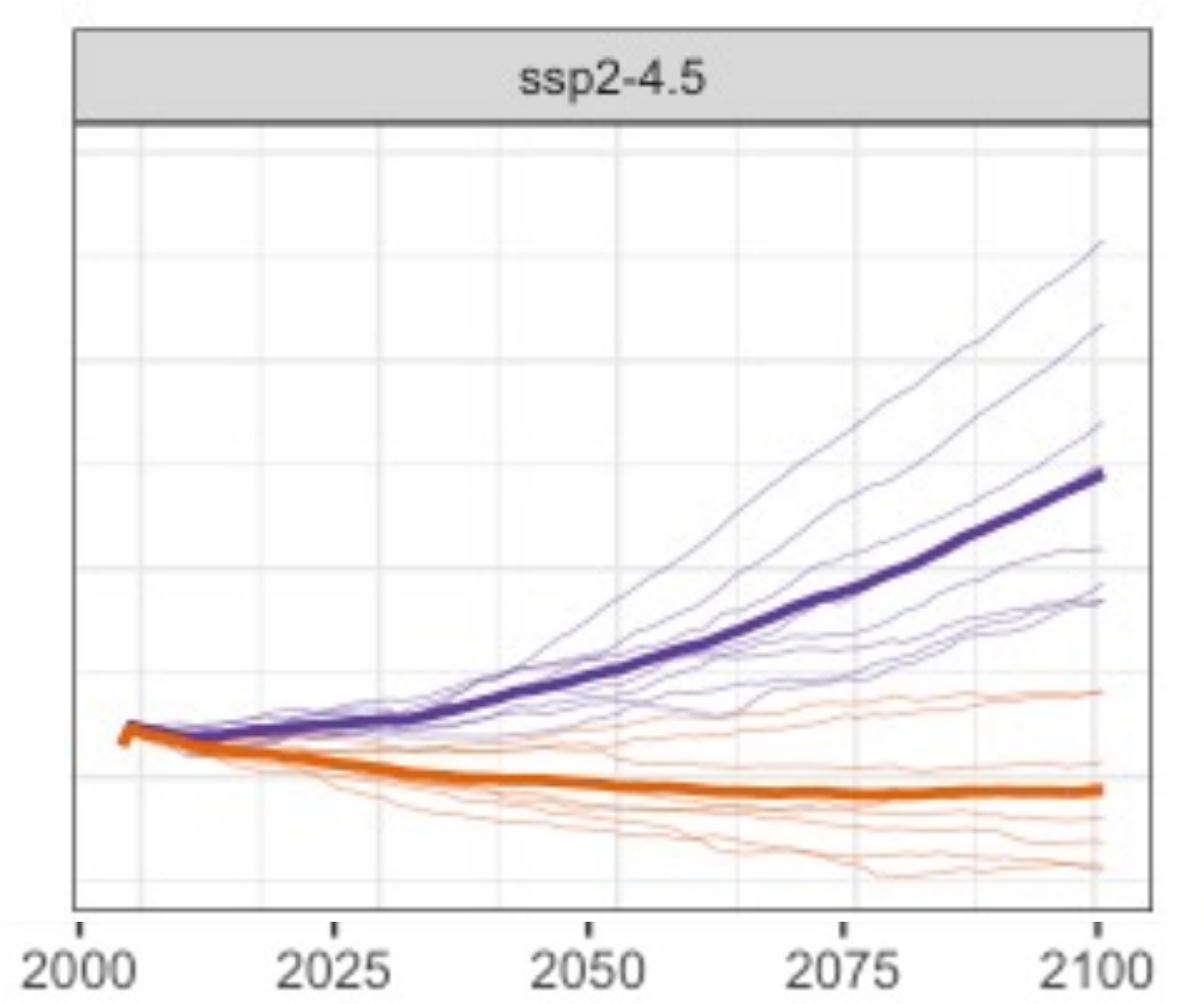
2) Stochastic Integral Projection Models, with

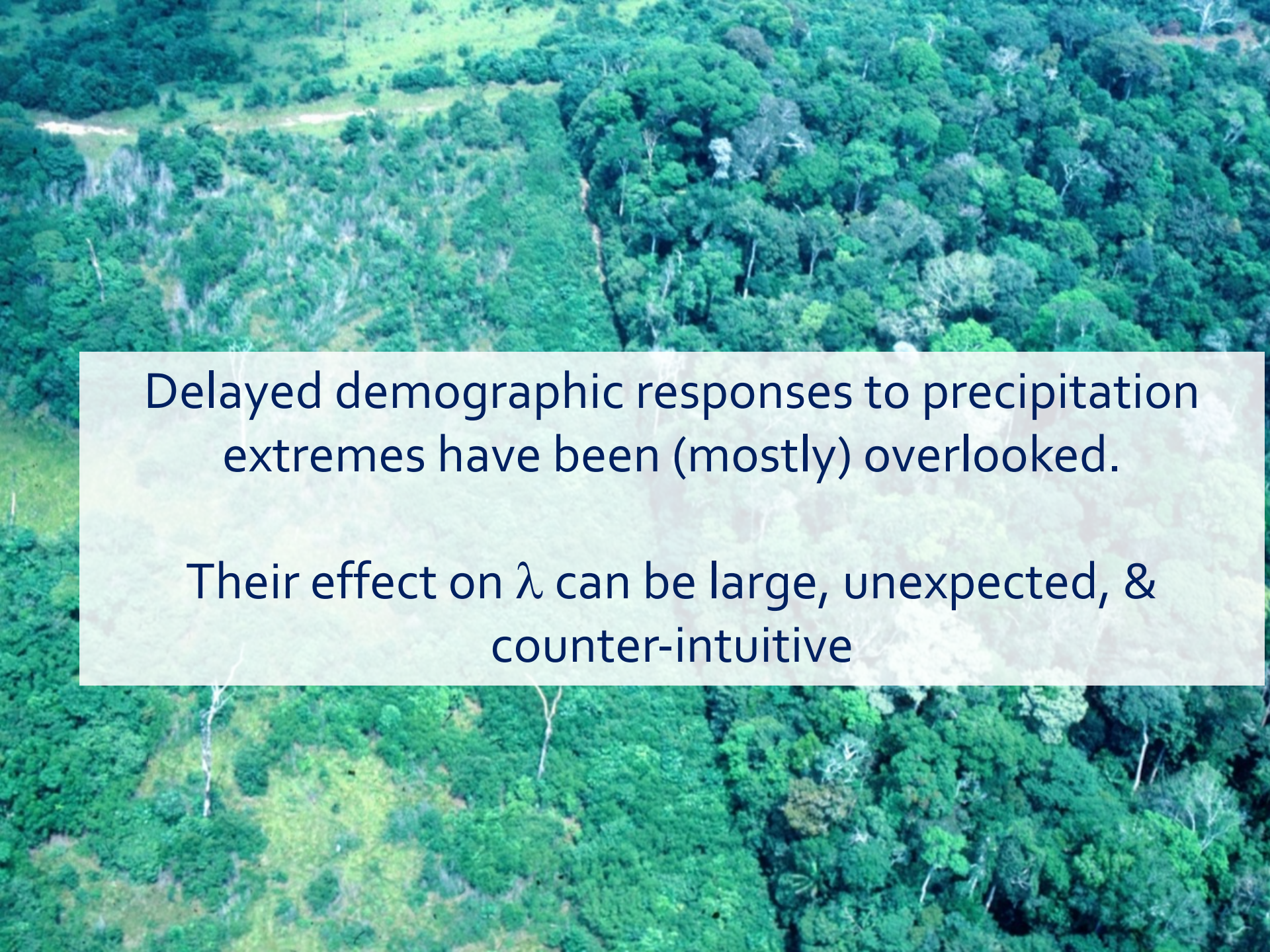
3) Parameterized with habitat specific-demographic surveys & lagged effects


Forest Fragments
Continuous Forest
ssp1-2.6
ssp2-4.5
ssp3-7.0
ssp5-8.5
N
1e+08
1e+06
1e+04
1e+02
2000
2025
2050
2075
2100
Year

Forest Fragments

Continuous Forest





Delayed demographic responses to precipitation extremes have been (mostly) overlooked.

Their effect on λ can be large, unexpected, & counter-intuitive