Beyond phenophase onset dates:

using observational data to link climate to the collective properties of communities and floras

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Director, *California Phenology Project*

California poppy (*Eschscholzia californica)*

NPN data can now be used to:

(1) **Compare closely related taxa** occupying contrasting climates to examine how phenological sensitivity has diverged.

(2) Detect the effects of climatic conditions on **community-level phenological metrics** (e.g., interspecific variance or synchrony in flowering onset).

(3) **Identify the climatic parameters that best explain variation in flowering metrics** (e.g., flowering onset, duration, termination date, and multiple cycles of flowering)

(4) Validate (or question) models constructed using herbarium data.

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Journal of Ecology 2017. 105: 1610-1622

BRITISH ECOLOGICAL SOCIETY

Journal of Ecology

doi: 10.1111/1365-2745.12774

Phenological responsiveness to climate differs among four species of *Quercus* in North America

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Western vs. Eastern Oaks

- Both groups of oaks respond to warmer/drier conditions by advancing vegetative bud break and/or the onset of flowering
- The California oaks are less sensitive to variation in temperature and rainfall across their range
- Individual California oak trees have multiple episodes of bud break and flowering each year, while trees of the Eastern oaks exhibit a single event.
- Whether these patterns apply to other genera is unknown.

NPN data can be used to:

(1) **Compare closely related taxa** occupying contrasting climates to examine how phenological sensitivity has diverged.

(2) Detect the effects of climatic conditions on **community-level phenological metrics** (e.g., interspecific synchrony in flowering onset).

(3) **Identify the climatic parameters that best explain variation in flowering metrics**

(4) **Validate or question models constructed using herbarium data**.

Received: 26 February 2018 | Accepted: 8 August 2018
DOI: 10.1111/gcb.14447

TECHNICAL ADVANCE

WILEY Global Change Biology

Overlooked climate parameters best predict flowering onset: Assessing phenological models using the elastic net

Isaac W. Park | Susan J. Mazer

Which climatic parameters best predict flowering onset?

How do models based on NPN data compare to those based on herbarium data?

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Funding information
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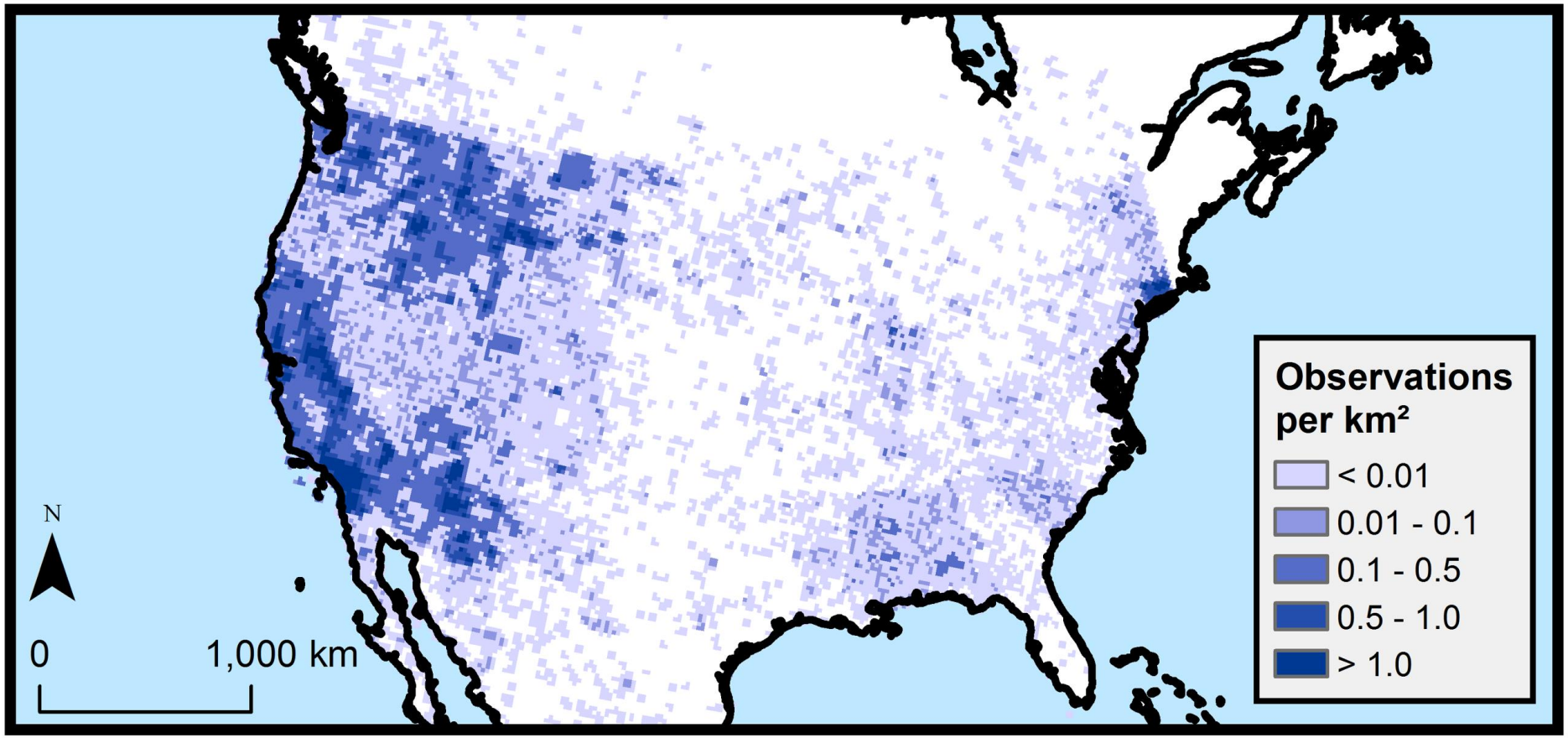
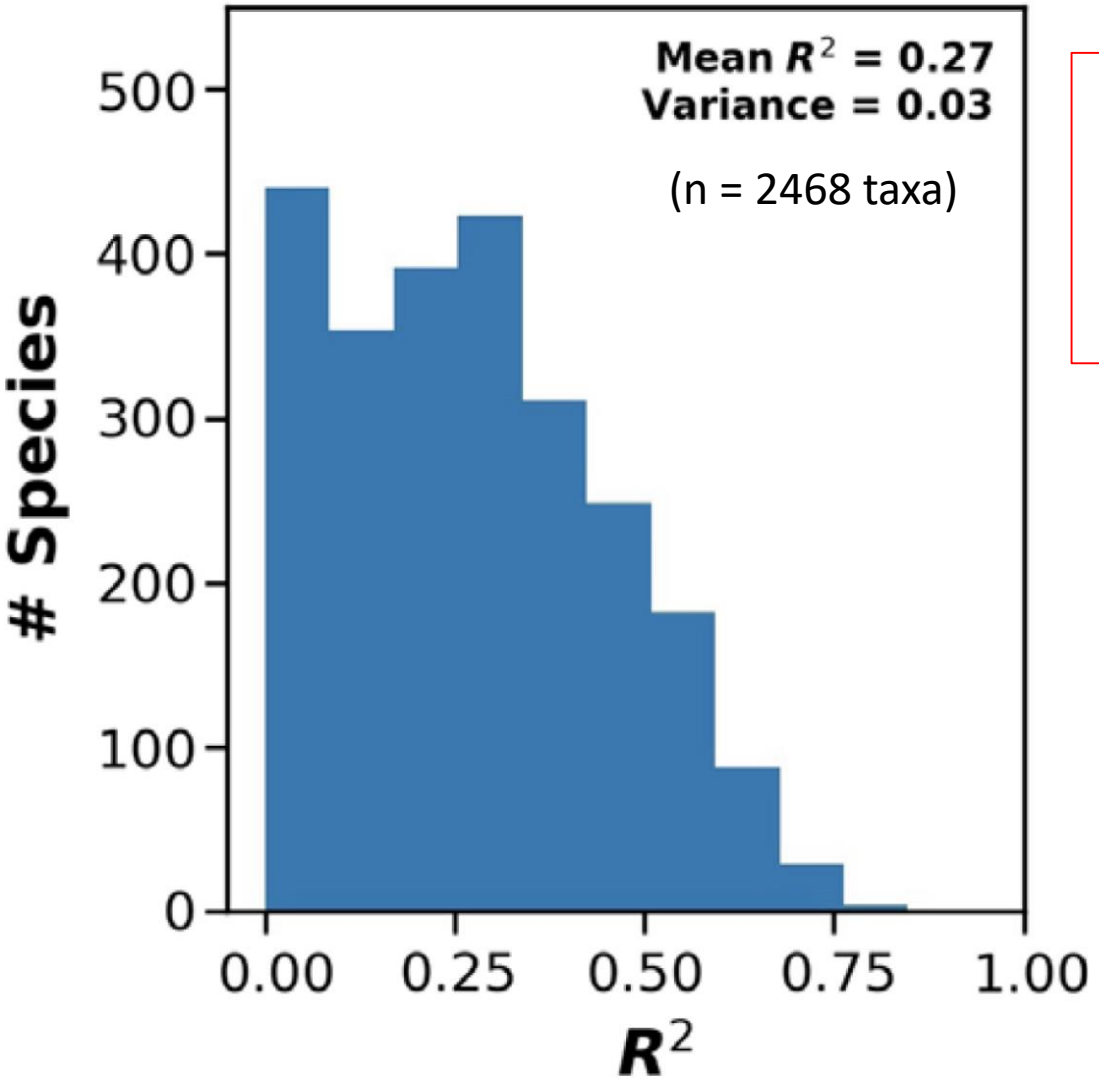


We eliminated all specimens not collected in flower (based on specimen label information).

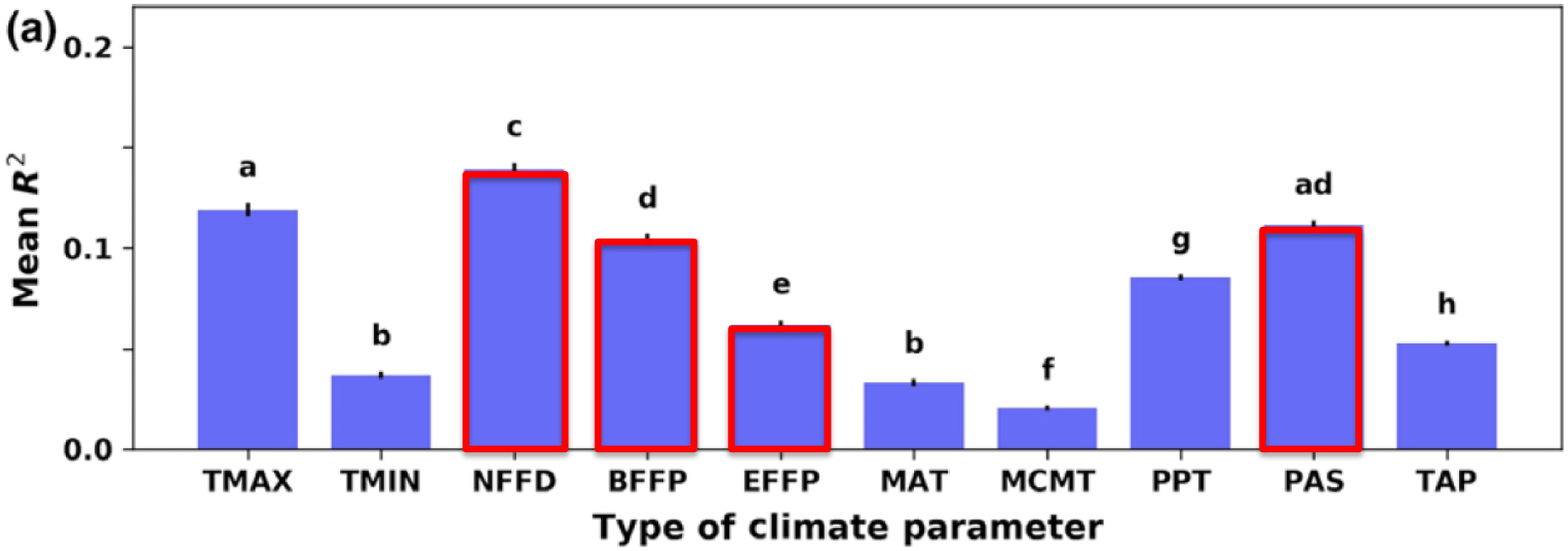
563,501 herbarium sheets collected in flower → 2468 taxa (including subspecies)

119 angiosperm families.



The mean number of variables retained = 9.3 climatic parameters (out of 25 tested variables)

Distribution of cross-validated R^2 values of all taxon-specific phenoclimatic models derived from herbarium data using elastic net regression.



NFFD: Number of frost free days in a given season

BFFP: DoY of the beginning of the frost-free period

EFFP: DoY of the end of the frost-free period

PAS: Precipitation as snow

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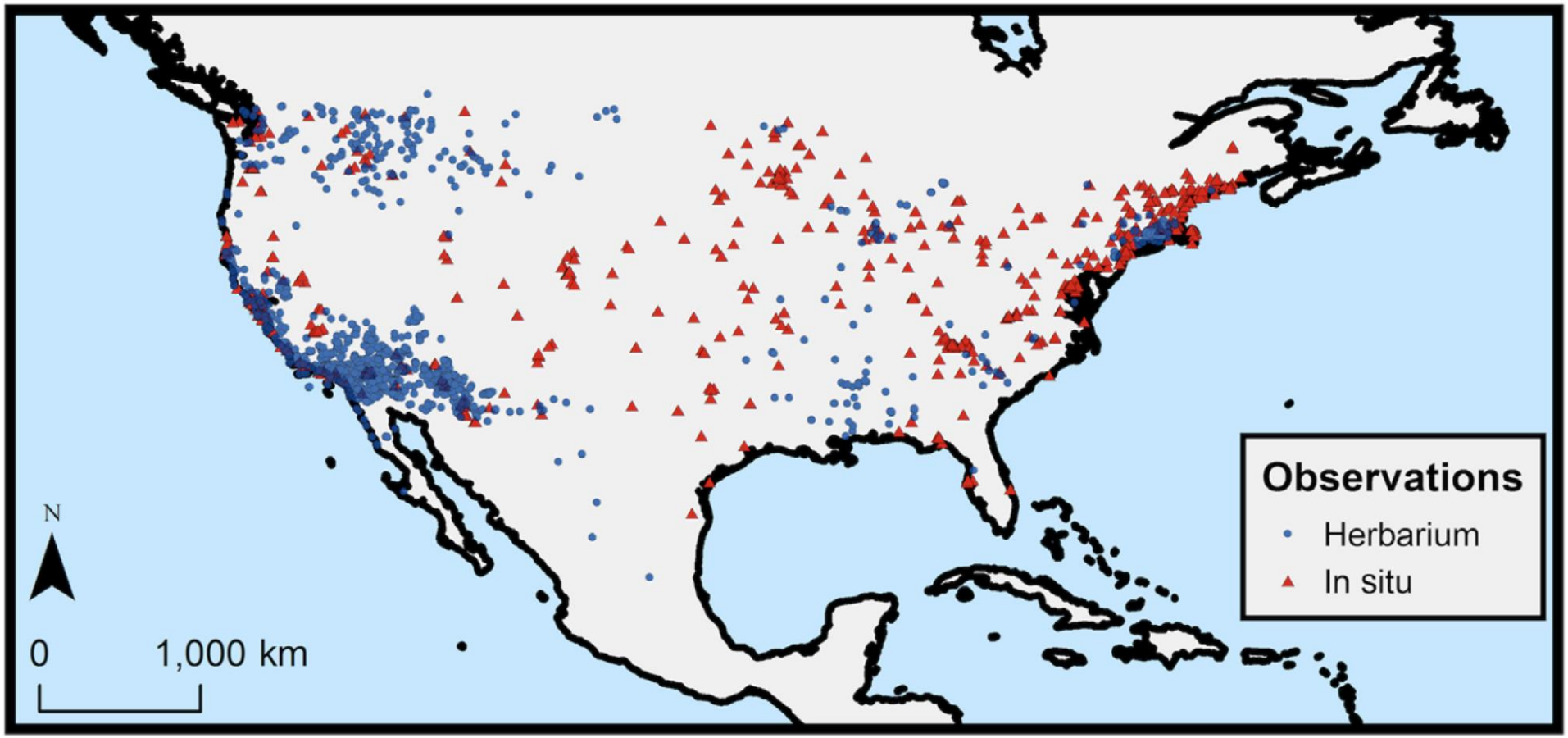
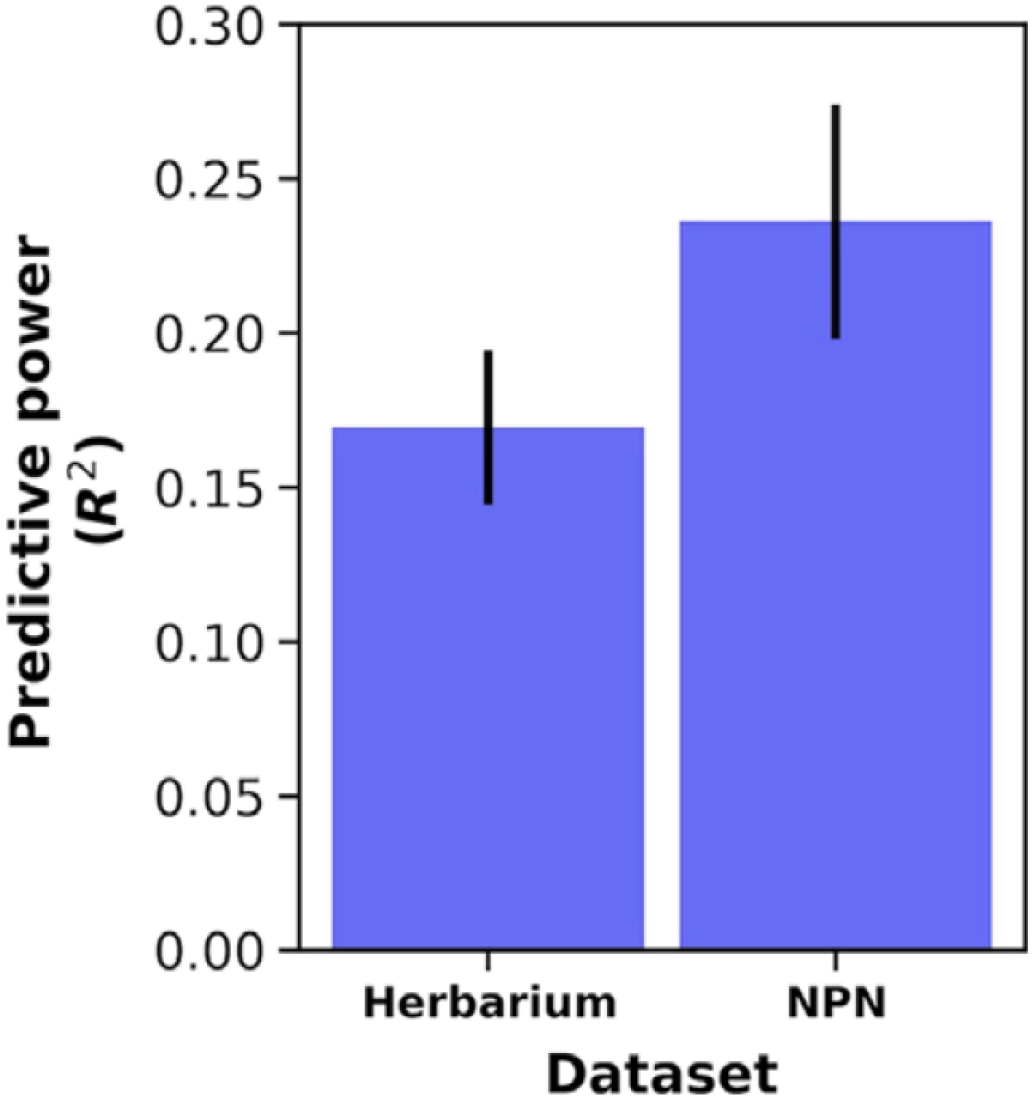


Distribution of herbarium specimens and in situ observations (NPNdb) of:

Baccharis pilularis
Cornus florida
Eriogonum fasciculatum
Larrea tridentata
Quercus agrifolia
Q. rubra
Symphorocarpus albus

USA-NPN: **1959 flowering onset dates**
accuracy ≤ 7 days
≥ 100 onset dates per species

Herbarium-derived: **1572 collection dates of specimens in flower**
accuracy unknown
≥ 100 specimens per species

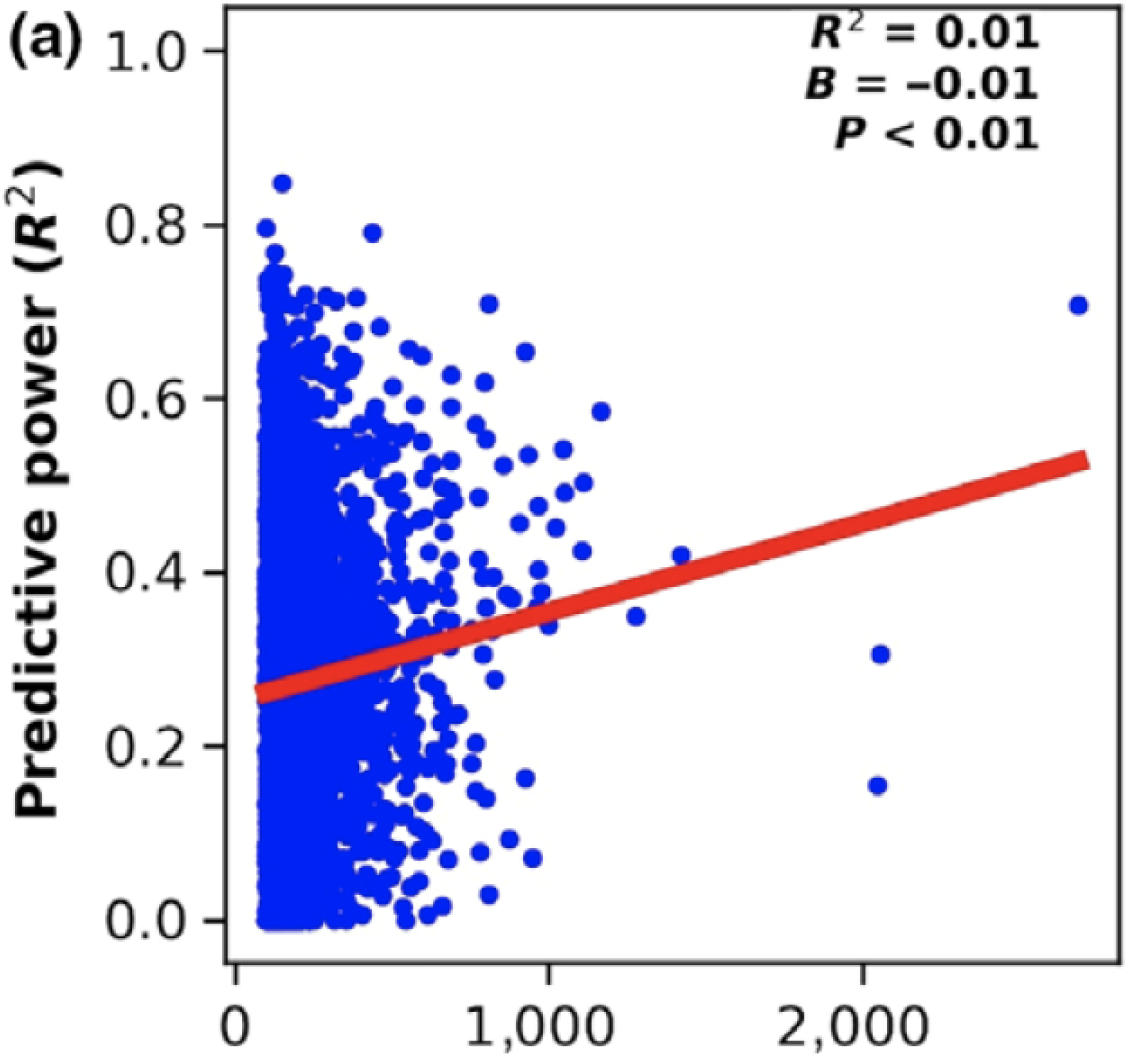


Mean R^2 values for the phenoclimatic models independently constructed using herbarium-derived records vs. NPN-derived observations for the same 7 species. The climatic variables retained in the herbarium- vs. NPN-derived models were nearly identical, although the coefficients differed.

Species	Predictive power (R^2) of models derived from herbarium records vs. USA-NPN observations Sample sizes in parentheses	
	Digital herbarium records	**In situ observations**
Baccharis pilularis	0.03 (213)	0.22 (726)*
Cornus florida	0.59 (132)*	0.19 (105)
Eriogonum fasciculatum	0.15 (263)	0.23 (492)*
Larrea tridentata	0.15 (542)	0.50 (161)*
Quercus agrifolia	0.01 (117)	0.07 (243)*
Quercus rubra	0.23 (103)	0.36 (128)*
Symphoricarpos albus	0.04 (202)	0.08 (104)*

?

Coast live oak (*Quercus agrifolia)*


(a)
R^2 = 0.01
B = −0.01
P < 0.01
Predictive power (R^2)
1.0
0.8
0.6
0.4
0.2
0.0
0
1,000
2,000
Sample size
(number of herbarium sheets)

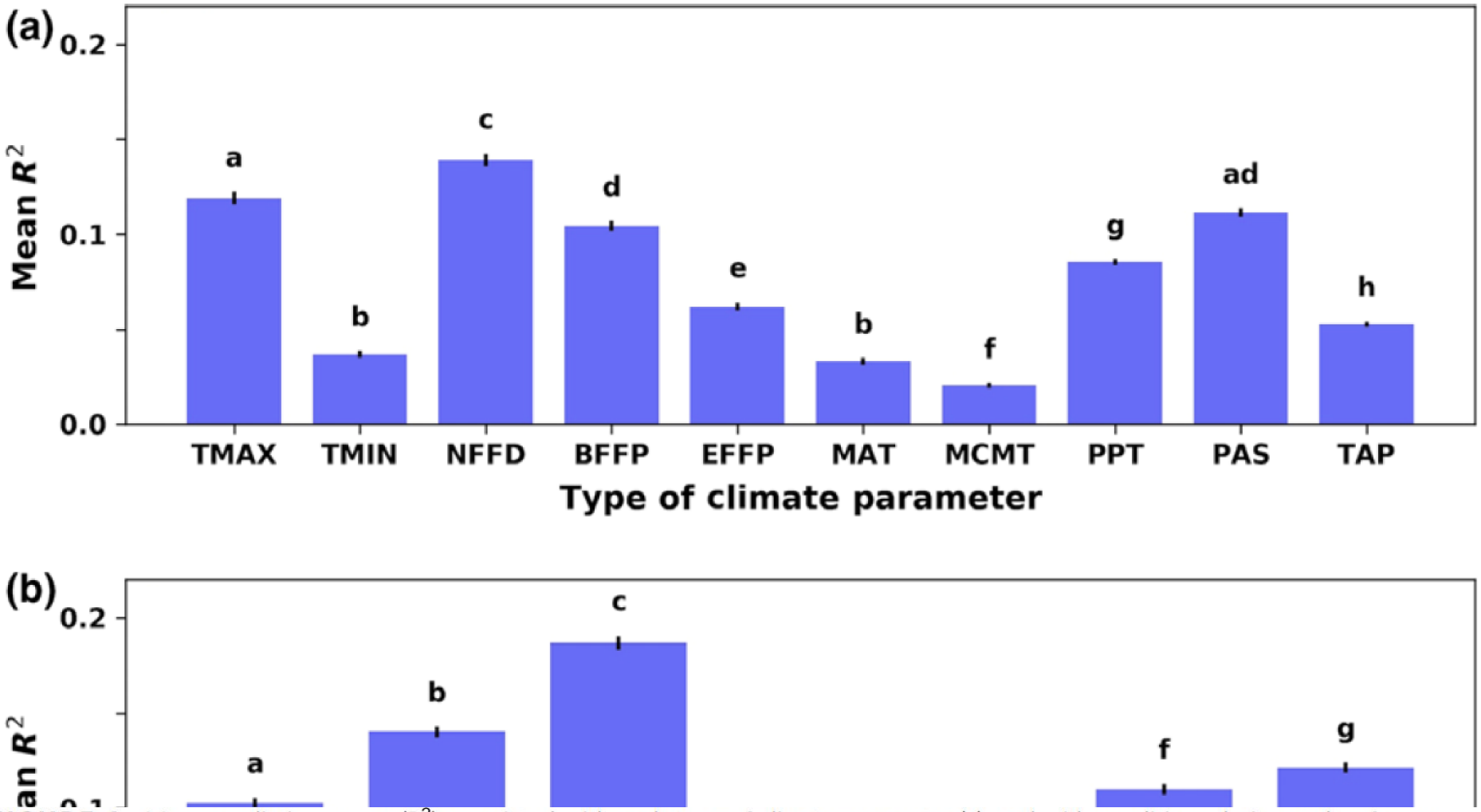


FIGURE 6 Mean predictive power (R^2) associated with each type of climate parameter (a), and with conditions during each reference period (b) in predicting the FD of all taxa included in this analysis and represented by herbarium records (n = 2,468 species), as derived from species-specific linear regression analyses conducted using 25-fold cross-validation. Climate parameters consisted of maximum mean seasonal temperature (TMAX), minimum mean seasonal temperature (TMIN), seasonal number of frost-free days (NFFD), date of the beginning of the annual frost-free period (BFFP), date of the end of the annual frost-free period during the prior year (EFFP), mean annual temperature of the prior year (MAT), mean temperature of the coldest month (MCMT), seasonal total precipitation (PPT), seasonal precipitation as snow (PAS), and total annual precipitation of the previous year (TAP). Vertical black lines indicate standard errors of the associated mean. Within each panel, letters that are shared between bars indicate groups that do not differ significantly with respect to their mean R^2 value, based on Tamhane's T2 tests