Coast redwood seedling survival across multiple years in regions modeled as no longer suitable for redwood establishment

West Valley College Pepperwood

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Despite the predictions of species climate models, coast redwood seedlings are surviving in part of the range deemed 'no longer suitable for establishment'

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In 2023 more new seedlings established than in the 5 previous years; these seedlings were also more resilient than the newer 2024 seedlings

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Monitored macro & micro-climate factors seem to influence new seedling survival

Introduction

Coast redwoods (*Sequoia sempervirens*) inhabit a narrow band of coastal California, and species models suggest climate change is contracting the suitable range significantly[1,2].
Early climate change effects are expected at range extremes, yet exceptional abiotic conditions may allow for seedling establishment and persistence in microsites located within areas modeled as outside the seedling climate envelope[3,4].
Pepperwood Preserve, at the far eastern edge of the species range, is at high risk of redwood loss, with only a few small scattered groves remaining.

Fig. 1*: Map of Northern California, showing (solid green) location of coast redwood groves in 2019 and (green cross-hatch) predicted range for coast redwoods in 2010 based on Fernandez et al. (2015) and an A2 emissions scenario. Base map from ESRI; current range in 2019 from USFS; modeled range shapefiles from Healy Hamilton. Blue asterisk shows approximate location of Pepperwood Preserve in Sonoma County.*

Study Background

Redwood areas at Pepperwood burned in 2017.
Seedling monitoring began in 2018, focusing on two 20x50m plots along an elevational gradient.
From 2018-22, we observed spring germination each year, but by year end, survival was generally <8%.
In late 2022, part of our plot study area burned in a prescribed fire, and that winter also brought atmospheric rivers that ended a prevailing drought.
Across the 2023 season, we observed significant seedling survival for the first time. The 2024 season allowed us to monitor *second-year* seedling response in sufficient numbers for the first time.

Data: seedling response

In 2023, seedling survival outpaced other years; in 2024, the second-year seedlings outperformed first-year seedlings.

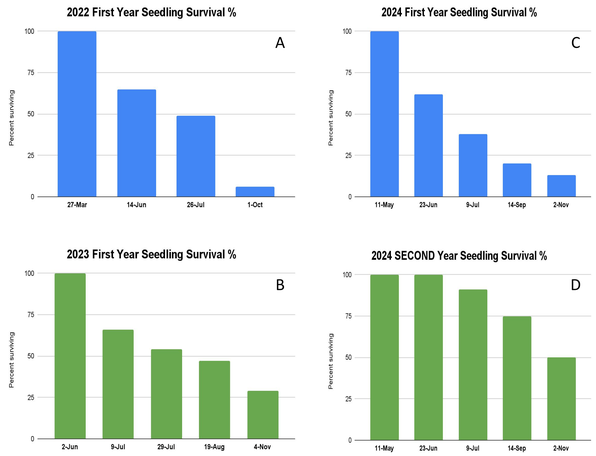

Fig. 2: *Percent first-year seedling survivorship across the season in 2022 (A), 2023 (B), and 2024 (C); percent seedling survivorship of second-year seedlings across 2024 (D).*

Data: climate/microclimate

2023 was warm and wet, not as hot or dry as other years

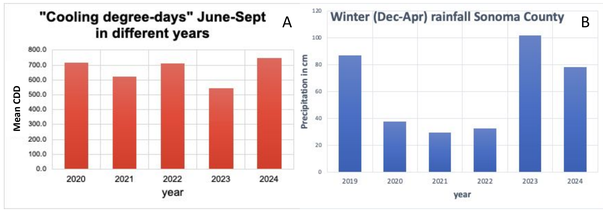

Fig. 3: *A: Cumulative time with summer temperatures above 18 C; B: winter rainfall in Santa Rosa. Use QR code for more detail on "cooling degree-days" (CDD) and weather stations/data sources.*

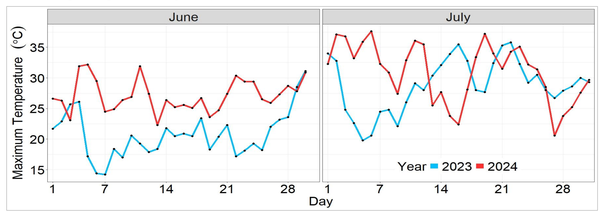

Fig. 4: *Maximum daily temperatures in June & July 2023 and 2024 from on-site datalogger measurements.*

Methods

New seedlings are flagged along transects within our study plots in spring each year; mortality and seedling heights are assessed across seasons and years.
Soil moisture is sampled at seedling microsites and at predetermined locations within our plots, using a Campbell Scientific Hydrosense II.
Temperature and relative humidity are measured at 30 minute intervals with Kestrel D2 data-loggers housed in radshields, 0.5 m from ground level.

Results/discussion

Coast redwood seedling survival across summers at Pepperwood has been poor since the Tubbs Fire in late 2017 (Fig. 2 A & C show examples). This pattern fit with models[1] suggesting this region is now outside the suitable range for redwood establishment. But, in 2023 seedling survivorship was higher at nearly 30%[5].
Three contributing environmental factors stood out. Rainfall in winter 2023 was significantly higher than in previous years, a controlled burn in parts of our site changed soil and microclimate characteristics, and the summer of 2023 was particularly mild (see Fig. 3A and Fig. 4).
First year seedlings have had high mortality in hotter and drier years, but the seedlings that had survived from 2023 were more resilient. In 2024, only 13% of *new* seedlings survived, but 50% of the second-year seedlings were alive at the end of the field season in November.

Conclusions

Recent research suggests that macroclimate based analysis may over-predict future plant species range shifts[3,6]. Our data suggest that the right combination of abiotic factors in a redwood seedling's first year may allow establishment in "unsuitable" locations[1].
Our next question pertains to establishment sustainability: is it possible, for example, that after three years most surviving seedlings will be able to handle environmental extremes?

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For more information, including abstract, author affiliations, literature cited, and supplemental data and discussion:

See our sister team's poster (Poster 11) to learn about drought stress effects on redwood needle structure

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