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# Relationship Between Trunk Cross-Sectional Area Growth and Water Stress in Garry Oaks *(Q. garryana)*: A Species of Conservation Concern


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## Introduction

In the Pacific Northwest, Garry oaks (*Quercus garryana*) provide habitats and support ecological diversity for over 627 species including mammals, fungi, and plants (Fuchs, 2001). Historically, Garry oak habitats were maintained by indigenous people's land stewardship (Blackburn & Andersen, 1993). Currently, Garry oak habitats have been reduced to less than 10% of their historical range due to changes in land management and fire suppression (Fuchs, 2001). Information to support restoration is needed. To support efforts to preserve and support Garry oaks in Pacific Northwest habitats, we aim to understand how habitat affects photosynthetic water-use efficiency and cross sectional growth, and which physiological measurements predict cross-sectional growth.

Garry oaks exist in a wide range of habitats, ranging from low to high canopy coverage, and often compete with conifers for resources to survive. Oaks in the forest and woodland habitat compete with conifers and have high to medium levels of canopy coverage. Oaks in the savannah do not compete with conifers and grow in large fields of grass with little to no canopy coverage (Stephens et al., 2020). In general, Garry oaks are shade-intolerant and need a high level of light exposure for maximum growth (Merz, 2015).

Plant growth is affected by access to water, light, and nutrients in the environment. Plants use these resources to go through photosynthesis which produces sugars and results in growth and cellular production (Lambers & Oliviera, 2020). Photosynthetic water-use efficiency ($d^{13}C$) is an integrated measurement that is affected by the resources used in plant growth (Vadabonceur et al., 2020; Figure 1). High levels of sun exposure and water stress (Ψ) can lead to impaired growth in plants (Sullivan & Eastin, 1975). Contrarily, less canopy coverage results in more sunlight which is needed for photosynthesis and Garry oak growth (Merz, 2015). Carbon and nitrogen are used to produce macromolecules needed for plant function and growth (Lambers & Oliviera, 2020). Leaf Carbon-Nitrogen ratio (C:N) is an indicator of leaf nutrition and health. A reduction in nitrogen relative to carbon (high C:N) is associated with loss of photosynthetic function in leaves (Chen et al., 2015).

## Key Questions & Hypothesis Diagram

### Key Questions

**1) Do Garry oaks in different habitats have differences in trunk cross-sectional growth and photosynthetic water-use efficiency ($d^{13}C$)?**

**2) Is Garry oak trunk cross-sectional growth predicted by Carbon-Nitrogen ratio, water stress (Ψ), and photosynthetic water-use efficiency ($d^{13}C$)?**

### Hypothesis Diagram

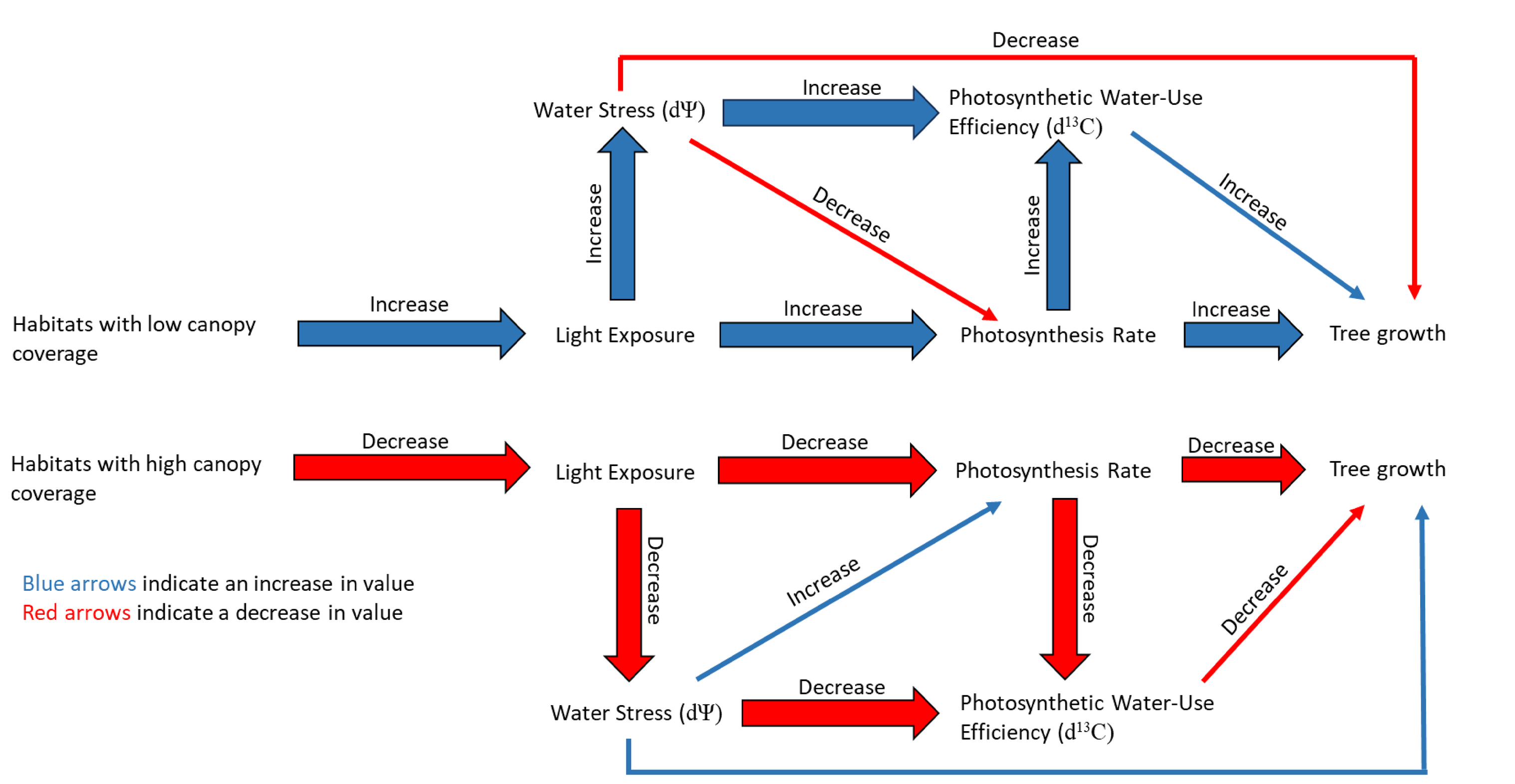


**Figure 1:** Visual of hypothesized biological mechanisms connecting growth and habitat to $d^{13}C$ and Ψ.


## Acknowledgments

This research occurs on privately owned land and is made possible thanks to landowners including Sarah & Ken Edwardsson, Rick Kipper, and the Republic Services Coffin Butte Landfill. Special thanks to all of the Oak Ecology Research Group students who have collected data over the years. This work is supported by Western Oregon University awards to ARH, GRH, and JSC and the Walker-Brodie award to JSC.


## Land Attribution

We are conducting this research on the land of the Cayuse, Umatilla, Walla Walla, Kalapuya, and Chepenefa who today are represented by the Tribes of the Grand Ronde and Confederated Tribes of Siletz Indians land. We offer gratitude to the land itself and those who have stewarded it for generations. We are grateful for the opportunity to study, learn, and work on this land and acknowledge our University is fundamentally tied to colonial developments in the Willamette Valley.


**Figure 2:** Study site with habitat classifications and brief descriptions of habitats

## Results

**1) Do Garry oaks in different habitats have differences in trunk cross-sectional growth and photosynthetic water-use efficiency ($d^{13}C$)?**

Garry oaks in the savannah habitat **grow at a greater rate** than Garry oaks in **other habitats** ($F = 14.81$; $Df = 3, 90$; $p < 0.05$; Figure 3) and have a **greater rate of photosynthetic water-use efficiency** ($F = 7.19$; $Df = 3, 160$; $p < 0.05$; Figure 4). The **effect of habitat** on growth ($F = 0.552$; $Df = 9$; $p = 0.833$) and photosynthetic water-use efficiency ($F = 0.694$; $Df = 9$; $p = 0.713$) was **independent of year.**

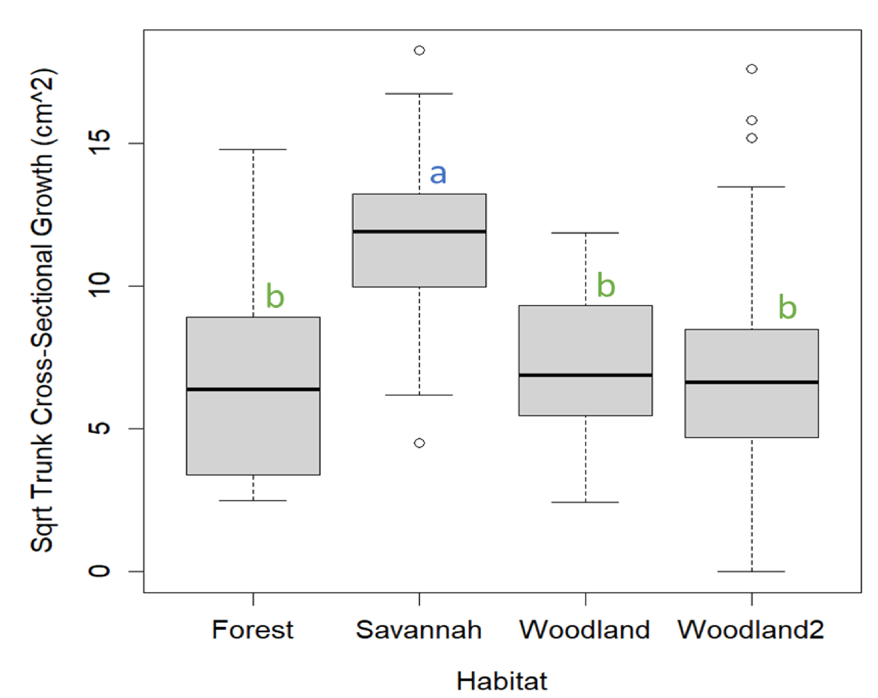


**Figure 3:** Box and whisker plot of habitat (n = 6-9 per habitat) compared to trunk cross-sectional growth (n = 30). Different letters indicate **statistically significant differences** according to Tukey's HSD.

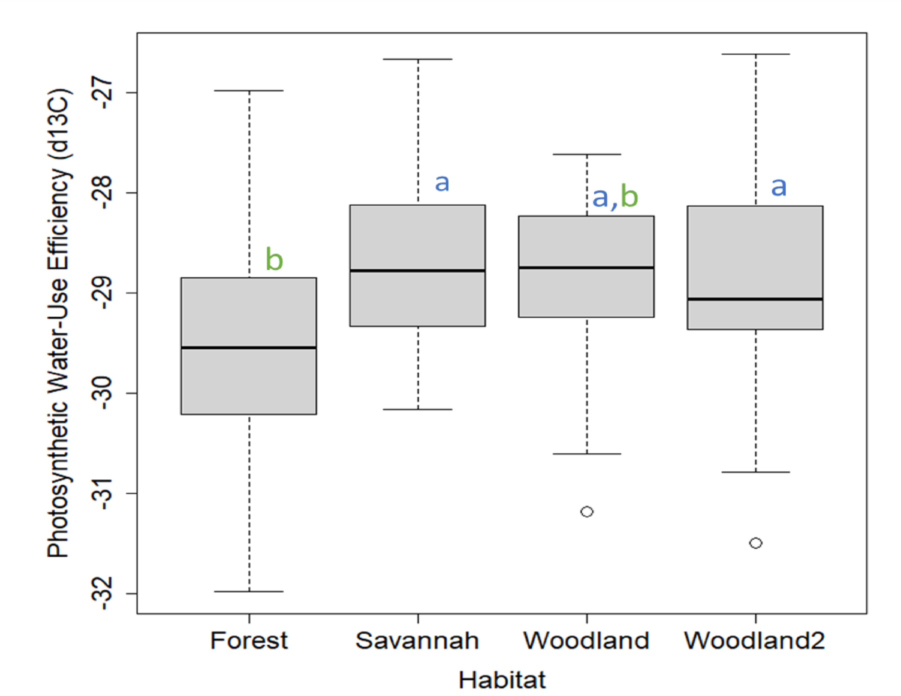


**Figure 4**: Box and whisker plot of habitat (n = 7-15 per habitat) compared to photosynthetic water-use efficiency (n = 47). Different letters indicate **statistically significant differences** according to Tukey's HSD.

**2) Is Garry oak trunk cross-sectional growth predicted by Carbon-Nitrogen ratio, water stress (Ψ), and photosynthetic water-use efficiency ($d^{13}C$)?**

**Photosynthetic water-use efficiency and year predicted trunk cross-sectional growth** (Figure 5; Table 3). Year predicting cross-sectional growth confirms that Garry oaks grow every year. No other variables in the fixed effect model predicted growth (Table 3) and all explanatory variables were **independent of year** (Table 3).

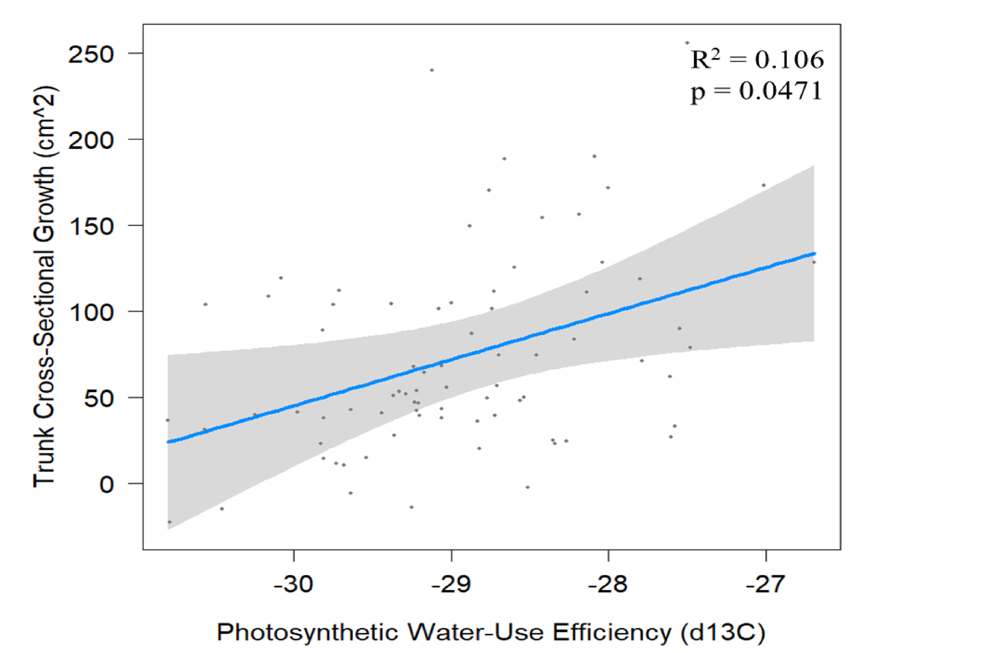


**Figure 5:** Fixed effect linear model (Adjusted $R^2 = 0.106$) showing trunk cross-sectional growth compared to photosynthetic water-use efficiency from 2019 to 2022 (n = 47). Each data point compares a tree's growth in a single year to photosynthetic water-use efficiency.

**Table 3:** Results of linear fixed effects model examining which physiological measurements best predict trunk cross-sectional growth and whether any measures had an interaction with year.

| | Df | F value | p-value |
|---|---|---|---|
| Delta Psi | 1 | 0.691 | 0.409 |
| Year | 1 | 8.23 | **0.00545** |
| C:N | 1 | 0.229 | 0.636 |
| $d^{13}C$ | 1 | 4.30 | **0.0471** |
| Delta Psi*Year | 1 | 0.423 | 0.516 |
| C:N*Year | 1 | 2.05 | 0.156 |
| $d^{13}C$*Year | 1 | 0.217 | 0.643 |
| Residuals | 70 | | |

## Conclusions

### 1) Garry oak trunk cross-sectional growth and photosynthetic water-use efficiency occur at a greater rate in savannah habitat

Garry oaks in the savannah have greater rates of growth and photosynthetic water-use efficiency compared to other habitats. Savannah has the least amount of canopy shade which is ideal for Garry oak growth (Merz, 2015). This aligns with the hypothesis that more sunlight increases photosynthesis water-use efficiency and rate of growth (Figure 1). Photosynthetic water-use efficiency by habitat and growth by habitat were independent of year (Figure 3). Differences due to habitat were not related to the change in years. Future Garry oak restoration efforts should create habitats that reduce canopy coverage and allow maximum exposure to sunlight to encourage growth.

### 2) Garry oak cross-sectional area growth is predicted by photosynthetic water-use efficiency ($d^{13}C$)

Greater photosynthetic water-use efficiency and year predicted trunk cross-sectional growth. Mature Garry oaks grow in trunk size every year and do so at a greater rate under low canopy coverage and high water stress. Leaf C:N did not predict growth. Nutritional content in the leaves did not vary enough in growing trees to affect growth. No physiological measurement in our model had an interaction with year. Measures of physiological variables were all independent of year (Table 3). These results suggest that Garry oaks have mechanisms that tolerate or avoid water stress while maintaining high rates of photosynthesis. Our fixed effects model only predicted 10.6 percent of trunk cross-sectional growth; other physiological measures may better predict the growth of Garry oaks.

## Methods

**Research site:**

Samples were collected at a 22-ha study research site (44°41'13.89"N, 123°13'30.15"W), located in the Willamette Valley, Oregon and in the middle of the range of the study species.

The research site has three habitat types: oak-savannah (<25% canopy cover), restored oak woodland (25-75% canopy cover), and mixed coniferous-deciduous forest (>75% canopy cover). Restored oak-woodlands are further categorized as woodland (logging to reduced tree density), or woodland 2 (logging to reduced tree density followed by understory restoration; Figure 1).

**Tree selection and foliage sample collection:**

Mature Oregon Garry oaks across different habitats were selected for study, resulting in 47 trees across four different habitat classes (Figure 2). For the subset of growing trees, only trees with a moderate positive relationship between year and growth (Pearson's Coefficient> 0.6) were chosen. Canopy material for leaf traits and trunk diameter at 1.5m above ground measurements were obtained during August 2019 to 2023. Sample collections for canopy material were made within two time periods, afternoon (12:30 PM to 7:00 PM) and predawn (2:00 AM to 6:00 AM).

Material was pole pruned were possible or obtained using a pneumatic cannon to place a wire saw attached to rigging into oak canopy fragments up to 30m above ground. Directly following cutting, branch samples were sealed in plastic bags and kept cool with ice. Field measurements were obtained within approximately 60 minutes of sampling.

Samples were transported to the laboratory within 8 hours and frozen at -20°C for later processing and trait analysis.

For tissue analysis a subsample of leaf blades were microwaved to denature enzymes, dried at 60°C until constant weight (at least 48h), then stored dry and frozen at -20°C. Prior to tissue analysis material was ball-mill homogenized

**Leaf Traits**

**Afternoon (Peak Ψ, MPa)** and **predawn (Baseline Ψ, MPa)** and **dΨ (Delta Ψ, MPa)** leaf water potential – tree water stress levels at the time of sampling were measured during field collection. A single relatively undamaged leaf was assessed with a Scholander-type pressure chamber (model 600 or 1000; PMS Instruments, Albany, OR). dΨ was calculated by taking the absolute value of peak Ψ and subtracting it from the absolute value of the baseline Ψ to find the difference, or dΨ

**Leaf photosynthetic water-use efficiency ($d^{13}C$, per mil), foliar carbon (C%, %), and nitrogen (N%, %)** contents were measured on bulked and homogenized leaf blades. Analyses were performed at the OSU Stable Isotope Laboratory (Corvallis, Oregon) and the Stable Isotope Core Laboratory (Pullman, Washington) by continuous-flow isotope ratio mass spectrometry using a Carlo Erba elemental analyzer (EA) connected to an EA-Delta Plus IRMS (Thermo Fisher Scientific, Waltham, MA). C% and N% were used to calculate C:N ratios.

**Trunk Growth Traits**

**Trunk Diameter (cm)** was collected by using diameter at breast height tape at 1.5 meters above ground level to find diameter based off of trunk circumference.

**Trunk Cross-Sectional Area ($cm^2$)** was calculated using the diameter to find the area of a circle using the equation A = π r2.

**Trunk Cross-Sectional Growth ($cm^2$)** was calculated using the trunk cross-sectional area of 2019 as a baseline. The cross-sectional area of the 2020-2023 had the baseline of 2019 cross-sectional area of 2019 subtracted from their calculated areas to find total growth.

**Statistics**

Trunk cross-sectional growth for each year (2019-2023) was analyzed in one model

Two two-way ANOVAs were conducted followed by a Tukey's HSD test to find differences in photosynthetic water-use efficiency by habitat and year and trunk cross-sectional growth by habitat and year.

For trunk cross-sectional growth (numerical response variable) the significance of numerous predictor (explanatory) variables and their interaction with year were assessed using linear fixed effects models and linear mixed effects models in R using the packages lmerTest, lme4. Predictor variables were first assessed for multi-co-linearity, and collinear variables were not put in the same model. In the random effect model, tree ID was used as the random effect to account for differences in individual tree measurements throughout multiple years. In all cases, model residuals were assessed for normality and homogeneity of variance:

Fixed Effects Model: Trunk Cross-Sectional Growth ~ dΨ + Leaf C:N + Photosynthetic Water-Use Efficiency + interactions by year

Mixed Effects Model: Trunk Cross-Sectional Growth ~ dΨ + Leaf C:N + Photosynthetic Water-Use Efficiency + (1|Tree ID) + interactions by year

We report results graphically here where the significance of the explanatory predictor variable was significant ($p<0.05$)

## References


Blackburn & Andersen. (1993). Before the Wilderness: Environmental Management by Native Californians

Chen D, Wang S, Xiong B, Cao B, Deng X. Carbon/Nitrogen Imbalance Associated with Drought-Induced Leaf Senescence in Sorghum bicolor. (2015). PLoS One.

Fuchs. (2001). Towards a Recovery Strategy for Garry Oak and Associated Ecosystems in Canada: Ecological Assessment and Literature Review. Technical Report GBEI/EC-00-030. Environment Canada, Canadian Wildlife Service, Pacific, and Yukon Region

Lambers & Oliveira. (2019). Plant Physiological Ecology.

Stephens et al. (2020). Restoration Treatments Reduce Threats to Oak Ecosystems and Provide Immediate Subtle Benefits for Oak-Associated Birds. Restoration ecology 29(1).

Merz, Matthew A. (2015). Physiological variation of Garry oak (Quercus garryana) seedlings to drought stress. All Master's Theses. 165.

Sullivan & Eastin. (1975). Plant Physiological Responses to Water Stress. Developments in Agricultural and Managed Forest Ecology 1.

Vadeboncoeur, Jennings, Ouimette, & Asbjornsen. (2020). Correcting tree-ring δ13C time series for tree-size effect in eight temperature tree species. Tree physiology 40(3).