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Geographic Chronicles

The Climate Response of *P. lambertiana*, *P. monticola*, and *P. jeffreyi* in Yosemite and Sequoia National Parks, California

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Abstract

This research investigates the sub-annual climate response of ten *Pinus lambertiana* and eight *Pinus jeffreyi* from Yosemite, and ten *Pinus monticola* and ten *Pinus jeffreyi* from Sequoia. We investigate the potential of using resin ducts to measure the earlywood and latewood of *P. lambertiana* and *P. monticola* and compare this growth with co-occurring, traditionally measured *P. jeffreyi*. Correlation analyses of ring widths with average monthly temperature, vapor pressure deficit (VPD), and precipitation were conducted. Our results show that the resin duct method performed poorly at both sites but better with *P. lambertiana* at Yosemite. Species at both sites generally have a positive correlation with precipitation. Earlywood and latewood correlations with climate were relatively weak. Temperature and VPD correlations were generally positive in the spring and negative in the summer months at both sites for all three species. These results reveal that future increases in temperature and VPD will leave these trees vulnerable to future droughts. More samples are needed throughout the Sierras to determine if the resin duct method can be used for sub-annual climate reconstructions, if these results can be generalized, and if sub-annual reconstructions are possible for these three species.

Keywords: tree rings, climate signal, earlywood, latewood, Sierra Nevada Mountains

Introduction

CALIFORNIA'S MAIN SOURCE of water is from precipitation in the Sierra Nevada Mountains (Jones 2015), and events such as droughts can have a profound negative effect on the state's water supply. This makes climate research imperative to further the understanding of climate variability throughout California. According to Bales et al. (2011), the Sierra Nevada Mountains account for 27 percent of the total precipitation in California, providing 60 percent of the state's total water supply. An increasingly

drying climate and rising temperatures negatively impact the Sierra Nevada snowpack (Bales et al. 2011) and subsequently the state's water security. Warming temperatures will cause earlier snowmelt and more precipitation falling as rain rather than snow (Kapnick and Hall 2010), reducing the annual average snow. The year 2014 had the driest recorded soil moisture for California in the last 1,200 years and, as of fall 2021, was on track to eclipse that record (Borunda 2021; Griffin and Anchukaitis 2014). Furthermore, three years or longer droughts are common in the state of California (Griffin and Anchukaitis 2014).

Meteorological records in the Sierra Nevada Mountains are not long enough to test and capture the long-term variability of climate (Cook et al. 1999; Stambaugh et al. 2011). Tree-ring chronologies in dendroclimatology represent the climatic conditions of their location over the lifespan of the tree (Meko, Stockton, and Boggess 1995; Speer 2010), making them ideal proxies for studying climate variability. The benefit of tree-ring data is that growth rings can be accurately dated annually and, in some cases, sub-annually (Griffin et al. 2013; Leavitt et al. 2011).

Pinus lambertiana (sugar pine), *Pinus jeffreyi* (Jeffrey pine), and *Pinus monticola* (western white pine) grow in mixed-conifer forests at high elevations (300 to 3,200 meters) in the Sierra Nevada Mountains and they tend to be the dominant species in old-growth stands (Habeck 1992; Kershner et al. 2008). These species are long-lived (up to 500 years) (Gucker 2007), and their longevity makes it possible to look back over hundreds of years of climate history using dendroclimatology. Their locations are favorable because they grow in undisturbed locations, at elevations where mixed-conifer forests are exceedingly productive (Bales et al. 2011). These three species in the Sierra Nevada Mountains are relatively well studied in the tree-ring literature (Hurteau, Zald, and North 2007; Slack et al. 2017; Slack, Kane, and Knapp 2021; Stephens 2001), but they appear to be underutilized in dendroclimate studies and specifically dendroclimate reconstructions in the region. Hurteau et al. (2007) found that annual growth rings of *P. jeffreyi* and *P. lambertiana* represent climate models well at a site in the southwestern Sierra Nevada Mountains. This is despite *P. jeffreyi* having a lagged response to climatic conditions at their sample site (Hurteau et al. 2007).

Recent studies in the southwestern United States have divided annual growth rings into earlywood (EW) and latewood (LW) (Griffin et al. 2013; Leavitt et al. 2011; Meko and Baisan 2001). EW represents the formation of cells that form in the cool season (October to April), and LW represents the formation of cells that form in the warm season (June to September) and are darker in appearance (Figure 1) (Griffin et al. 2013; Meko and Baisan 2001). *P. jeffreyi* have a clear delineation in the transition from EW to LW; however, this transition is subtle

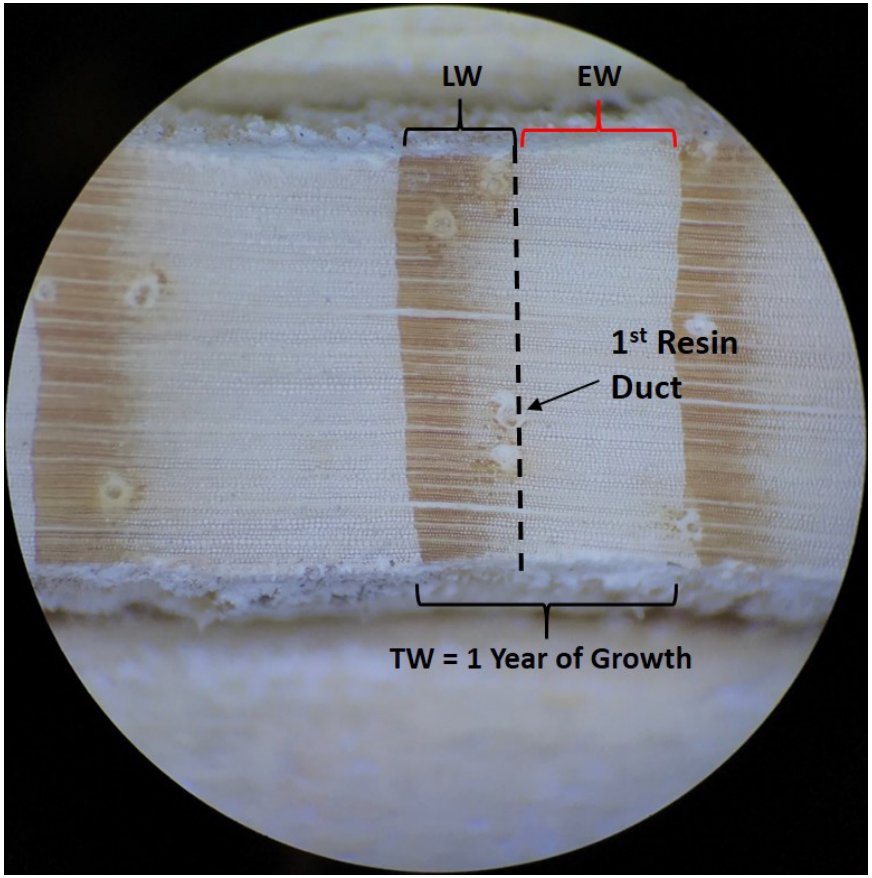

Figure 1. Earlywood (EW; black), latewood (LW; red), and the first resin duct of the ring of P. monticola dashed line represents EW/LW delineation.

and undetectable in the cells of *P. lambertiana* and *P. monticola.* This gradual change in cell colors makes it difficult to distinguish the boundary of the EW and LW, making it hard to produce sub-annual reconstructions.

Matheus et al. (2017) examined the EW and LW of *Pinus edulis* (pinyon pine) using resin ducts to delineate the EW and LW boundary and showed that EW could be used to reconstruct cool-season precipitation in *P. edulis* (Matheus et al. 2017). Resin ducts are large vertical vessels found in conifers, they are used for transporting resin which is used for protection and closing wounds (Richter et al. 2004; Werker and Fahn 1969; Wimmer and Grabner 1997). Traumatic resin ducts can form as the result of stress or a wound (fire, beetle outbreak, infection, etc.) (Bannan 1936; Nagy et al. 2000; Richter et al. 2004; Slack et al. 2017; Thomson and Sifton 1926); however, similar to *P.*

edulis, the resin ducts of most conifers form where the LW boundary begins (Richter et al. 2004; Werker and Fahn 1969; Wimmer and Grabner 1997). Duct formation along the LW boundary makes it practical to use these ducts to delineate the LW boundary in species where this boundary is not discernable (Matheus, Maxwell, and Harley 2017; Richter et al. 2004; Werker and Fahn 1969; Wimmer and Grabner 1997).

In this study, we investigate similarities in the EW, LW, and total wood (TW) ring width of *P. jeffreyi*, *P. lambertiana*, and *P. monticola*. The resin duct method is applied to measure the EW and LW ring widths of *P. lambertiana* and *P. monticola* and standard methods are used to measure *P. jeffreyi*. Because the EW/LW boundary of *P. jeffreyi* can be determined using traditional dendrochronology methods and is co-occurring with the other two species, they should exhibit the same climate response. High correlations between the ring width measurements of *P. jeffreyi* and *P. lambertiana* as well as *P. monticola* could justify the use of the resin duct method. Additionally, this is one of the first studies to examine the sub-annual climate response of *P. jeffreyi, P. lambertiana,* and *P. monticola*. This will be done by correlation analysis of tree-ring widths with existing climate data. Through these analyses we (1) determine the performance of the resin duct method in measuring the EW and LW in *P. lambertiana* and *P. monticola*, (2) learn the sub-annual climate response of each species, and (3) determine the feasibility of sub-annual climate reconstructions of each species at our sample sites.

Methods

Sample Collection

Samples for this study were collected from two sites, Wolverton (36.6°N, 118.7°W) in Sequoia National Park, and Gin Flat in Yosemite National Park (37.77°N, 119.77°W) and have elevations of 2,745 m and 2,100 m, respectively (Figure 2). Both sites receive most of their precipitation from December to March with January being the wettest period and August being the driest (PRISM 2020). In the Sierra Nevada Mountains at elevations above 1,524 m, snowpack supplies storage of water needed for forest growth in the late spring to early summer (Bales et al. 2011). This makes these locations well suited to test the resin duct method in *P. lambertiana* and *P. monticola,* as there should be a strong climate signal in the EW. *P. jeffreyi* grows abundantly at both sites, making it ideal to compare to *P. lambertiana* and *P. monticola* at Gin Flat and Wolverton, respectively (there were few *P. lambertiana* at Wolverton and no *P. monticola* at Gin Flat). Ten *P. jeffreyi* and ten *P. monticola* were sampled at Wolverton, and ten *P. jeffreyi* and ten *P. lambertiana* were sampled at Gin Flat as close to one another as possible.

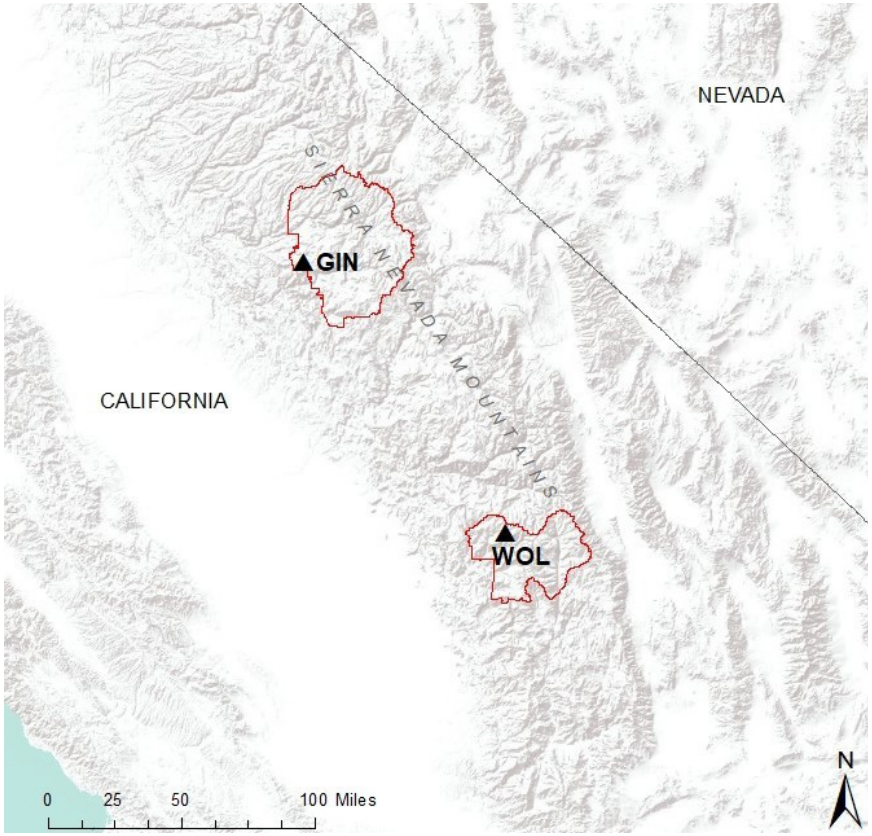

Figure 2. Tree-ring sample sites. Gin Flat (GIN) in Yosemite National Park, and Wolverton (WOL) in Sequoia National Park.

Dendrochronology methods used to collect and prepare the samples were based on procedures described by Stokes and Smiley (1996), Fritts (1976), and Speer (2010). A targeted sampling approach was used to select specific trees at each site. This approach is suitable to find older trees based on their features because samples with the most rings are desirable. Trees on a slope were targeted because of the increased likelihood of their roots being responsive to the melting snow or precipitation running down the slope (Speer 2010). Trees having visual signs of disturbance or damage (broken limbs, fire or rockfall scars, dieback or yellowing needles, etc.) were avoided to reduce the number of traumatic resin ducts produced by the tree.

Two cores were extracted at breast height (~1.2 m) from each tree using a handheld 5 mm increment bore. Both cores were taken from opposite sides of the tree, parallel to the slope to reduce the impact of asymmetrical

tree growth on the rings (Fritts 1976; Speer 2010). Once extracted, the cores were placed inside individually labeled paper straws to protect and dry them, and then placed in a plastic map tube for further protection and transport.

Samples were sanded with consecutively finer sandpaper to improve the visibility of each ring, rings were counted, and the list method was used for visually cross-dating the rings (Fritts 1976; Speer 2010; Stokes and Smiley 1996; Yamaguchi 1991). Twenty cores were used for analyses for both species at Wolverton and from *P. lambertiana* from Gin Flat; however, only 16 cores were used from *P. jeffreyi* at Gin Flat due to four of the cores being damaged from heart rot or too twisted to mount correctly.

Ring Width Measurement

The transition between the EW and LW in most conifers is typically identified by a decrease in cell lumen size and an increase in cell wall thickness this results in a darker color in the ring for a given year at the EW and LW boundary (Speer 2010; Werker and Fahn 1969; Wimmer and Grabner 1997). In *P. jeffreyi*, the transition from EW to LW was easily distinguishable and could be measured using traditional methods. Unlike *P. jeffreyi,* the EW to LW boundary was not easily discernable in all the rings of *P. lambertiana* and *P. monticola*. Because the boundary was not clear, the resin duct method was implemented to potentially delineate the EW from the LW boundary in *P. lambertiana* and *P. monticola* (Matheus et al. 2017).

When measuring using the resin duct method, the first resin duct that is located in the tree ring is used to delineate the EW and LW boundary (Matheus et al. 2017). Matheus et al. (2017) found that due to the low frequency and lack of temporal pattern of rings without resin ducts, 8-14 percent (12.5 percent and 15.8 percent for *P. monticola* and *P. lambertiana* respectively at our sites), the proportion of the EW to LW was not significant to the final LW climate correlations. Thus, rings without resin ducts are divided in half for consistency across sites and species and to simplify the measurement process (Matheus et al. 2017). Each sample of *P. jeffreyi*, *P. lambertiana*, and *P. monticola* was measured under a microscope using a Velmex micrometer accurate to 0.001mm. There were a total of five missing rings between all the cores from both sites. The measurements of the TW, EW, and LW were then recorded in Measure J2X software (Voorhees 2000).

Samples were cross-dated to ensure accuracy using COFECHA (Holmes 1983). COFECHA provides an inter-series correlation that is a measure of the signal strength common to all the sampled trees at the site. COFECHA statistically verifies the tree-ring dates assigned to each core ($p < 0.01$). The biological growth trend of TW, EW, and LW for each species was removed using a cubic smoothing spline with frequency response at the 0.5 wavelength equal to 70 percent of the sample length (Cook and Peters 1981; Griffin et al. 2011). Removing the biological growth trend helps separate the lower frequency climate data from the higher frequency noise associated with forest dynamics. A ratio of the biological growth trend and the measured widths was used to create tree-ring indices for each core (Cook 1985). The influence of the previous year's growth on the current year's growth was removed from the EW, LW, and TW with autoregressive modeling (Box and Jenkins 1976; Meko 1981). The final chronologies were creating using a robust bi-weight mean for each site and species by averaging the indices for each core from each site (Cook, Shiyatov, and Mazepa 1990). Finally, the LW was adjusted (LWa) to remove the influence of the EW growth by taking the residuals of the regression of LW on EW, thus removing the dependence of the LW on the EW (Meko and Baisan 2001).

Climate Data

Parameter-elevation Regression on Independent Slopes Model (PRISM) 4 km-gridded monthly average temperature, vapor pressure deficit, and precipitation was downloaded for the closest grid to each site for 1895 to 2017 (PRISM 2020). PRISM data are created by the interpolation of individual station data and screened for use in climatological studies. PRISM data were used as there were no meteorological station data available for these remote sites. At the 4 km resolution, these data are spatially coarse. However, trees respond to climate over a much larger area than the sample sites alone, and PRISM data are also frequently used in the literature (Crawford, Griffin, and Kipfmueller 2015; Lepley et al. 2020; Meko et al. 2011). Each climate variable was correlated with the EW, LWa, and TW of the standardized chronologies using DendroClim 2002 (Biondi and Waikul 2004). DendroClim 2002 correlates the current year (t) and the previous year (t-1) monthly variables with the current year's ring widths. The previous year and current year correlations are used to show the relationship the previous year's conditions have on the current year's tree growth (Biondi and Waikul 2004). For example, a tree that is hot and stressed in the previous year will have a carryover effect into the current year. We expect there to be positive correlations for EW, LWa, and TW with precipitation. There should be positive correlations in the spring for EW and TW, with negative correlations in the summer for LWa and TW with temperature and VPD. Furthermore, the EW having the strongest correlation with climate variables in spring months and the LWa having the strongest correlation with climate variables in summer months would indicate the EW and LWa were measured correctly.

Results

Ring Width Measurement

The inter-series correlations for *P. jeffreyi*, *P. monticola*, and *P. lambertiana* chronologies are all statistically significant ($p < 0.01$, Table 1). *P. monticola* at Wolverton has the highest inter-series correlation coefficient of 0.585 ($p < 0.01$). Correlations of the TW between the species at each site were significant (Table 2), indicating that all of the species at each site respond similarly to environmental and climatic variables. However, the r-value of the correlated TW between *P. jeffreyi* and *P. monticola* at Wolverton was relatively low (r=0.241, $p < 0.05$).

All r-values of the EW, LWa, and TW between the *P. jeffreyi* (the control) and *P. monticola* and *P. lambertiana* are statistically significant, except for the LWa between *P. monticola* and *P. jeffreyi* from Wolverton (Table 2). Although the correlations are significant, they are still relatively low. The tree species at Wolverton have the lowest correlations indicating the resin duct method performed poorly at this site (EW r=0.222, $p < 0.05$; LW r=0.023, $p = 0.80$). EW and LW correlations at Gin Flat (EW r=0.316, $p < 0.05$; LW r=0.301, $p < 0.05$) are higher than the values from Wolverton.

Table 1. Inter-series Correlation.

Site/ Species	Number of Cores	Average Age	Inter-series Correlation*
WOMO	20	325.6	0.585
WOJE	20	196.5	0.541
GFLA	20	116.8	0.500
GFJE	16	244.5	0.517

*$p < 0.01$

Table 2. Early Wood and Late Wood Width Correlations for Wolverton and Gin Flat.

P. monticola vs. *P. jeffreyi* (Wolverton)		
EW R-values	LW R-values	TW R-values
0.222*	0.023	0.241*
P. lambertiana vs. *P. jeffreyi* (Gin Flat)		
EW R-values	LW R-values	TW R-values
0.316*	0.301*	0.401*

* $p < 0.05$

Climate Sensitivity

All seasons hereafter are defined as winter (December through February), spring (March through May), summer (June through August), and autumn (September through November).

Temperature

The correlation analyses of temperature at the Wolverton site for both species (*P. monticola* and *P. jeffreyi*) were not similar. Unlike *P. jeffreyi*, the LWa for the *P. monticola* did not correlate and had no signal for temperature. The year 2021's late summer temperature positively correlates with the EW, LWa, and TW of the *P. jeffreyi* (Figure 3). There are positive correlations for the EW and TW of the *P. monticola* for spring 2021.

The correlation analysis with temperature at Gin Flat for both species (*P. lambertiana* and *P. jeffreyi*) are comparable. Both species have negative correlations for the EW and TW in the spring 2020 (Figure 3). *P. jeffreyi* has a negative correlation in 2020's late summer and autumn seasons for its EW and TW. The correlation then shifts into a positive correlation for the EW and TW in winter 2020. There is no correlation between the LWa of *P. jeffreyi* for the temperature at Gin Flat, and *P. lambertiana* only showed a weak positive correlation for November 2021 and a weak negative correlation for March 2020.

Vapor Pressure Deficit

The correlation analysis of VPD at Wolverton for both species was not similar. *P. jeffreyi* had positive LWa correlations scattered throughout 2020 and 2021 (Figure 4). The only negative correlations for *P. jeffreyi* was for late spring 2020 for the EW and June 2021 for the EW and TW. *P. monticola* has mostly negative correlations with VPD, except for a positive correlation in spring 2021 for the EW and TW.

At Gin Flat, both *P. jeffreyi* and *P. lambertiana* have similar correlations. Both have negative correlations for 2020's spring months for the EW and TW (Figure 4). These negative correlations are also similar for both species in the 2020's spring months for the EW and TW for temperature. One significant difference between the climate responses for both species at this site is that *P. jeffreyi* had stronger negative correlation values overall than *P. lambertiana*.

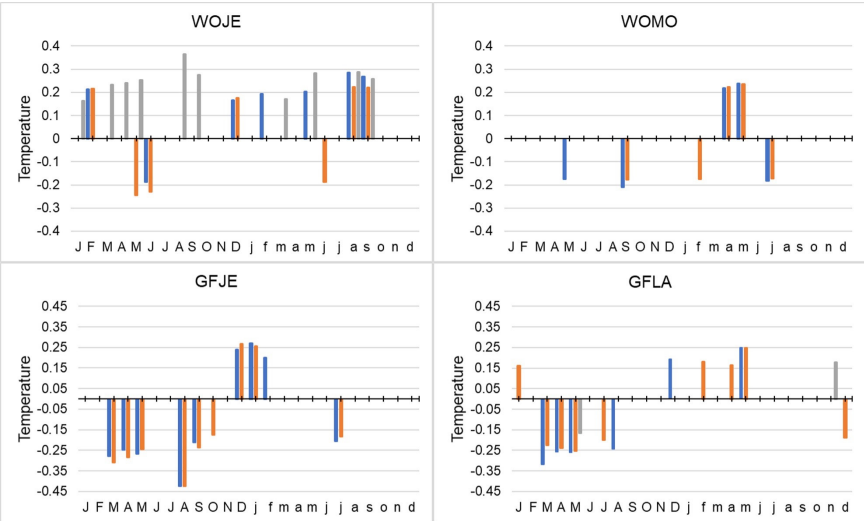

Figure 3. Significant correlations (p < 0.05) of monthly temperature correlations (uppercase = previous year; lowercase = current year) of the EW (orange), LWa (gray), and TW (blue) of P. jeffreyi *(WOJE top left) and* P. monticola *(WOMO top right) at Wolverton, and of* P. jeffreyi *(GFJE bottom left) and* P. lambertiana *(GFLA bottom right) at Gin Flat.*

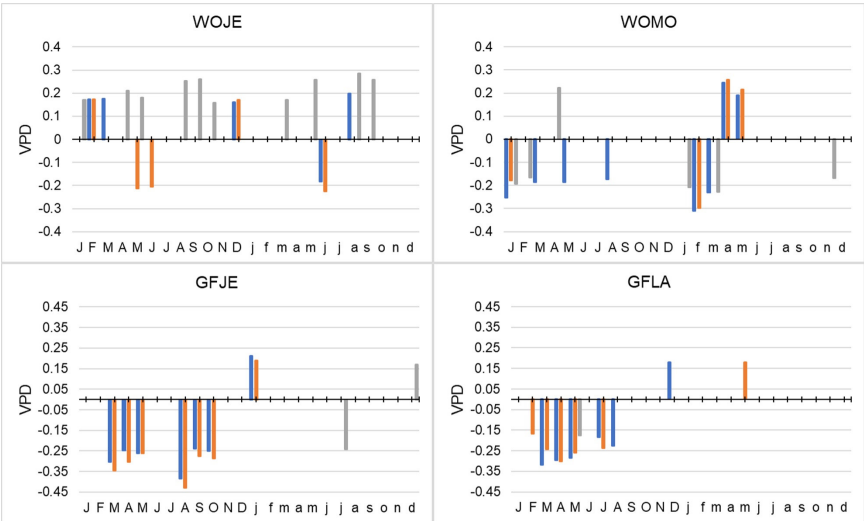

Figure 4. Significant correlations (p < 0.05) of monthly vapor pressure deficit correlations (uppercase = previous year; lowercase = current year) of the EW (orange), LWa (gray), and TW (blue) of P. jeffreyi *(WOJE top left) and* P. monticola *(WOMO top right) at Wolverton, and of* P. jeffreyi *(GFJE bottom left) and* P. lambertiana *(GFLA bottom right) at Gin Flat.*

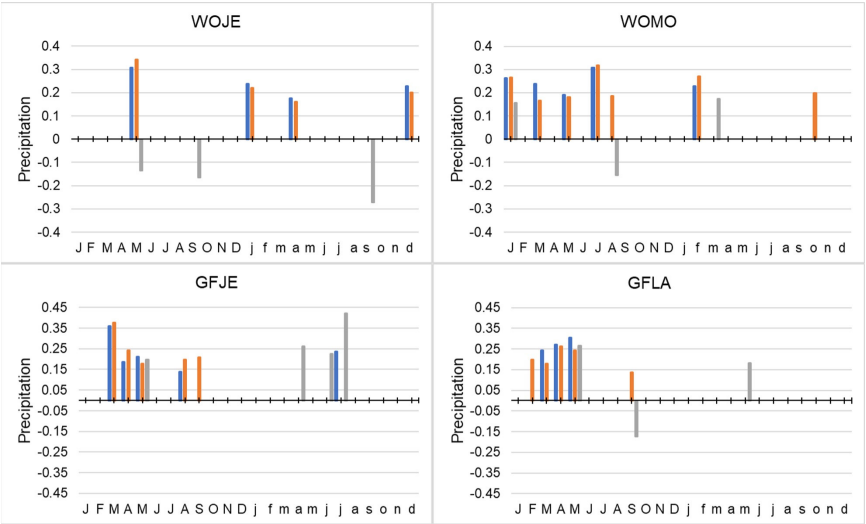

Figure 5. Significant correlations (p < 0.05) of monthly precipitation correlations (uppercase = previous year; lowercase = current year) of the EW (orange), LWa (gray), and TW (blue) of P. jeffreyi *(WOJE top left) and* P. monticola *(WOMO top right) at Wolverton, and of* P. jeffreyi *(GFJE bottom left) and* P. lambertiana *(GFLA bottom right) at Gin Flat.*

Precipitation

The correlations between precipitation and ring widths at Wolverton were positive for both species, except for a few LWa ring widths that negatively correlated with precipitation. However, the only comparable correlations between the two species were the positive correlations with the EW and TW widths in March 2020 (Figure 5). Positive correlations for the EW and TW in *P. jeffreyi* were in 2021's January, April, and December (Figure 5). The precipitation correlations for *P. monticola* were positive for the EW and TW and scattered from winter through early summer.

The precipitation correlation analyses between *P. jeffreyi* and *P. lambertiana* at Gin Flat were positive and similar. The year 2020's spring months influence the EW and TW positively for both species, with the LWa additionally being influenced in May for both species (Figure 5).

Discussion

Ring Width Measurement

EW and LWa width correlations derived from measurements utilizing the resin duct method indicate that the resin duct method should not be used to measure the EW and LW for *P. monticola* at Wolverton. Because the EW and

LW widths rely on the boundary between the EW and LW being accurately delineated, we can't be certain that the EW or LW was properly measured as the LWa correlations were not significant between the species. The resin duct method was more effective for the *P. lambertiana* sampled in Gin Flat with similar results as Matheus et al. (2017).

Two plausible explanations for the low correlations at Wolverton are (1) the sample site is too spread out for species to be considered co-occurring, and (2) resin ducts in *P. monticola* did not form along the EW/LW boundary. Trees at Wolverton were spread over a large area with clusters of *P. monticola* and *P. jeffreyi* being somewhat disjunct. Due to the size of the site, there was a difference in elevation between the two species. *P. monticola* were sampled at 3,049 m and *P. jeffreyi* were sampled at 2,134 m. Additionally, due to the site being along Kings Canyon, the *P. monticola* were sampled on a steeper slope and were less densely populated than *P. jeffreyi*. Consequently, these species are not experiencing the same common growth signal and therefore cannot necessarily be considered co-occurring species.

The results suggest that the resin duct method may be valid for measuring EW and LW ring widths of *P. lambertiana* at Gin Flat. *P. lambertiana* measurements significantly correlated with those of *P. jeffrey*i. These results were similar to Matheus et al. (2017). However, our correlations were lower. The low correlations at Gin Flat in this research could be attributed to resin ducts forming as a result of damage to the pines (fires, beetles, etc.) and would thus cause the boundary between the EW and LW to be erroneous. Damage occurring to the tree in the early to middle of the growing season could lead erroneously to the assignment of the EW/LW earlier in the ring (Matheus et al. 2017). A larger sample size would help reduce the impact of traumatic resin duct formation as it is not likely that every tree would be damaged in a given year.

Climate Sensitivity

There were various responses to climate in the EW, LWa, and TW for *P. jeffreyi* and *P. monticola* sampled at Wolverton. However, these signals were not comparable, which is expected due to the low correlation coefficients between the species of the EW and LW ring widths. At a minimum, we would expect the TW climate response to be consistent for both species since the methods for measuring the TW for both species were the same; however, this was not the case. These inconsistencies make it difficult to understand the limiting factors of growth at the Wolverton site. This is further evidence that Wolverton should be treated as two separate sites, one for *P. jeffreyi* and the second for *P. monticola*.

The climate response for *P. jeffreyi* sampled from Wolverton has a mix of negative and positive correlations. These correlations are sporadic between each month making it difficult to interpret the results. It does seem as though sub-annual data can be extracted from *P. jeffreyi* as the LWa has a stronger climate signal (temperature and VPD) in the summer months when LW is typically added than the EW and TW. However, this is not the case in the spring months for all of the variables as the EW does not have the strongest signal. This is likely due to an issue in site selection. The *P. jeffreyi* were all sampled on a gentler slope than *P. monticola*, making it difficult to determine a limiting factor (Speer 2010). If the slope is not steep enough the roots could have access to water resources year-round (Speer 2010).

The climate response results for *P. monticola* are not easily interpreted. Unlike *P. jeffreyi*, there are no physically meaningful climate signals associated with LWa in the summer months, further indicating that the resin duct method performed poorly with *P. monticola* at Wolverton. Temperature and VPD correlations with EW and TW are mostly negative at Wolverton until the spring. This could indicate that in the future, years with higher winter temperatures and subsequently higher VPD will stress the trees and negatively affect the available soil moisture for spring growth (Ficklin and Novick 2017). Similarly, Temperature and VPD are in synch in April and May with positive correlations. This potentially supports the importance of the timing of spring temperatures for ending dormancy at higher elevations (Barnett et al. 2008; Zhang, Friedl, and Schaaf 2006). Future reconstructions, if any, should only use the TW for *P. monticola* at this site.

Temperature and VPD correlations with LWa are not prevalent for either of the species at Gin Flat. These findings imply that temperature and VPD are not important to the LW growth for both species at this site, a contrast from previous sub-annual climate studies (Griffin et al. 2011; Matheus et al. 2017; Meko and Baisan, 2001; Leavitt et al. 2011). *P. lambertiana* and *P. jeffreyi* have negative correlations for temperature and VPD between EW and TW ring widths. Indicating that these trees are potentially vulnerable to increasing winter and spring temperatures. Ficklin and Novick (2017) found that increasing temperatures will increase VPD and adversely affect forest health.

Precipitation has positive correlations with EW, LWa, and TW. The LWa is more responsive to precipitation in both *P. jeffreyi* and *P. lambertiana* than Temperature and VPD at Gin Flat. The stronger significant correlation of *P. lambertiana* EW width with precipitation indicates that this species can be used for cool-season precipitation reconstructions; these results are similar to the findings in Matheus et al. (2017). Additionally, these results generally

show stronger EW correlations in the spring months than LWa and TW and stronger correlations of LWa in the summer months than TW and EW for both species. This further supports the feasibility of using traditional methods for measuring the EW and LW in *P. jeffreyi* and the resin duct method for measuring the EW and LW in *P. lambertiana*.

Conclusion

This study examined the efficacy of the resin duct method on *P. monticola* and *P. lambertiana* in comparison with co-occurring *P. jeffreyi* for identifying the climate response and creating sub-annual reconstructions of climate variables at two different sites in the Sierra Nevada Mountains. The insignificant EW, LWa, and TW correlations between traditionally measured *P. jeffreyi* and *P. monticola* measured with the resin duct method indicate that method performed poorly at Wolverton. Additionally, correlations of climate variables with ring widths indicate that the two species were responding differently to the climate. Further, consideration of the Wolverton sample site coupled with these results suggests that these two species are not truly co-occurring. These findings make it impossible to verify that the resin duct method can be applied to *P. monticola* at Wolverton and thus not useful for sub-annual climate reconstructions.

The results suggest that it is possible to use the resin duct method for delineating the EW and LW boundary in *P. lambertiana* at Gin Flat. Correlations between the EW, LWa, and TW of traditionally measured *P. jeffreyi* and *P. lambertiana* measured using the resin duct method were significant, albeit relatively weak. The strongest climate signal occurred between EW and precipitation for both *P. jeffreyi* and *P. lambertiana*, indicating that a sub-annual precipitation reconstruction using the EW could be feasible.

The EW had a stronger spring climate signal than LWa and TW, and the LWa had a stronger summer signal than EW and TW, for *P. jeffreyi* at both sites and *P. lambertiana* at Gin Flat. This is further evidence that the EW and LWa were measured properly (for *P. jeffreyi* at both sites and *P. lambertiana* at Gin Flat) because we would expect the spring climate to affect the EW as it grows in the spring and the summer climate to affect LW growth as it is added in the summer. The results indicate that *P. jeffreyi* could be used for sub-annual reconstructions, but the climate signal is not the same at both sites. Further sampling of *P. jeffreyi* throughout the Sierra Nevada Mountains is needed to generalize the limiting factors for the species.

The response of *P. jeffreyi* and *P. lambertiana* at Gin Flat as well as *P. monticola* from the Wolverton site with temperature imply that future increases in temperature and associated increases in the VPD coupled with a higher frequency of drought could have a profoundly negative impact on the species at these sites. Additionally, the negative correlations of temperature and VPD in 2020's growth for these species could indicate that it can take longer than a year to recover from drought.

In the future, more samples of *P. monticola* and *P. jeffreyi* located closer together could clarify the sub-annual climate response of *P. monticola* and determine with reasonable certainty if the resin duct method works. Additionally, more samples should be collected for analysis as this will likely improve the correlation values and strengthen the argument that the resin duct method is feasible for *P. monticola* and *P. lambertiana*. Samples should be collected at more sites in the Sierra Nevada Mountains to determine if the resin duct method can broadly be used for measuring the EW and LW in *P. lambertiana.*

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The Effects of In-store Marketing of Infant Formula and Lactation Support Products Among Stores in Black and White Zip Codes Across Los Angeles County

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Abstract

The World Health Organization adopted the International Code of Marketing of Breastmilk Substitutes to prompt governments to regulate the marketing of artificial supplementation. This code was designed to protect the most vulnerable (babies) by ending unethical infant formula marketing. The United States (U.S.) signed on to support this code, yet there is little governance to enforce it. As a result, infant formula marketing continues to disproportionately target Black families and undermine efforts for breastfeeding promotion in the U.S. This is problematic as rates of breastfeeding among Black populations are consistently the lowest compared to other races/ethnicities (with White populations having highest breastfeeding rates). To gain a deeper understanding of the social barriers to breastfeeding among ethnic minority lactating persons, the current study investigates in-store marketing and health claims of infant feeding products across Black and White communities in Los Angeles County. Trained researchers utilized observational methods to explore marketing aspects and health claims of infant formula, follow-on formula, and galactagogues products in June 2019. This was a cross-sectional study that included 47 retail stores in Black (N=24) and White (N=23) communities across 20 zip codes. Findings indicate that stores in majority White

zip codes, compared to those in majority Black zip codes, had greater multi-pack discount marketing of infant formula and bottled purified water marketed for mixing infant formula (17.4 percent Black vs. 60.9 percent White, p <0.01). Additionally, stores in majority White zip codes, compared to those in majority Black zip codes, had more infant formula products and galactagogue beverage products with health claims on their label. The results of this study suggest a minimal difference in in-store marketing and use of health claims on labels for infant formula, follow-on formula, and galactagogues products between stores in the communities included in this study. Overall, the findings underscore an opportunity for the marketing and education of safe and quality galactagogue products for persons who may be struggling with initiating and maintaining lactation.
Key Words: maternal and infant health, artificial breast milk substitute, marketing strategies, breastfeeding, health disparities

Introduction

OVER RECENT DECADES, infant mortality has been a vital indicator of population health and well-being for the United States (Hummer 1993). Specifically, data trends between national findings and Los Angeles have shown that the infant mortality rates are highest for Black infants (Sankar et al. 2015). Various reasons have been attributed to the high infant mortality rates in Black infants including maternal exposure to interpersonal racial discrimination leading to very low birthweight (Collins et al. 2004). According to the Office of Minority Health, non-Hispanic Blacks have 2.3 times the infant mortality rate as non-Hispanic Whites (Center for Disease and Control 2020). The substantial ethnic/racial disproportion of infant mortality poses a public health concern and underlines the need to address this persistent epidemic.

Within the existing literature, scholars have identified an association between suboptimal breastfeeding and infant mortality, with Black infants having the lowest prevalence of breastfeeding initiation and duration (Sankar et al. 2015). Various institutional factors have been found to disproportionately affect breastfeeding/reproductive health outcomes among Black women, such as structural racism (e.g., residential segregation, exposure to adverse neighborhood conditions), discriminatory practices (e.g., time and space in workplace for expressing breastmilk, public breastfeeding shaming, less access to paid parental leave), and marketing of artificial supplementation (e.g., infant formula) to Black communities (Culhane and Elo 2005; Tanaka 2005; Langellier, Chaparro, and Whaley 2012; DeVane-Johnson et al. 2018; Goodman, Williams, and Dow 2021). Because a majority of the health claims by infant formula companies are backed by market/consumer research rather than scientific evidence, having a deeper understanding of the types of infant feeding products being promoted to the public is critical for the advancement of maternal and child health (The Changing Markets Foundation 2017).

Currently, the global artificial breast milk substitute industry is exponentially rising and is estimated to reach 22.1 billion by 2025 (Global Market Insights Inc. 2019). The World Health Organization (WHO) has urged a global adoption of the International Code of Marketing of Breastmilk Substitutes (restricts/regulate marketing of these products; Margulies 1997). Though the United States Food and Drug Administration (USFDA) regulates the nutritional content of commercially available infant formula, it does not regulate the marketing of commercially available infant formulas (e.g., prevents allergies, promotes better sleep) or the disclosure of added sugar content in all infant formulas (The Changing Markets Foundation 2017). Consequently, unclear and inconsistent labeling leaves consumers unaware of the harmful number of added sugars found in infant formula. Some formulas contain double the sugar per serving than a glass of soda, otherwise absent in breastmilk (Bridge, Lomazzi, and Bedi 2020). This is concerning because added sugars can lead to diabetes and obesity later in a child's development (Bridge, Lomazzi, and Bedi 2020). The widespread marketing by the infant formula industry has had and will continue to have an adverse impact on breastfeeding rates (Kaplan and Graff 2008).

In the U.S., racism and classism in distribution of affordable quality resources and geography are primary predictors of breastfeeding (Burnham et al. 2022). Past literature has shown geographic distribution of breastfeeding support (mother-to-mother support groups, peer counselors) that favors communities that were White, affluent, and suburban (Grubesic and Durbin 2021). Further geographic disparities in the use of highly specialized formula that is inconsistent with scientific and evidence-based practices has attributed to the marketing efforts of formula companies (Kemp 2006). In a local report in Los Angeles County, the two geographic areas with highest infant mortality rates also have the highest rates of preterm births, the lowest exclusive breastfeeding rates at three months, the fewest lactation support resources, and the highest number of households with annual incomes between $12,813 and $41,400 (BreastfeedLA 2019). Moreover, there is a new crisis with infant formula shortage (slowing distribution; recalls due to bacterial contamination) that is disproportionately harming low-income families. Thus, infant mortality rates are linked to how much and where food is distributed (Padilla 2022).

The increasing adoption of infant formula by working-class people (e.g., manual or industrial) as a result of a lack of paid parental leave and/or adequate paid parental leave coupled with the widespread awareness of artificial breast milk substitutes are the primary factors catapulting the growth of this market (Global Market Insights Inc 2019). There are alternatives to artificial breast milk substitutes with an insufficient milk

supply such as pasteurized donor human milk. Yet, limitations in access to donor milk exist. The lack of education on the use of galactagogue products (i.e., medications or substances that may assist in lactation promotion), inequitable access to lactation support and resources, and persistent promotion of artificial breast milk substitutes in certain communities create barriers that hinder Black individuals' ability to optimally breastfeed.

Studying the marketing of safe galactagogue products within communities of color will further the understanding of social barriers to breastfeeding among ethnic minority lactating persons. Ultimately, this will restrict artificial breast milk substitute marketing on maternal and child well-being. Literature studying the role of in-store marketing of galactagogue products is sparse. Thus, there is a need to add to this body of literature. The current study investigates in-store marketing and health claims of infant formula and galactagogue products across Black and White communities in Los Angeles County.

Methods

Study Sample

Forty-eight stores were initially included in the sample. Of the 48, observational audits were completed in each store except for one in the White community (i.e., refused to participate). Thus, the final sample consisted of 47 stores, 24 in predominately Black neighborhoods and 23 in predominantly White neighborhoods. Per established definitions, store type was comprised of convenience, retail, grocery, discount, pharmacy, and other (Henriksen 2016). Selection of retail stores was based on data from the American Community Survey (U.S. Census Bureau 2017) and utilized a two-step approach (Baezconde-Garbanati et al. 2017; Blackman et al. 2019). Within the larger Los Angeles County area, we focused on two distinct geographical areas (Figure 1). Within Figure 1, the darker blue areas indicate the selected zip codes with higher proportion of White residents, while the darker green areas indicate the selected zip codes with higher proportion of Black residents. In Figure 2, the top ten zip codes with the highest proportion of White residents were chosen for this study and categorized as predominantly White neighborhoods. Similarly, the top ten zip codes with the highest proportion of Black residents were chosen for this tudy and categorized as predominately Black neighborhoods (Figure 3). Policy Maps was used as a safeguard to ensure the accuracy of the racial composition of the chosen zip codes (PolicyMaps and Census 2013-2017). Within the chosen zip codes, retail stores were then randomly chosen using the Women, Infant, and Children (WIC) list of stores. Trained data collectors used online searches, telephone calls, and drive-by visual verification to confirm that stores were still in operation and open to the public. The Institutional Review Board has reviewed all study activities and deemed that this study does not involve humans and therefore does not require its approval.

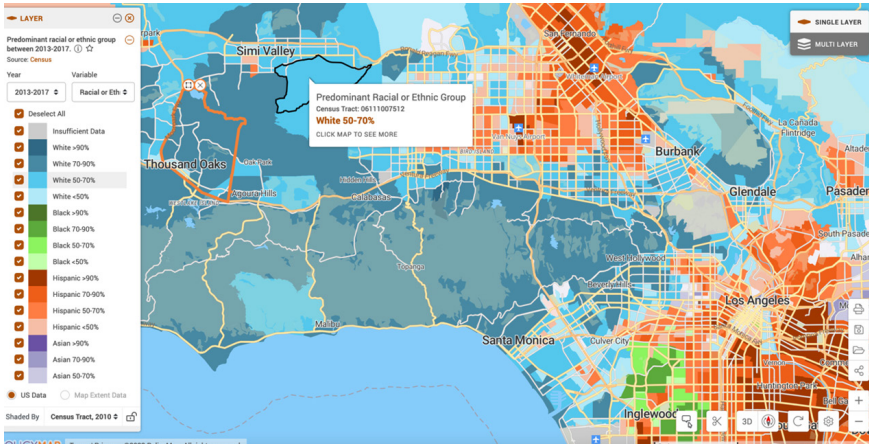

Figure 1. Map of Greater Los Angeles (PolicyMaps and Census 2013-2017).

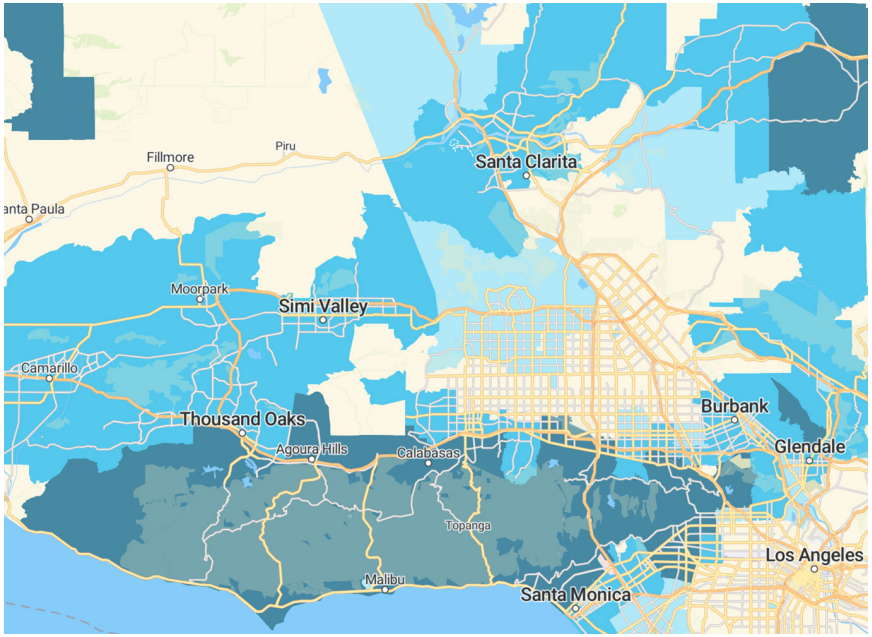

Figure 2. Map of the top ten zip codes with the highest proportion of White residents (PolicyMaps and Census 2013-2017).

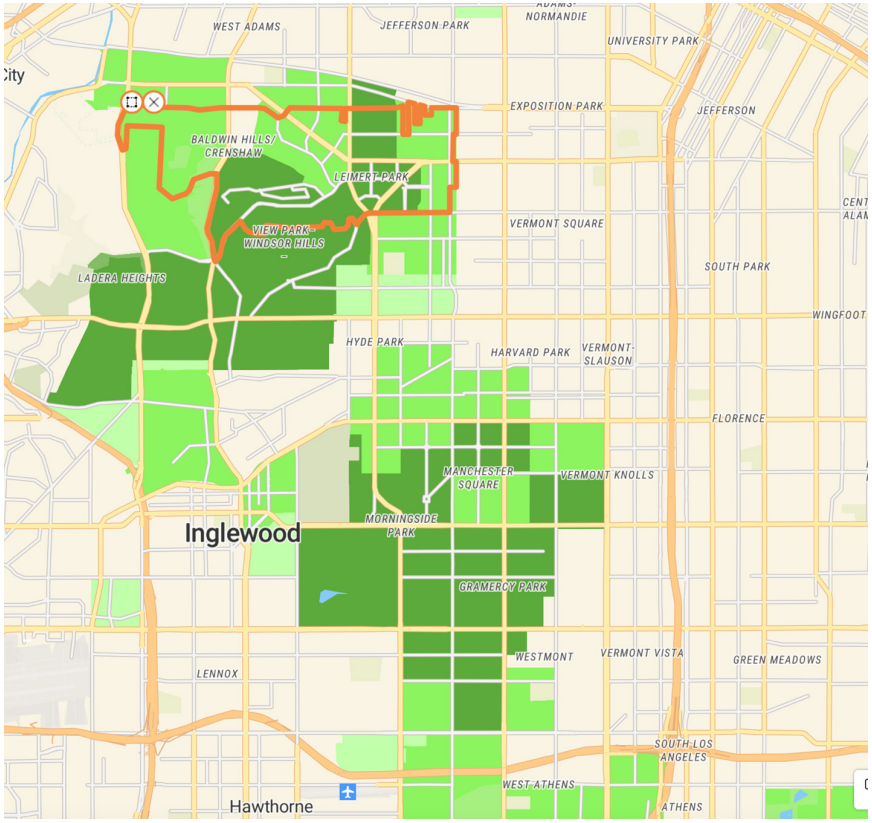

Figure 3. Map of the top ten zip codes with the highest proportion of Black residents (PolicyMaps and Census 2013-2017).

Data Collection

An observational audit was adapted from a Standardized Tobacco Assessment for Retail Settings (STARS; Henriksen 2016). STARS was designed to be a low-cost method to assess retail tobacco product marketing and provide observational data to inform tobacco control policy, planning, and practice. For this current study, only the marketing items will be described. The total number of marketing tactics and health claims included in this study was 14. Each trained data collector went through a two-day training and conducted practice audit runs in four stores. Each data collector completed the audit independently. An inter-rater reliability of 0.90 was achieved after conducting observations in four stores during pilot testing. Data were collected over a three-week period in June 2019. One store in the non-Hispanic White zip codes refused data collection and was dropped from the analysis.

Measures

Infant Formula

The following types of infant formula products were included: concentrated liquid, powder, ready-to-use formula, follow-up concentrated liquid, and follow-up powder. Infant formula is designed as an artificial supplementation for infants, and follow-on formula is designed for babies ages 6 months and up.

Galactagogue Products

The following three types of galactagogue products were considered in this study: supplements (e.g., vitamins), beverages (e.g., teas), and cookies. Across both products the top manufacturers were examined. These products contain ingredients that are designed to initiate and maintain lactation (e.g., galactagogues-fenugreek, blessed thistle) and may have added iron, vitamins, folic acid, and unsaturated fats. Further, persons with insufficient breast milk output who are not receptive to lactation counseling may be interested in therapy with herbal galactagogues that initiate and maintain lactation (Bazzano 2016).

Bottled Purified Water

Bottled purified water was defined as with or without added fluoride; may have added minerals such as calcium, magnesium, and potassium for taste; no nutritional benefits; marketed for parents to use when mixing infant formula.

Retail Characteristics

The following retail characteristics were included: WIC and Supplemental Nutrition Assistance Program (SNAP) voucher acceptance, median household income of store zip code, and whether alcoholic beverages were sold. SNAP and WIC approved stores were identified through a national list and were verified by the presence of signs posted in the store. National median household income (MHI) was found to be about $60,000 according to the U.S. Census Bureau for families and households (United States Census Bureau n.d.). In Los Angeles County, the MHI was $65,000. When broken down between races the MHI was $40,000 among Black households and close to $66,000 among non-Hispanic White households. Lastly, stores were examined to see whether they sold alcoholic beverages (Y/N).

Marketing Tactics

Marketing tactics included number of items on interior advertisement (e.g., Were infant formula products advertised inside the store?), number of items on price promotions (e.g., Buy two, receive $10 gift card), number of items on cross-product promotions (e.g., promotions with diapers/wipes), number of items on multi-pack discounts (e.g., two for $11), and number of items on exterior advertisement (e.g., Were infant formula products advertised outside the store?).

Various Health Claims

Health claims for infant formula products and galactagogue products were examined. For infant formula products, the following health claims were examined: support brain/cognitive development, maximize absorption/minimize malabsorption, reduce gastrointestinal discomfort (i.e., gas, fussiness), support immune system, non-genetically modified organic (GMO), organic or USDA organic (label present on container Y/N), and pediatrician recommended (label present on container Y/N). For galactagogue products, the following health claims were examined: promotion of healthy milk supply, health benefits beyond galactagogues, non-GMO, and organic or USDA organic. Organic and USDA Organic were combined into a single variable. Data collectors looked for the presence of the aforementioned health claim labels on the product.

Analyses

Chi-squared tests were run to compare the presence of retail characteristics as well as the use of various marketing tactics (i.e., interior advertisement, exterior advertisement, cross-product promotion, price promotion, multi-pack discounts, and various health claims) for different infant feeding products between stores in Black and White zip codes. The present study focuses on the following types of infant food products: 1) infant formula, 2) galactagogue products (i.e., beverages, supplements, and cookies), and 3) bottled purified water. All analyses were conducted in IBM Statistical Packages for Social Sciences (SPSS) version 26.

Results

Retail Characteristics

Table 1 describes the total number, proportion, and chi-squared comparisons of selected retail characteristics across stores in Black and White zip codes. Stores within White zip codes, as compared to those in Black zip codes, sold more alcohol (83.3 percent Black vs. 100 percent White, $p < 0.05$), whereas there were no significant differences in the number of WIC- or SNAP-approved stores between Black and White zip codes. Across the Black zip codes, a total number of 56 stores accepted WIC vouchers; across the White zip codes, only 29 stores accepted WIC vouchers.

Infant Formula

The total number, proportion, and chi-square comparisons of different marketing tactics and various health claims of different infant food products across stores in Black and White zip codes are shown in Tables 2 and 3, respectively. Stores within White zip codes, as compared to those in Black zip codes, had greater promotion of multi-pack discounts (17.4 percent Black vs. 60.9 percent White, $p < 0.01$). Additionally, Table 3 shows stores within White zip codes had significantly more infant formula products that claimed the following benefits: support eye development (50 percent Black vs. 95.7 percent White, $p < 0.01$) and non-GMO (41.7 percent Black vs. 69.6 percent White, $p = .054$). No significant differences were found between stores in Black versus White zip codes for interior advertisement and price promotions. Furthermore, there were no significant differences found between stores in Black and White zip codes for infant formula products that claimed the following benefits: support brain/cognitive development, maximize absorption/minimize malabsorption, reduce gastrointestinal discomfort (i.e., gas, fussiness), organic or USDA organic, and pediatrician recommended. The following marketing tactics were absent from all stores and therefore excluded from analyses: cross-product promotion and exterior advertisement.

Table 1. Comparison of various retail characteristics between stores in Black and White zip codes.

	Total (N=47)		Stores in Black zip codes (N=24)		Stores in White zip codes (N=23)		p-value
	N	Row %	N	Row %	N	Row %	
FOOD SUPPORT PROGRAMS							
WIC	31	66	18	75	13	56.5	0.18
SNAP	7	14.9	3	12.5	4	17.4	0.64
ABOVE MEDIAN HOUSEHOLD INCOME							
United States (MHI: $60,336)	24	51	-	-	-	-	-
Black (MHI: $40,232)	-	-	16	66	-	-	-
Non-Hispanic White (MHI: $65,845)	-	-	-	-	23	100	-
ALCOHOL	43	91.5	20	83.3	23	100	.041*

*Table 1. Significance is at <0.05; MHI = Median Household Income

Table 2. Comparison of various marketing tactics between stores in Black and White zip codes.

	Total (N=47)		Stores in Black zip codes (N=24)		Stores in White zip codes (N=23)		p-value
	N	Row %	N	Row %	N	Row %	
INTERIOR ADVERTISEMENT							
Infant Formula	16	34.04	6	25	10	43.48	0.18
Galactagogue Products	3	6.38	0	0	3	13.04	0.07
Bottled Purified Water	6	12.77	2	8.33	4	17.39	0.35
PRICE PROMOTION							
Infant Formula	4	8.51	2	8.33	2	8.7	0.97
Galactagogue Products	0	0	0	0	0	0	-
Bottled Purified Water	0	0	0	0	0	0	-
MULTI-PACK DISCOUNTS							
Infant Formula	18	38.3	4	17.39	14	60.87	.002*
Galactagogue Products	0	0	0	0	0	0	-
Bottled Purified Water	17	36.17	3	12.5	14	60.87	.001*

*Table 2. Significance is at <0.05

Galactagogue Products

As shown in Table 3, stores within White zip codes, as compared to those in Black zip codes, had significantly more galactagogue beverage products that claimed the following benefits: non-GMO (8.3 percent Black vs. 39.1 percent White, $p < 0.05$) and organic or USDA organic (12.5 percent Black vs. 39.1 percent White, $p < 0.05$). No significant differences were found between stores in Black versus White zip codes for health claims for galactagogue cookies and galactagogue supplements. Additionally, Table 2 shows that there were no significant differences found between stores in Black versus White zip codes for interior advertisement of galactagogue products. The following marketing tactics were absent from all stores and therefore excluded from analyses: cross-product promotion, exterior advertisement, cross-product promotion, and multi-pack discounts.

Table 3. Comparison of various health claims between stores in Black and White zip codes.

	Total (N=47)		Stores in Black zip codes (N=24)		Stores in White zip codes (N=23)		p-value
	N	Row %	N	Row %	N	Row %	
INFANT FORMULA							
Support brain/cognitive development	46	97.87	23	95.83	23	100	0.32
Maximize absorption/ minimize malabsorption	2	4.25	0	0	2	86.96	0.14
Reduce gastrointestinal discomfort (i.e., gas, fussiness)	27	57.44	11	45.83	16	69.56	0.1
Support Immune system	43	91.49	21	87.5	22	95.65	0.32
Support eye development	34	72.34	12	50	22	95.65	.000*
Non-GMO	26	55.32	10	41.67	16	69.56	.054*
Organic/USDA Organic	4	8.51	2	8.33	2	8.7	0.97
Pediatrician Recommended	46	97.87	23	95.83	23	100	0.32
GALACTAGOGUE COOKIES							
Promote healthy milk supply	2	4.26	2	8.33	0	0	0.16
Health benefits beyond galactagogues	1	2.13	1	4.17	0	0	0.32
Non-GMO	5	10.64	1	4.17	4	17.4	0.14
Organic/USDA Organic	3	6.39	0	0	3	13.04	0.07
GALACTAGOGUE SUPPLEMENTS							
Promote healthy milk supply	3	6.38	2	8.33	1	4.35	0.58
Health benefits beyond galactagogues	0	0	0	0	0	0	0
Non-GMO	6	12.77	2	8.33	4	17.39	0.35
Organic/USDA Organic	2	4.26	1	4.17	1	4.34	0.98

Table 3 (continued). Comparison of various health claims between stores in Black and White zip codes.

	Total (N=47)		Stores in Black zip codes (N=24)		Stores in White zip codes (N=23)		p-value
	N	Row %	N	Row %	N	Row %	
GALACTAGOGUE BEVERAGES							
Promote healthy milk supply	7	14.89	3	12.5	4	17.39	0.16
Health benefits beyond galactagogues	2	4.26	2	8.33	0	0	.013*
Non-GMO	11	23.4	2	8.33	9	39.13	.036*
Organic/USDA Organic	12	25.53	3	12.5	9	39.13	.036*

*Table 3. Significance is at <0.05

Bottled Purified Water

As shown in Table 2, stores within White zip codes, as compared to those in Black zip codes, had greater promotion of multi-pack discounts, (12.5 percent Black vs. 60.9 percent White, p =.001). No significant differences were found between stores in Black versus White zip codes for interior advertisement. The following marketing tactics were absent from all stores and therefore excluded from analyses: cross-product promotion, exterior advertisement, and price promotions. Furthermore, observations of health claims for bottled purified water products were not collected and therefore were excluded from analyses.

Discussion

The present study sought to explore the in-store marketing tactics of artificial breastmilk substitutes and galactagogue products in Black and White communities within Los Angeles. Overall, there were little differences found in in-store marketing between stores in Black and White communities across infant formula products and galactagogue products. For both Black and White communities, stores lacked the use of any type of in-store marketing. However, when in-store marketing was present, it was predominantly for infant formula products. Furthermore, there was little to no marketing for galactagogue products across stores in both communities. This is not surprising, as infant formula companies have commonly marketed through other sources including hospitals via discharge packs (Rosenberg et al. 2013), mass media via TV, radio, magazines, newspapers, and the internet, and sending free samples in the mail (Waite and Christakis 2016; Zhang, Carlton, and Fein 2013). In addition, results indicated that there was greater marketing of health claims for infant formula than for galactagogue products. The current findings highlight the ubiquitous nature of the artificial breastmilk substitute market and stress the need for increased efforts towards products that may be helpful in initiating and maintaining lactation for persons who may be having difficulty with adequately producing breastmilk.

The high amount of marketing for infant formula, as compared to galactagogue products, is concerning because of its adverse impact on consumer behaviors and breastfeeding rates, morbidity, and mortality (Piwoz and Huffman 2015). Consumers often struggle to discern between health claims that are supported by significant scientific support and those that are not (U.S. Government Accountability Office 2011). This is problematic because many of the marketing claims used by formula companies lack substantial evidence (Belamarich, Bochner, and Racine 2016; Hughes, Landa, and Sharfstein 2017). Regardless, research has shown that caregivers endorse these claims and mistakenly believe these products provide nutrition that is not present in other forms of food such as breastmilk (Romo-Palafox, Pomeranz, and Harris 2020). Unfortunately, subscription to these insubstantial marketing claims have increased the odds of serving infant formula over breastmilk (Romo-Palafox, Pomeranz, and Harris 2020). Conversely, prenatal exposure to breastfeeding information through mass media has shown to have a positive impact on intentions, initiations and intended duration of breastfeeding (Zhang, Carlton, and Fein 2013). To combat the widespread promotion of infant formula, further action needs to be taken to promote breastfeeding through the same channels as formula companies (Kaplan and Graff 2008).

These findings are of particular importance when discussing the significance of breastfeeding in Black communities. In a review conducted by Spencer and Grassley (2013), breastfeeding reduces the incidence of many disease processes that are specific to Black populations while increasing positive health outcomes. Therefore, holding infant formula companies accountable for the marketing that is done in underserved communities such as Black populations is critical primarily when discussing health equity among the most vulnerable (e.g., infants).

Limitations

Though this study adds to an imperative area of study on nutrition and marketing with regards to infant formula, there are some limitations to consider. First, this study was concentrated in the southwest region of the country; hence, these findings cannot be generalized to other areas of the

country. Second, most of the work was done at different retail locations in person; given that we are now in the Digital Age, it may make sense that some of the marketing tactics could be done through media sources, at home mail, pediatricians/obstetrician offices/clinics, and online which could draw to various populations.

Future Directions

Future studies within this area of research should include examining areas across the U.S. with populations that differ with regards to socioeconomic status, race/ethnicity, education, and employment status. Within the past decade, digital marketing of breastmilk substitutes via retail websites, social media, and family/parenting sites have been on the rise (Harris and Pomeranz 2020). With the challenges the COVID-19 pandemic poses to face-to-face business, digital marketing is now more relevant than ever. Hence, future studies should explore the impact of digital marketing on child-bearing populations. The current study uses observational methods and chi-squared tests as its primary method of analyses. Future studies should incorporate more advanced research methodology to study geographical disparities in marketing of breastmilk substitutes including the Gini coefficient, Theil entropy index, and spatial statistical modeling. Given this study focused on urban areas, future studies are encouraged to include rural areas as they are often excluded.

Conclusion

The goal of this study was to explore the disparities in in-store marketing of infant feeding products between stores in Black and White communities. However, the current findings uncovered a widespread inadequacy of breastfeeding promotion, as compared to artificial breastmilk substitutes, in the retail space. The pervasive and unethical marketing of artificial breastmilk substitute continues to undermine efforts to increase breastfeeding rates. With the disproportionally higher risk of suboptimal breastfeeding and infant mortality among Black populations, coupled with affordable, quality lactation counseling/education, paid parental leave, the promotion of safe, quality galactagogue products through marketing for those who desire this type of therapy is vital for significant reduction in Black-White breastfeeding inequities.

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BOOK REVIEW

Learning GIS Using Open Source Software: An Applied Guide for Geo-spatial Analysis

Kakoli Saha and Yngve K. Frøyen. New York: Routledge, 2022. 226 pp., figures, appendices, notes, references, and index. $145 hardcover (ISBN 978-0367487454)

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LEARNING GIS USING Open Source Software: An Applied Guide for Geo-spatial Analysis is an excellent addition to the list of textbooks written in recent years in the area of GIS using open-source software. The lead author, Kakoli Saha, is a well-known researcher with 15 years of experience in the field of geography and has written several research papers with GIS applications in geography and planning. The co-author, Yngve Frøyen, is a Norwegian planner with three decades of research, teaching, and publications in the areas of physical planning and sustainable urban transportation. The book in particular offers knowledge on the tools and techniques in GIS, and how these methods can be applied to real-world projects in the areas of urban and regional planning on the Indian subcontinent using open-source software.

As its platform, *Learning GIS Using Open Source Software* employs QGIS, a free and open-source software that users can utilize for geographic information system-based analysis. It is often stated that "knowledge is power and should be utilized to unite humankind, bring prosperity and not divide and perpetuate inequality." GIS software can be expensive, excluding most students and researchers from learning and applying GIS methods for solving geographic and location-based decision making. This is especially the case in the Global South. Thus, open-source GIS software makes the technology available to a larger section of the world's population, making it more inclusive and diverse, and thereby providing South Asian researchers an opportunity to make informed spatial decisions. An important strength of this book is that it features an easy-to-understand format. The book opens by discussing the concept of a GIS task and then elaborates on data requirements and methodology, followed by a tutorial that allows the student to learn

how to operationalize the method in a real-world context. Each chapter closes with a concise summary and a list of references.

Learning GIS Using Open Source Software is divided into eleven chapters. Chapter one establishes the motivations underlying the volume and provides a foundation along the themes of "conceptual directions on GIS," "open-source GIS," and the "role of GIS in spatial analysis" with reference to the fields of planning and architecture. The second chapter delves into the concept of open-source software with a highlight on GIS, paying special attention to its relevance in the Indian context. The chapter further elaborates the notion of Quantum GIS or QGIS. Chapter three deals with the topic of spatial referencing of GIS data. A spatial reference system is the coordinate system used to store Earth coordinates and its association with the GIS data. The following chapter deals with the issue of representing the real world in a GIS database. Real-world features can be represented by points, lines, and polygons in two GIS data types: raster and vector. Raster data is any pixelated (or gridded) data where each pixel is associated with a specific geographical location representing continuous data. Further, vector data are utilized to represent features on the Earth's surface using points, lines, and polygons representing discrete objects. In addition, the chapter discusses editing and topology in GIS.

Moving deeper into the volume, chapter five offers a historical overview of mapmaking in the Indian and global contexts. The authors elaborate on selected themes such as classification of maps, the role of topographical maps, and the importance of GIS relative to computer-aided design (CAD) in making maps, and the introduce the notion of Web Map Service and Open Street Maps. The sixth chapter addresses thematic maps and illustrates their importance in representing qualitative and quantitative maps. The succeeding chapter investigates the topic of database management system (DBMS), which is the underlying structure that stores data in the form of attribute tables. It further explains how utilizing tutorials helps the researcher understand types, functions, and relationships between tables. Additionally, chapter eight addresses the issue of terrain representation in a GIS data model and analyzes digital elevation models (DEM) and triangular irregular network (TIN). Subsequently, chapter nine discusses at great length the history of geospatial analysis in GIS and diligently explains geoprocessing tools and map overlay techniques. The penultimate and concluding chapters focus on the application of GIS for transportation planning. The authors exert considerable effort in their discussion of network analysis and the variety of tools such as optimal route calculation, shortest distance path, origin-destination cost matrix, and service facility location.

Overall, *Learning GIS Using Open Source Software* represents an excellent contribution to the GIS and open-source bodies of literature. It is a vital textbook for students and researchers in the areas of geography, planning, and cognate fields in social sciences. The only recommendation I would offer to the authors would be to provide more examples and tutorials from other social science disciplines such as environmental studies, sociology, political science, and economics. Nevertheless, I will keep this book in my collection of research methodology textbooks because it is easy to read and comprehend, containing engaging tutorials that help in understanding challenging concepts in GIS with focused emphasis on South Asia.

Geographic Chronicles

2022 CGS Annual Conference Award Winners

JOE BEATON POSTER AWARDS

Undergraduate:

FIRST PLACE:

Katharine Mackay, UC Santa Barbara, "Evaluation of NDVI and EVI as Measures of Food Availability for Fruit-eating Monkeys"

SECOND PLACE (tie):

Alondra Olagues, CSU San Bernadino, "Yellow Fever Found in Golden Tamarin Monkeys Causing Population Decline"

SECOND PLACE (tie):

Otto Schmitt, Cal Poly Humboldt, "The Effects of Rising Sea Levels in Humboldt County on FedEx Ground"

PAPER OR ANALOG CARTOGRAPHY AWARDS

Undergraduate:

FIRST PLACE:

Yuichi Ambiru, Cal Poly Humboldt, "Iceland, the Island of Volcano and Glacier"

DIGITAL CARTOGRAPHY AWARDS

Undergraduate:

FIRST PLACE:

Angela Valladares, Cal Poly Humboldt, "The Great Earthquakes of September 19th"

SECOND PLACE:

Denise Allen, CSU Fullerton, "The Writing is on the Wall: Murals, Artists, and Community in Long Beach, California"

TOM MCKNIGHT PAPER AWARDS

Undergraduate:

FIRST PLACE:

Midori Gonzales, CSU Fullerton, "Bea-utility: Exploring the Utility Box Murals of Glendale, California"

SECOND PLACE:

Jessica Ledesma, CSU Dominguez Hills, "Understanding the Impact of Climate Change on Treeline Ecotone of the White Mountains in California Using Geospatial Technology"

Graduate:

FIRST PLACE:

Aliza White, CSU Fullerton, "Analyzing the Relationship Between Climate, Mule Deer Population, and Tree Rings in California from 1948-2009"

GEOSYSTEMS AWARDS

Undergraduate:

Anthony Lucero, Cal Poly Humboldt, "Drone Photogrammetry: Using an Unmanned Aerial Vehicle (UAV) to Represent the Underrepresented"

Graduate:

Angelo De Guzman, CSU Dominguez Hills, "Post-wildfire Vegetation Response Lidar Analysis of the Wildland-urban Interface: A Case Study of the 2009 Station Fire"

DAVID LANTIS SCHOLARSHIP

Graduate:

Andrew Wallace, CSU Fullerton

SOCIAL JUSTICE AWARD

Emilio Espinal and Eduardo Villanueva-Gonzalez, Cal Poly San Luis Obispo, "Housing Segregation in the United States: A Review of *The Color of Law*"

2022 CGS Annual Conference Proceedings

FACULTY OR PROFESSIONAL PAPER PRESENTATIONS

Raju Bista, CSU Dominguez Hills, "Recent Climate Has Contrasting Influence on Radial Growth of Co-occurring Birch and Fir in Dhorpatan, Nepal"

Abilities of species to face the changed environmental conditions depend on their trait variabilities. *Abies spectabilis* (Himalayan Silver Fir) and *Betula utilis* (Himalayan Birch) are co-occurring tree species in many sub-alpine forests of the Nepal Himalayas. To assess the climatic influence on species-specific growth trends, tree ring-width chronologies of both species–from Dhorpatan Hunting Reserve, Nepal–were correlated with temperature and precipitation. Correlations revealed contrastive temporal changes in radial growth of these species. Significant warming that occurred after the 1970s coincided with the divergent growth rates. While climate sensitivity of fir growth has been shown weakened, birch radial growth has been declining with increasing temperature, especially due to spring being warmer and drier. In summary, recent warming has been unfavorable for birch, and fir growth appears to surge. The contrasting growth trends may imply that changing climate will likely alter community dynamics in the area.

Parveen Chhetri, CSU Dominguez Hills, "How are Treelines of the Nepal Himalayas Responding to Climate Change?"

The alpine treeline ecotone is an important component of the mountain ecosystems of the Nepal Himalayas, playing a vital role in the livelihood of indigenous people and provides ecosystem services. We applied remote sensing (RS), geographic information science (GIS), and field-based dendroecological approaches to investigate factors controlling the treeline ecotone. Topography and disturbance are the main factors controlling the treeline at the landscape scale. At the local scale, poor regeneration was observed at the treeline ecotone. Low regeneration at the treeline ecotone suggests site-specific biotic and abiotic controlling factors. Seedling and sapling establishment at the treeline is limited by a lack of moisture, the absence of suitable microsites, and the presence of herbivores. Most treelines we studied are not advancing or will not advance in the near future because of topography, human disturbances, and low recruitment.

John Menary, CSU Dominguez Hills, "World Geography and the Quest for A.I."

Well documented are the diverse ways that artificial intelligence [A.I.] surrounds us. Its causes are clear, but the consequences are controversial, now being described and explained. What is to be its impact on geography is less well understood, though A.I. has accompanied geospatial technology. This paper is a futuristic journey into artificial intelligence's pathway and place in educational geography. Discussion centers on World Geography and the training of preservice geography teachers working toward a Social Studies credential.

Irene Naesse, Orange Coast College, "Korean Dramas: What I Learned During Quarantine"

Korea is everywhere. From our cars to our appliances to the containers and ships that transport these goods to our shores. K-pop fans organized a phantom ticket purchasing scheme that undermined a campaign event in the 2020 presidential election. How did this happen? Korean dramas provide a clue. Join me for a journey through Korea using the lens of the Korean drama. Economic inequality, generational trauma, reunification, and globalization are just some of the topics we will examine. Gamsahamnida!

GRADUATE STUDENT PAPER PRESENTATIONS

Angelo De Guzman, CSU Dominguez Hills, "Post-wildfire Vegetation Response Lidar Analysis of the Wildland-urban Interface: A Case Study of the 2009 Station Fire"

Past wildfires were Mother Nature's method of promoting biodiversity and maintaining a functioning ecosystem. In spite of this, climate change and human disturbances have altered fire regimes, which impact vegetation recovery after wildfires. There is a direct threat to human populations at the wildland-urban interface (WUI), where vegetation encroaches on roads and houses. Using prediction models such as elevation, soil burn severity, post-fire soil erosion, and spectral indices including the NDVI and nDBR, a review of the Station Fire (2009) was carried out. Above-ground biomass (AGB) was then compared with visual accounts to detect differences in vegetation rebound between WUI and non-WUI regions. Despite having similar regeneration patterns, WUI and non-WUI areas had similar AGB, and vegetation recovery rates were slower in WUI. To better understand wildfire regeneration patterns, future work should account for slope and aspect.

Aliza White, CSU Fullerton, "Analyzing the Relationship Between Climate, Mule Deer Population, and Tree Rings in California from 1948-2009"

This study aims to evaluate whether tree rings can be utilized as an accurate proxy for the reconstruction of deer population trends in California. I investigate whether a relationship exists between mule deer population, soil moisture, and tree rings in the state of California between the years of 1948 and 2009. Proxies such as tree rings would be invaluable for the management of wild ungulates, which is crucial for maintaining ecosystem health. Correlations were calculated using existing deer harvest variables, climate, and tree-ring data. The results observed indicate that the initial hypothesis was not entirely supported and that a reconstruction would not be possible because deer harvest was not well correlated with tree rings. The findings suggest that mule deer populations are affected by climate indirectly and that the response is delayed. Further research is needed to determine whether dendrochronology could be used to monitor other species for the purpose of conservation.

UNDERGRADUATE CARTOGRAPHY

Denise Allen, CSU Fullerton, "The Writing is on the Wall: Murals, Artists, and Community in Long Beach, California"

In cities across California and the United States, public art has been utilized for a range of purposes, including beautification, economic development, and community cohesion. Long Beach's Cambodia Town is home to the largest concentration of Cambodians outside of Southeast Asia. This map focuses on the Cambodia Town Mural Project, a collection of eight public murals created by a local art nonprofit, presenting the murals, highlighting the artists, and revealing their perspectives on this project. The map, an interactive mixed-media presentation, reveals the value of studying public art not just as a product but as a process.

Yuichi Ambiru, Cal Poly Humboldt, "Iceland, the Island of Volcano and Glacier"

Angela Valladares, Cal Poly Humboldt, "The Great Earthquakes of September 19th"

Mexico City, known as the "sinking city," has been greatly impacted by two major earthquakes. Many deaths have been caused by these catastrophes, and city planners are trying to prevent this from happening again. By being able to map regions that are more susceptible to structural collapses, there will be a better understanding of possible solutions. The use of maps could hopefully save the people of Mexico City in the case of another natural disaster.

UNDERGRADUATE STUDENT PAPER PRESENTATIONS

Brenda Aguirre, Cal Poly Humboldt, "Keystone Species: Why Should We Care About the Sea Stars?"

Keystone species are organisms that are essential and helpful to the environment because they define the entire ecosystem. The main points of my research are discussing what makes the sea star a keystone species, what their diet consists of, and the significance of their die-offs, as well as highlights how severe the disease Sea Star Wasting Syndrome is because many researchers are unable to come up with a concrete answer. This paper focuses on the California location and will be discussing how the climate in Southern California and in the northern part will affect the sea star population, making them susceptible to the Sea Star Wasting Syndrome.

Denise Allen, CSU Fullerton, "Abusive Agriculture: Examining the Exploitation of H-2A Visa Guest Workers in the United States"

Commercial agriculture in the United States has a variety of adverse environmental and social impacts, with particular impacts on agricultural guest workers. H-2A visas provide a mechanism for non-citizens to come to the United States and work in the agricultural sector on a temporary basis. Most H-2A guest workers employed in the United States come from Mexico and have low levels of formal education and English language attainment compared to the U.S.-born agricultural workers. These characteristics make H2-A agricultural guest workers even more susceptible to exploitation. This paper provides an overview of the H2-A program and examines some of the physical and financial ways that H2-A agricultural guest workers are exploited, including underpayment, poor housing conditions, and human trafficking. The paper then outlines potential solutions and concludes with a call for action.

Midori Gonzales, CSU Fullerton, "Bea-utility: Exploring the Utility Box Murals of Glendale, California"

This paper explores spatial and thematic patterns of murals on utility boxes in Glendale, California, to understand the interactions between people and public art in this diverse city. As part of a public art program, Glendale annually commissions various local and regional artists to paint murals on utility boxes. Over 150 utility boxes were field surveyed, photographed, mapped, and analyzed thematically and spatially. Demographic data and information from Glendale's Arts and Culture Commission were used to provide context for results. The majority of the murals on Glendale's utility boxes are in commercial areas. Most of the boxes feature art depicting two general types of elements: nature and people. Although murals are a particularly ephemeral feature of cities, analyzing the themes and locations of utility box murals provides insight into how this unique and understudied form of public art functions in an urban environment.

Jessica Ledesma, CSU Dominguez Hills, "Understanding the Impact of Climate Change on Treeline Ecotone of the White Mountains in California Using Geospatial Technology"

The alpine treeline environment is an important component of high-altitude mountain ecosystems. California has one of the highest positioned treelines in the US. Recent studies have indicated treelines are advancing due to recent temperature increases. Though significant scientific studies have been carried out regarding treelines of California, there is still a lack of consistent data on treeline position, nature, and dynamics at individual mountains and range scales. Therefore, I will apply geographic information systems (GIS) to address the following: What is the current treeline position of the White Mountains, what is the role of topographic factors in controlling the treeline spatial pattern, and how has climate affected the region's treeline? The information obtained through this study would be useful in predicting the future directions of vegetation changes at the treeline ecotone. The major contribution of this research will be to address the treeline and climate change-related research gap in California.

Anthony Lucero, Cal Poly Humboldt, "Drone Photogrammetry: Using an Unmanned Aerial Vehicle (UAV) to Represent the Underrepresented"

Rural geographic communities tend to be in places that lack access to high-quality imagery, unlike their more populated counterparts. These areas are often overlooked, leaving data acquisition in the hands private sector remote sensing professionals. High-resolution topographic surveying is often related to high costs by use of expensive equipment and requires fundamental skills to operate the equipment effectively. This research explores how relatively inexpensive consumer-grade aerial imagery devices can fulfill the data demand for underrepresented communities. Combining photogrammetry, structure-from-motion, and computer vision techniques I create ultra-high-resolution imagery, digital surface models, and a 3D scene reconstruction from multi-view aerial photography. Through these remotely sensed methods, I create a dataset with a ground resolution of 2.3 cm and a latitude/longitudinal RMS of 4.7 cm. The methods and results outlined in this research demonstrates how in-house data acquisition can be used to create an individualized high-quality dataset to represent the underrepresented.

Alina Medina, Cal Poly Humboldt, "Climate Change Effects on Coastal Sitka Spruce and Western Hemlock"

Studies have shown that climate change is affecting coastal fog and snowmelt, which coastal trees like Western Hemlock and Sitka Spruce rely on. These trees are only found along the west coast ranging from Alaska to Northern California. What we do not know is how the trees located in the southernmost point are reacting to the climate compared to trees located further north. This research project will investigate how these two species are reacting to the changing climate in different locations. My objective is to document and analyze Sitka Spruce and Western Hemlock core samples from Mendocino and Humboldt counties by making a map and charts showing what areas are being affected. Using a methodology that incorporates field research, archives, and different data sets, my research will address what changes are already occurring, where they are occurring, and whether the trees further south are showing any signs of stress.

Eduardo Villanueva-Gonzalez, Cal Poly San Luis Obispo, "Housing Segregation in the United States: A Review of *The Color of Law*"

Richard Rothstein's *The Color of Law* (2017) is an investigation into how the U.S. government deliberately imposed and supported racial segregation in cities across the nation. Rothstein rejects the common notion of de facto segregation, segregation from private practices and individual decisions, and argues that public policy was systematically put in place by all levels of government to ensure the separation of African Americans from whites, making it de jure segregation. Issues such as FHA/VA support of suburban housing, restrictive covenants, redlining, racial zoning, public housing, interstate freeway systems, and other policies were instrumental in exploiting and geographically separating African Americans. The purpose of this paper is to review *The Color of Law* and identify these key issues from the book and explain their significance both past and present. Additional research is also done, highlighting examples from California as they relate to the issues addressed in the book.

UNDERGRADUATE STUDENT POSTER PRESENTATIONS

Brad Ellis, Cal Poly Humboldt, "Significant Cave Nomination: Protecting a Valuable Resource"

Nominating a cave to be significant through the Federal Cave Protection Act of 1988 is currently the only way to protect a cave and its resources through the Forest Service. As a team of researchers, we explored the Bridger-Teton National Forest to find, research, map, and nominate caves as significant so they could be known to professional land managers. A team of Forest Service volunteers and employees were able to successfully find a cave named "Forget Me Not" and are in the process of submitting the paperwork to establish it as a significant cave.

Emilio Espinal, Cal Poly San Luis Obispo, "Housing Segregation in the United States: A Review of *The Color of Law*"

Richard Rothstein's *The Color of Law* (2017) is an investigation into how the U.S. government deliberately imposed and supported racial segregation in cities across the nation. Rothstein rejects the common notion of de facto segregation, segregation from private practices and individual decisions, and argues that public policy was systematically put in place by all levels of government to ensure the separation of African Americans from whites, making it de jure segregation. Issues such as FHA/VA support of suburban housing, restrictive covenants, redlining, racial zoning, public housing, interstate freeway systems, and other policies were instrumental in exploiting and geographically separating African Americans. The purpose of this paper is to review *The Color of Law* and identify these key issues from the book and explain their significance both past and present. Additional research is also done, highlighting examples from California as they relate to the issues addressed in the book.

Neil Gillies, CSU San Bernadino, "Hydraulic Fracturing: The Detrimental Impacts and the Alternatives that Can Protect Our Environment"

Katharine Mackay, UC Santa Barbara, "Evaluation of NDVI and EVI as Measures of Food Availability for Fruit-eating Monkeys"

Estimates of food abundance are central in studies of primate behavior and are usually comprised of visual measurements from the ground, yielding crude estimates of food biomass. This method is time- and labor-intensive, especially in tropical rainforests where most primates live. Remote-sensed data is a powerful alternative for calculating vegetation indices (VIs). We tested two VIs derived from NASA's Moderate Resolution Imaging Spectroradiometer dataset as estimates of (1) food availability and (2) energy balance for fruit-eating monkeys in western Uganda. We calculated NDVI and EVI for six groups of red-tailed monkeys (*Cercopithecus ascanius*) over four years. There was no relationship between the VIs and fruit production; however, fruit production also did not correspond directly with monkey energy balance. Instead, the interaction between NDVI and fruit production predicted energy balance. These findings indicate that more research is needed to disentangle the relationships among plant reproduction, VIs, and consumer energetic condition.

Alondra Olagues, CSU San Bernadino, "Yellow Fever Found in Golden Tamarin Monkeys Causing Population Decline"

The Golden Tamarin monkey (*Leontopithecus rosalia*), inhabiting the Atlantic coastal region of southeastern Brazil, is rare and endangered. Newly found yellow fever cases are contributing to potential decline of the population. This research was collected through monitoring and observation of the newly absent Golden Tamarin monkeys from their territories. Lure methods such as vocalization recordings were used in the forest to estimate the population size throughout the species' geographic distribution. While reviewing additional contributors, the findings resulting with this disease include a rise in disappearances and positive cases since the first infected Golden Tamarin was discovered in 2018. Documenting the species' population will determine the strategies of conservation efforts. Once at 200 individuals, they now have increased the population to 2,500. Many other species directly or indirectly interconnected with the Golden Tamarin monkey will be affect. Potential vaccines for non-human primates can be foreseen in the future.

Otto Schmitt, Cal Poly Humboldt, "The Effects of Rising Sea Levels in Humboldt County on FedEx Ground"

Due to climate change, polar ice caps are melting at unprecedented rates and causing the sea to rise. One area that is experiencing sea level rise the fastest in the west coast of the United States is Humboldt County. This is due to the Mendocino triple junction off the coast of Humboldt. One company that will be affected in the area is FedEx Ground. Due to rising sea levels, many towns will be affected by flooding roads and drivers will not be able to make deliveries, resulting in possible job loss or relocation. This project illustrates how the areas of Humboldt County along with FedEx Ground will be affected. I create a map using ArcGIS Pro with an overlay of sea level rise predictions and a layout of delivery routes as well as conducting interviews with the drivers/employees whose routes are in the affected areas.