Invasive pine tree impacts on coastal scrub vegetation in the Marin Headlands.

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ABSTRACT

In southern Marin County, large expanses of coastal scrub vegetation have been colonized by Monterey pine (*Pinus radiata*) cultivars. To determine the impact of pine invasion on coastal scrub vegetation, floristic surveys were conducted in 20 blocks that consisted of invaded and uninvaded plots. An invaded plot contained two subplots located under the canopy of an isolated Monterey pine while a paired, uninvaded plot contained two subplots located in coastal scrub adjacent to each pine. Pine trees utilized ranged in size from 2.8 to 119 cm basal diameter. Our results showed that understory native cover and species richness decreased linearly as trees increased in size. Also, the cover and depth of litter found in the understory, which was mostly composed of pine needles, were positively correlated with tree size. Understory exotic plant cover and richness did not show any correlation with tree size. When comparing invaded (*P. radiata* understory) versus uninvaded coastal scrub based on size-class of trees, only the understories of medium- (16 – 40 cm basal diameter) and large-sized trees (40 – 120 cm) exhibited lower native cover and species richness. Coastal scrub under small trees (2 – 16 cm) did not differ compared to paired, uninvaded scrub. Thus, removing *P. radiata* cultivars before they reach a size of around 16 cm basal diameter will likely minimize negative effects from individual trees. However, removal of larger trees is also important for numerous reasons, one of which is to limit recruitment.

METHODS

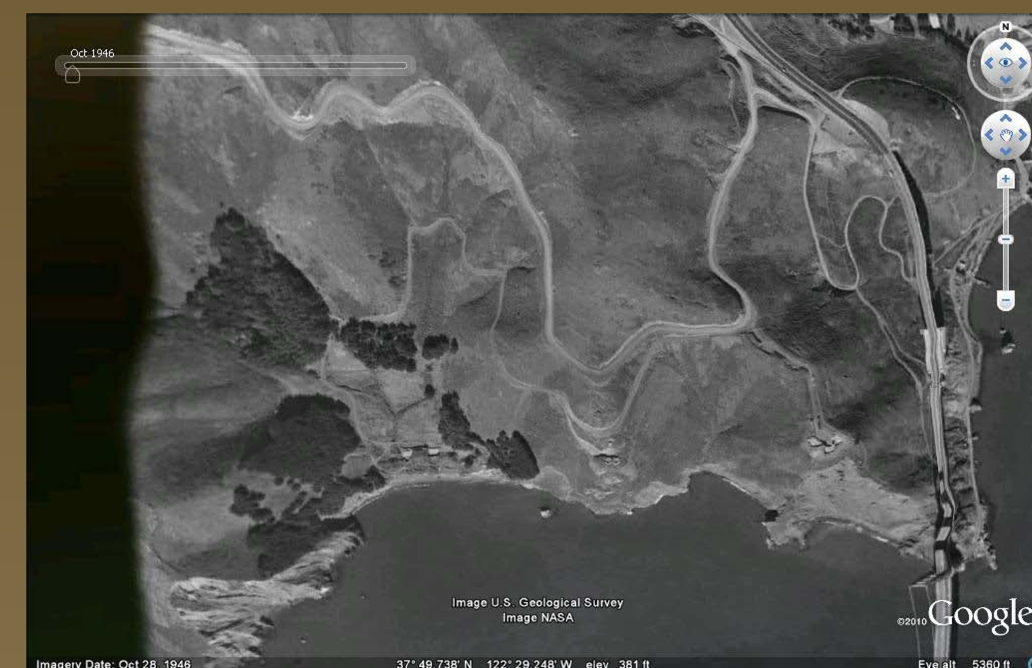
Within coastal scrub vegetation found along the southern most ridge of hills in Marin County, we selected 20 *P. radiata* individuals that varied in size from saplings to large, mature individuals. All of the trees selected were isolated individuals (not growing amongst or adjacent to other *P. radiata* individuals or other tree species).

Parameters measured per tree:
- Diameter of canopy
- Basal diameter of tree trunk

To asses the impacts of *P. radiata* on vegetation, a quadrat (1 x 0.5 m) was placed under the canopy of a tree, half-way between the dripline and the base of the tree trunk on both the uphill and downhill sides of the trunk. Then, two quadrats were randomly placed in the surrounding uninvaded coastal scrub on similar slope and aspect as the reference tree.

The parameters measured within each quadrat included:
- Species Richness (native and exotic)
- Cover (%) of native and exotic plant life-forms (annual forb, annual grass, perennial forb, perennial grass, fern, shrub, tree)
- Cover (%) of litter (P. radiata litter & other plant litter)
- Litter depth (taken at center of quadrat and 25 cm off center to the right and left)

Data Analyses:
Linear regression was used to determine the relationship between tree size and the abiotic & biotic parameters measured under each tree. Principal components analysis (PCA) was used to compare under tree quadrats with those found in uninvaded coastal scrub. With PCA scores from Axis 1, linear regression was used to see if the difference between paired under and open quadrats increased as trees increased in size. Lastly, t-tests were used to compare native vegetation between paired under and open quadrats for three different size classes of trees.



Kirby Cove 1946

Kirby Cove 2007

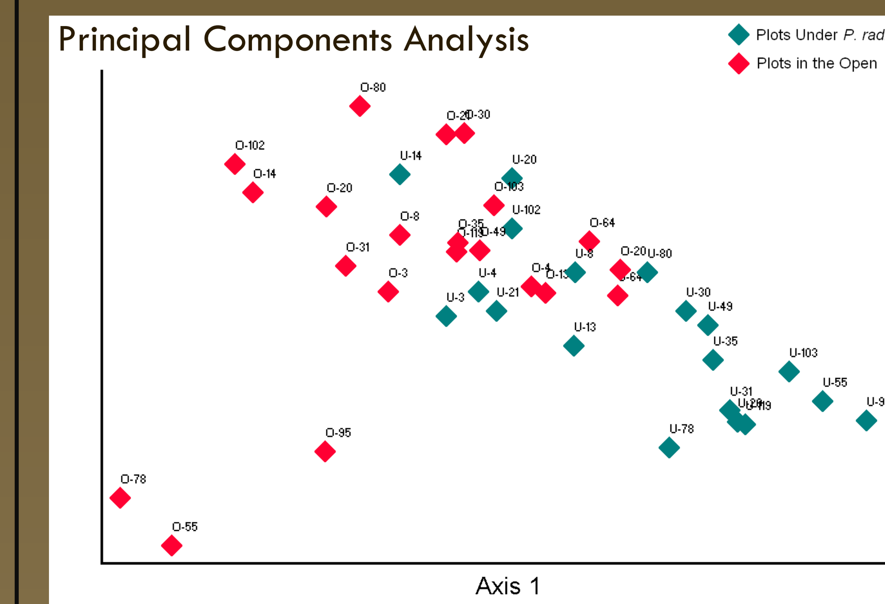
Prior to becoming part of Golden Gate National Recreation Area, cultivars of exotic tree species, like Eucalyptus, Monterey Cypress, and Monterey Pine, were planted in select areas by the military and CA state parks. These species have since expanded with Monterey Pine being especially effective at recruiting long distances from planted sites.

Figures A and B depict the spread of *P. radiata* cultivars near Muir Beach and Greengulch. Figure C depicts the sampling design used for each *P. radiata* sampled (blue = under canopy quadrats; red = reference uninvaded quadrats).

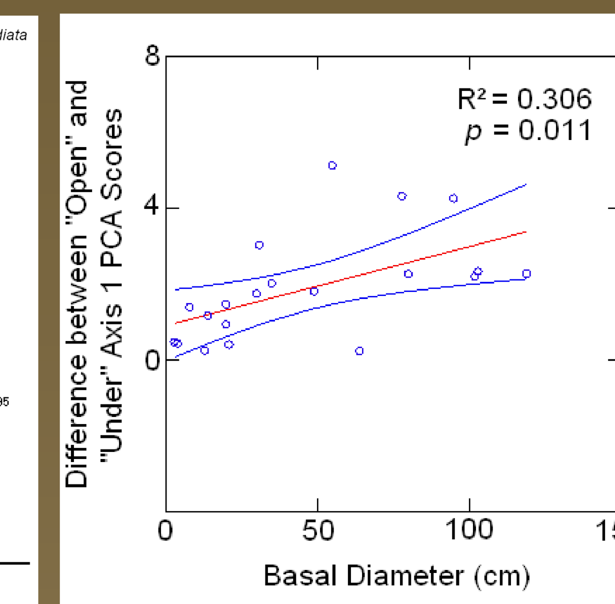
Table 1. Results from linear regressions showing the relationship between *Pinus radiata* size (basal diameter and crown diameter) and parameters measured under *P. radiata* canopies.

Under Canopy Parameters	*Pinus radiata* Parameters					
	Basal Diameter			Crown Diameter		
	R^2	Coefficient	p-value	R^2	Coefficient	p-value
Canopy Coverage by P. radiata	**0.239**	**0.297**	**0.029**	**0.267**	**0.018**	**0.02**
Bareground Cover	0.002	-0.006	0.862	0	0	0.941
Litter						
-*P. radiata* Cover	**0.536**	**0.491**	**0.000**	**0.467**	**0.026**	**0.001**
-Other Plant Cover	**0.266**	**-0.162**	**0.02**	0.14	-0.007	0.104
-Depth	**0.292**	**0.069**	**0.014**	**0.23**	**0.003**	**0.032**
Exotic Plants						
-Species Richness	0.002	-0.001	0.85	0.011	0	0.662
-Absolute Total Cover	0.038	0.011	0.41	0.167	0.001	0.073
Native Plants						
-Species Richness	**0.23**	**-0.027**	**0.032**	**0.229**	**-0.002**	**0.033**
-Shrub Richness	**0.284**	**-0.021**	**0.016**	**0.24**	**-0.001**	**0.028**
-Perennial Grass Richness	0.004	-0.001	0.794	0.003	0	0.805
-Perennial Forb Richness	0.016	0.004	0.592	0.01	0	0.676
-Annual Forb Richness	**0.202**	**-0.007**	**0.047**	**0.26**	**0**	**0.021**
-Fern Richness	0.027	-0.002	0.493	0.024	0	0.515
-Absolute Total Cover	**0.176**	**-0.323**	**0.066***	0.166	-0.018	0.075
-Shrub Cover	**0.239**	**-0.333**	**0.029**	**0.228**	**-0.018**	**0.033**
-Perennial Grass Cover	0.056	0.028	0.316	0.09	0.002	0.199
-Perennial Forb Cover	0.001	0.011	0.887	0	0	0.94
-Annual Forb Cover	0.134	-0.012	0.112	0.09	-0.001	0.198
-Fern Cover	0.01	-0.017	0.67	0.003	0	0.83
Relative Total Cover	0.033	-0.037	0.442	0.143	-0.004	0.1
Relative Shrub Cover	0.089	-0.249	0.201	0.093	-0.014	0.192

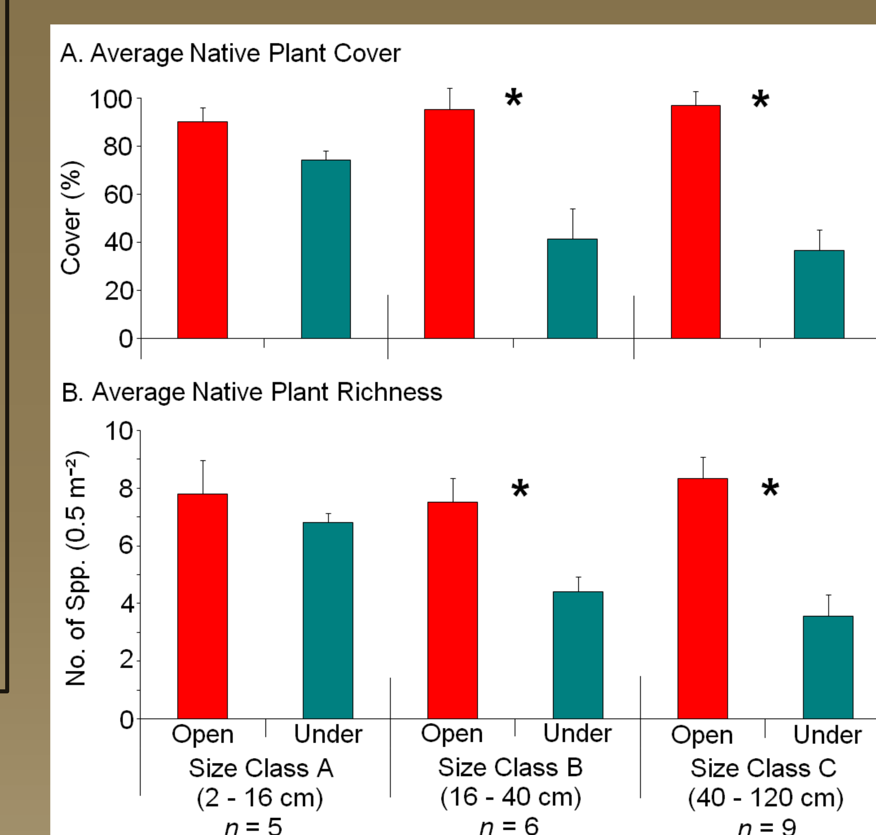
Significant correlations are in bold. *p-value greater than 0.05 but still considered significant.



PCA was based on exotic annual cover, native annual cover, native shrub cover, and native species richness. Only Axis 1 was meaningful, representing 47% of the variance.



Linear regression showing the relationship between tree size and dissimilarity in vegetation between paired, open and under *P. radiata* plots.



Mean native plant cover (A) and native species richness (B) between paired, open (uninvaded) and under *P. radiata* plots for three size-classes of trees. Asterisks indicate significant differences between open and under plots, within a size-class, based on t-tests at α = 0.05.

RESULTS

As *P. radiata* trees increase in size:
- Cover of *P. radiata* litter increases
- Depth of *P. radiata* litter increases
- Native plant cover decreases
- Native plant species richness decreases
- Exotic plant cover does not change (for species other than *P. radiata*)
- Exotic plant richness does not change (for species other than *P. radiata*)

In general, coastal scrub vegetation found under *P. radiata* becomes increasingly different than uninvaded coastal scrub as trees become larger.
Specifically, when comparing vegetation among different size-classes of trees, those in the medium and large size-classes exhibited significantly lower native plant cover and species richness under their canopies compared to paired, uninvaded coastal scrub.

DISCUSSION

Pinus radiata cultivars have been planted throughout the world and are invasive on at least three other continents besides N. America. Impacts to understory vegetation have been recorded in plantations and naturalized stands on other continents. No studies have examined the impact of isolated trees.

Findings from this study suggest that in order to minimize the negative influence of *P. radiata* cultivars, trees should be removed before reaching a basal diameter of 16 cm. However, it is possible that other sampling methods could detect negative effects of trees much smaller than 16 cm basal diameter. Also, other vegetation types besides coastal scrub may be more sensitive to *P. radiata*. Thus, invasive *P. radiata* cultivars should be removed as early as possible.

Wildfires can dramatically increase the abundance of *P. radiata*, as has been observed in Australia and South Africa. There are many reasons to remove *P. radiata* cultivars besides those mentioned here.