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CBES 600

Project 1

Understory Composition and Edge Effects on Canopy Density in Hawaiian Forest Fragments

Abstract

In Hawaii, numerous lava flows can create forest fragments that are called kipuka. These forest fragments can suffer from edge effects as the surrounding matrix habitat starts out being barren, and then is colonized by an assemblage of pioneer species. Edge effects can cause forest canopy to decrease in density nearer to the edge. The size of the kipuka strongly dictates the severity of the edge effects with smaller kipuka being more affected. The presence or absence of certain understory species may be affected by the density of the canopy and the subsequent effects of light, and moisture. We show that the presence of ‘uluhe ferns (Dicranopteris linearis) are significantly correlated with canopy density. ‘Uluhe ferns prefer light environments with low canopy cover. ‘Uluhe are a predominantly matrix species, but are present in kipuka with a lower average canopy density and smaller size. This suggests that they have an affinity for light, and that they take advantage of the edge effects of smaller kipuka to colonize them. The invasive growth habit of ‘uluhe may affect the ecosystem assemblage of kipuka in which they’re present by preventing ohi’a seedlings from taking root.

Introduction

On the island of Hawaii, the forest is in a continual state of disruption and re-growth. Lava flows from the active volcanoes, and when lava decimates the vegetation in an area, it naturally goes through 3 phases of succession. The first phase is dominated by lichens and mosses. The propagules for these lichens can invade from kipukas, which are small areas of forest missed by lava flows. The lichens act to break down the lava into a more plant friendly substrate. The second stage of succession is dominated by ‘uluhe ferns (Dicranopteris linearis), which form dense mats covering the surface. Meanwhile, all of this plant material is collecting and forming a substrate for later growth. ‘Uluhe ferns are a light loving species that will also block ohi’a (Metrosideros polymorpha) seedlings from growing. The third stage is dominated by Cibotium tree ferns, which form the dense understory of the Metrosideros dominated canopy (Muller-Dombois & Boehmer 2013).

The focus of this paper will be the 1855 lava flow and forest kipuka adjacent to the Kaumana trail on Hawaii. Kipuka fragments are surrounded by a matrix of lava flows of uniform age and successional stage, which is in the second stage dominated by ‘uluhe ferns. There are four distinct kipukas within 1 kilometer of each other that will be studied. Two are small at roughly 5000m^2 each, and two are larger at 20000m^2. The fragments are named according to Figure 1.

Figure 1: Test sites showing all numbered kipukas. The location is following the kaumana trail south of the saddle road.

These small forest fragments are surrounded by substrate at an earlier successional stage, meaning that edge effects are going to be prominent in these habitats. In similar fragmented habitats in Central Amazonia, it was found that understory density decreased with increasing distance from the edge, and canopy density increased. The reason given for this is that wind likely damages stands of trees that have less support from adjacent trees (Malcom 1994). Additionally, the penetration of light will tend to increase at the edge, and the relative humidity will decrease at an edge due to this lessening of canopy cover. These effects can combine to create a fragment environment that differs with the size of the fragment. The reason for the disparity in edge effects in differing fragment sizes is due to how the amount of perimeter in a fragment scales more slowly in proportion to the area. (Murcia 1995).

We expect to find a difference in canopy densities between large and small kipuka due to their edge effects, with small kipukas having a lower overall canopy density, and large kipukas having a higher density. Considering the differences in light, moisture, and edge effects expected in differing sizes of kipuka, our suspicion is that differences in the understory vegetation and species composition will be observed in relation to the light received at ground level through the canopy.

There are a multitude of understory species that can be observed, however our list has been reduced to four easily identifiable species that are commonly found in the kipuka understory. The first species is the ‘uluhe ferns which were discussed earlier. The ‘uluhe ferns have been stated in Muller-Dombois & Boehmer (2013) to show affinity for light, so the prediction is that they would be seen preferentially in areas with a lower density canopy.

Alternatively, we might find that ‘uluhe show no preference for canopy density. A second species of interest were Hapu’u tree ferns (Cibotium spp.). Muller-Dombois & Boehmer (2013) indicated that these ferns prefer shady understory in the later successional stages of Hawaiian forest, therefore we would expect that they would be seen preferentially in areas with greater canopy cover. Alternatively, Hapu’u ferns may show no preference for canopy density in forest understory. The Two other species surveyed were pa’iniu (Astelia menziesiana), a readily identifiable monocot, and maile (Alyxia oliviformis), which is a vining plant often used in lei making.

Methods

The study sites chosen were forest fragment kipuka accessible from the Kaumana trail. A table of random numbers between 0 and 359 were generated to give compass headings. In kipuka’s 22, 20, 19, and 18, locations approximately in the center of each were chosen and a compass heading was chosen. A stick with orange flagging tape tied to it was used as a marker, and thrown in the direction of the given compass heading. The spot where the stick landed was the sample site. The species of plants in a 1 meter radius were tallied for their presence and number, and a forest densiometer was used to take the percent cover. The densiometer was held level to take a canopy density reading for each cardinal direction. In kipukas 22 and 20 which were smaller, a location was chosen in the center, and returned to after each throw in order to avoid going outside the kipuka edge. In kipukas 18 and 19 the stick was thrown from the previous sample site to the next. This created a radial spokes pattern in the smaller and a wandering pattern in the larger fragments.

For analysis of plant samples, the four canopy density measurements from each cardinal direction at each site were averaged to give a representative canopy density above each sample site.

Results

‘Uluhe were present in kipukas 22 and 20, but not 18 and 19. Maile was present in kipukas 18 and 19, but not in sufficient numbers to make any comparison, and so will not be discussed. Hapuu ferns were found in all four kipukas tested. Pa’iniu was present in all four kipukas. A logistic regression was performed for each species where the presence or absence was the binary factor, and the canopy density the continuous factor. The only species that showed any correlation of presence and absence to canopy density was ‘uluhe ($p=0.004184$ and pseudo R^2 (Cox and Snell) of 0.4932), (See Figure 2). Pa’iniu ($p=0.5065$, $R^2=0.01460$) and hapu’u ($p=0.06373$, $R^2=0.1083$, Figure 3) showed no significant relationships of canopy density to their presence or absence.

Kipukas 18 and 19 had similar average density as a group, which was different from kipukas 22 and 20, which had a lower average value. The distribution of canopy density for each kipuka was right skewed (See Figure 4). A Kruskal-Wallis test and Dunn pairwise comparison performed on the canopy density measurements with kipukas as groups showed that there are two distinct groups when differentiated by average canopy density $p=1.516x10^{-07}$ (Figure 4).

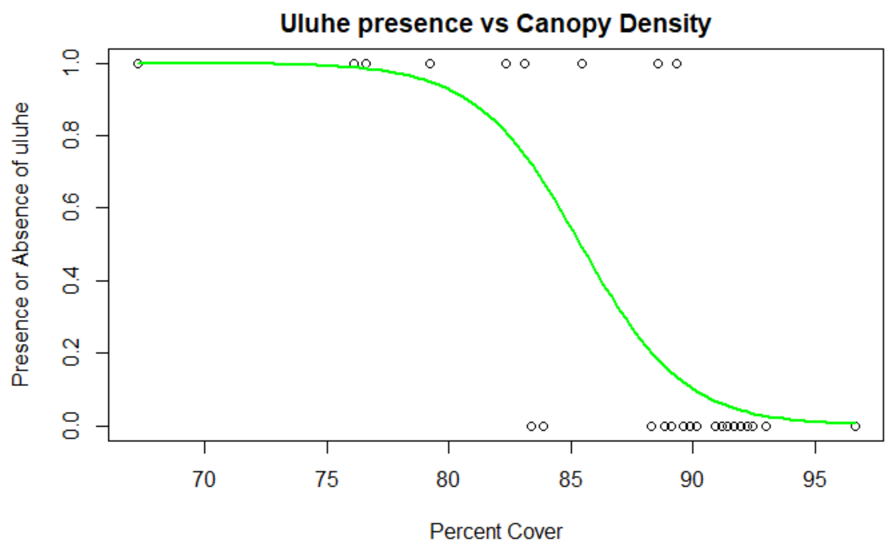

Figure 2:A logistic regression showed a significant correlation of canopy density to the presence of 'uluhe ferns.

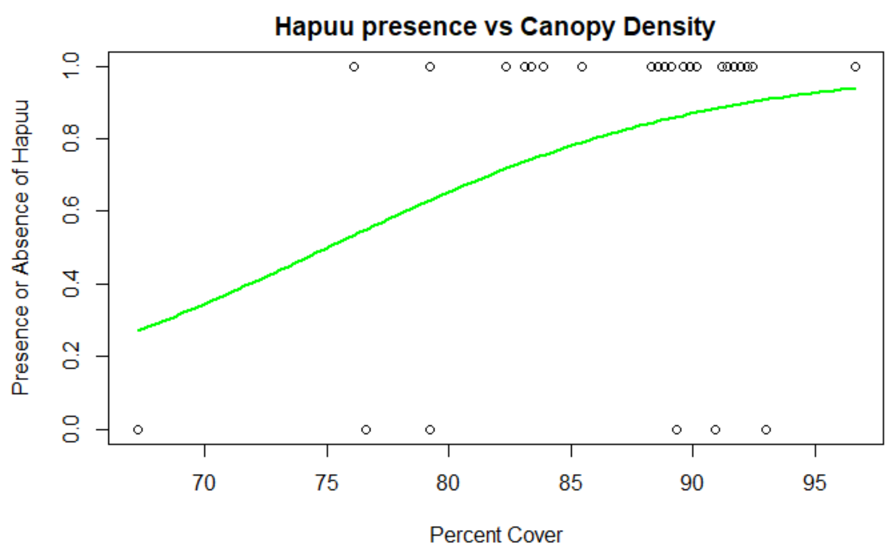

Figure 3:Hapu'u ferns did not seem to show any preference in regards to canopy cover. Their presence was recorded across a wide variety of canopy densities.

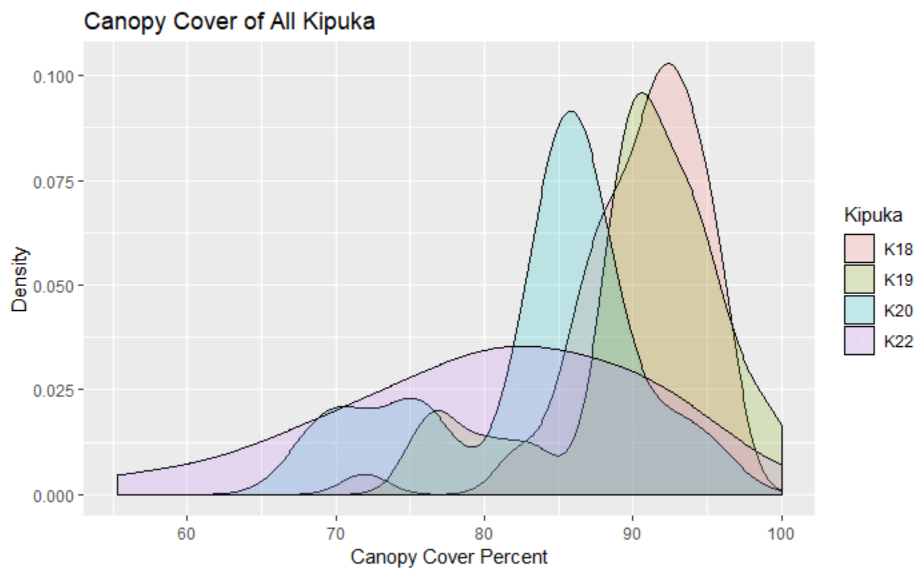

Figure 4: The distribution of canopy cover percentages in each kipuka labeled by color. Note that the distribution is right skewed for each of them.

Discussion

The fact that ‘uluhe ferns showed a noticeable preference for sites within the kipukas with a lower canopy density supports the results expected by Muller-Dombois & Boehmer (2013) about ‘uluhe. Not supported however was the expectation that hapu’u ferns would prefer a lower light environment facilitated by a higher canopy density. This may indicate hapu’u ferns have a larger tolerable range of light environments.

Also tested and supported were the findings of Malcom (1994) and Murcia (1995) which suggested that smaller forest fragments would have a greater impact from edge effects that reduced canopy density and increased understory density. Also worth noting is that only the smaller fragments had ‘uluhe ferns present within them. This may also be blamed on the edge effects which lowers overall canopy density, lowers the moisture and increases available light, ultimately allowing intrusion of ‘uluhe ferns from the surrounding matrix. The larger kipukas with higher canopy density did not have intrusion of ‘uluhe ferns, which may be linked to their higher overall canopy density and lower light level. It may be worth testing the canopy density and understory density of ‘uluhe ferns at differing distances from the kipuka edge from larger and smaller kipukas. This would help in understanding the degree to which edge effects are at play in forest fragments of differing sizes, and if fragment size has a protective effect against ‘uluhe intrusion.

All of the fragments tested had a right skewed distribution of canopy cover percentage, which may indicate a constant biological pressure to maximize canopy density. This could either indicate that the fragments are in the process of maximizing their canopy density, or regularly suffering from disturbances that break the canopy such as trees falling. It is possible that there is a combination of these effects.

It was stated that ‘uluhe ferns frequently block Metrosideros seedlings from growing through competitive exclusion. It may be of interest to study the long term effects this has on small forest fragment persistence, to see if the population of living Metrosideros decreases over time due to lack of replacement seedlings. This would suggest that smaller forest fragments are at more risk of reversion to appear like an earlier successional stage after their creation than large fragments. One positive side effect may be that the dense growth habit of ‘uluhe might block invasive species from taking hold. This suggests ‘uluhe may be a potential tool for community assemblage ecology in Hawaii, but more research is needed.

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