WOODY PLANT COMMUNITIES ALONG AN ELEVATION GRADIENT IN MOOREA, FRENCH POLYNESIA

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Abstract. Plant communities vary in relatedness, diversity, abundance, and morphological traits over spatial scales. This holds true along elevational gradients, where different elevations have different environmental filtering, resulting in varying species compositions. This study aims to shed light on the extent to which the aforementioned community characteristics vary along the elevational gradients of Moorea, French Polynesia. Plots were placed over 5 elevations in which species diversity, abundance of individuals within each species, and leaf and plant physiological traits were measured. It was determined that species at the highest elevation exhibited higher relatedness than by chance. In addition, native species were found to increase in abundance with elevation and leaf mass was found to be greater at lower elevations. Species richness and accumulation appear to increase with increasing elevation and the species compositions found at the different elevations are significantly different from one another.

Key words: community structure; trait mapping; community phylogenetics; species richness; Moorea, French Polynesia

INTRODUCTION

A community is a collection of populations occupying the same geographical area at the same time (Fauth et al. 1996). The study of communities exposes the taxonomic make up of a habitat, as well as the interactions, abundance, and distribution of those species comprising it. Communities can be studied from a classical community ecology perspective or from a phylogenetics perspective. Classical community ecologists study the interactions among species and how they are influenced by abiotic and biotic factors (Webb et al. 2002). Phylogeneticists examine the evolutionary relationships among different groups of organisms in a community. Phylogenetics is the study of how closely related species have evolved throughout time (Kress et al. 2009; Fauth et al. 1996). These two approaches both study taxonomic interactions, but phylogenetics adds an evolutionary basis exploring how species have come to have the traits and distributions they have today, while traditional community ecology looks at the environment these species inhabit.

Community phylogenetics has created a new approach to investigate how communities are assembled and how evolution has driven that assembly (Cavender-Bares et al. 2006). Community Phylogenetics consists of investigating the phylogenetic foundation of local assemblage diversity and characterizing evolution and biogeography from a community perspective (Webb et al, 2002). Community phylogenetics is a relatively new field that provides more accurate information on relatedness and diversity of species in communities that can be compared within a greater geographic environment (Cornwell & Ackerly, 2009). This field also provides a significant new way to investigate how relatively important abiotic and biotic factors are in structuring local communities and provides more precise data about the range of species presence and the level of their relatedness within a local assemblage (Swenson et al., 2006).

The richness of species in a community also provides a valuable means of investigating the role that environmental filtering plays in community composition and is a fundamental component of understanding diversity within a community (Gotelli & Colwell, 2001). When investigating the composition of a community, the species richness has been known to increase as abundance of individuals, number of samples collected, and sample area increase (Colwell et al. 2012). Measuring species richness is important for comparing local communities and for determining the degree in which these local communities have been colonized by source pools (Gotelli & Colwell, 2001).

The field of community ecology investigates trends in abundance and distribution of species. These patterns can be seen along various spatial scales and can vary among the assemblages within these scales. This implies that there may be different principles applying to the assemblages throughout these spatial gradations (Leibold et al. 2004). Plant communities in particular have many known trends based on which environment they are found in. Plant species and their characteristics are selected for mostly through abiotic filtering. The ability to successfully survive and reproduce in varying abiotic conditions, such as temperature, precipitation, windiness, and sun exposure, determines whether the composition of a plant community, both taxonomically and morphologically.

Plant communities in tropical forests have a more specific set of environmental parameters. Tropical forests have high temperatures, large amounts of precipitation, and high annual sun exposure, therefore they are highly hospitable environments and tend to have very high biodiversity. In fact, tropical forests are much more diverse than temperate forests, particularly in terms of vascular plants (Gentry, 1998). There is, however, a relatively greater range in species richness of woody plants among tropical forests as compared to among temperate forests (Gentry, 1998). The degree of biodiversity found in tropical forests depends upon ease of dispersal.

Moorea, French Polynesia is a high oceanic island, meaning that it originated from an under water volcano in the middle of the ocean (Mueller-Dombois, 1998). It is about 2.2 million years old and has a tropical forest ecosystem. Tahiti, and likewise Moorea, is described as a moist forest with a mean annual temperature of 25°C, annual precipitation of 3101mm, and potential evapotranspiration of 700mm annually (Mueller-Dombois, 1998). Due to its physical isolation it is difficult for organisms to disperse to it and as a result, it has a relatively low biodiversity. In addition, Mooreas highest peaks are around 1,200m and as Gentry observed in the tropical forests of the Andes, altitudinal effect on species richness is not seen until 500m, further limiting the biodiversity on an altitudinal scale (Gentry, 1998). The original plant colonists on Polynesia are from a wide array of origins and their success was shaped by environmental, morphological, and physiological influences as well as good dispersal methods. Today, a large amount of the plant biodiversity in Polynesia is coastal strand species, which are for the most part introduced, however many endemic species can be found inland (Mueller-Dombois, 1998).

In this study, I investigated trends in species relatedness, plant morphology, and species richness along an elevational gradient on the island of Moorea in French Polynesia. I mapped the phylogenetic relatedness of the plants, morphological trends, and species abundance within each community and among the communities at each elevation, thereby examining evolutionary and environmental patterns. I hypothesized that the net relatedness of species will be higher at higher elevations as a result of there being more endemic species in these communities. I also hypothesized that there would be a greater abundance of native species at high elevations, because they are more equipped to withstand the more extreme conditions, and that there would be a greater abundance of introduced species at the lower elevations because it is at a closer proximity to the ocean, where most species disperse from. In addition, I predicted that species richness would be greater at lower elevations because there is a wide variety of introduced species found there. I hypothesized that at higher elevations the average plant height would be smaller because it is windier and less moist there and that the average leaf size would be smaller because there is more direct sunlight and the leaves want to limit their sun exposure. I predicted that there would be: a higher proportion of plants with a drip tip at lower elevations because this allows them to get rid of excess water and the lower elevations are more moist, a higher proportion of serrated leaves at higher elevations because it is drier there, and a higher proportion of compound leaves at lower elevations because leaflets are better heat exchangers.

METHODS

Study site

This study took place on Mt. Mouaputa in Afarieatu on Moorea, French Polynesia at 17°32'S and 149°47'W. GPS of every plot can be found in Appendix A. There are 5 sites, which span along an elevational gradient at 0-50m, 175-225m, 325-350m, 480-515m, and 680-720m. Mt. Mouaputa contains a tropical rainforest habitat with temperatures between 22°C and 30°C. This study took place during

the end of the dry season and the beginning of the wet season, resulting in relatively high levels of humidity and precipitation.
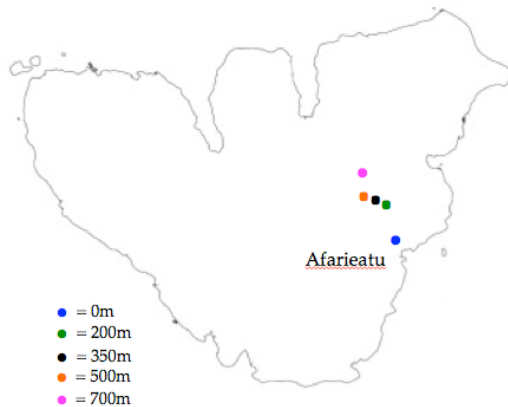

FIG. 1. Map courtesy the of Geospatial Innovation Facility at UC Berkeley. Sites sampled in this study were on Mt. Mouaputa in Afarieatu, Moorea, French Polynesia.

Data Collection

All of the data was collected over a one-month period, between October 15 and November 14. Seven 5-m² plots were placed within the parameters of each elevational site. The sites include forest regions that were at least 20m from roads, streams, and major disturbances and were off the trail by at least 5m. The plots were at least 10m apart from each other. The sites were visited on average between 0800h and 1600h. Each plot was only visited once. Within each plot every vascular, woody plant organism was noted, including abundance and identification of every species and abundance of individuals of each species. 10 leaves from each species were collected and a description of the plot was noted, including a soil description, slope gradient, canopy cover, and temperature. Descriptions of individuals from each plant species were also taken, including the diameter at breast height, height, and any unique features. The diameter was either taken at breast height, or if the plant did not reach breast height it was taken at the tallest point that was still woody. Only plants above 30cm were measured. All of the measurements were made by myself or by a partner and confirmed by myself using the same measuring tape, to verify that the measurements were always consistent and unbiased.

FIG. 1. Map courtesy of Geospatial Innovation Facility at UC Berkeley. Sites sampled in this study were on Mt. Mouaputa in Afarieatu, Moorea, French Polynesia

The plants were identified either in the field or if the identity of a species was uncertain they were identified using the Moorea Biocode Project, the Moorea Digital Flora Project (Mudrock & Hinkle, 1999), Flora Socierensis (Welsh, 1998), or by Jean-Yves Meyer (personal contact) or Brent Mishler (personal contact). Each collected leaf, from every species on every elevation, was then weighed in order to find an average leaf mass found on each elevation. Physical vouchers were collected and are held in the University and Jepson Herbarium at UC Berkeley. The height and dbh of the plants, the presence of dentation, compound structure, and drip tip in the species, the abundance of individuals, and whether the species were native or introduced to Moorea were also recorded in order to consider community patterns in canopy, leaf shape, rarity of species, and composition of native vs. introduced species.

Data Organization

The raw data from this study was organized in excel. Abundance data was compiled with a column for elevation, a column for the plot number within each elevation, and then all of the species sampled with their abundances from each plot. Trait data was also organized by elevation, species found in each elevation, and their data on height, dbh, status of native or introduced, total abundance, and presence or absence of drip tip, compound structure, or serration in leaves. Also, a list of all of the woody plants on Moorea was compiled and organized by family, genus, and species and was then transformed into the Newick format using Phylomatic software so that a phylogenetic tree could be made of the species pool in Mesquite and relatedness could be measured in Phylocom.

Data Analysis

Using the Moorea Biocode Project, Moorea Digital Flora Project (Mudrock & Hinkle, 1999), Phylocom (Webb, Ackerly, and Kembel, 2008), and Mesquite software (Maddison & Maddison, 2011) I have created a phylogeny of the species pool of all of the woody, vascular plants on Moorea. I then placed all of the species that I have found throughout my sites

onto this phylogeny, organized by elevation at which they were found, to determine the relatedness and dispersal of these species. Using Phylocom, I created a null model phylogeny (Webb et al. 2002), by randomly picking however many species were found at each elevation, from the total pool phylogenetic tree. This was done 999 times until a null phylogeny was created, which represents the average phylogenetic dispersal of the species found on each elevation out of all of the woody plants on Moorea. I can compare this to the actual phylogenetic distance of the sampled species to determine if the species are more or less normally related than expected.

I ran an analysis of variants test (ANOVA) in order to determine if there's a greater significant difference between categories than within a category. I ran this text on the trends in native vs. introduced species over an elevation gradient (Figure 7), leaf mass over an elevation gradient (Figure 2), plant community height over an elevation gradient (Figure 3), number of species over an elevation gradient (Figure 5), and species accumulation compared with the number of samples (Figure 6). After determining that there was a significant difference, I then ran a Tukey test on mass over elevation and species accumulation over species sampled in order to see at which elevations there was a significant difference. I ran a ChiSquare test to determine the significance of the difference in abundance of native and introduced species at each elevation (Figure 6) and the difference in the number of species found at the different elevation to have an individual trait, such as drip tip (Figure 4). All of the above analyses were done in R (R Development Core Team 2013)

Finally, I used EstimateS to calculate woody plant species diversity by quantifying species richness (Figure 6). I used species accumulation curves (plots of the mean number of species per species sampled) with 95% CI, and rarefaction to a common sample size using "S(est)" in EstimateS version 9.1.0 (Colwell *et al.*, 2012, Colwell 2013).

RESULTS

Trait Mapping

There was a significant difference in mass of the leaves collected from all of the species present at each elevation over the different elevations (ANOVA: P = 7.52e-05, F = 15.84),

as is seen in Figure 2. The mean values of the leaf masses decrease beginning at 200m (mean values: 0m = 0.68, 200m = 1.05, 350m = 0.85, 500m = 0.40, 700m = 0.35). More specifically, the individual elevations that had significant differences between each other were tested with a Tukey test (500m-200m: p = 0.0021, 700m-200m: p = 0.00048, 500m-350m: p = 0.015, 700m-350m: p = 0.0031). This test shows that there are only significant difference between 500m and 700m with 200m and 350m.

The heights of individuals from all of the species at each elevation were measured (Figure 3). There was no statistically significant trend in height difference (ANOVA: p = 0.49). The mean height values at each elevation were also found (mean values: 0m = 2.77m, 200m = 2.58m, 350m = 3.69m, 500m = 2.97m, 700m = 2.53m).

The woody plants sampled at each elevation were characterized based on if had certain morphological traits (Figure 4). Using a ChiSquare test leaves with the compound structure were not found to have any significant difference among the elevations (p = 0.16), serrated leaves were not found to have any significant difference among the elevations (p = 1), drip tip leaves were found to be statistically more common in low elevations than high (p = 0.0044).
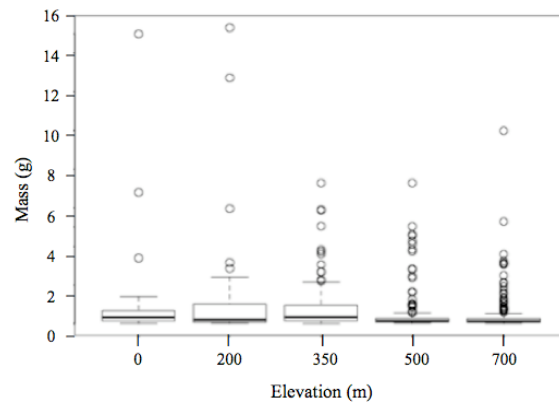

FIG. 2. Leaf mass along the elevational gradient. Black bar represents the average leaf mass at each elevation, the upper and lower parts of the box the upper and lower 25% quartiles, and the circles outside of the plot are the outliers. There's a significant trend in mass decreasing with increasing elevation.
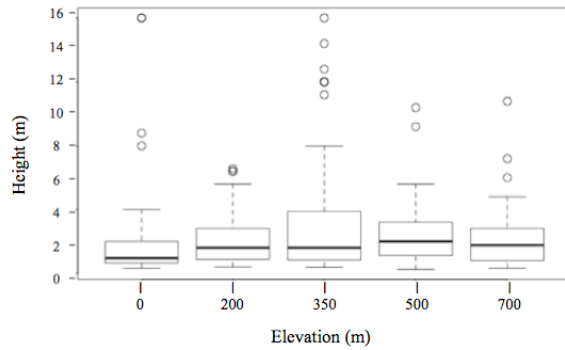
FIG 3. Height of woody plants sampled at each elevation along the gradient. Black bar represents the average leaf mass at each elevation, the upper and lower parts of the box the upper and lower 25% quartiles, and the circles outside of the plot are the outliers. There is no significant trend.
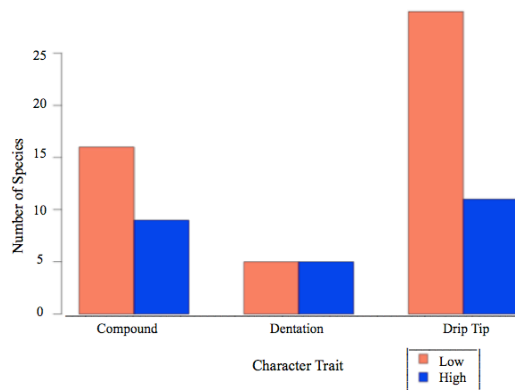

FIG 4. Abundance of species displaying the specified character traits as compared between low and high elevations. Low=0m, 200m, 350m; High=500m, 700m.

Community Phylogenetics

I tested the relatedness of the species sampled at each elevation compared with the normal relatedness of that many species randomly selected from the woody plant species pool using Phylocom software. The mean nearest phylogenetic taxon (MNTD) is significant lower than expect by chance (p = 0.042) at 700m. The average distance, weighted by abundance, between two random individuals drawn from the species sampled at 700m (MPD, -a argument) is significantly lower than expected by chance (p < .001). The average distance, weighted by abundance, to the closest relative of a different species for each individual in the species sampled at 700m (MNTD, -a argument) is significantly lower than expected by chance (p=0.012).

There are also significant trends in clustering of abundance distributions at the higher elevations (NRI, -a argument: 350m = 1.05, 500m = 1.24, and 700m = 2.36.

Species Richness and Community Composition

A species richness graph, displaying the number of species found at each elevation can be seen in Figure 5. There is a statistically significant increase in species richness as elevation increases (ANOVA: DF = 1, F = 45.37, p = 0.0067).

A species accumulation curve, measuring the accumulated species sampled over the number of sampling instances, can be seen in Figure 6. There was found to be a statistical significance among the species accumulation on all of the elevations (ANOVA: p = 2.62e-05, F = 23.82). More specifically, the individual elevations that had significant differences between each other were tested with a Tukey test (500m-200m: p = 0.0021, 700m-200m: p = 0.00048, 500m-350m: p = 0.015, 700m-350m: p = 0.0031).

The number of species that are native and introduced at each elevation is displayed in Figure 7. A ChiSquare test was performed to determine statistically significant differences between the number of species sampled that are native and introduced at each individual elevation as well as among all of the elevations and none of the values were statistically significant. Then, an ANOVA test was performed and the difference in the number of native species over the elevational gradient was found to be statistically significant (p = 0.0021, F = 102.3), although the number of introduced species over the elevational gradient was not found to be significant.

A discriminant analysis of the species composition among the different elevations was performed in Figure 8. A MANOVA was performed on this ordination in order to analyze multiple variables. The species composition was found to be statistically significantly different between the different communities (Wilks' Lambda = 4.20e-5, F = 5.90, DF = 84, P-value < .0001)
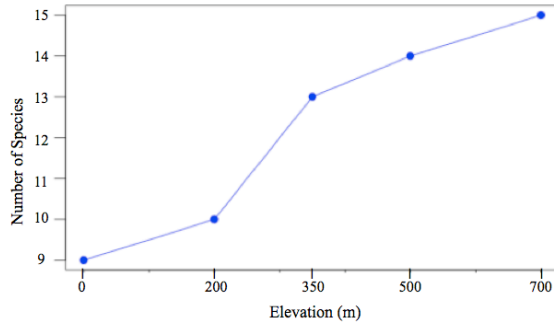
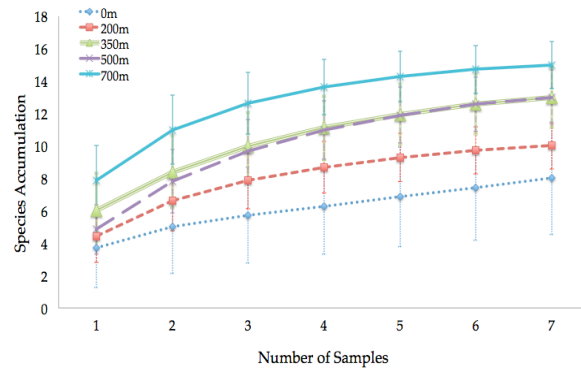FIG 5. The number of species sampled at each elevation significantly increased as elevation increased.

FIG 6. A species accumulation curve, representing species diversity over the different elevations. The elevations showed statistically significant differences in accumulation.
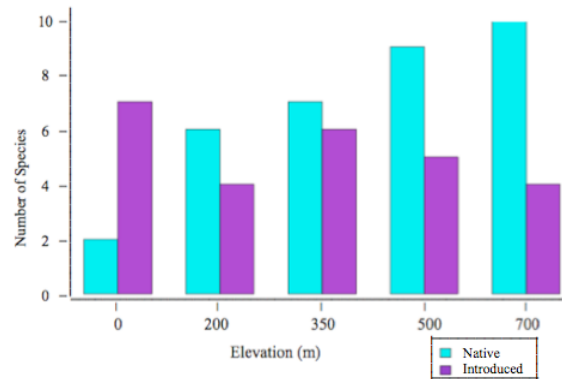

FIG 7. Abundance of native vs. introduced species found along the elevational gradient. The difference in the abundance of native and introduced species is not significant, but the trend of abundance of native species over the elevational gradient is significant.
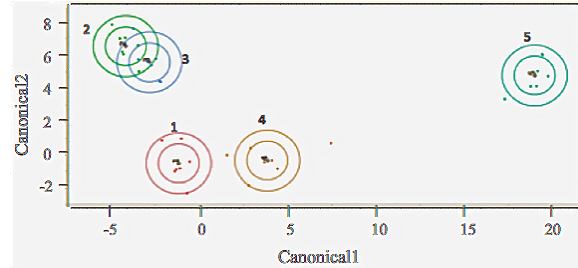

FIG 8. Discriminant analysis of community composition. Each species is considered a variable, clumped with the other species in its elevation, and compared to the other elevation clusters in order to determine how similar the species compositions are. These clusters are significantly different.

DISCUSSION

Trait Mapping

Environmental conditions and abiotic factors vary along an elevation scale. The different habitats found on different elevations filter for specific morphological characteristics that are most advantageous in that environment. Some physiological characteristics are global trends, but they vary in prevalence depending on the biome and local ecosystem (Reich, 1999). Leaf mass is a characteristic that is non-uniform on an environmental scale and can be representative of either leaf thickness or area. In this study leaf mass significantly decreases as elevation increases ($p = 7.52e\text{-}05$) (Figure 2). Although this is contributed to by leaf thickness, it is most likely a greater representation of the trend in leaf surface area. Lower elevations most likely have heavier leaves because it is a more hospitable environment: the soil has more nutrients, it's warmer, it's less windy, and there's a lot of rain. Therefore, both leaves and the whole plants themselves are able to grow much larger here. In addition, because the plants grow taller and there is a thicker canopy there is more competition for light, resulting in the leaves to grow even larger. This idea of an increase in plant height can be supported by Figure 3. Although there isn't a statistically significant difference in the heights of woody plants along the elevational gradient there is a clear trend of decreasing height from 350m to 700m (means = 3.69, 2.97, 2.53 accordingly).

The change in the degree of canopy cover over the elevational scale has far reaching implications on the environmental filtering of the plant life in that habitat. The level of sun

exposure, as indicated by canopy cover, as well as other factors have a large influence on the morphological characteristics of the leaves themselves (Figure 4). For example, the presence of a drip tip in a leaf is seen to be significantly higher at low elevations (p = 0.0044). Since there is less sun exposure in the lower elevations, when it rains the water doesn't evaporate as easily, resulting in leaves carrying pools of water. The drip tip, therefore, can be explained as an adaptation for a mechanism to "drip" off the excess water. There are many other trends in morphological traits along the elevational gradient, however the other trends tested in this study, compound structure, and dentation, proved to have a statistically insignificant difference between the low and high elevations. This may be because these adaptations are designed to be most fit in drier environments, and although the higher elevations have more sun exposure, they also experience more rainfall.

Community Phylogenetics

Community phylogenetics interprets community composition from an evolutionary perspective, looking at the taxa present in a community, and in what abundance, in order to speculate how that community evolved into what it is today. The Net Relatedness Index (NRI) is a standard metric showing the relatedness between the taxa sampled as compared to the relatedness of taxa randomly selected from the total species pool. The NRI expresses whether communities exhibit normal relatedness, higher than normal relatedness ("clustering") or lower than normal relatedness ("evenness") (Webb, Ackerly, Kembel. 2011). Elevations 0m, 200m, and 350m show slight trends in over-dispersion (NRI=-0.20, -0.77, and -0.41 accordingly), while elevations 500m and 700m show slight trends in clustering (NRI=0.51 and 0.51). Over-dispersion in a local assemblage is either an indicator of competition among closely related species or distantly related species having converged phenotypically to the same niches (Webb et al, 2002). Phylogenetic clustering it could be because of abiotic filtering, as environmental conditions select for closely related taxa that share similar traits (Swenson et al. 2006; Webb et al, 2002). Phylogenetic clustering could also indicate habitat-use being a conserved trait within the species pool (Webb et al, 2002). We can also look at the NRI weighted by taxa abundance

in order to determine if abundance distributions are phylogenetically clumped or over-dispersed at each elevation. The plant community at 0m exhibits slight trends in clustering of species abundance (NRI, -a argument = 0.55) and at 200m there is a minor trend in evenness (NRI, -a argument = -0.52), but at elevations 350m, 500m, and especially 700m there are more significant trends in clustering of abundance distributions (NRI, -a argument = 1.05, 1.24, and 2.36 accordingly).

The Nearest Taxon Index (NTI) assesses how closely related individual taxa are to other taxa in their community. When individuals are more closely related to their closest relatives, in the community, than expected they are phylogenetically clustered and when they are less closely related, as expressed by negative NTI values, it indicates evenness (Webb, Ackerly, Kembel. 2011). The plant communities at 0m, 200m, and 350m express evenness (NTI = -0.83, -1.21, and -0.89 accordingly), whereas the communities at 500m and 700m exhibit signs of clustering (NTI = 0.96 and 1.69 accordingly). In addition, the abundance distributions of NTI can be calculated and these values express how often individuals are found to be closely related to their close relatives (Webb, Ackerly, Kembel. 2011). With the exception of the community at 200m (NTI, -a argument = -0.98), this phenomena is seen in high abundance at all of the other elevations (NTI, -a argument = 0.64, 0.68, 1.21, 1.69 in order from highest to lowest elevation). Individuals are closely related in higher abundance to their close relatives as elevation increases.

The only significant p values were found at 700m. The mean nearest phylogenetic taxon (MNTD) is significant lower than expect by chance (p=0.042). This result is indicative of phylogenetic clustering at the highest elevation. When the phylogenetic distance is weighted by taxa abundance, the average distance between two random individuals drawn from the sample (MPD, -a argument) is significantly lower than expected by chance (p < .001). This result suggests that there is low species diversity on the highest elevation and/or there is high abundance in the species that are present there. Also weighted by taxa abundance, the average distance to the closest relative of a different species for each individual in the sample (MNTD, -a argument) is significantly lower than expected by chance (p=0.012). These results suggest that species found in high abundance at 700m that are more likely to be closely related.

Considering that no other elevations were found to have significant p values, trends in species diversity, although present, may not be substantial below 700m, reflecting a similar assessment made by Gentry (Gentry, 1998).

Species Richness and Community Composition

Species Richness is an indicator of biodiversity within a community. Comparing species richness of local assemblages can display patterns of biodiversity along a scale within the larger community. The species richness of a habitat can also show how successful the studied organism is in that environment and therefore exposes the environmental preferences of that organism. In this study the number of species significantly increases with elevation (p = 0.0067) (Figure 5). Therefore, this information could be indicative of woody plants being more successful at higher elevations and the biodiversity at the higher elevations being greater.

There could be other factors contributing to the trend of species richness increasing with elevation. For example, it is possible that there was too small of a sample size and only those species that are abundant were sampled. In fact, this does appear to be the case. Figure 6 displays a species accumulation curve, which shows the number of species accumulated with each additional sample of the woody plants at each elevation. Accumulation curves provide the most accurate representation of species richness because they contain the basic information necessary to compare richness on a variety of taxonomic levels and allow for standardization of datasets (Gotelli & Colwell, 2001). We are able to plot unified species accumulation curves by combining rarefaction and extrapolated curves. The species accumulation curve is modeled asymptotically to estimate species richness throughout the entire plant community at that elevation (Colwell et al. 2012). This curve is expected to reach its asymptote, indicating that a representative number of species have been sampled. Although an asymptote wasn't reached it is still clear that there's a statistically significant difference in the species accumulation at each elevation (p = 2.62e-05) and that the higher the elevation is the more species are present. However, this curve also shows that the higher elevations are saturating and appear as though they're close to reaching their asymptote, whereas the lower elevations are still continuing on an upward trend. This indicates that the higher elevations are more homogenous, being composed of a relatively intermediate number of species that are high in abundance, so more of the total number of species present can be sampled with a small sample size. It also indicates that the lower elevations are more heterogeneous and are composed of many rare species and when sampled with a small sample size many of them are not accounted for. This could be because the lower elevations are easier to invade and contain a large variety, in low abundance of invasive weeds. The higher elevations may represent a refuge where native plants, that have occupied the island for a long time and therefore are in high abundance, have gradually moved as new plants have invaded. In fact, this trend can be seen in Figure 7, which exhibits a notable trend in invasive plants being found in high abundance at lower elevations as well as showing a statistically significant increase in native woody plant species as elevation increases (p = 0.0021).

It is important to understand the composition of a community. This can be done by regarding each species as a variable, clustering those species into the elevations in which they were found, and determining if there's any over lap or dispersion in the species composition among elevations. Figure 8 is an ordination that shows that there is a significantly greater difference among the species compositions of the different elevations than within each elevation (p < 0.0001). Elevations 200m and 350m have a high amount of over lap because they share many of the same species, whereas elevation 700m is very distant from the other elevations because it has a highly different composition than the other elevations. This difference in composition among elevations provides insight into the changing environment along the elevational gradient. Habitat filtering selects for certain species that will be successful under the abiotic conditions of an environment. This ordination (Figure 4) implies that the abiotic conditions are different along the gradient and therefore select for different species, with different traits, that are more fit for those conditions. Multivariate analysis simultaneously examines numerous variables. It is important in community ecology data because multiple species can be considered, they are affected by many environmental factors, they have many testable traits, and they are sampled multiple times (Gauch, 1982).

Community ecology provides a means of investigating the interactions, abundance, and distribution of species over an environmental scale. Looking at a broad study organism, such as woody plants, provides extensive insight into elevational trends. In addition, doing this study on a remote, oceanic island is the ideal site because the native plants that arrived were solely influenced by what was able to get to this island and was then fit enough to colonize it. After this initial colonization, over the past 2 million years, new species have more easily been able to arrive on Moorea, due to human introduction, allowing us to see the gradual changes in the composition of a community resulting from increased competition and environments filtering for only the species that are the most fit in that habitat (Mueller-Dombois, 1998). The diversity, abundance, and trends of species within this community can be further investigated. This study could be expanded upon by looking at more morphological traits, doing a similar study on another mountain as a small scale meta analysis, doing a similar study with another organism, such as ferns, or looking at a different gradient other than elevation, such as proximity to streams or aspect.

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APPENDIX A

List of GPS coordinates for each plot sampled at on each elevation site.

0-2: 17°32'53.52"S	149°47'22.08"W	0-3: 17°32'53.04"S	149°47'23.58"W
0-4: 17°32'52.80"S	149°47'23.58"W	0-5: 17°32'34.98"S	149°47'23.88"W
0-6: 17°32'34.50"S	149°47'24.66"W	0-7: 17°32'35.04"S	149°47'23.82"W
200-2: 17°32'17.94"S	149°47'49.44"W	200-3: 17°32'15.84"S	149°47'48.78"W
200-4: 17°32'17.82"S	149°47'46.92"W	200-5: 17°32'19.20"S	149°47'52.38"W
200-6: 17°32'18.48"S	149°47'52.08"W	200-7: 17°32'18.66"S	149°47'52.86"W
350-2: 17°32'15.30"S	149°47'56.10"W	350-3: 17°32'14.34"S	149°47'56.70"W
350-4: 17°32'13.86"S	149°47'56.76"W	350-5: 17°32'14.76"S	149°47'57.48"W
350-6: 17°32'14.76"S	149°47'57.48"W	350-7: 17°32'13.98"S	149°47'58.14"W
500-3: 17°32'10.62"S	149°48'7.14"W	500-4: 17°32'9.36"S	149°48'8.46"W
500-5: 17°32'10.32"S	149°48'7.38"W	500-6: 17°32'9.78"S	149°48'7.02"W
500-7: 17°32'10.92"S	149°48'6.84"W		
700-2: 17°31'36.42"S	149°48'12.18"W	700-3: 17°31'41.16"S	149°48'10.32"W
700-4: 17°31'40.98"S	149°48'10.08"W	700-5: 17°31'40.14"S	149°48'10.38"W
700-6: 17°31'39.54"S	149°48'10.74"W	700-7: 17°31'38.58"S	149°48'11.76"W

The first number in each series (e.g. 0, 200, 350, 500, or 700) describes the elevation of the plot. The second number, following the hyphen, in each series (e.g. 1, 2, 3, 4, 5, 6, or 7) describes the plot number.

*Note: the original GPS used at sites 0-1, 200-1, 350-1, 500-1, 500-2, and 700-1 provided inaccurate coordinates and therefore these points were not provided.