EFFECTS OF AN INVASIVE TREE SPECIES (*FALCATARIA MOLUCCANA)* ON UNDERSTORY DIVERSITY IN MO'OREA, FRENCH POLYNESIA

BENJAMIN J. WONG

Environmental Science Policy and Management, University of California, Berkeley, California 94720 USA

Abstract. *Falcataria moluccana* is an introduced species commonly grown on Mo'orea, French Polynesia as a timber species. It has also escaped cultivation and spread extensively throughout many parts of the island. *F. moluccana* has been known to affect ecosystems in a variety of ways, and so has become a species of concern throughout Polynesia. In this study, I investigated potential impacts of this prolific invasive species on the understory flora of the island, comparing diversity internal to stands of *F. moluccana* to that exterior to stands. My results indicate that no significant changes in diversity are present regardless of location or local abundance of *F. moluccana*; however, possible impacts of scale and other invasives must be considered to fully understand how *F. moluccana* might influence the diversity of the island.

Key words: invasives, community ecology, Falcataria, *invasive impacts, Mo'orea, diversity*

INTRODUCTION

Invasive plants have enormous potential to alter ecosystems in which they can successfully establish and spread. They are capable of outcompeting natives in a variety of habitats, as well as making the habitats less suitable for other plants in the future (Hellman et al. 2011), impacting the growth, abundance, diversity, and reproductive fitness of plants in the habitats they invade (Vila et al. 2011). Some species are capable of transforming the environment around them to such a large extent that they exclude plants that had evolved there for millennia.

On relatively young tropical islands like Mo'orea, French Polynesia, a common attribute of successful invaders is the ability to fix atmospheric nitrogen (Olyarnik et al. 2008). Since the soil resource ratio on islands such as Mo'orea is highly lacking in nitrogen and rich in Phosphorus, native plants have remained successful by being highly efficient utilizers of nitrogen (Durand & Goldstein 2000). Invasive nitrogen fixers, however, can fundamentally alter this delicate balance by introducing large amounts of biologically available nitrogen into the ecosystem by way of root exudates and leaf litter (Allison et al. 2006). It has been shown on the island of Hawaii that nitrogenous leaf litter from the invasive tree *Falcataria moluccana* can have a fundamental effect on a variety of characters of the ecosystem (Hughes & Denslow 2005). Because leaf litter is one of the primary contributors to soil composition, the altered soil chemistry resulting from the influx of high nitrogen Falcataria litter impacts the diversity and abundance of soil microorganisms, as well as their associated enzymes for breaking down litter (Allison et al 2006). The nitrogen laden litter of *F. moluccana* has also been shown to affect invertebrate diversity on streams in Hawaii, where the tree is highly invasive, establishing the potential invasive Fabaceae have to affect ecosystem diversity (Atwood et al. 2010). Invasive N-fixing acacias, also in the Fabaceae family, have been shown to reduce the diversity of plants in invaded ecosystems (Hellman et al. 2011).

Forests invaded by the tree species *F. moluccana* can be considered to be fundamentally altered novel ecosystems because of changes in the quantity of N cycling and organic leaf litterfall (Hughes & Denslow 2005). How, then, do the plant communities of these new ecosystems compare to those of outside stands of *F. moluccana*? In a recent study of thirteen invasive plants, eleven were found to significantly affect the diversity of their host ecosystem (Hejda et al. 2009).

My study addresses the question of how presence of Falcataria moluccana alters the understory species composition on Mo'orea, French Polynesia. I hypothesize that *F. moluccana* will reduce the diversity of understory species relative to that outside of stands of *F. moluccana*. Given that it grows in a variety of habitats, such a change would mean that *F. moluccana* has the potential to homogenize the flora of the landscape, reducing the total diversity of both species and habitats.

METHODS

Study Organism

Falcataria moluccana is a fast growing woody legume in the family Fabaceae and the subfamily Mimosoideae. Originally native to the Papua New Guinea and eastern Indonesia, it is known to grow prolifically and invasively in many locations throughout the tropics, particularly in disturbed areas. A nitrogen fixer, it is known to substantially alter the N-dynamics of an ecosystem, potentially enabling it to facilitate other invasive species (Binkley 1997). It is also known for its characteristic broad canopy, which can create extensive shade. However, *F. moluccana* canopies at the time of study were drastically altered by drought and so densiometer readings were not taken into account.

Study sites

In order to investigate differences in interior and exterior diversity underneath stands of *F. moluccana*, I established twenty-five paired sets of eight subplots each. Each set consisted of four subplots interior to a stand of *F. moluccana* and four subplots exterior to the stand. These 25 sites were further divided into 5 different locations: Maharepa, Pihaena, Opunohu, Vaiare South, and Vaiare West (Figure 1). To place these plots, I first located ten by ten meter stands of *F. moluccana* that exceeded a threshold of more than one meter of aggregated circumference at breast height. I later converted this measurement to aggregated

Figure 1- Map showing locations of 5 study areas.

cross-sectional area at breast height; however, circumference was a more accessible field metric. Within the ten by ten meter blocks, I placed four three by three meter square subplots. For each of these subplots, I surveyed the complete diversity underneath, recording both the species and quantity of all plants encountered. In order to establish comparable exterior plots, I measured fifteen meters from the exterior of the *F. moluccana* canopy in each of the four cardinal directions and placed subplots at each of those locations. I placed them there with the rational that fifteen meters was close enough to maintain similarity of physical habitat, but far enough to remain exterior to any competitive effects of *F. moluccana.*

Statistical Analysis

After summing subplots for interior and exterior to give a plot total, I calculated Shannon's index of diversity for all plots, taking into account both species richness and evenness (Figure 2).

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Figure 2- Equation for Shannon's index of diversity, where p_i is the ratio of individuals of a given species over the total individuals within the site and S is the total number of species.

After calculating Shannon's index, I subtracted the exterior value for each site from its paired interior value to return a value representing the change in diversity, ΔH'. Negative values of ΔH' indicate a loss in diversity within the *F. moluccana* plots, while a positive value would indicate an increase. I then analyzed these values using a t-test to determine whether the mean change significantly differed from zero to detect an island-wide change in diversity.

I also sought to understand how different sites might have been affected differently by *F. moluccana*, for which I compared the means of the change in Shannon's values across my five different sites. I also generated a principal component analysis sorted by site name.

Finally, to investigate how quantity of *F. moluccana* may have been controlling the magnitude and direction of change in Shannon's index, I performed a regression between the aggregated cross-sectional area at breast height and the value of Shannon's index.

I performed all statistical analyses using JMP statistical analysis suite (JMP, Version 9 2011).

RESULTS

I found a large diversity of □H′ values, from the maximum gain in diversity, 0.99, to the maximum loss of diversity,-1.36. Most, however, had very little change, with the distribution of values showing no significant variation from zero (t-test, df=24, p=.27). (Figure 3)

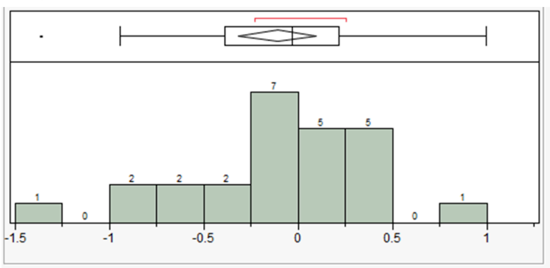

Figure 3-Histogram showing distribution of □H′ values

When divided amongst the 5 sites surveyed, no site had a discernibly different set of values for Int-Ext. The only departures from the -.5 to .5 range are the outlying maximum and minimum. (Figure 4) Cluster analysis further showed closer linkages between interior and exterior plots at a given location than between interior plots between sites. (Figure 5)

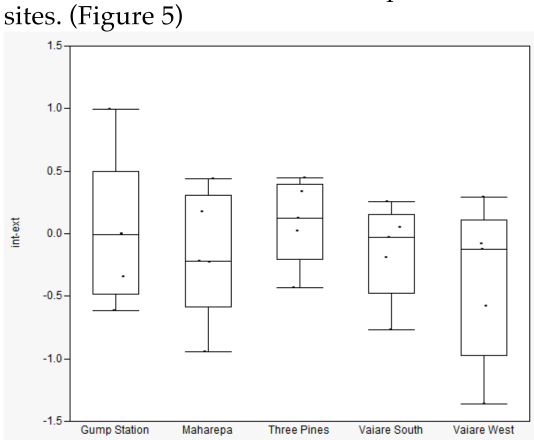

Figure 4- Box plots showing the distribution of □H′ by site.

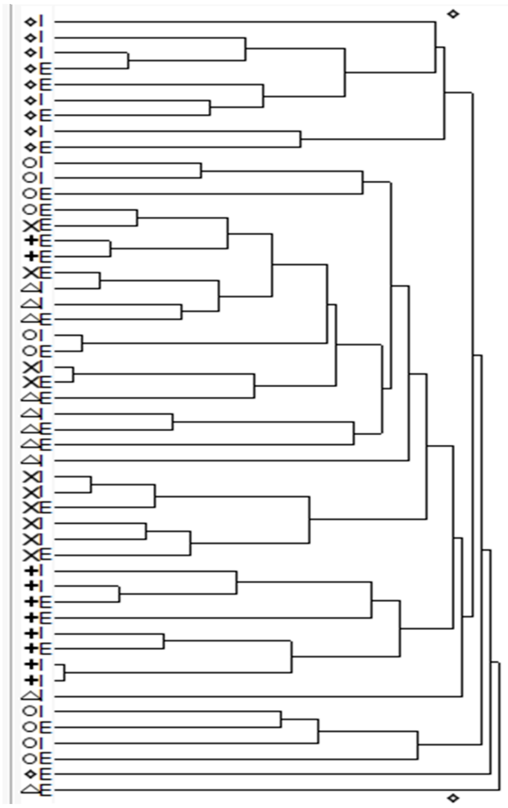

Figure 5- Cluster analysis of sites, with symbols representing location.

When I analyzed the effect of aggregated cross-sectional area at breast height versus □H′, an increase in area showed no effect on the change in diversity (linear regression, R^2=0.005, P=.73)(Figure 6)

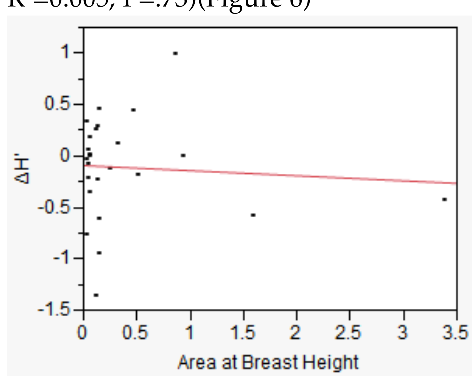

Figure 6- Regression comparing □H′ and aggregated area at breast height.

DISCUSSION

My data showed that some plots gained diversity and other plots lost diversity, with no overall trend. This did not meet with my initial hypothesis, which supposed that the presence of *F. moluccana* would result in an overall loss of diversity. This does, however, support the findings of a past meta-analysis of the effects of invasive plants which suggests that for a given introduction, effects can vary in both magnitude and direction (Vila, et al. 2011). So although *F. moluccana* invasion was not shown to have significant effects on diversity in the scenario, it should not be assumed to be an innocuous invader. Rather, its effects in each ecosystem which it invades must be considered separately. It has also been shown that invasion success is not necessarily correlated with effect size (Vila, et al. 2011), a fact supported by my study, as *F. moluccana* is incredibly widespread and successful, but found to have no effect on diversity even over a variety of densities, as shown by my cross-sectional area result.

My initial hypothesis of altered diversity under *F. moluccana* was predicated on the assumption of altered ecosystem function due to *F. moluccana* presence. However, Mo'orea is already home to highly invaded terrestrial ecosystems, especially at the low- and mid-elevations I studied (Meyer 2004). Many species that have already invaded Mo'orea have similar characteristics to the ones I assumed would alter ecosystem function. For example, *Leucaena leucocephala*, *Inga feuilleei*, and *Inocarpus fagifer* are all nitrogen-fixing Fabaceae that are capable of providing the same nitrogen supplementation that *Falcataria* would provide (O'Dowd et al. 2003). So, due to the influences of past invasions, it is possible that the potentially strong impact of *F. moluccana* was diluted.

All corroborating data aside, however, it is possible my sampling failed to detect existing changes in diversity resulting from *F. moluccana* invasion. It has been suggested that studies that compare exterior and interior plots such as mine suffer from a "space for time" bias (Gaertner et al. 2009). This implies that by comparing two spatially different sites, I did not necessarily compare identical habitats with only *F. moluccana* presence as a variable, but rather compared sites with potentially significantly different physical environments. "Space for time" suggests that studies such as this should be conducted with transplants of the invasive, allowing the change over time to be observed and limiting potential confounding variables. It is also likely that my decision to spread sites out over 5 locations diluted the efficacy of my sampling. As shown by my cluster analysis, differences between locations were much greater than those between interior and exterior plots, suggesting that, had I focused my sampling effort on a single location, I could have found a more significant change. Even though within a given site the mean ΔH' was not significantly different than zero, it cannot be concluded that no change occurred, as the sample size is simply too small to draw adequate conclusions.

Because of possible problems with sample size and methodology, more data should be collected before the implementation of management decisions. *F. moluccana* is an enormous presence on the island of Mo'orea, and, due to its value as a timber species and ability to spread and persist, it is not likely to disappear. Future monitoring will be critical to ensure that *F. moluccana* does not begin to affect the ecosystem on a larger scale. Temporal studies showing effects of *F. moluccana* over time, as well as more intensive sampling, would both serve to better inform us of the possible threat posed by this invasive.

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