THE DISTRIBUTION AND ROLE OF AN INVASIVE PLANT SPECIES, LANTANA CAMARA, IN DISTURBED ROADSIDE HABITATS IN MOOREA, FRENCH POLYNESIA

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Abstract. Invasive species are known to displace native habitat and threaten biodiversity. *Lantana camara* has invaded over 60 countries and island groups and is one of the top invasive plant species in French Polynesia. Few studies discuss the relationship between *L. camara* and anthropogenic disturbances, though it is known to be associated with disturbance. I surveyed the major roadsides of Moorea, French Polynesia for *L. camara* cover in association with environmental factors, resulting in an estimated *L. camara* roadside area cover of 1.99%. *L. camara* presence was significantly correlated to roadside habitat types, highest in areas of agricultural disturbance. *L. camara* presence and area cover were positively correlated to soil moisture and slope. Faunal species richness was higher in areas where *L. camara* was present. Germination experiments reared no results over six weeks. However, in a vegetative growth experiment, cuttings had greatest height growth over two weeks under the heaviest shaded of three light treatments. I predict that the current range of *L. camara* on Moorea could expand to shaded areas with sufficient soil moisture, slope, and intermediate disturbance, conditions typical of higher elevation habitats on Moorea.

Key words: Lantana camara, invasive species, anthropogenic distrbance, roadside habitat

INTRODUCTION

Invasive species pose a threat to the biodiversity and ecological structures of native habitats that may be of conservation value (Schei 1996, Mack et al. 2000). Disturbance is a major factor in determining the invasibility of native ecosystems (Hobbs 1991). For example, habitat disturbance caused by anthropogenic activity may free up light and nutrient resources to facilitate some invasive species establishment via broken canopies and bare soil, depending on disturbance type and frequency (Christen and Matlack 2006). Certain forms of disturbance, such as road construction that create edge habitat, are correlated with the establishment and distribution of some invasive plant species (Pauchard and Alaback, 2004).

Anthropogenic disturbance may also play a role in the invasion of French Polynesia by *Lantana camara* L., a thorny shrub thought to have originated in Central and South America, and naturalized in over 60 countries or island groups (Sanders 1987, Day et al. 2003). *L. camara* reached Tahiti in 1853 as an ornamental plant (Jacquier 1960, Swarbrick et al. 1995) and has since established on the Austral, Marquesas, Society, and Tuamotu islands (Meyer 1998). *L. camara* may be dispersed through faunal seed dispersal and vegetative growth throughout large ranges of elevation and climate (Rajendran et al. 2001, Swarbrick et al. 1998, Matthew 1971). The presence of *L. camara* is continuing to spread, and has been listed as one of the top threats to the biodiversity of French Polynesia (Meyer 2004) due to its potential to displace native habitat, increase fire disturbance intensity, and damage pastures and forestry (Swarbrick et al. 1995, Alfonso et al. 1982).

Biological control programs have been employed in the past century to deal with *L. camara* invasions in at least 33 countries to date (Julien and Griffiths 1998). *L. camara* was one of the first organisms tested with biological control agents in Hawaii in 1902 (Perkins and Swezey 1924) and has since been a major study organism for biological control methods including insect, fungal, and bacterial releases (Thomas & Ellison 2000). *L. camara* biological control programs have varied in success due to the organism's great climatic range and genetic diversity that goes beyond the target abilities of most biocontrol agents (Thomas & Ellison 2000).

Many *L. camara* studies focus on biological control applications approaches to preventing further invasions (Broughton 2000). Fewer studies have focused on the prediction and prevention of *L. camara* invasions through the management of land use and anthropogenic activity, though some studies have found that the reproductive success of *L. camara* is significantly correlated to the size of anthropogenic forest gaps (Totland et al. 2005) as well as the intensity of natural and anthropogenic disturbances including overstory removal and fire (Duggins & Gentle 1998). Other types of anthropogenic activity known to be associated with *L. camara* include the construction of roads, railways, and canals, in addition to forest edges created by logging and fire (Day et al. 2003).

My study investigated the distribution and ecology of *L. camara* in disturbed roadside habitats and *L. camara* growth in a series of pot experiments to identify factors that may influence its invasion in Moorea and reveal its ecological role in these marginal habitats. Moorea, French Polynesia has a largely non-native low-elevation flora due to increased susceptibility of disturbed lowland habitats to invasive species establishment and persistence. The island of Moorea may serve as a model for studying the distribution and ecology of *L. camara* invasion since it occurs in a range of disturbed habitat types including forest edges, neglected land plots, agricultural areas, and gardens. I surveyed the roadsides of Moorea to determine the distribution and characteristics of *L. camara* establishment on a gradient of habitat disturbances to find a relationship between the success of *L. camara* and environmental factors associated to disturbed habitats such as increased levels of establishment in areas of increased levels of sunlight, moisture, and anthropogenic disturbance. I also surveyed the biotic communities supported by *L. camara* patches to investigate the relationship of *L. camara* to the faunal makeup of disturbed habitats to determine if *L. camar*a presence has a significant affect on faunal species richness and diversity that may be important to the native faunal communities of Moorea. Furthermore, I examined the response of *L. camara* seeds and cuttings to a gradient of light treatments to isolate factors potentially contributing to establishment. With information on the distribution and establishment of *L. camara* in disturbed habitats, I will discuss possible implications for predicting and preventing further *L. camara* invasion into the remaining native habitat of Moorea, French Polynesia.

METHODS

Study site

Moorea is a high island located in the Society Islands of French Polynesia. This study was conducted alongside the major roads of Moorea, within a 50-m elevation range.

Field survey for distribution

A total area of 3 m (perpendicular to road) by 10 m (parallel to road) was surveyed alongside the island perimeter road, Route 91, at every 0.25 km over 5 randomly selected 2-km sections of the road. In addition, similar sites alongside three interior-reaching roads were surveyed (total survey area=1710 m^2). All sample areas were located on the hillside of the road (higher elevation location). The area of *L. camara* cover was recorded within the bounds of the sampling area. The greatest branch length of any *L. camara* occurrence within the sampling area was recorded in addition to the presence or absence of any flowering individuals as indicators of establishment success (Sharma et al. 2005). Semi-dominant plant species occurring within the sampling area were noted. The percent canopy cover was determined by using a densiometer along a 10-m long transect (parallel to road) through the middle of the sampling area, recording canopy presence or absence at every meter point. The light intensity was determined with a digital light meter, recording one measure at the 3-m point and one at the 5-m point of the 10-m transect line. Slope was visually assessed. Elevation and slope aspect were determined using a handheld GPS unit (Garmin E-trex). 10 mL of a soil profile were collected at every site and soil moisture was quantified using the gravimetric method by comparing the soil sample dry weight (soil dried in oven) to its original wet weight. Notes taken on each sampling area included the disturbed habitat type (1-forest edge, 2-neglected land plots, 3-agricultural land, 4-garden or yard, 5- paved area), adjacent habitat descriptions, and weather conditions.

Field survey for biotic community

To analyze the relationship between habitat and the establishment of *L. camara*, data from non-random survey areas for *L. camara* were used, in addition to data from the distribution survey with *L. camara* presence.

The non-random survey targeted *L. camara* patches of various sizes and locations, following the distribution survey methods. 17 non-random *L. camara* sites were also surveyed for fauna (mostly insect) by sweep netting and hand collecting one of every different organism seen. The organisms were later separated into morphospecies. Three pitfall traps (120-mL cups half filled with dilute dish soap water) were set out for 24 to 48 hours at five *L. camara* sites. Three pitfall traps were also set out next to each of the five sites in areas covered with the common invasive herb, *Wedelia trilobata*, and without *L. camara.*

Germination experiment

15 sets of 20 seeds of standard origin were potted in a random arrangement of three light treatments created by varying layers of shade cloth. Seeds were collected from fruiting *L. camara* individuals along Route 91 that occurred naturally on the island, whether ripe or unripe, and allowed to ripen before planting. The seeds were planted 6 cm beneath the soil surface of the pot in generic potting soil and left outdoors at 5 meters elevation, 50 meters from the shore in an open field. Pots were watered once a day except on rainy days, and signs of germination were quantified after six weeks.

Vegetative growth experiment

18 cuttings containing three nodes each were obtained from one naturally occurring *L. camara* individual from Moorea. Cuttings were planted in individual pots in generic potting soil, within 15 meters of the germination experiment and under similar conditions. Initially, all cuttings were allowed to establish under full sunlight for one week. The cuttings were then arranged into 6 rows and three light treatments created by varying layers of shade cloth to establish light treatment A (~2,000 lux), treatment B (~20,000 lux), and treatment C (~80,000 lux). Each cutting was measured for leaf number and height above soil surface over two weeks under light treatment conditions. The cuttings were watered once a day except on rainy days. The soil moisture of every pot was determined 24 hours after one of the waterings, using the gravimetric method. Dry root and aboveground masses were quantified using an electronic scale after three weeks.

Data Analysis

All statistical analysis was performed using JMP 7.0 (Copyright 2007 SAS Institute Inc.) Correlations between *L. camara* cover area and measured habitat conditions were analyzed using single regression analysis and ANOVA. *L. camara* percent cover on the roadsides was extrapolated from percent cover estimates made over all of the distribution sampling sties. *L. camara* presence (versus absence) over different roadside habitat types was analyzed using the likelihood-ratio test. Comparisons of species richness and diversity (Shannon Diversity Index) from pitfall trapping between areas of *L. camara* presence and absence were made with a paired sample t-test. Comparisons of leaf number, height, and belowground biomass between light treatments were made using a series of single factor ANOVAs; pairwise comparisons were made with Tukey HSD post hoc tests.

RESULTS

Field survey for distribution

L. camara was present in 24.6% of all distribution survey sites, covering a total of 1.99% of all distribution survey area. The *L. camara* cover area within the 30- m^2 survey areas ranged from 0.25 m^2 to 6.16 m^2. The mean cover in survey sites where *L. camara* was present was 19.8%, representing 5.956 m^2. *Wedelia trilobata* was highly associated with roadside habitats and was present in 47.4% of all distribution survey sites.

L. camara presence versus absence was correlated to edge type by the likelihood-ratio test ($p<0.0292$). *L. camara* presence occurred most in roadside habitats of agricultural areas (edge type 3) and least in roadside habitats consisting of highly disturbed and paved areas (edge type 5, Fig. 1).

Forest edge roadside habitats (edge type 1) also had least *L. camara* presence compared to agricultural roadside habitats (edge type 3). No significant relationship was found between *L. camara* cover area and light intensity and *L. camara* cover area and canopy cover. However, *L. camara* cover area was positively correlated with soil moisture levels ($p<0.0191$, Fig. 2).

When analyzing the area of *L. camara* on slopes greater than 0 degrees, there was a significant positive correlation ($p<0.0498$, Fig. 3).

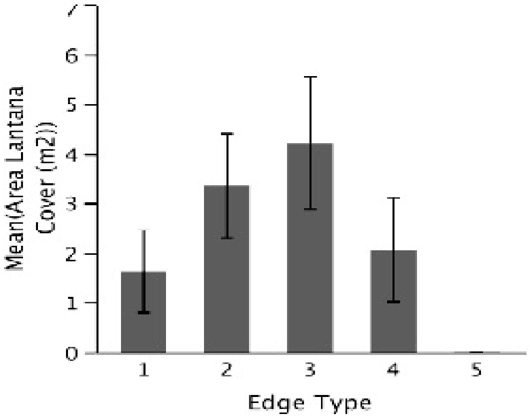

Fig. 1. Comparisons of area of *L. camara* cover between different roadside habitat types (1-forest edge, 2-neglected land, 3-agricultura l land, 4-garden or yard, 5-paved area). *L. camara* presence occurs most in agricultural areas (edge type 3) by the likelihood ratio test ($p<0.0292$, N=72).

Field survey faunal community makeup

The overall faunal species richness was significantly higher with *L. camara* presence versus absence by paired sample t-test ($p<0.0087$) (Fig. 4). Mean species richness was higher in sites with *L. camara* presence and was significantly different from sites without *L. camara* ($p<0.0087$). However, the biodiversity (Shannon Diversity Index) was not significantly different between sites with *L. camara* presence and absence.

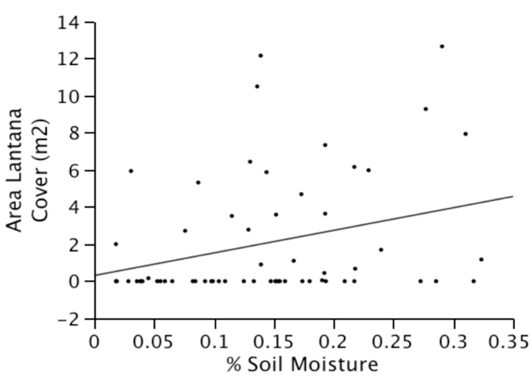

Fig. 2. Increasing *L. camara* cover with increasing soil moisture levels ($p<0.0191$, $R^2=0.09$, N=61).

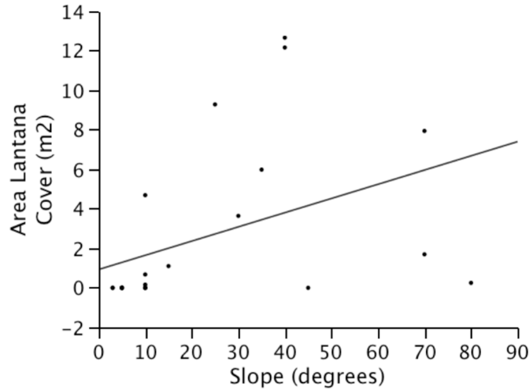

Fig. 3. Increasing *L. camara* cover with increasing slope ($p<0.0498$, R2=0.17, N=23).

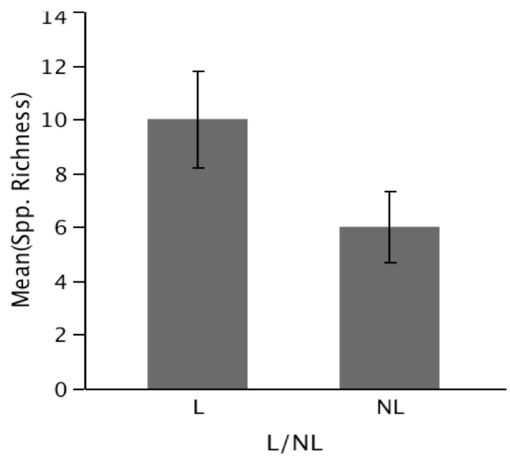

Fig. 4. Species richness is significantly greater in sites with *L. camara* presence (L) in comparison to sites without L. camara (NL) by paired sampling t-test ($p<0.0087$, N=10).

Germination experiment

No seeds germinated in any of the three light treatments within six weeks of planting. No signs of germination were found upon analyzing the potted soil after six weeks. Seeds remained either aborted or dormant.

Vegetative growth experiment

Leaf count growth did not differ significantly between the three light treatments (Treatment A-heavily shaded, Treatment B-lightly shaded, Treatment C-not shaded), though treatment B had the highest mean leaf number growth. Mean height growth significantly differed between the three light treatments. Mean height growth was highest in light treatment A (heavily shaded) and lowest in light treatment C (not shaded) (Fig. 5). There were no significant differences of root mass growth and root mass to aboveground mass ratio between the three light treatments. The soil moisture of pots did not differ significantly between light treatments.

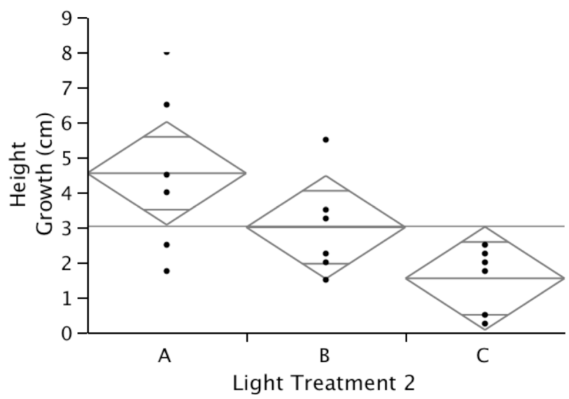

Fig. 5. The mean height growth differs significantly between light treatments. (P<0.0256, N=18).

DISCUSSION

Because there is a significant area of roadside habitats occupied by *L. camara*, there is justified concern for the potential for the invasive species to displace and damage the remaining native habitats of Moorea, French Polynesia. The prevention of *L. camara* establishment may be effectively focused on areas where it may more likely establish, including areas of sufficient agricultural disturbance, soil moisture, slope, and shade.

L. camara appears to support a higher number of faunal species as compared to invasive species, *Wedelia trilobata* alone. The year-round flowering of *L. camara* in Moorea may account for a consistent biomass that may feed a faunal community that consumes the fruit, nectar, and leaves, adding a layer of structural complexity for faunal species to inhabit. Because *L. camara* often occurs simultaneously with *Wedelia trilobata*, the surveyed *L. camara* sites may have encompassed the species richness of a faunal community supported by both invasive species. The community supported by *L. camara* includes a number of invasive faunal species, including those of Formicidae and Apidae, which may have negative predatory effects on the native communities of Moorea. Future studies are needed to observe the interactions between invasive plant species and the faunal community they support, including aspects of species richness, species diversity, and native/invasive makeup of the community to assess the threat of *L. camara* and other invasive plant species on native faunal communities.

L. camara germination did not occur within six weeks of planting, though seed dispersal may still be an effective way for *L. camara* to establish in disturbed habitats due to the potentially large number of seeds produced by individuals year-round. In the vegetative growth experiment, the cuttings established without much difficulty under sufficient soil moisture and sunlight conditions. The heavily shaded light treatment was ideal for vegetative growth in terms of height, implying that vegetative growth in *L. camara* is shade tolerant to a certain degree, making *L. camara* establishment into shaded areas possible. Degraded forest edges with slight canopy damage may be vulnerable to *L. camara* establishment by vegetative growth and invasion.

Maintaining intact forests and decreasing anthropogenic disturbances including overstory removal may decrease the occurrence of *L. camara* on roadsides (Duggins & Gentle 1998), in addition to other invasive species such as *Wedelia trilobata*. Disturbed habitat created by roadsides may serve as starting points for *L. camara* to establish and spread into higher elevation and native habitats via roads and agricultural land where intermediate disturbance occurs through harvesting and grazing. This conclusion may be applicable to the management of higher elevation roads and gaps, where there is a higher occurrence of forest edge habitat types and intermediate disturbances (personal observation), by conserving remaining intact forest edges. The higher elevation areas of French Polynesia contain rare native habitats that are threatened by invasive species (Meyer 2004) and may be protected by the prevention of further invasive species establishment and expansion.

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