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Plant community composition changes following Twolined spittlebug (P*rosapia bicincta*) infestations in Hawaii rangelands

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Abstract

Twolined spittlebug (TLSB), *Prosapia bicincta* (Hemiptera: Cercopidae) was first detected in 2016 in the South Kona district of Hawai´i Island where it had damaged over 2,000 acres of rangeland. In 2017, four locations were selected for monthly monitoring of TLSB activity, population dynamics, and changes in plant community composition. Two monitoring sites were at the center of the infestation while the other two were located outside the northern and southern boundaries to estimate the rate of spread. At each location a series of 100-m long transects were established along elevational gradients between 500 and 1,850 m. Along each transect, ten 0.25-m^2 quadrats were placed every 10 m on alternating sides of the transect. In each quadrat, data were collected on vegetative cover and height, plant species composition, live and dead grass cover (%), nymph and adult abundance, and nymph-plant associations. The surveys revealed that between 2017-2023, TLSB expanded its range to over 72,183 ha, primarily in pastures of Hawai´i's most important forage grasses, Kikuyu (*Pennisetum clandestinum*) and pangola (*Digitaria eriantha*). TLSB was detected between ~500-1,700 m in elevation and activity was highest during the wet season (Apr-Oct). Mean TLSB densities (126 nymphs/m^2) in pastures located between 1,000-1,300 m in elevation were significantly higher than in pastures between 500-999 m (64 nymphs/m^2) and >1,300 m (20 nymphs/m^2). Pastures with the highest TLSB densities experienced the greatest decrease in mean grass cover (30%) and greatest increase in mean forb (76%), bare ground (39%), and shrub (7%) cover. Landscape-level changes were observed in rangelands damaged by TLSB as shown by the loss of forage grass cover and subsequent replacement by invasive weeds including Pamakani (*Eupatorium adenophorum*), wild blackberry (*Rubus* spp.), fireweed (*Senecio madagascariensis*), and Hilograss (*Paspalum conjugatum*). The establishment and spread of TLSB has devastating impacts on the ecosystem services Hawaii rangelands provide.

Introduction

Twolined spittlebug (TLSB), *Prosapia bicincta* (Say), is a pasture and turfgrass pest native to southeastern United States (Shortman et al. 2002, Thompson and Carvalho 2016). Twolined spittlebug negatively impacts rangelands by feeding on important forage grasses (Byers and Wells 1966, Shortman et al. 2002). In 2016, TLSB was detected in the South Kona district of Hawai´i Island (Wilson et al. 2023). Between 2017 and 2020 the pest rapidly expanded its range at rate of over 14,000 ha per year (Wilson et al. 2023) and by the end of 2021 occupied over 72,183 ha across the South Kona district.

The Hawai´i beef industry is economically, culturally, and ecologically important to the state. Over 142,000 head of beef animals are managed across nearly 300,000 acres of rangelands (20% of Hawai´i's land mass) that are managed by over 1,300 ranches. The value of Hawai´i-raised beef cattle is estimated to be more than $48 million annually (USDA-NASS 2022). Over 60% of the beef cattle in the state are raised on the island of Hawai´i where the TLSB currently poses the most significant threat.

High density TLSB infestations often result in nearly 100% die back of key pasture grasses including Kikuyu (*Pennisetum clandestinum*) and pangola (*Digitaria eriantha*) grasses. The loss of these important livestock forages provides entry for the establishment of low-quality forage, weeds, and invasive plants, including Pamakani (*Eupatorium adenophorum*), wild blackberry (*Rubus spp.*), fireweed (*Senecio madagascariensis*), and Hilo grass (*Paspalum conjugatum*). Twolined Spittlebug's rapid rate of spread and apparent preference for Kikuyu and pangola grass creates the potential for the pest to spread throughout the islands and cause irreparable harm to large areas of valuable rangelands. Consequently, this pest threatens the economic sustainability of the Hawai´i livestock industry, reduces the ecosystem services derived from these landscapes, and ultimately harms Hawai´i communities through decreased agricultural revenue and reduced food security.

Methods

In 2017, four separate locations were selected for long-term, monthly monitoring of TLSB activity and population dynamics, and changes in plant community composition. Two the monitoring sites were at the center of the initial infestation while the other two sites were located outside of the northern and southern boundaries of the known distribution of the pest to estimate the rate of spread. At each location, a series of transects were established along elevational gradients between 500 and 1850 m. A total of 17 transects were established across the four sample sites. Along each transect ten sample points were systematically established every 10 m alternating between the left and right side of the transect line. A 0.25 m^2 ring was used at each sample point to record vegetative cover by species, percent live and dead grass by species, vegetation height by functional group (grass, forb, shrub), and a count of TLSB nymphs and adults. Along each transect, one adult sweep net sample was collected. All data were collected across all transects and sites monthly. Generalized linear mixed models (GLMM) were used to determine if season and elevation influenced TLSB nymph and adult abundance while accounting for random effects (location and year). For each GLMM, season and elevation were fixed effects grouped categorically by wet (April – October) or dry (November – March) season, and low (500-999 m), mid (1,000 – 1,300 m), or high (> 1,300 m) elevation. Tukey's pairwise comparisons were conducted to evaluate seasonal and elevational trends. Plant community data were quantified by mean percent cover by functional group (grass, forb, and shrub) or bare ground for each transect. Changes in percent cover by functional group or bare ground were assessed over the study period. A Wilcoxon-Mann-Whitney test was used to compare changes in mean grass cover and determine if grass cover varied significantly between years for each elevational category.

Results

Twolined Spittlebug Population Distribution

The monthly surveys revealed that the TLSB expanded its range from approximately 28,102 ha in 2017 to over 72,034 ha by 2021 (Fig. 1).

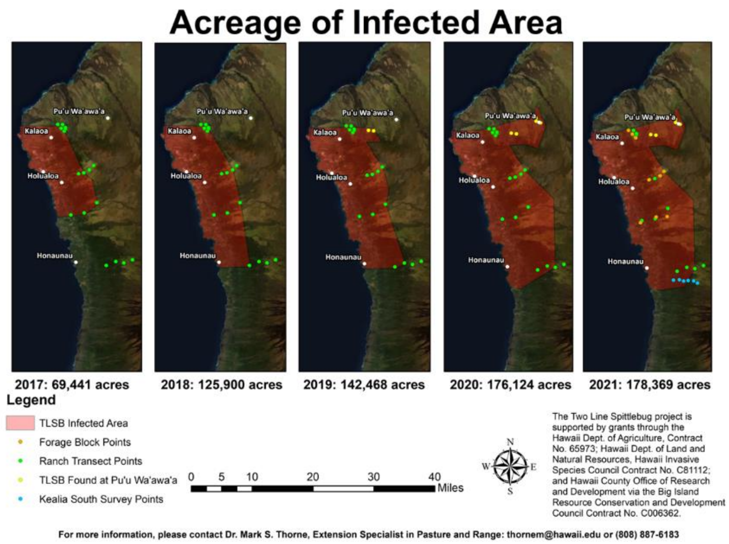

Fig. 1. Twolined Spittlebug population distribution between 2017 and 2021 within the South Kona District of the island of Hawai΄i.

Results showed that season and elevation were good predictors of nymph (X^2 = 138.9, df =1, P≤0.001) and adult (X^2 = 148.79, df=1, P≤ 0.001) abundance. Mean nymph and adult abundance was significantly (P<0.0001) higher in the wet season compared to dry season months across all sites and years. Nymph abundance coincided with the wet season (April – October) with little activity between November and March (dry season). Of all nymphs sampled 95% were collected in the wet season and 5% during the dry season. Adult activity also coincided with the wet season, but peak abundance was highest between May and November and lowest from December through April. Of all the adults sampled, 94% were collected in the wet season and 6% in the dry season.

Elevation had a significant effect on the timing and abundance of both nymph and adult population dynamics (Fig. 2). The highest abundance of nymphs and adults were detected at the mid elevation (1,000 – 1,300 m), followed by the low elevation (500 – 999 m) sites. The high elevation (> 1,300 m) category had significantly lower nymph and adult abundance than the mid and low elevation categories.

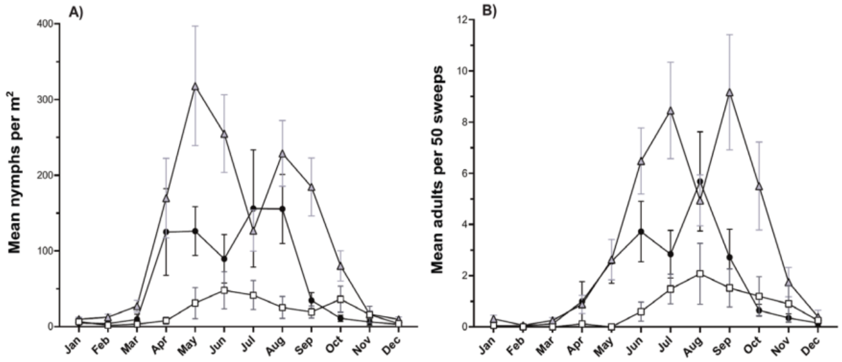

Fig. 2. Seasonal variation of Twolined Spittlebug A) nymph and B) adult abundance (mean ± SEM) by elevation. Low elevation = 500-999 m (black circles), mid elevation = 1,000-1,300 m (grey triangles), and high elevation > 1,300 m (white squares).

Plant Community Composition

Twolined Spittlebug nymphs were detected on 32 different plants. Grasses accounted for 72% of the associations, while legumes (16%), sedges (6%), and forbs (6%) made up the remainder. Mean grass cover decreased significantly over the study period at the low (73% vs 57%; W=1749, P-0.0004) and mid (68% vs. 47%, W=3852, P<0.0001) elevations, but did not vary significantly at the high elevation (89% vs 90%; W=1243, P=0.975). As grass cover decreased, forb cover and bare ground increased, while shrub cover remained constant (Fig. 3).

Discussion and Implications

The nymph and adult abundance patterns observed in our study follow closely with the lifecycle of the Twolined spittlebug in its home range. In Florida, the TLSB lifecycle from egg to egg averaged 76 days which included 19 days for egg hatch, 50 days for nymph development to adult, and 7 days until the adult female begins laying eggs (Fagan and Kuitert 1969). Under optimal conditions the entire lifecycle of duration, plus time needed for the next generation of nymphs to hatch is about 95 days. The distinct abundance peaks and synchronous activity indicate two generations of TLSB per year in the Kailua-Kona pastures. The rapid and synchronous outbreak of nymphs with the arrival of the wet season suggest that TLSB eggs enter diapause prior to the dry season followed by a period of postdiapause quiescence (Pires et al. 2000, Sujii et al. 2001). At this stage of postdapause quiescence, eggs can respond under humid conditions and stimulate immediate eclosion, resulting in abrupt synchronous first population peak (Pires et al. 2000, Sujii et al. 2001. Peck 2002).

Precipitation varies widely across the island of Hawaii and this variability becomes more extreme with drought conditions (Luo et al. 2024). The temporal differences in abundance patterns of TLSB observed in this study were likely influenced by the year-to-year variation in rainfall and the onset of drought conditions late in 2020. Likewise, the spatial variation in TLSB abundance was likely influenced by the variability in microclimates that occur over short distances due to the abrupt elevation changes across the Kona rangelands. Moreover, drought effects did not manifest evenly across the Kona rangelands, so differences in plant community responses across sites may have contributed to variation in habitat suitability for TLSB over time, impacting their distribution and abundance.

The changes in groundcover reported in this study suggest that TLSB infestations have caused widespread and long-term damage to Kona rangelands dominated by Kikuyu and pangola grasses, ultimately resulting in landscape transformation through invasion and establishment of invasive weeds and low-quality forage grasses (Wilson et al. 2023). Damage caused by the invasion of TLSB in Hawai´i will necessitate a shift in the conventional rangeland management practices. Management of TLSB in Hawai´i rangelands will need to be developed based on site-specific information due to variation in elevation, climate conditions, and plant communities across the island of Hawai´i.

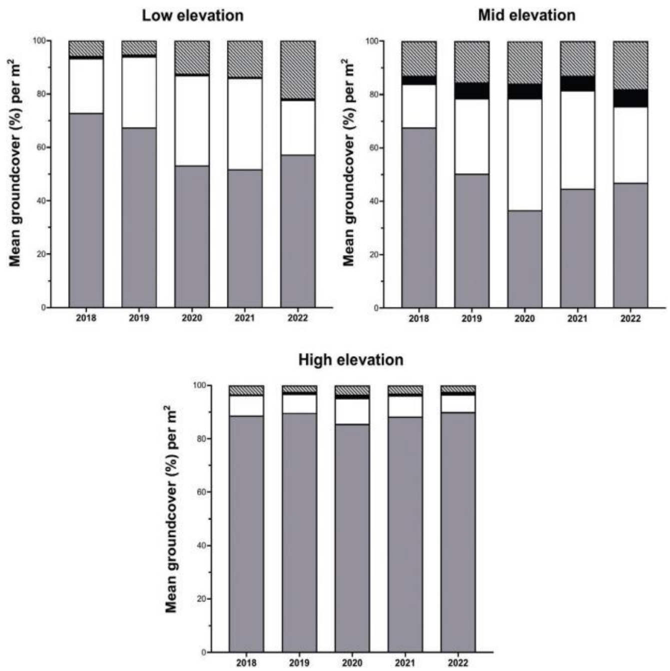

Fig. 3. Annual variation in proportion of mean groundcover in low (500-999 m), mid (1,000-1,300 m), and high (> 1,300 m) elevations groups over the study period across all four sample sites in the North and South Kona districts on the island of Hawai´i. From top to bottom of the bars, grass cover shown in dark grey, forb cover in white, shrub cover in black, and bare ground in light grey strips.

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