Investigating the Role of a Cryptic Life Stage in Fern Community Assembly

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Introduction

Ferns have a complex life cycle, alternating between morphologically distinct sporeophyte (spore) and gametophyte (haploid) generations. The majority of the life-span of each generation is nutrientally and physically independent from the other. This characteristic makes ferns uniquely although hypogeous and seed plants also have alternation of generations. In these plants one life phase is completely dependent on the other. Fern gametophytes, as the sexual phase of the life cycle, are particularly significant to fern evolution. However, due to their highly cryptic nature, typically <1 cm in size and lacking morphological characters for species-level identification, the ecology of fern gametophytes is virtually unknown.

The goal of this project is to analyze ecological traits of fern gametophytes and sporophytes in a phylogenetic context to elucidate the processes driving community assembly and evolution in an island fern flora.

Study Site and Methods

Figure 1: World map centered on French Polynesia. Red circles indicate location of Tahiti. Green Moorea and Tahiti. Red triangles indicate sampling sites.

Moorea and Tahiti are part of the Society island archipelago, one of the most isolated island chains in the world (Fig. 1). The island supports several habitat types, including coastal forest, low elevation rainforest, and cloud forest. The Tahitian fern flora comprises ~150 species (Nitta, 2011), and it is phylogenetically diverse, including 129 families of Smith et al. (2010). This encompasses a variety of habitat preferences (e.g., epiphytic, epigeic, terrestrial), sporophyte morphologies, and gametophyte morphotypes.

- We constructed DNA libraries using chloroplast rbcL, to use for phylogenetic analysis and identification of field-collected cryptic gametophytes.
- We conducted field surveys along an elevational gradient to investigate species ranges of both sporophytes and gametophytes. Sporophyte diversity was sampled in 10 x 0 m plots, and gametophytes in 50 x 50 cm subplots. Sampling plots were located at ca. 200 m intervals along an elevational gradient from 200 m to 2000 m.
- We analyzed physiological (e.g., desiccation tolerance and morphological traits [e.g., morphology, frond anatomy]) in a phylogenetic framework to investigate how characteristics of both the gametophyte and sporophyte influence fern community assembly.

Results

Over 1600 fern gametophytes were collected across the gradient; of these, 1514 (95%) were successfully identified to species using the DNA barcode marker. Species richness was higher for sporophytes (total 124 spp) and gametophytes (total 27 spp) per plot than gametophytes (total 27 spp) per plant. Sporophytes reached maximum richness at mid elevations; however, this humped distribution was not observed in gametophytes. Most gametophytes occurred near conspecific sporophytes. However, gametophytes of 60 species were observed growing in plots that lacked conspecific sporophytes (in Fig. 3). Furthermore, gametophytes of two species, P. alboatra and M. calyptrodes, were found which indicate to completely lack sporophytes on Moorea or Tahiti (arrows in Fig. 3).

Figure 2: Observed species richness of fern gametophytes (blue triangles) and sporophytes (red triangles) along an elevational gradient from 200 m to 2000 m, n = 25 sites total.

Figure 3: Maximum likelihood rbcL phylogeny of ferns of Moorea and Tahiti inferred using MrBayes (Stanley et al., 2006) and scaled to be ultrametric using r8s (Sanderson, 2003). Colored dots indicate gametophyte morphotypes. "X" indicates gametophyte observed growing without sporophytes. Arrows indicate gametophyte lacking sporophytes on Moorea or Tahiti. Familiar names after Smith et al. (2006) on right.

Figure 4: Community phylogenetic structure (mean phylogenetic distance of MPD between sporophytes and gametophytes) along an elevational gradient from 200 m to 2000 m. The MPD values indicate over-dispersion in these values indicating significant Felsenstein correlation of SL mean phylogenetic distance for sporophytes. Communities significantly different from null distribution in black: n = 22 sites total.

Conclusions

The results of our study suggest that, despite the developmental link between fern sporophytes and gametophytes, community assembly dynamics may differ between these two generations. Although phylogenetic community structure of gametophytes does not change with elevation, sporophytes become more clustered at higher elevations. Furthermore, we found gametophytes of multiple fern species that do not exceed the range of their sporophytes. Consequently, these gametophytes need to have non-conspecific morphologies. The ability of fern gametophytes to persist in favorable microhabitats even when the conditions do not allow growth of the sporophyte may be important for the evolutionary success of ferns.

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Figure 5: Polypodiaceae

Figure 6: Onychiaceae

Figure 7: Ophioglossaceae

Bibliography
