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Introduction

Carnivorous plants bridge the gap between producer and predator, obtaining some nutrients directly from the soil through uptake in the roots and by supplemental resources, especially nitrogen, which is obtained from captured prey. The southeastern coastal plain of the U.S. is possibly the richest area in the world for carnivorous plant diversity, with Florida being the home to more species than any other state (Hermann 1995). Unfortunately, seasonally aquatic or semi-aquatic habitats such as bogs and seepage savannas, which support carnivorous species including sundews and pitcher plants, are extremely fragile ecosystems that are particularly sensitive to human-caused disturbances. These anthropogenic disturbances range from outright habitat destruction to prolonged dry-downs caused by declines in the water table and alteration of natural fire regimes which may be critical in the maintenance of these communities.

Although it is exceedingly difficult to monitor the health of an entire community or ecosystem, this assessment may be greatly facilitated with the use of "indicator species." Indicator species are typically plant or animal species that serve as surrogates (and early warning systems) for monitoring the health of an ecosystem, typically in lieu of expensive detection equipment (Primack 1998). For the past 1½ years, we have been collecting baseline data on the population dynamics and growth morphology of the hooded pitcher plant, *Sarracenia minor*.

The ultimate goal of this project is to develop a model of *S. minor* morphology under various environmental conditions, which can then be used to assess the overall health of these ecosystems. Because *S. minor* is sensitive to disturbance it may be a good candidate for use as an indicator species. Decline in habitat quality should be detectable as changes in the population dynamics and morphology of *S. minor*, thereby indicating that intervention may be necessary to maintain habitat viability.

For instance, a population that consists primarily of large mature individuals indicates that the habitat may not be suitable for the recruitment of new progeny into the population. This alteration in population morphology suggests that leaf litter may be too deep for young propagules to become established and that a controlled burn, which removes thick layers of litter, may be required to restore the ecosystem to acceptable levels of ground cover that support sensitive species such as *S. minor*.

Methods

Morphological data was collected from randomly sampled plants from three populations of *S. minor* on the campus of UNF. Two of these populations (designated A and C) are relatively close in proximity and are located in damp (standing water is often present), open conditions on the northern end of the campus. The third population (designated B) is located near the southern edge of the campus and is situated in a much drier habitat consisting primarily of large pines and loblolly bays that have encroached on the site. As a result, this population is located under a much more closed tree canopy and the ground is covered by deep layers of leaf litter (up to 30 cm deep in some locations). The sample size for each population was 25, 29 and 25 for A, C and B respectively.

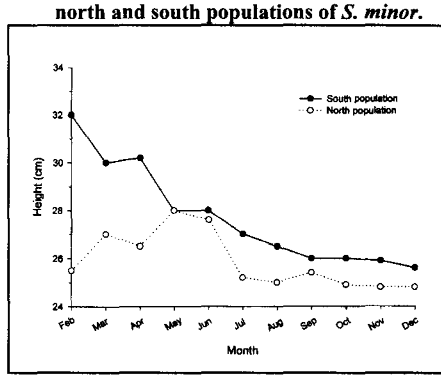
For each individual that was sampled, measurements of several morphological characters were collected including: 1) number of pitchers; 2) number of phyllodia (non-pitcher leaves); 3) greatest width of ala (wing of the pitcher); 4) width of the pitcher column (base of the pitcher, in cm); 5) hood height (excluding column, in cm); 6) thickness of the nectar roll (in cm); diameter of the pitcher (immediately below the nectar roll, in cm); and 7) greatest width of the hood (in cm). The measurements were collected from the tallest whole pitcher (i.e. damaged pitchers that were missing sections were not used) of each specimen. All measurements were recorded to the nearest 0.1-mm using handheld digital dial calipers.

Plant characteristics from both populations were placed in a correlation matrix and analyzed with the statistical program SAS (version 9.3). Morphological variation both within and between populations was assessed using principal components analysis (PCA). This technique essentially localizes variables (morphological measures in this case) in *s*-dimensional space, with each dimension representing a coordinate axis in space and different measurements taken from the plants. Plants that are similar in their morphological characteristics will cluster together as a group. The analysis produced three principle components from the data, with each principle component representing a weighted function of the measurements and accounting for the maximum variance in a hierarchical fashion. This technique allows the visualization of the morphological variation both within and between populations of *S. minor*.

Results

The three principle components generated from the data explained over 88% of the variation observed among the three populations of *S. minor*. (Note: due to their close proximity and the similar morphological characteristics, Populations A and C were pooled for presentation in the figures). The first principal component (PC I), which represents general size differences among the three populations, accounted for most of the morphological variation observed among the populations. Plants in the southern population (A) tend to be significantly larger than plants from the northern populations (A and C) (Fig. 1).

Figure 1. Mean height (cm) of tallest pitcher in north and south populations of *S. minor*.



The second principal component (PC II), which accounted for approximately 18% of the variance, was largely a reflection of the different number of phyllodia (pitchers) possessed by individuals of three populations (Fig. 2). Plants from the south population (B) tended to have more pitchers per plant than those from the two northern populations (A and C). The last principal component (PC III), which was weighted primarily for the width of the ala, explained approximately 7% of the variance in the data set. Although plots of PC I on PC II and PC II on PC III had a small degree of overlap between the northern populations (A and C) and southern population (B), both suggested that *S. minor* from the two locations has a distinct morphology (Figs. 3 and 4).

Figure 2. Mean number of pitchers in north and south populations of *S. minor*.

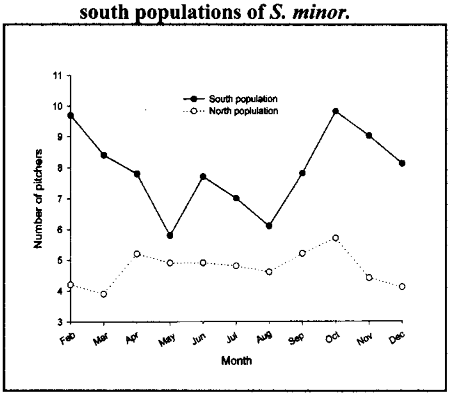


Figure 3. Principle components analysis (PC I on PC II, see text for details) of north (A and C) and south (B) populations of *S. minor*.

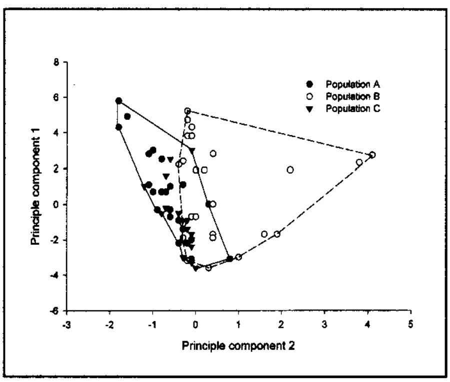
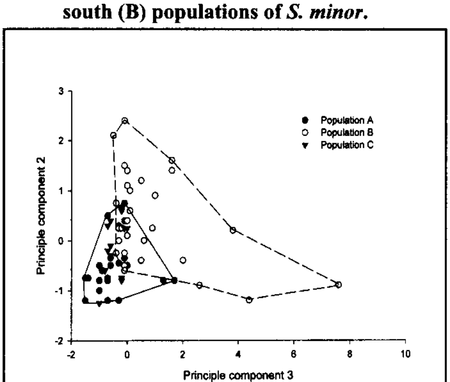


Figure 4. Principle components analysis (PC II on PC III, see text for details) of north (A and C) and south (B) populations of *S. minor*.



Discussion

Our initial results have been very encouraging. It appears that morphological structure of *S. minor* populations may provide useful information about environmental factors affecting plant growth. For instance, *S. minor* from the southern population are generally taller and possess significantly more pitchers than plants from the northern location. Several reasons may explain the differential growth form exhibited by the two populations. First, *S. minor* in the southern population is typically found growing in deep leaf litter (primarily pine needles from slash and longleaf pine), with depths of 23-30 cm.

As a result, this population contains few juvenile plants because they are unable to effectively germinate through deep layers of leaf litter. Thus, the overall size of plants at this site is skewed toward large individuals and recruitment of new progeny into this population may be very limited. This population may eventually go extinct once these mature individuals die because no new recruits are becoming established in the population. In addition, these plants possess significantly more pitchers per plant than conspecifics in the northern population. This pattern may be due to decreased levels of soil nutrients (especially nitrogen) at the southern site compared to the northern site. As a result, individuals at the southern site may develop significantly more pitchers, enabling them to capture more prey. The increase in captured prey in these plants may provide enough supplemental nitrogen for individuals to survive at this site.

The results of this pilot study suggest that growth morphology of *S. minor* is influenced by local environmental conditions. If specific growth forms reflect the environmental conditions at a site, then populations exhibiting deviations from "normal" growth patterns may provide strategies for successful intervention to prevent further decline of these semi-aquatic habitats and the concomitant extinction of *S. minor*. For instance, a corrective measure that might be implemented at the site of the southern population would be to remove leaf litter, either manually or by the use of a controlled burn. Removal of leaf litter should allow the germination of seedlings and the establishment of new recruits into the population. In addition, the higher mean number of pitchers per plant at this site suggests that soil nitrogen may be particularly low. Thus a controlled burn, which would turn much of the leaf litter's biomass into an ash and provide a natural fertilizer, may be a preferred intervention technique, compared to simply removing large amounts of leaf litter from the site.

Future research will include a detailed assessment of the correlation between plant morphology and various abiotic (environmental) and biotic factors. In addition to abiotic factors, the genetic structure of a population may also influence the growth form of *S. minor*. Genotypic differences among populations can have a considerable influence on plant morphology because various plant genotypes often express differential growth forms. Therefore, if little or no gene flow exists among populations, then genotypic effects may have a significant influence on plant morphology both within and among populations. This is due to the fact that each population will consist of only a handful of genotypes rather than possessing individuals that cover the entire spectrum of genetic variation within the species.

References

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