

ASSESSING THE REPRODUCTIVE BIOLOGY OF THE SANTA ANA RIVER WOOLLY STAR, *Eriastrum densifolium* ssp. *sanctorum* (MILLIKEN) MASON (POLEMONIACEAE)

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Abstract

This study assessed factors that affect reproductive success of *Eriastrum densifolium* ssp. *sanctorum* (*Eds*), a self-incompatible endangered perennial plant. It determined whether seed production is limited by resource allocation or pollinator activity and examined the influence of predation. Hummingbirds and the Giant Flower Loving Fly were the most common pollinators. Reproductive success of *Eds* appears to be both pollinator and resource-limited and was affected by predation. Mean fertilization success was high for Study Site One and low for the others. However, Site One had the lowest percentage of fertile seeds and the highest percentage of abortion. Pollinator limitation occurred up to seven seeds per capsule and above that number resource limitation predominated. *Eds* on Sites One and Five had the highest percentage of fertility and predation rates. Clearly, high predation may influence *Eds* population growth.

Introduction

The Santa Ana Woolly Star, *Eds*, is a member of the *Polemoniaceae*, a self-incompatible perennial sub-shrub 25-75 cm tall. It has leafy stems, dull gray-green leaves, and short branches (Figure 1). Its floral heads are terminal and woolly with colors that range from lavender blue to purple, pink, or white and its throat and tube are generally yellow or white. *Eds* is a distinct subspecies of *Eriastrum densifolium*, defined by the corolla tube length, which is three times that of the calyx (Brunell and Whitkus, 1999). *Eds* is one of the twelve most endangered plants in California (York, 1987). *Eds* was listed as an endangered subspecies in 1987, under the Federal Endangered Species Act of 1973. The study area is located in the floodplain of the Santa Ana River north of Redlands, San Bernardino County, California (Figure 2). The goal of the study is to ascertain whether seed production is limited by resource allocation or pollination activity, and to determine the influence of predation upon *Eds* reproduction.



Figure 1. Adult *Eds* plant.



Figure 2. Location of the study sites in Highland CA, USA

Materials, Methods and Results

Primary Pollinator Observations: Three plots (a,b,c) were established at each of the four study sites. Each plot contained a group of about 25 healthy *Eds* plants. These plots were located 25 -30 meters from each other within each study site. Three dawn-to- dusk observations were performed at each of the four study sites during the flowering season for a total of 168 hours. Plants were observed continuously from 0600 to 2000 hours on each of the observation days. Within each hour, each plot was observed for 10 minutes. (See Figure 3 for results).

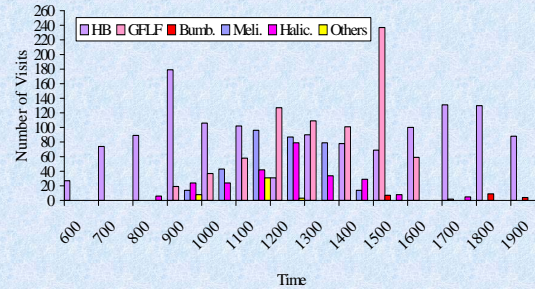


Figure 3. Total visits per hour observed for the major pollinators at all sites during the *Eds* flowering season of 2000. HB: Hummingbirds, GFLF: Giant Flower Loving Fly, Bumb.: Bumblebees, Mei.: digger bees - Melissodes spp., Halic.: halictid bees. Others include: Honeybees, White-Lined Sphinx Moth, the Giant Swallowtail and Cabbage White butterflies.

Fruit Collection and Seed Count: Three floral heads with mature fruits were collected randomly from each sampled plant at each of the four study sites. Fertile and infertile fruits were determined. Three capsules were collected randomly from each floral head, the total number of seeds was counted for each of these capsules and the mean seed number per fruit was calculated. To determine if there was resource or pollinator limitation, seeds were classified into four different categories: 1 seed / capsule; 2-4 seeds / capsule; 5-7 seeds / capsule, and more than 8 seeds / capsule. Five samples from each category were selected. Mean seed weight was calculated for each category for each site. (See Tables 1 and 2).

Site	Number of heads	Total flowers / head		Percent of fertile flowers/head	Fertile flowers / head		Infertile flowers / head	
		Mean	S.D.		Mean	S.D.	Mean	S.D.
1	150	34.71	10.31	39.1	13.57	7.42	21.14	11.33
2	150	33.28	10.20	26.2	8.72	6.64	24.56	11.27
3	150	33.39	8.02	22.7	7.58	5.85	25.81	9.13
5	150	33.16	10.03	29.3	9.71	6.88	23.45	9.62

Table 1. Results of one way analysis of variance in number of flowers produced during the *Eds* flowering season of 2000.

Site	N=	Seeds / capsule		Fertile seeds / capsule		Infertile seeds / capsule	
		Mean	Total	Mean	Percent	Mean	Percent
1	358	5.2	1874	3.3	64.4	1207	35.6
2	364	5.6	2044	4.6	82.7	1691	47.3
3	375	5.9	2227	4.8	80.9	1802	49.1
5	227	4.7	1085	3.9	82.9	899	41.1

Table 2. *Eds* Seed set per site. N = capsules examined per site.

Resource/ Pollinator limitation: In order to determine if there were resource or pollinator limitation, a curvilinear regression was completed. The R-squared is over 80%, and P value is < 0.001. When graphed in this manner, (Figure 4), the data indicate that there is pollinator limitation occurs up to seven seeds per capsule, whereas resource limitation in capsules with eight or more seeds. As depicted in (Figure 5), the percentage of pollinator limitation among *Eds* study sites is three times greater than resource limitation.

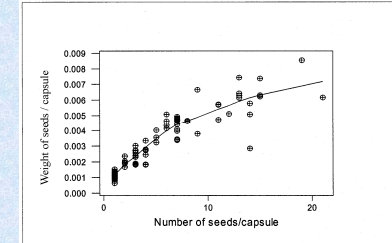


Figure 4. This is a plot of weight per capsule (mg) vs category, with a running average superimposed (a "Loess smooth" from Minitab).

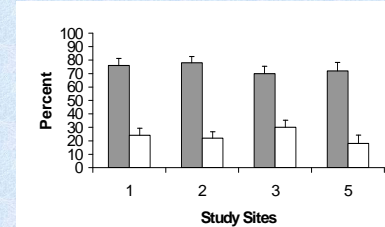


Figure 5. Percentage of pollinator limitation (black bars), resource limitation (white bars) among the study sites (mean + 1 SE).

Predation: Fruit and seed predation were determined by counting the capsules containing either developing larvae or evidence of their presence. If a larva had finished eating the seeds and left the ovary, frass was found in the hollowed fruit capsule and an exit hole was found in the ovary wall. I counted fruits and seeds chewed by larvae and calculated the percentage of predation from the total number of fertile fruits for each site (Table 3). Specimens of the predators, which were found in the capsules, were sent for identification to the Plant Pest Diagnostic Center of the California Department of Food and Agriculture (CDFA) in Sacramento, California (Figures 6 and 7).

Site	Number of heads with predation	Fertile flowers/ site	Fruits eaten by larvae	Percent of predation
1	69	2036	746	36.6
2	48	1309	158	12.1
3	23	1137	33	2.9
5	125	1457	910	62.5

Table 3. The degree of predation on *Eds* fruits based on total number of fertile flowers per site.



Figures 6, 7. Two types of predators lepidopteran larvae and a mealybug.

Conclusion

- *Eds* is a self-incompatible perennial and relies on insects and hummingbirds for its reproductive success.
- Hummingbirds and the Giant Flower Loving Fly were the most common pollinators with the highest number of visits overall. However, digger and halictid bees were more common pollinators at Sites One and Two.
- Reproductive success of *Eds* appears to be, in this study, 75% pollinator limited, 25% resource limited, and is also affected by a high predation rate.
- Pollinator limitation appears to be greatest up to seven seeds per capsule and above that level resource limitation appears to prevail.
- Predators of *Eds* significantly reduce the number of seeds set on the successfully pollinated flowers.
- There is a positive correlation between the level of predation and seed set, at least during the *Eds* 2000 flowering season.
- A full understanding of the exchange between increased apparency to pollinators and predators awaits specific delimitation of the properties of individual plants on Sites One and Five that make them more attractive to both groups of insects.

LITERATURE CITED

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