Interim report: *Demographic and reproductive analysis of Pectis imberbis* A. Gray

Findings:

In order to parameterize Integral Project Models (IPMs) for demographic analysis, a continuous state variable, typically a metric of size, must explain variation among individuals in reproduction and survival. As a proximate step towards model and census protocol development, we collected a variety of size measurements on *Pectis imberbis*, including 1) height of longest stem, 2) summed height of all stems, 3) stem number, 4) leaf number, and 5) length of the longest leaf. We then built statistical models and used the Aikaike Information Criterion (AIC) to compare model performance in predicting inflorescence number. Models explored single factor predictors (e.g., height), as well as composite factors that represented combinations of state variables (e.g., leaves*height), and included both linear and polynomial fits. A total of 24 models were tested (**Table 1**).

Of the 24 models tested, height of the longest stem was the best predictor of floral production (**Table 1; Fig. 1 & 2**). To reduce census effort, we omitted time-consuming measurements that did not improve predictions of floral production. We measured size, counted floral number, and recorded the status of 785 *P. imberbis* individuals in total by August 2019. During our initial data collection trip, we identified additional factors, including browse by deer and the apparent co-occurrence with 'nurse' plants, which could influence *P. imberbis* performance. Of the 785 individuals measured, 72% were browsed, likely by Coues deer. Browse was positively related to floral production ($\chi^2 = 46.52$, $p < 0.01$; **Fig. 3 & 4**), though this does not necessarily imply that browse benefits *P. imberbis* fitness. We also observed that *P. imberbis* frequently occurred in bunch grasses or near shrubs, which indeed reduced browse rates ($\chi^2 = 11.25$, $p < 0.01$; **Fig. 5**); however, plants that occurred in close proximity to other plants produced fewer flowers per unit size relative to those growing without competition ($F = 6.18$, $p = 0.02$; **Fig. 6**). This relationship provides one possible explanation for the positive effect of browse on floral production. While co-occurring plants decreased browse rates, they also reduced performance through competitive effects. Additionally, maximizing reproductive effort is a common response of plants to stressful conditions, and typically corresponds with a cost in growth and survival, providing another possible explanation of the observed browse-flower production relationship. Moreover, since larger plants tended to be browsed more frequently, and the relationship between size and reproduction is nonlinear, this observed pattern may result simply from browsing preference. Continued monitoring of *P. imberbis* and including an early season census to capture pre-browse size metrics will help to elucidate the relationship between browse and fitness metrics.

In addition to measuring *P. imberbis* demography, we are also are conducting germination trials to better understand constraints on reproduction. Thus far, germination rates have been low, though we are still trialing seed treatments. We also applied breeding system treatments in fall 2019, but are still in the process of analyzing those data. During the census, we observed floral herbivory by the beetle, *Acmaeodera amplicollis* (**Fig. 7**), which may also affect *P. imberbis* reproductive rates.

Table 1. Model rankings produced by AIC scores.

Model ranking	Model	Predictor variable description	Linear / Polynomial	log transformed (Y/N)	df	AIC
1	Height+I(Height^2)	Height of the longest stem	Polynomial	N	4	218.83
2	logHeight + I(logHeight^2)	Height of the longest stem	Polynomial	Y	4	222.69
3	Height	Height of the longest stem	Linear	N	3	227.61
4	logHeight	Height of the longest stem	Linear	Y	3	234.02
5	HeightLeafNum+I(HeightLeafNum^2)	Height of the longest stem * Leaf number	Polynomial	N	4	236.86
6	HeightLLL+I(HeightLLL^2)	Height of the longest stem * Longest leaf length	Polynomial	N	4	237.4
7	logHeightLeafNum	Height of the longest stem * Leaf number	Linear	Y	3	237.48
8	logHeightLeafNum+I(logHeightLeafNum^2)	Height of the longest stem * Leaf number	Polynomial	Y	4	237.63
9	HeightLeafNum	Height of the longest stem * Leaf number	Linear	N	3	238.65
10	TotalHeight	Summed height of each stem	Linear	N	3	239.85
11	logTotalHeight	Summed height of each stem	Linear	Y	3	241.06
12	logTotalHeight +I(logTotalHeight^2)	Summed height of each stem	Polynomial	Y	4	241.77
13	TotalHeight+I(TotalHeight^2)	Summed height of each stem	Polynomial	N	4	241.83
14	HeightLLL	Height of the longest stem * Longest leaf length	Linear	N	3	241.99
15	logLeafNum	Total leaf number	Linear	Y	3	244.46
16	LeafNum	Total leaf number	Linear	N	3	245.38
17	LeafNum+I(LeafNum^2)	Total leaf number	Polynomial	N	4	246.03
18	logLeafNum+I(logLeafNum^2)	Total leaf number	Polynomial	Y	4	246.08
19	logHeightLLL+I(logHeightLLL^2)	Height of the longest stem * Longest leaf length	Polynomial	Y	4	251.78
20	logHeightLLL	Height of the longest stem * Longest leaf length	Linear	Y	3	251.95
21	logLLL	Length of the longest leaf	Linear	Y	3	255.87
22	LLL	Length of the longest leaf	Linear	N	3	255.94
23	LLL+I(LLL^2)	Length of the longest leaf	Polynomial	N	4	256.25
24	logLLL+I(logLLL^2)	Length of the longest leaf	Polynomial	Y	4	256.85

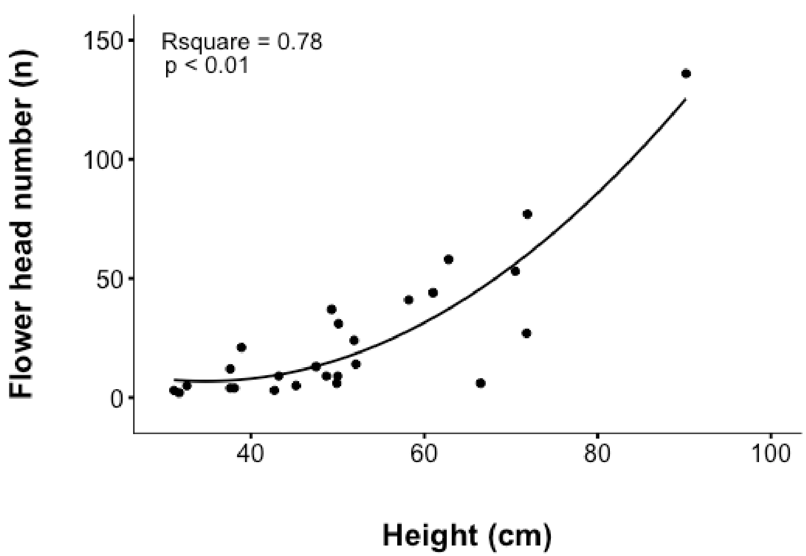

Fig. 1. Model of best fit. Height of the longest stem predicts the number of floral heads.

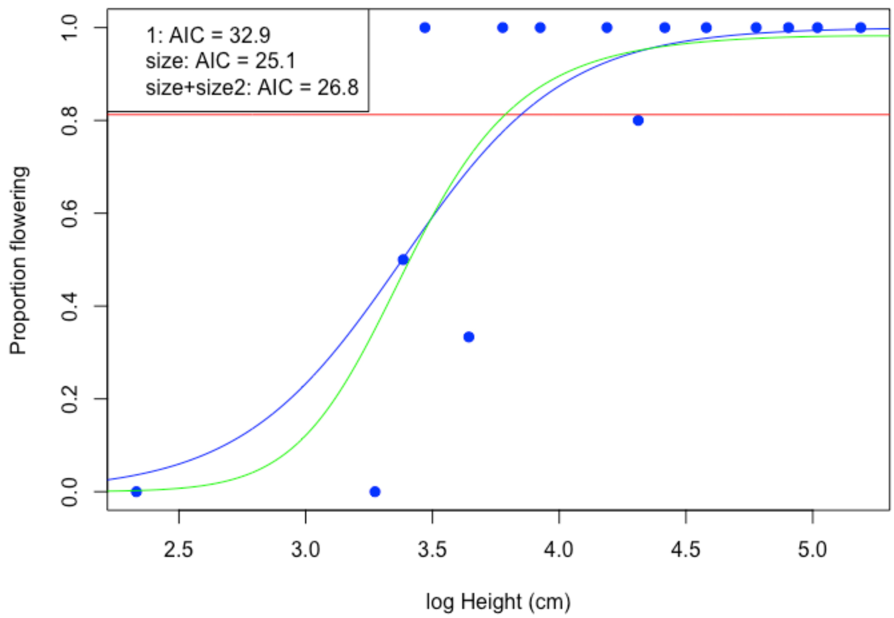

Fig. 2. Comparison of linear and polynomial models using log transformed height as a predictor variable for the likelihood of individuals flowering.

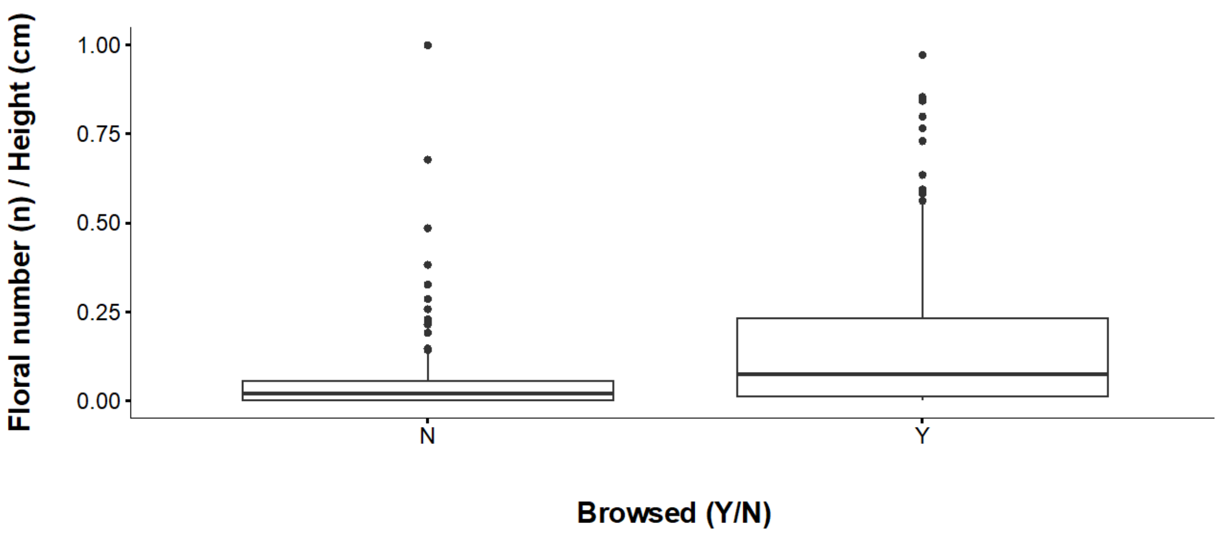

Fig. 3. The effect of browsing on floral production per unit size.

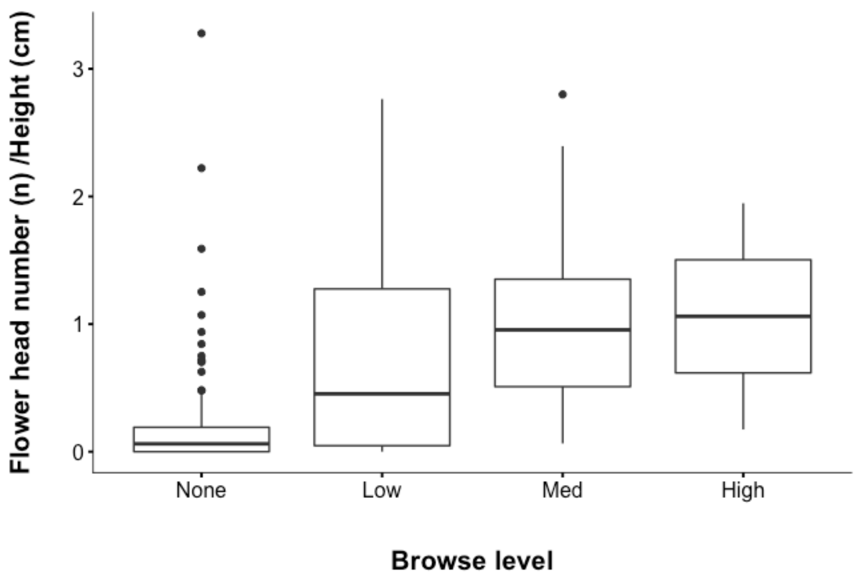

Fig. 4. Response of floral head production relativized by size to differing levels of browse intensity.

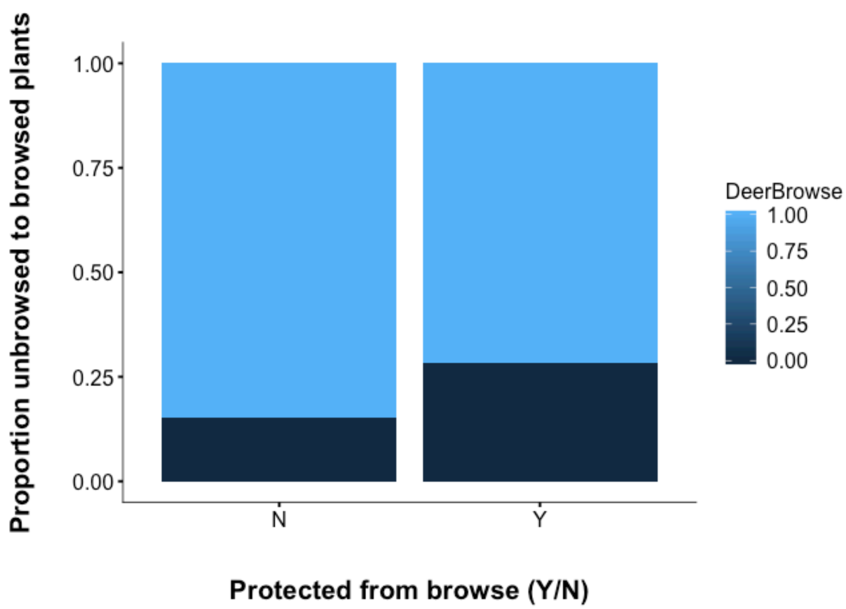

Fig. 5. The proportion of browsed plants of plants protected and unprotected by plants.

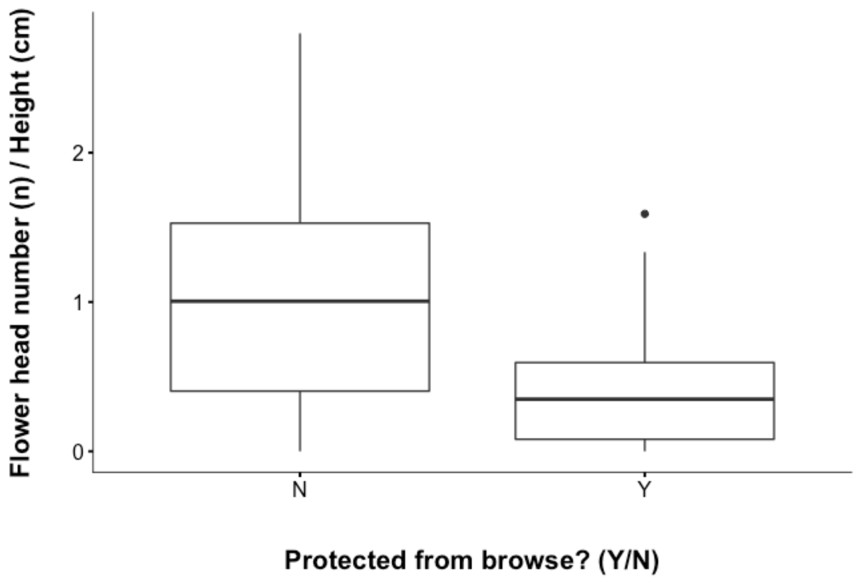

Fig. 6. Floral head production per unit size for protected and unprotected *P. imberbis*.

Fig. 7. *Acmaeodera amplicollis* observed predating *P. imberbis* flowers.

Other required information

Funding sources and amounts:
USFSW: $35,000

Whether specimens were collected:
Around 100 seeds were collected for germination trials.

Confirmation of Research dates:
We will revisit the *Pectis* population in spring / summer / fall of 2020.

Abstract:
Pectis imberbis A. Gray is an endemic plant species native to southern Arizona with ***fewer than 400 known individuals in existence***. Resurveys of known *P. imberbis* sites suggest significant decline in abundance over the last two decades and have documented ***the extirpation of 9 populations and 1 sub-population***. Initial decline of *P. imberbis* is believed to have resulted from overgrazing by domesticated livestock; other potential threats include competition with non-native species, increased drought severity and frequency, mining, road construction, and recreational activities (Phillips et al. 1982). In addition to these extrinsic stressors, rarity itself may reinforce population decline by reducing *per capita* reproduction (the Allee effect) and decreasing offspring viability when inbreeding results in the expression of deleterious alleles. Currently, little is known about the breeding system, lifespan, survival, or reproductive rates of *P. imberbis*, and no comprehensive assessment of *P. imberbis* pollinators has been conducted. Obtaining this basic biological knowledge is a ***critical and urgent first step towards developing an effective recovery plan for this species***, which is currently on a trajectory towards extinction. In summer 2019, we measured 785 plants at the Coronado National Memorial in order to parameterize demographic models. Of measured plants, 72% were browsed presumably by Coues deer, which were observed grazing at the population. Deer browse was not negatively related to floral production, while co-occurrence of *P. imberbis* with other plants, like bunch grasses and shrubs, which protected *P. imberbis* from browse, correlated to a decrease in floral production. This perhaps indicates that 'nurse' plants benefit *P. imberbis* by reducing browse, while negatively impacting growth and reproduction through competitive effects. Further research is needed to elucidate constraints on *P. imberbis* population growth.

Signed by Julie Crawford on 8-21-2020; Received March 12, 2020

Julie Crawford