Supplementary Materials for: Floral phenology of an Andean bellflower (*Centropogon granulosus*, Lobelioideae) and pollination by Buff-tailed Sicklebill (*Eutoxeres condamini*)

Note: All data and scripts used in this study will be deposited in the Dryad Digital Repository in coordination with the Editorial Office.

Visit duration

To estimate the duration of *E. condamini* visits, we considered that the camera traps took photos in sets of five, lasting less than 3 seconds. To make a conservative estimate, we assume the five photos take 3 seconds. For any 5-photo set in which *E. condamini* appears, we assume 3 seconds visitation. For example, during visitation, if *E. condamini* appears in two 5-photo sets, we assume a 2 x 3 second (= 6 second) visit, even if the hummingbird appeared in only a subset of the 10 photos.

Landmarking and calculating curvature

In Figure 1 (main text) we present a graphical illustration of the range of pollination niches within the centropogonids. To compute total curvature (sensu Boehm et al., 2021), we used the following protocol. First, images were imported into tpsUtil (Rohlf, 2015). This .tps file is used by tpsDig (Rohlf, 2015) for landmark assignment. We then placed the following two landmarks on each flower: (A) the base of the dorsal side of the corolla tube where the petals attach to the receptacle and (B) the apex of the dorsal petal. Nine additional sliding semi-landmarks were then placed between the two landmarks, outlining the dorsal arc of the corolla tube. For the hummingbirds, the following two landmarks were placed on each bill: (C) the base of the dorsal side of the upper mandible (exposed), and (D) the apex of the bill. Nine semi-landmarks were placed between these landmarks.

The .tps file generated by _tpsDig_ was then imported into R v.4.1.1 via `readmulti.tps()` from `geomorph` v.4.0.0 (Adams et al., 2013). We then fit interpolating splines to each landmark configuration, and computed total curvature using `curvr` v.0.0.1 (Boehm, 2021).

Phenological modeling

To model flowering phenology of *C. granulosus*, we fit the following linear model to the rate of anthesis and senescence for each inflorescence that produced at least five flowers (n = 5 controls, n = 5 pollinator excluded):

$$n_i = \beta_0 + \beta_1 * days + \epsilon$$

Where n_i is the cumulative number of flowers produced on an inflorescence at $days$=i, β_0 is the intercept, β_1 is the flowering rate, and ϵ is the residual error.

To determine if pollinator exclusion affected the total number of flowers produced, we fit the linear model:

$$n_{total} = \beta_0 + \beta_1 * treatment + \epsilon$$

Where β_0 is the intercept, β_1 is a coefficient, and ϵ is the residual error.

Figure S1. Fused anther hairs forming a scale and serving as a lever to deposit pollen (red arrow). This individual has finished the male phase and is in transition to the female phase — the stigma will continue to extend past the scale and unfold when receptive (white arrow).

Figure S2. Trait matching in Buff-tailed Sicklebill and C. granulosus observed at the study site. Photo used with permission from J. Heavyside (UBC).

Figure S3. Wire cages used to exclude avian visitors from accessing the nectaries of C. granulosus. Further details on the design can be found in Sun et al. (2017).

Figure S4. Still frames extracted from a video recording of E. condamini pollinating C. granulosus. A: The hummingbird approaches and inspects an inflorescence without any open flowers. B: A second inflorescence with an open flower is approached. C: To insert its bill, E. condamini hovers below the flower opening and tilts its head backwards. D: During feeding, its head is at eye-level with the corolla opening and the anther/stigma is in contact with the crown.

Figure S5. A long-nosed bat (Glossophaginae) recorded near an inflorescence of C. granulosus with several developing berries.

Figure S6. A rodent (Muridae, bottom left) recorded near an inflorescence of C. granulosus (top left) with several developing berries.

Figure S7. Signs of frugivory of a C. granulosus berry.

Figure S8. Herbivory of a C. granulosus flower by a larval lepidoptran.

Figure S9. A stingless bee (Meliponini) collecting pollen from an anther scale of C. granulosus.

Figure S10. Inflorescence of C. granulosus with a multitude of peduncle scars (red arrow) suggestive of an extended flowering peak.

Figure S11. Buff-tailed Sicklebill visiting Heliconia aemygdiana Burle-Marx, and using the floral bract as a perch during feeding.

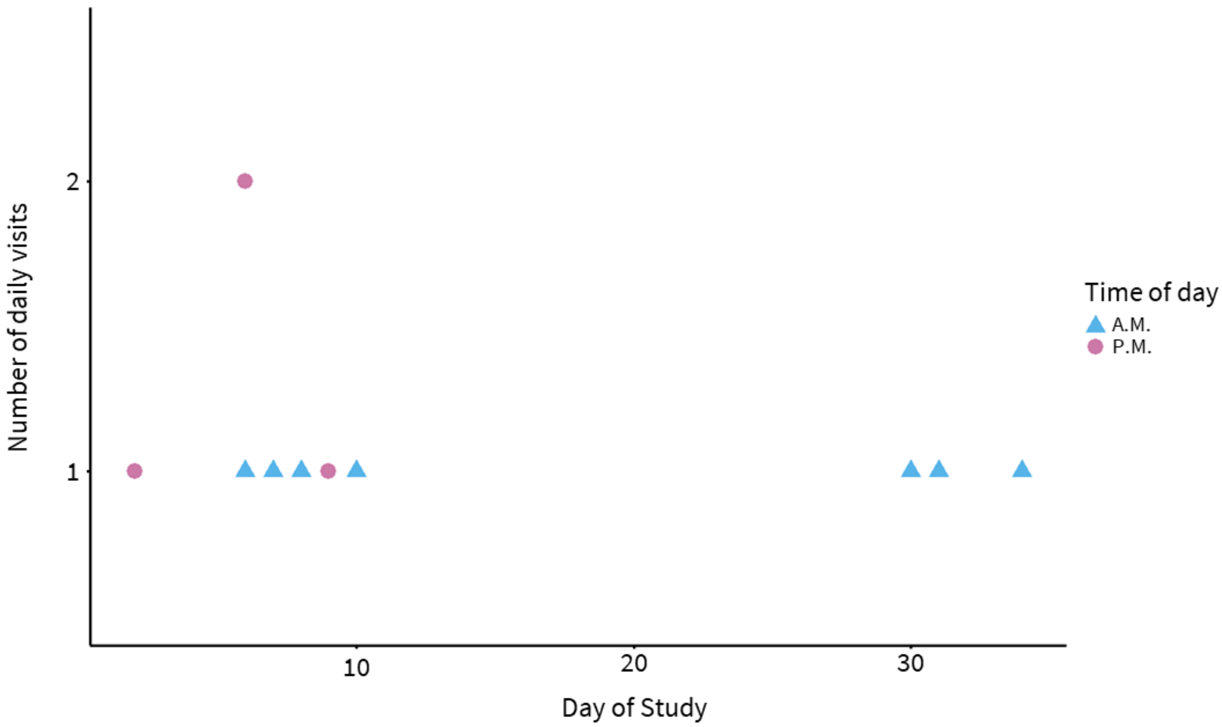

Figure S12. Recorded visits to C. granulosus by Buff-tailed Sicklebill. Visit data is compiled from six C. granulosus individuals (see: Table S3). 'AM' is defined as 12:00am-11:59am and 'PM' is 12:00pm-11:59pm'.

Table S1: Locations in San Pedro monitored for Sicklebill visitation to C. granulosus. The first column lists the C. granulosus individual identifiers.

ID	latitude	longitude	elevation
CNTRPGN 1-10	-13.05684	-71.54469	1306.706
CNTRPGN 11	-13.05603	-71.54515	1301.995
CNTRPGN 12-15	-13.05928	-71.54773	1381.661
CNTRPGN 16-20	-13.05900	-71.54666	1323.870
CNTRPGN 21-23	-13.05921	-71.54690	1330.937
CNTRPGN 24-32	-13.05932	-71.54778	1345.147
CNTRPGN 33-41	-13.05821	-71.54805	1359.792
CNTRPGN 42	-13.05720	-71.54699	1370.250
CNTRPGN 43-50	-13.05728	-71.54672	1368.063
CNTRPGN 51-53	-13.05563	-71.54676	1358.099
CNTRPGN 54-60	-13.05696	-71.54784	1398.831

Table S2: Stages of floral development in C. granulosus.

Stage	Description	Median duration (days)
A	Flower primordia appears above bracts. No curvature and red-orange pigmentation is not continuous around the base. Flower up to 9 mm tall (as measured from the top of the bracts). Basal diameter up to 4 mm.	22.3
B	Initiation of curvature, creating 90 degree angle. Red-orange pigmentation is continuous around the base. Flower up to 10 mm tall. Basal diameter up to 6 mm.	6.1
C	Growth phase. 180 degree angle formed. Red-orange pigmentation outweighs yellow. Flower 14 to 20 mm tall. Basal diameter 6 - 8 mm.	6.3
D	Pre-anthesis. >180 degree angle formed. Flower 30 mm tall. Basal diameter 7 - 8 mm.	8.6
E	Anthesis. Mature male-phase flower. Flower 34 -36 mm tall. Basal diameter 7 - 8 mm.	2.6
F	Female-phase flower. Pistil grows overtop of the pollen trap. Flower up to 36 mm tall. Basal diameter up to 10 mm.	2.4
G	Senescing flower. Petals wilting but retained. Basal diameter 8 - 10 mm.	5.3

H	Berry development. Petals senesced and lost. Basal diameter grows from 11 - 17 mm.	24.2

Table S3: Camera trap records of E. condamini.

Date observed	Time of day	Feeding mode	Temperature (Celsius)	Centropogon ID	Flower ID
Aug_18_2017	12:36	hovering	19	1	1
Aug_22_2017	10:38	hovering	21	1	1
Aug_22_2017	10:38	hovering	21	1	2
Aug_22_2017	15:54	hovering	20	1	1
Aug_22_2017	10:39	hovering	20	2	1
Aug_23_2017	10:24	hovering	19	1	2
Aug_24_2017	7:17	perching	17	1	1
Aug_24_2017	7:17	hovering	17	1	2
Aug_25_2017	16:27	inspecting	19	3	NA
Aug_26_2017	5:52	hovering	15	4	1
Sep_15_2017	5:24	hovering	16	5	1
Sep_16_2017	5:56	inspecting	15	5	NA
Sep_19_2017	5:36	perching	14	5	2
Sep_19_2017	7:15	perching	16	6	1

Table S4: Camera trap records of S. geofryii.

Date observed	Time of day	Feeding mode	Temperature (Celsius)	Centropogon ID	Flower ID
Sep_11_2017	9:58	hovering	20	7	1
Sep_11_2017	13:03	hovering	22	7	1
Sep_11_2017	13:55	hovering	23	7	1
Sep_11_2017	15:01	hovering	23	7	1
Sep_11_2017	16:11	hovering	22	7	1
Sep_14_2017	10:44	hovering	21	7	2
Sep_14_2017	11:42	hovering	22	7	2
Sep_14_2017	13:10	hovering	21	7	2
Sep_14_2017	14:32	hovering	21	7	2
Sep_14_2017	16:54	hovering	21	7	2

References

Adams, D. C., and Otárola-Castillo, E. 2013. geomorph: an R package for the collection and analysis of geometric morphometric shape data. *Methods in Ecology and Evolution*, *4*(4), 393-399.

Boehm, M. M. A. 2021. curvr: an R package for measuring total curvature from landmarked specimens. R package version 0.0.1. https://github.com/mannfred/curvr.

Boehm, M. M. A., J. E. Jankowski, and Q. C. B. Cronk. 2021. Plant-pollinator specialization: Origin and measurement of curvature. *The American Naturalist*: https://doi.org/10.1086/717677.

Rohlf, F. J. 2015. The tps series of software. *Hystrix*, *26*(1).

Sun, S.-G., Z.-H. Huang, Z.-B. Chen, and S.-Q. Huang. 2017. Nectar properties and the role of sunbirds as pollinators of the golden-flowered tea *Camellia petelotii*. *American Journal of Botany* 104: 468–476.