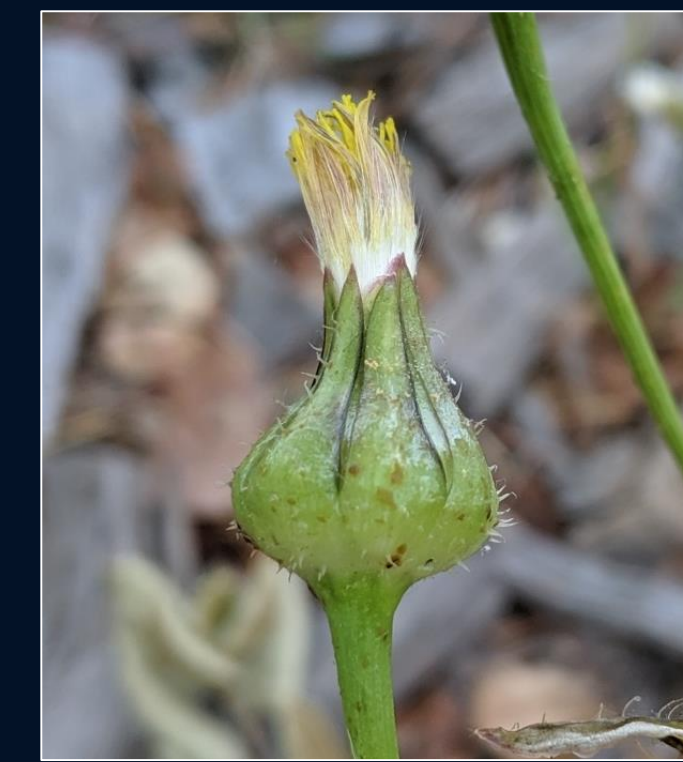


Enlisting community scientists to study a range-expanding plant, *Urospermum picroides* (L.) F.W. Schmidt, yielding a revised distribution map and recommendations for public engagement through iNaturalist

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Introduction to *Urospermum picroides*

Urospermum picroides (L.) F.W. Schmidt is an annual herb in the Asteraceae native to the Mediterranean Region. Typically quite rare in California as a weed of disturbed areas, it appears to have rapidly expanded its introduced range in western North America as well as deepened its foothold in areas where it already occurred. The species is reported to have somewhat broad habitat requirements and weedy tendencies, which has likely aided its expansion into North America, South America, South Africa, and Australia.

The species is distinctive among all Asteraceae in the combination of two sets of features. First, it has liguliflorous heads with only a single series of phyllaries that are fused at their bases and are of approximately the same length (**Figure 1A-B**). The second feature pertains to the fruits; both *Urospermum* species have a hollow 'tail' at the fruit apex as the name alludes (**Figure 1C**; Greek 'uro-' meaning tail, and '-sperma' meaning seed). **Figure 2** shows heads of the morphologically similar *Sonchus oleraceus*, which has multiple series of phyllaries of different lengths. Fruits on *Sonchus* and other liguliflorous Asteraceae have no 'tails' on their fruits.

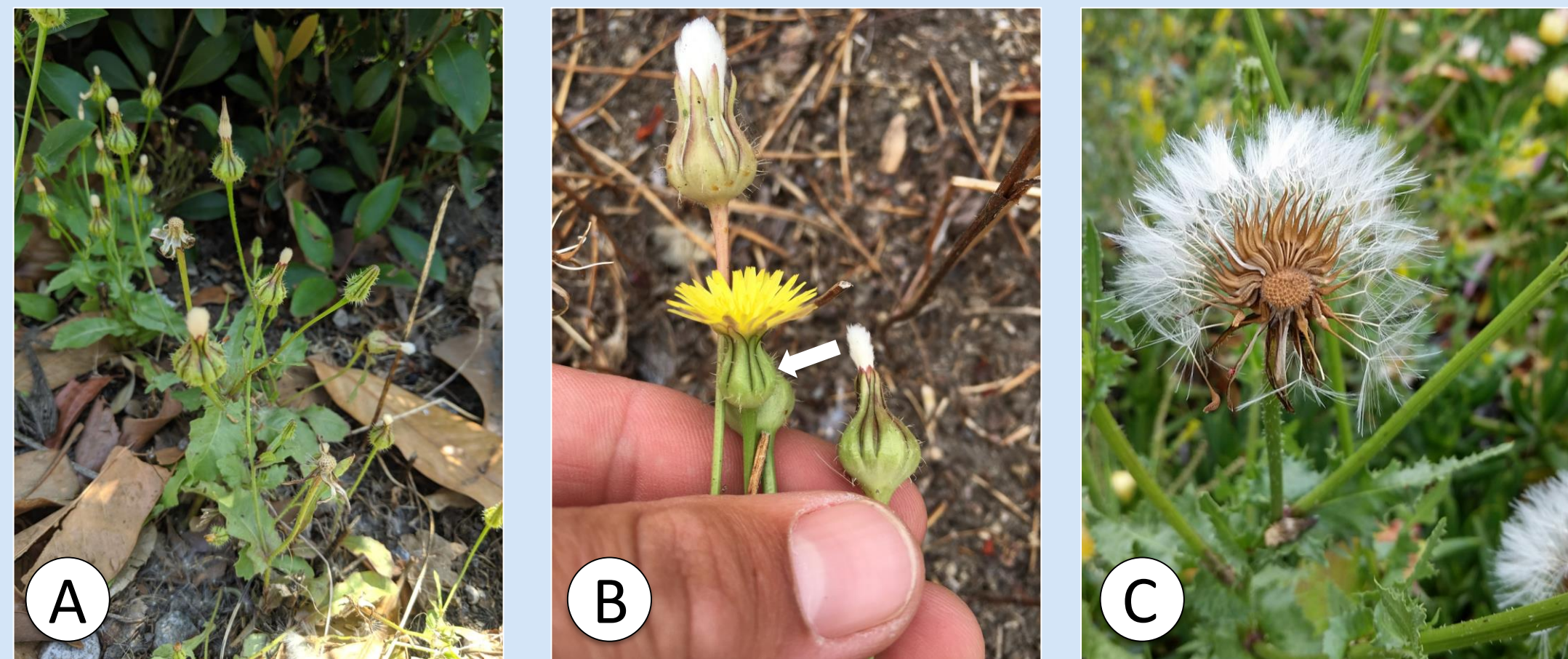


Figure 1A-C. Images of *Urospermum picroides*. **A.** plant habit; **B.** heads in flower, arrow showing single series of phyllaries; **C.** head in fruit.



Figure 2. Heads of *Sonchus oleraceus*, arrows showing multiple series of phyllaries.

With the increase in range and prevalence of *U. picroides* in early spring 2019, we initiated an iNaturalist project with these **goals**:

- 1) to engage community scientists to gather observations of *U. picroides* that could be used to update our understanding of the current distribution of the species and
- 2) to increase public awareness of this species, given its apparent spread to new regions of the state.

Using iNaturalist to study *U. picroides* distribution

Upon noticing the apparent increase in range and prevalence of *Urospermum picroides* during the winter months of 2018-2019, we initiated a community science project to map the species through the iNaturalist app. After launching in March 2019, the project was promoted through targeted messaging in the application as well as through postings on social media (e.g., Facebook). We confirmed all iNaturalist observations reported to be *U. picroides* in western North America. Furthermore, we performed targeted searches of iNaturalist observations of similar genera to seek mis-identifications as well as observations not determined to minimum rank.

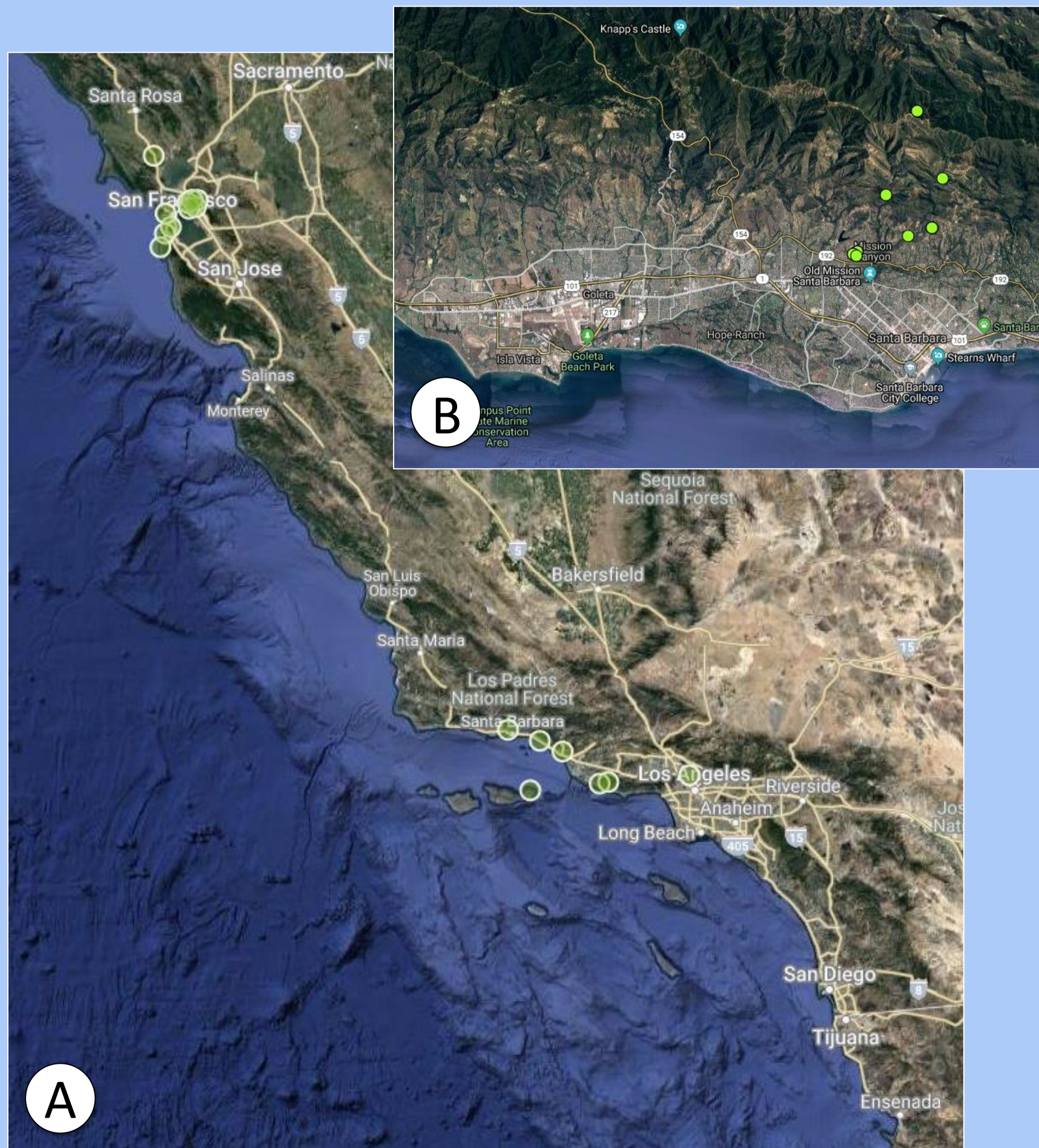


Figure 3A-B. Map showing observations of *Urospermum picroides* prior to March 2019. **A.** iNaturalist observations from coastal California and Baja California; **B.** herbarium specimens from Santa Barbara Region.

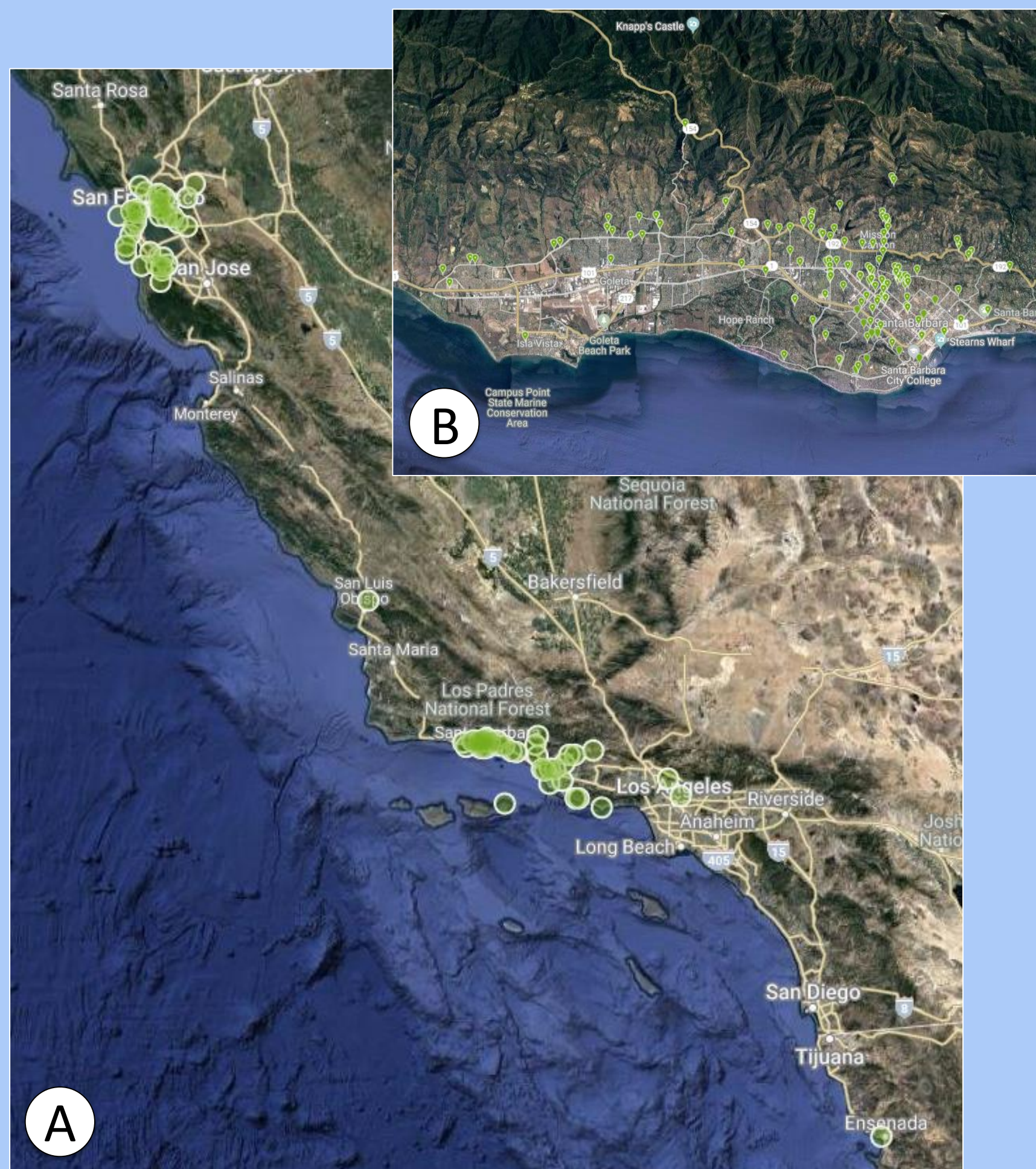


Figure 4A-B. Map showing iNaturalist observations of *Urospermum picroides* since March 2019. **A.** coastal California and Baja California; **B.** Santa Barbara Region.

Results and Discussion

When the project was initiated, the species' North American range could be inferred from only 48 unique collection events in herbaria and 25 observations on iNaturalist (**Figure 3A-B**). Between March 2019 and the present, 51 iNaturalist users have made 335 new observations, a 4-5-fold increase in the number of georeferenced data points for this species (**Figure 4A-B**). As we suspected, the North American range of *U. picroides* was not accurately represented by herbarium specimens. Through the project, users have documented many dozens of new localities, two new county records (Marin and San Luis Obispo counties), and one new country record (Mexico). iNaturalist users also documented what appears to be increased densities within the known range of the species, both in the Bay Area and Santa Barbara/Ventura county regions.

Achieving success with iNaturalist projects

Figure 5A-C and **Table 1** show some examples of attributes that could affect project success. Ideal iNaturalist projects will be well-optimized on many axes. An imbalanced design may be inadvertently organism-optimized (O) or user-optimized (U), which could have different outcomes with respect to project success. **Table 1** lists and describes some project attributes and their potential effects when not considered.

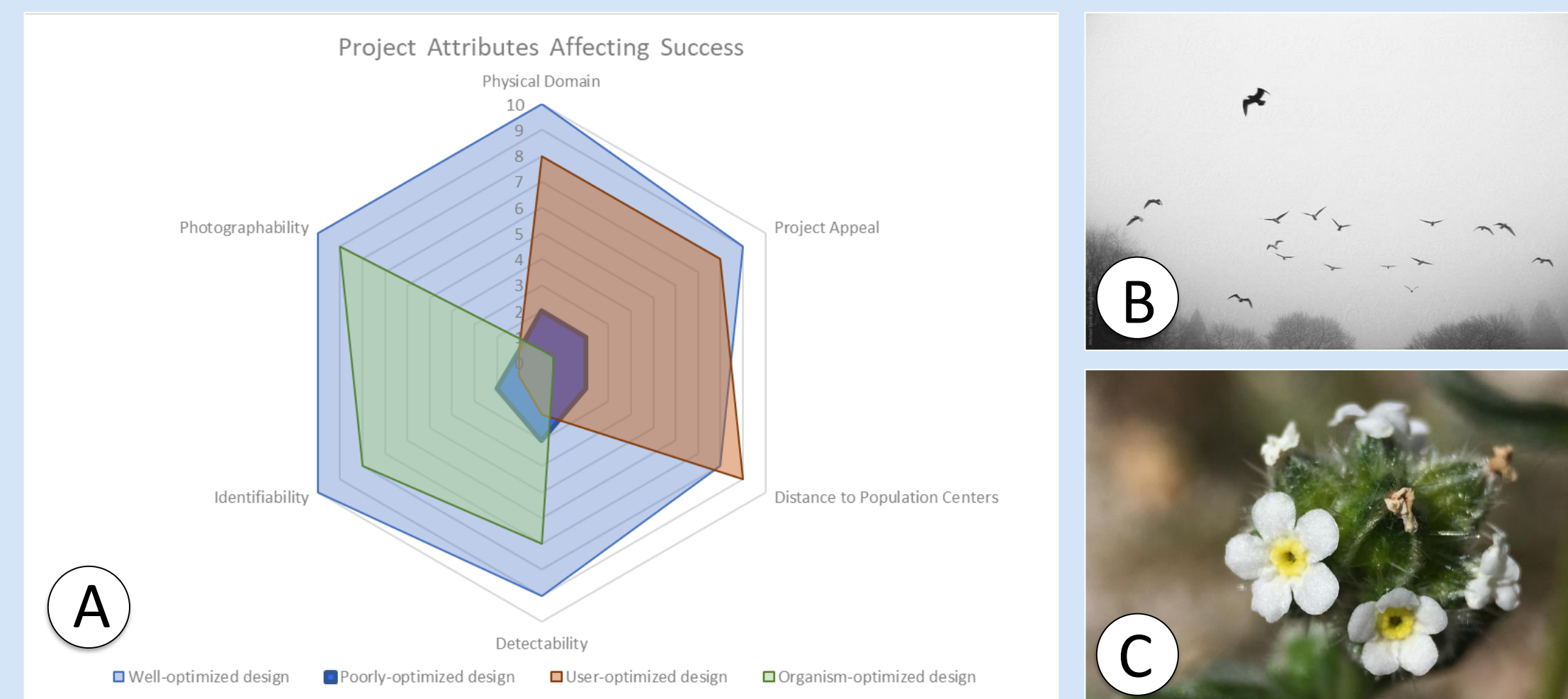


Figure 5A-C. Selected project attributes affecting success. **A.** Radar plot showing optimization on six potential axes; **B.** Birds, often with poor photographability; **C.** *Cryptantha*, poor identifiability in most photos.

Table 1. Project attributes and their potential effects.

Project Attribute	Description	Potential effect
Detectability (O)	Ease of detection	Difficult to locate, even when present
Identifiability (O)	Ease of identification 1) in field and 2) via photos	Difficult or impossible to identify
Photographability (O)	Ease of photographing with standard smartphone	Poor photographic quality
Biological domain (U)	Relative size of biological question (e.g., # taxa)	Project too diffuse
Data complexity (U)	Ease of gathering required data	Metadata too cumbersome
Distance to cities (U)	Proximity to engaged, iNaturalist users	Low participation
Expert engagement (U)	Likelihood of expert IDs in app	Low ID rate; high error rate
Interactions (U)	Interactions between variables	Unpredictable project conditions
Physical domain (U)	Relative size of geographic footprint	Diffuse engagement; >> stakeholders
Project appeal (U)	Relative project appeal	Low participation
Project duration (U)	Length of project	Attenuated participation, attrition

Acknowledgements

We thank the nearly 50 other iNaturalist users who documented *Urospermum* with us during our project. We also thank Ken-ichi Ueda, cofounder of iNaturalist, for his development of this remarkable application and for his support during this project.