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Chorizanthe orcuttiana (Polygonaceae): Comparative Vegetative Morphology with Two Co-Occurring Taxa and New Observations on its Phenology

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ABSTRACT

Chorizanthe orcuttiana Parry is a federally listed endangered plant species that is endemic to southern California. Because of the diminutive size of the plants and their morphological similarity to other co-occurring species, especially in the earlier growth phases, *in situ* identification of this taxon can be challenging. Moreover, phenological progression in this taxon is not fully documented. We provide the first detailed account of: (1) morphological comparisons of *C. orcuttiana* with two co-occurring and similar looking taxa during the vegetative growth stage, and (2) the phenological development in *C. orcuttiana*. Our observations will assist botanists, biologists, and ecologists who must rely on the correct identification of the taxon in the early life stages. We also documented that anthesis in *C. orcuttiana* begins earlier than previously reported.

INTRODUCTION

Approximately 5,000 plant species are considered native to California, of which 26% are considered endemic to the state [1]. This botanical diversity of the region emerges from diverse topographies, climate, and soils in the California Floristic Province, which is also a global biodiversity hotspot [2]. The diverse ecological conditions have provided many opportunities for niche specialization by the endemic species that are often geographically restricted to very small spatial patches [3]. Of the 2,270 plant taxa including species, sub species and varieties registered in the California Native Plant Society's inventory as rare, endangered or with limited distributions, 57% (1,288) are endemic to the state [4]. Chorizanthe is one of the rare genera that is comprised of species that are mostly endemic to the arid coastal and desert regions of California [5].

The genus Chorizanthe belongs to the family Polygonaceae, and the species within the genus are commonly known as spine flowers which are characterized by spiny looking inflorescences given the presence of straight or hooked spines at the tips of the involucral teeth. The genus is comprised of 50 species worldwide that are distributed across western North America and South America [1]. Forty of the known Chorizanthe species are considered native to North America [6]. California appears to be the center of diversity for the genus in that the state hosts 33 of the 40 North American species [1].

C. orcuttiana Parry (San Diego spineflower) is an annual species that is endemic to San Diego County in southern California. Currently, the taxon is listed endangered under the Endangered Species Act of the United States and California Endangered Species Act (CESA) with a Rare Plant Rank of 1B.1 [7,8]. Plants occur in the coastal sage scrub habitat in sandy soils [1,5] (self-generated unpublished data) **(Figure 1a).** These soils are derived from sandstones and sedimentary rocks which underlie the coastal plains [9]. The climate in San Diego County is similar to Mediterranean climate. The coastal areas to which *C. orcuttiana* is restricted, receives mean annual precipitation of 25 cm, and has mean minimum and maximum temperatures of 13°C and 21°C, respectively [9].

Within its habitat, plants of *C. orcuttiana* frequently co-occur with similar looking species and are generally difficult to

distinguish; this is especially true in the early parts of the annual life cycle **(Figure 1b)** of the species when plants are either too small or do not have reproductive structures. Two taxa that commonly confuse the identification of *C. orcuttiana* in the vegetative life stage are *Mucronea californica* Benth. (Polygonaceae) and *Camissoniopsis bistorta* (Nutt. ex Torr. and A.Gray) W.L.Wagner and Hoch (Onagraceae). Although detailed descriptions of the floral morphology of *C. orcuttiana* are available [1,5,6], they are not sufficient to identify the plants *in situ* in the non-reproductive stage. Further, evidently anthesis was previously reported to occur later in the growing season and was associated with inflorescence expansion and branching [1,4] **(Figure 1c and 1d).** We provide evidence that plants enter anthesis earlier in the growing season and branching occurs post-anthesis.

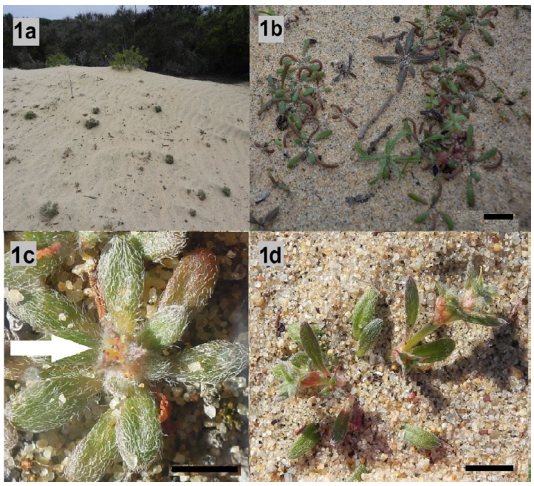

Figure 1. Habitat and flowers of *Chorizanthe orcuttiana*. (a). Habitat of *Chorizanthe orcuttiana*, *Mucronea californica* and *Camissoniopsis bistorta* in coastal sage scrub in San Diego County, California. (b). Young plants of *Chorizanthe orcuttiana*, *Mucronea californica* and *Camissoniopsis bistorta* growing intermixed in coastal sage scrub in San Diego County, California. Scale bar=0.5 cm (c). *Chorizanthe orcuttiana* flowers bundled in centre with light yellow tepals and pink anthers (shown with arrows). (d). Cymose inflorescence development in *Chorizanthe orcuttiana* with reddish involucral tubes and green teeth with hooked awns.

Scope of Study

In this study, we present the vegetative characters that can be utilized to distinguish *C. orcuttiana* from two co-occurring and similar looking species. We also describe the phenological development of *C. orcuttiana* throughout its relatively short growing season.

1. We provide data to assist scientists in reliably identifying the plants of *C. orcuttiana* in mixed populations, especially when plants are in the very early vegetative states, to conduct scientific studies with a higher degree of confidence.

2. This study provides information on the correct time of anthesis in *C. orcuttiana* to aid scientists in conducting pollination and reproductive biology studies.

Germination and Vegetative Growth

Chorizanthe orcuttiana can be observed above-ground in its natural habitat in mid to late January. However, it is challenging to distinguish it among several co-occurring plant species at this entirely vegetative life stage **(Figure 1b).** Until approximately early February, majority of the *C. orcuttiana* plants have a basal rosette of leaves that are light green in color and have soft white pubescence on them **(Figure 2a).** Entire rosettes are approximately between 0.5 and 5.0 cm in diameter. Two types of leaf shapes can be observed in different individuals of *C. orcuttiana* where one type is oblanceolate characterized by obtuse leaf apex with a reddish tinge on the upper surface of leaves **(Figure 2a)**, and the other is slightly elongated **(Figure 2b)** [6].

Similar to *C. orcuttiana,* the young vegetative plants of *M. californica* also have small basal rosettes of elongated leaves between mid-January to late-February. However, some *M. californica* plants show rounded leaf apices while others may have truncated leaf apices **(Figure 2c).** While the leaves of *C. orcuttiana* are sericeous and covered with dense white silky hairs, the leaf surface of *M. californica* is slightly papillate with few white papillate structures on the surface. Additionally, leaves of *M. californica* are ciliate with the presence of coarse hairs along the edges of leaves which can assist in distinguishing it from *C. orcuttiana* in the pre-anthesis growth stage **(Figure 2c).**

Simultaneously, *Camissoniopsis bistorta* is found in a wide range of plant sizes with a mean rosette size of approximately 2-3 cm. Individual plants of *C. bistorta* are slightly easier to distinguish from the other two species by virtue of their purplish-gray leaves with dense white coarse pubescence and purple undersides. Specifically, it can be distinguished from *C. orcuttiana* by the coarse pubescence, acute leaf apices, and apical leaf curving in comparison **(Figure 2d).**

Flowering, Inflorescence Development and Branching

C. orcuttiana flowers are at first tightly bundled in the center of the rosette and each individual flower is enclosed inside an involucre. Each flower is between 1.5 and 1.8 mm in diameter [1] (personal observation). Floral petals are light yellow in color with

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light green to off-white filaments that hold pink-red anthers **(Figure 1c).** The timing of anthesis i.e., maturation of anthers and full expansion of flower in *C. orcuttiana* has apparently been misconstrued and somewhat misreported in literature. 'Flowering' has been generally confused with post-anthesis inflorescence expansion and branching given that flowering is reported to occur between March and May when plants are in fact branched [1,4,10,11]. In contrast, we have documented the presence of clustered flowers within the rosettes of individual plants earlier in the growing season before plants start branching **(Figure 1c).** This phenological stage was observed in mid-February across three years from 2014-2016 as opposed to the branched morphology that occurs several weeks later. To substantiate the consistent occurrence of anthesis earlier than it has been previously reported, 15 plants of *C. orcuttiana* were selected haphazardly in mid-February in each year and anthesis was documented for each individual plant [1,4]. A *Fisher's Exact* Test was used to test the hypothesis of no difference in time of anthesis across the three years. The results (P>0.05) supported that anthesis occurred uniformly in February of each year.

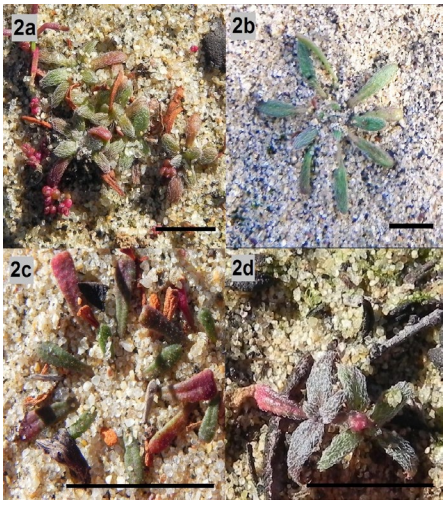

Figure 2. Morphology of plants in mid-February. (a). Oblanceolate sericeous leaves of *Chorizanthe orcuttiana* with soft white hairs. (b). Elongated sericeous leaves of *Chorizanthe orcuttiana* with soft white hairs. (c). Round apexed and truncate apexed leaves of *Mucronea californica* with slightly papillate leaf surface. (d). *Camissoniopsis bistorta* leaves with white coarse pubescence and acute apices. Scale bars=0.5 cm.

Within approximately 30 days of anthesis, plants of *C. orcuttiana* initiate branching, grow larger, and range between 1 and 17 cm in diameter. By this time in mid-March, the leaves may also appear slightly darker green in comparison to their lighter color in the earlier growth stages. At times, a purplish hue may be observed at the apices of leaves, however, this is not a consistent characteristic across all plants. Additionally, reddish-yellow stems are also visible. Inflorescences (i.e., clusters of involucres) can be observed at the nodes of expanding stems **(Figure 1d)** and also in the center of the rosette. Each inflorescence is cymose and is composed of small clusters of 2-3 involucres. Involucral tubes are more clearly visible and are reddish in color by this time while involucral teeth appear green **(Figure 1d).**

In comparison, plants of *M. californica* essentially remain vegetative at this time of the year although a few exhibit tightly closed buds in the center of the rosette. These plants also assume a slightly upright form **(Figure 3a)** by this time with inflorescence initials becoming visible at the center of the rosette. Conversely, yellow flowers appear on *C. bistorta* and its vegetative plants which are more numerous, have leaves appearing dark green with maroon margins and a reddish to whitish mid-rib **(Figure 3b).** Some younger plants of *C. bistorta*, however, may still exhibit the purplish to gray leaf color due to thick cover of white hairs as observed earlier in the season.

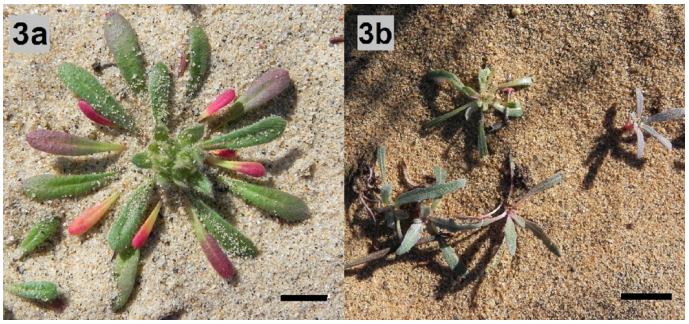

Figure 3. Morphology of plants in mid-March. (a). *Mucronea californica* with initiation of floral structures development. (b). *Camissoniopsis bistorta* with silvery-grey leaves on different individuals. Scale bars=0.5 cm

Maturation of Involucres

Within another 30 days, some flowers remain visible on plants of *C. orcuttiana* although a majority of the flowers fade by this time of the growing season. Maturing involucres can be observed on the fully expanded reddish-yellow stems **(Figure 4a).**

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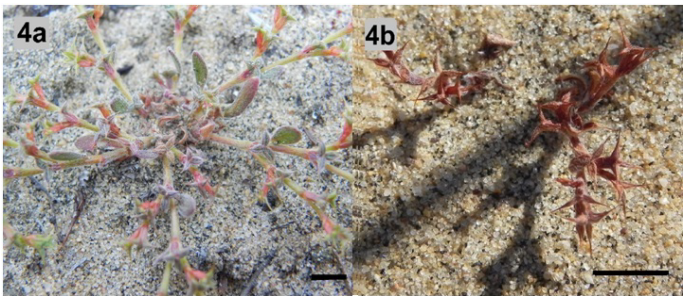

Figure 4. Morphology of plants in mid-April and mid-May. (a). *Chorizanthe orcuttiana in* mid-April with maturing involucres on reddish-yellow stems. (b). Dried *Chorizanthe orcuttiana* plants in mid-May with yellowish stems and reddish involucres.

Plant Senescence and Seed Dispersal

Within an additional 30 days and by mid-May, almost all of *C. orcuttiana* plants mature fully with tissues becoming dried although plants remain intact and rooted in place. Involucres assume a reddish color and stems a light yellow color by this stage of development of *C. orcuttiana* plants **(Figure 4b).** Senescence and fruit maturation continues in *C. orcuttiana* over the next 30-60 days. While many dried plants still remain visible, often with portions of stems missing and majority of the *C. orcuttiana* plants covered by sand by mid-July, the remaining plant structures disintegrate easily when touched slightly. It is possible that some whole involucres become 'planted' in place through this mechanism. Several stem pieces, broken off at nodes and with involucres remaining attached to them, could be located at a distance of approximately 30-40 cm from where the plants were clustered (personal observation). This indicates that the fruits may also be dispersed by wind. Additionally, the hooked spines of the involucres latch on to clothing, hair, and gear, indicating that seed dispersal may also occur when involucres become attached to animals that frequent the habitat.

Besides the several consistent features, we also discerned some atypical and previously unreported morphological features in each species through our observations. In *C. orcuttiana*, we observed a constriction giving rise to a spatulate structure at the distal end of leaf **(Figure 5a).** Leaves of *C. bistorta* also sometimes show a constriction with spatulate structure at the distal end, which is similar in appearance to the spatulate structure observed in *C. orcuttiana* **(Figure 5b).** However, in contrast to *C. orcuttiana*, this spatulate structure in *C. bistorta* is not hairy as the rest of the leaf.

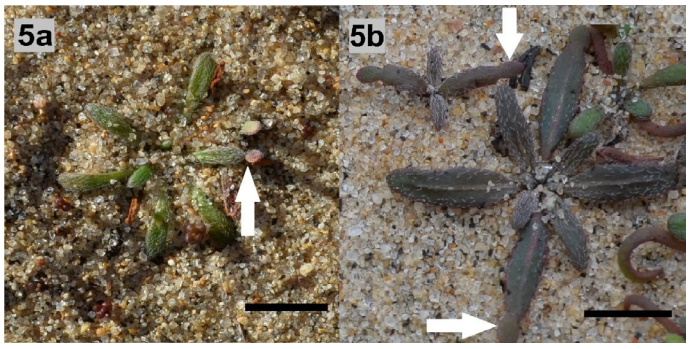

Figure 5. Irregular structures (shown with arrows) observed in *Chorizanthe orcuttiana* and *Camissoniopsis bistorta* (a). Presence of a spatulate structure at the leaf distal end of *Chorizanthe orcuttiana* which is consistently hairy as the rest of the leaf. (b). Presence of a hairless spatulate structure at the leaf distal end of *Camissoniopsis bistorta*. Scale bars=0.5 cm.

DISCUSSION

C. orcuttiana is potentially threatened with extinction due to the limited size of its populations, reduced and modified habitat, and the changing climate. However, its small stature and lack of immediate horticultural interest have resulted in a lack of scientifically generated biological and ecological information on the species. Additionally, it remains a possibility that individuals of *C. orcuttiana* are surviving in some remaining habitats but remain undiscovered. For instance, one of the previously known populations was presumed extinct and had not been observed since 1987 but plants were recently documented at the site in 2011 [8]. Regardless, the species remains one of the most restricted and imperiled plants within the California Floristic Province and on Earth.

We describe the morphology of *C. orcuttiana* and present its distinguishable features, especially in comparison to the co-occurring and closely-resembling species to enable researchers and conservationists to correctly identify these taxa, particularly in their early vegetative states. It is to be noted that our observations were consistent across three years between 2014 and 2016. Also, we carefully examined all available herbarium specimens from past years to strengthen our documentation.

Additionally, each involucre of *C. orcuttiana* has two bracts at the base of the involucral tube. One of these bracts is laminar, oblanceolate and awn-less while the other is greatly reduced, linear, acicular, terminated by straight short awn [6]. This feature is

not mentioned frequently in literature. It is possible that this character is absent in some of the extant populations or that this is not a uniform character for distinguishing the species. Regardless, this story presents the characteristics that can be utilized to distinguish *C. orcuttiana* from co-occurring species, and provides information on the anthesis period of *C. orcuttiana.*

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