I present archaeobotanical evidence for intensive and long-term harvesting of edible geophytes in the Brodiaea complex, most likely blue dicks (Dichelostemma capitatum), during multiple seasons on California's Santa Cruz Island. Ethnographic data indicate that Brodiaea corms were an important food source throughout prehistoric California, usually harvested in the late spring–early summer, after flowering. However, at least two ethnographic sources may suggest multiple seasons of harvest, an idea supported by careful examination of seasonal morphological changes in modern and ancient Brodiaea corms. Archaeobotanical identification of features associated with these morphological changes allows inferences about the specific seasons in which Brodiaea corms were harvested, a conclusion that has the potential to provide higher resolution seasonality data for geophyte remains recovered in western North America and other areas around the world.

Geophytes were an important food source around the world, particularly in Mediterranean climate zones (Anderson 2005; Deacon 1993; Deacon 1984; Ertu? 2000; Gott 1982; Kelly 1995; Klein 1975; Laden and Wrangham 2005; Marean 2010a; Opperman and Heydenrych 1990; Vincent 1985; Wohlgemuth 2010). Geophytic plants are characterized by an underground storage organ (incl. tubers, bulbs, corms, and rhizomes), from which the leaves and flowers originate perennially. Most geophytes are well adapted to Mediterranean climates, experiencing seasonal dormancy, where aboveground parts die back and the underground storage organ conserves nutrients until favorable environmental conditions return (Dafni et al. 1981; Rankärf 1934:65; Rundel 1996; Schlising and Chamberlain 2006; Vaughton and Ramsey 2001). Generally rich in carbohydrates and other nutrients, many geophytes provided foragers and farmers with a source of energy that complements diets where sources of whole proteins are regularly available from resources such as shellfish, fish, birds, and mammals (Erlandson 1988). In South Africa, Marean (2010a, 2010b) suggested that Middle Stone Age exploitation of shellfish and geophytes was significant in the development of anatomically modern humans, based on abundant ethnographic and archaeobotanical evidence for the use of Watsonia sp. corms, which are morphologically similar to Brodiaea, and other geophytes as far back as 22,000 years ago (Deacon and Deacon 1999; Deacon 1984; Klein 1975, 1977; Opperman and Heydenrych 1990; Parkington and Poppenpoel 1968;
Wadley 1993; Wells 1965). In Island Southeast Asia and Oceania, corms of the taro plant (Colocasia sp.) were a significant, carbohydrate-rich cultivar that was often consumed alongside protein-rich marine resources (Furey 2006; Greenwell 1947; Sand 1996).

In western North America, geophytes have long been recognized as important food sources, including camas (Camassia sp.) and wapato (Sagittaria sp.) in the Pacific Northwest, biscuit-root (Lomatium sp.) and yampah (Perideridia sp.) in the Great Basin, and species in the Brodiaea complex throughout western North America (Anderson 2005; Prouty 1995; Todt 1997). The Brodiaea complex is described by Fay and Chase (1996:446) as “perennial herbs, with a corm, having a tunic of parallel or reticulate fibers and lacking alliaceous [onionlike] chemistry.” A corm is technically an underground stem, resembling a bulb, but with a solid internal structure, rather than layers of fleshy scales like an onion. The Brodiaea complex currently includes three closely related genera described as “Brodiaea sensu lato” (s.l.) (Brodiaea spp., Dichelostemma spp., and Triteleia spp.), and four “satellite genera” (Androstephium spp., Bloomeria spp., Muilla spp., and Triteleiopsis spp.) found in western North America (Pires and Sytsma 2002:1342). These seven genera are morphologically similar with overlapping biogeographic ranges, but Dichelostemma capitatum has by far the widest distribution, from Oregon to Baja California, including all the islands off the coast of Alta and Baja California except for San Geronimo and Natividad, and from the Pacific Coast east to Utah and New Mexico (Junak et al. 1995:278; Keator 1968; Schlising and Chamberlain 2006).

As described here, corms in the Brodiaea complex (hereafter referred to simply as Brodiaea) undergo significant seasonal morphological changes, whereby a new corm replaces the old annually. These seasonal changes can be used to determine the season of harvest in carbonized archaeological specimens. Occurring largely in western North America, Brodiaea were an important food source, as they are high in carbohydrates and fiber, in addition to vitamins and minerals such as iron and manganese (Gilliland 1985; Martin and Popper 2001). Ethnographic literature suggests that most geophytes, including Brodiaea, were harvested during the spring or early summer (Anderson 1997:153; Prouty 1995:15–19; Timbrook 2007:75). However, archaeobotanical evidence from carbonized Brodiaea corms recovered from the Diablo
Valdez site (CA-SCRI-619/620) on Santa Cruz Island (Figure 1) suggests that ancient people also harvested them during the fall. In the sections that follow, I discuss ethnographic evidence of geophyte use and Brodiaea in particular, Brodiaea corm biology and seasonal morphological changes the plant undergoes during winter (Figure 2:A–D), spring (Figure 3), summer (Figure 4:A–C), and fall (Figure 5:A–C), and the paleobotanical remains from a nearly 6,000-year sequence at Diabolo Valdez (Figure 6:A–C; Tables 1–2).

**Brodiaea Complex**

The genera included in Brodiaea have a convoluted taxonomic history, having been variously classified within the Lily (Lilaceae), Onion (Aliaceae), and Amaryllis (Amaryllidaceae) families over the past century, and only recently classified within their own family, Themidaceae (Baldwin et al. 2012; Fay and Chase 1996; Hoover 1940; Keator 1968; Pires and Sytsma 2002; Preston 2006; Schlising and Chamberlain 2006). A closely related group of corm-producing geophytes in Themidaceae, the *Milla* complex, occur in Mexico and include four genera (*Dandya* sp., *Bessera* sp., *Milla* sp., and *Petronymphe* sp.; see Pires and Sytsma 2002). *Milla* corms are very similar to those of Brodiaea, separated largely by biogeographic distribution and corm coat characteristics. The corms of the *Milla* complex have “membranous tunics of minute parallel fibers” whereas Brodiaea corms have “fibrous-reticulate tunics” (Pires and Sytsma 2002:1353).

As botanists have debated taxonomic classifications through the years, genus and species names have changed numerous times. Heterotypic synonyms (year assigned in parentheses) for blue dicks (*Dichelostemma capitatum*) alone include *Hookera pulchella* (1808), *Brodiaea insularis* (1886), *Brodiaea capitata* var. *alba* (1891), *Dichelostemma insulare* (1907), *Dipterostemon insulare* (1912), *Brodiaea capitata* var. *insularis* (1918), and *Hookera pauciflora* (1925; see Gov-aerts 2011; Keator 1968). These variable names can make it difficult to determine which genus or species are being referenced in various ethnographic accounts. Here, I refer primarily to *Bro-
**Gill**] USING SEASONAL MORPHOLOGICAL CHANGES IN *BRODIAEA* Corms TO DETERMINE SEASON OF HARVEST 641

*Figure 3. Flower head cluster of *D. capitatum* at the end of a single flower stalk.*

diae, although the most likely candidate for the archaeobotanical corms recovered on the Channel Islands is the blue dick (*Dichelostemma capitatum*), based on modern distribution, abundance, and overall fecundity. Despite the significant impacts of historical overgrazing in the past, the flora of the northern Channel Islands has been steadily recovering since the removal of grazing animals in recent years. Blue dicks are now particularly abundant, found in a variety of soils and habitats, at all elevations, and on all eight of the Channel Islands (Gill 2013; Gill and Erlandson 2014; Junak et al. 1995). Archaeobotanical identification of carbonized *Brodiaea* corms to one

**Figure 4. A: Corm with fibrous outer coating; B: Corm with fibrous outer coating removed. Note the remnant withered corm and adventitious roots from the previous year attached at the base; and C: Base of corm with remnant old corm removed. Note the smooth sides around the base of the corm (June 6, 2013). Centinela, Santa Cruz Island, California.**
genus or another is difficult, however, as the taxonomic classifications used to differentiate genera by botanists are typically based largely on leaf and flower structure.

Ethnographic Use of Geophytes

Ethnographic information for the Santa Barbara Channel region and other areas of California, the Great Basin, and Columbia Plateau indicate that geophytes generally were harvested in the spring

Figure 5. A: Adventitious roots just beginning to emerge, exhibiting peaklike features around the basal margins; B: Emergence of adventitious roots at base and leaf shoot on top; and C: Adventitious roots continue to grow once fully emerged. Note that adventitious roots form around the basal margins of the corm only (September 26–30, 2013). Centinela, Santa Cruz Island, California.

Figure 6. A: Carbonized corms with no adventitious root growth (Locus 3, Stratum 2); B: Carbonized corms with emerging adventitious roots (Locus 2, Stratum 8, Roasting Pit Feature); and C: Carbonized corms with adventitious root scars (Locus 2, Stratum 8, Roasting Pit Feature).
Table 1. Radiocarbon Age Estimates and Adventitious Root Features on Archaeobotanical Corms from Diablo Valdez, Locus 2

| Stratum | Level (cm) | Feature       | D-AMS Lab # | \(^{14}\)C ± 1σ | Material | \(\delta^{13}\)C | \(^{14}\)C cal B.P. | Age Range (2σ) | Cultural Period | Adventitious Root Stage | Not Determined |
|---------|------------|---------------|-------------|----------------|----------|---------------|----------------|----------------|----------------|-----------------------|---------------|
|         |            |               |             |                |          |               |                |                |                | Present | Emerging | Absent |                               |
| 1       | 0-20       | —             | 3046        | 226 ± 24       | C        | -37.1        | 150–190 (p = .42) | Late            | 12 .39          |                         |               |
| 2E      | 20–23      | —             | 3976        | 421 ± 28       | A        | -24.0        | 335–350 (p = .05) | Late            | 7 .36           |                         |               |
| 2B-1    | 23–30      | Hearth clearing pit | 3972        | 3331 ± 34      | C        | -22.3        | 3470–3640 (p = .99) | Early          | 4 .10           |                         |               |
| 2F      | 23–40      | —             | 3047        | 4008 ± 29      | C        | -32.0        | 4420–4530 (p = 1) | Early           | 39 .93          |                         |               |
| 2H      | 44–56      | House floor   | 3048        | 4035 ± 31      | C        | -34.3        | 4420–4580 (p = .98) | Early          | 20 5.13          | 9 2.89               | 2 .72          | 313 11.51       |
| 3       | 48–87      | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 48 .169          |                         |               |
| 4       | 87–97      | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 1 .12           |                         |               |
| 5       | 97–112     | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 16 .38          |                         |               |
| 6       | 112–124    | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 5110–5130       |                         |               |
| 7       | 124–136    | Roasting pit  | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 5170–5280       |                         |               |
| 8A      | 136–152    | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 5170–5280       |                         |               |
| 8B      | 152–156    | —             | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 5170–5280       |                         |               |
| 9       | 156–167    | Roasting pit  | 3047        | 4157 ± 31      | C        | -27.4        | 4580–4770 (p = .80) | Early           | 5170–5280       |                         |               |
| 10A     | 167–180    | —             | 3974        | 4445 ± 23      | C        | -26.7        | 4960–5070 (p = .59) | Early           | 26 .166         |                         |               |

\(^{a}\)C = corm, A = manzanita pit (Arctostaphylos spp.)
\(^{b}\)Calibrated at 2σ with CALIB 7.0 (Stuiver and Reimer 1993)
Table 2. Radiocarbon Age Estimates and Adventitious Root Features on Archaeobotanical Corms from Diablo Valdez, Locus 3.

| Stratum | Level (cm) | Feature | D-AMS Lab # | $^{14}$C ± 1σ | Material* | $\delta^{13}$C | $^{14}$C cal B.P. Age Range (2σ)b | Cultural Period | Adventitious Root Stage |
|---------|------------|---------|--------------|---------------|-----------|-------------|--------------------------------|-----------------|------------------------|
| 1       | 10–20      | —       | 3978         | 623 ± 28      | C         | -13.2       | 550–615 (p = .60) 615–660 (p = .40) | Late            | Present — — — — — — 19 .71 |
| 1A      | 16–22      | —       | —            | —             | —         | —           | —                              | Late            | — — — — 3 2.29 36 2.82 |
| 2       | 20–40      | —       | 3973         | 2331 ± 22     | C         | -28.4       | 2330–2360 (p = 1)           | Middle          | 1 .01 1 .01 3 2.54 44 5.84 |
| 2A      | 30–50      | Hearth  | —            | —             | —         | —           | —                              | Early           | — — — — — — 6 .12 |
| 3       | 41–50      | —       | 3050         | 2464 ± 25     | C         | -27.2       | 2370–2410 (p = .10) 2430–2620 (p = .59) 2630–2710 (p = .31) | Early           | — — — — — — -2 .05 |
| 4       | 45–60      | Hearth  | —            | —             | —         | —           | —                              | Early           | — — — — — — 3 .15 |
| 5       | 60–69      | —       | 3975         | 2961 ± 21     | C         | -25.6       | 3060–3220 (p = .99) 3230–3240 (p = .01) | Early           | — — — — — — 29 1.06 |
| 6       | 63–71      | —       | —            | —             | —         | —           | —                              | Early           | — — — — — — 6 .1 |
| 7       | 71–85      | —       | —            | —             | —         | —           | —                              | Early           | — — — — — — 31 .52 |
| 8       | 85–105     | —       | 3051         | 3320 ± 29     | C         | -19.0       | 3470–3630 (p = 1)           | Early           | — — — — — — 19 .36 |
| 9       | 114–120    | —       | 3052         | 3875 ± 33     | C         | -28.2       | 4160–4170 (p = .01) 4180–4200 (p = .04) 4230–4420 (p = .95) | Early           | — — — — — — 5 .09 |
| 10A     | 105–114    | —       | —            | —             | —         | —           | —                              | Early           | 1 .01 — — — — 19 .6 |
| 10B     | 114–135    | —       | —            | —             | —         | —           | —                              | Early           | 3 .08 — — — — -26 .46 |
| 11      | 130–169    | —       | 3967         | 4919 ± 28     | M         | .9          | 4800–4980 (p = 1)           | Early           | 2 .03 — — — — 27 .54 |
| Total   | 8          | .14     | 1 .01        | 6             | 4.83      | 272         | 13.42                          |                 |                        |

*C = corm; M = mussel shell (Mytilus californianus)

b Calibrated at 2σ with CALIB 7.0 (Stuiver and Reimer 1993)
before, during, or after flowering, depending on the particular geophyte used (Anderson 1997:153; Anderson and Rowney 1999:233; Prouty 1995:15–19; Timbrook 1993:56, 2007:75). This is especially true of regions where non-corm producing geophytes were particularly important, such as camas, biscuitroot, and yampah. Some of these geophytes, such as biscuitroot and yampah, were available for only a few weeks in early spring, and others, such as camas, were harvested during flowering to avoid the poisonous death camas (Zigadenus sp.), which have bulbs similar to camas but have white rather than blue flowers (Prouty 1995). Spring harvests of geophytes in the Pacific Northwest, northern Great Basin, and Columbia Plateau were important for securing sufficient food reserves to last through the long winter months, and some estimates of dietary contribution suggest the spring geophyte harvest supplied nearly 50 percent of the annual caloric intake (Hunn 1990; Prouty 1995:22).

A folk term for geophytes common throughout western North America is “Indian potato” (Anderson and Rowney 1999; Todt 1997). According to Todt (1997:255), in the Klamath Basin the term “Indian potato” or “tule potato” refers to wapato, an aquatic plant that produces a perennial tuberous rhizome. Elsewhere, and throughout much of California, “Indian potato” often refers to the corms of species within Brodiaea (Todt 1997). Other common names for Brodiaea seen in the ethnographic literature include “cacomite,” “wild hyacinth,” and “grass-nut” (Anderson 1997:19; Timbrook 2007; Todt 1997). The term cacomite is often attributed to early Spanish explorers, although the term derives from a Nahuatl word (cacomitl), defined as “certain roots that have the flavor of chestnuts,” indicating the importance of a similar edible geophyte (likely Milla) in Central Mexico (Molina 1571:11).

Among Chumash informants of the Santa Barbara Channel region, the term cacomite was most commonly applied to blue dicks (D. capitatum), while other geophytic plants such as the mariposa lily (Calochortus sp.) were referred to as “another kind of cacomite” (Timbrook 2007:75). The Chumash used the term shiq’o’n to describe the plant “as having blue flowers and a root like garlic” (Timbrook 2007:75). Ethnographic accounts suggest the corms were dug using a digging stick weighted with a perforated stone, once the flowers had died back in late spring or early summer (Sutton 2014; Timbrook 2007). They could then be eaten raw, but were more commonly taken back to the village or temporary camp to be cooked in a roasting pit. Fernando Librado, a Chumash consultant to ethnographer John Harrington, indicated that shiq’o’n was particularly important on the islands, where several families were involved in harvesting and cooking large quantities in large roasting pits that often measured more than a meter across (Anderson 2005:295; Gill 2013; Hudson and Blackburn 1983:213; Timbrook 2007:75).

**Ethnographic Indicators for Season of Harvest**

Most California ethnographic accounts of the season of harvest for Brodiaea suggest a late spring–early summer harvest, usually in June, after flowering and going to seed (Anderson 1997:154; Anderson and Rowney 1999; Harrington 1930; Lawton et al. 1976; Timbrook 2007:75). In an article translating Karuk stories from the Klamath area, however, Harrington [1930:131] indicates another season of harvest for Brodiaea: ‘Atáytcükkinatc, a name given to the Cacomite, Brodiaea capitata Benth., when the top is only about 3” above the ground. The entire plant is gathered at this stage early in April and is baked in the ashes wrapped with Blue-bell or other leaves and is eaten by the hungry Indians. After the Cacomites pass this stage they are not molested until they get mature in midsummer, when they are called tayi-?. A swampy place where tayi-? is found is designated at either stage of growth by the special name ‘icrdvic.

Harrington’s description is consistent with other ethnographic references to a spring harvest, but he notes that cacomites are harvested again in midsummer after they “mature,” at which point they are given a different name. The assignment of two different names to the same plant in different seasons is intriguing, and this practice may have occurred elsewhere in California as well. The separate name (‘icrdvic) given specifically to “a swampy place where tayi-? is found” is also interesting. There may be several advantages to collecting corms in wet areas during any season.
As noted by early botanical research, the “ Corms growing near water as a rule produce more offsets than those in drier habitats” (Smith 1930:926), which would result in an overall higher abundance of corms in areas that are consistently subject to wetter conditions than others. Digging corms with a digging stick may also be easier in wet areas simply because wetter soils are easier to penetrate. This may be especially true of soils after they are subjected to the long, hot summers typical of Mediterranean climates (author’s personal observation).

As with the Karuk, it is possible that the Owens Valley Paiute also harvested Brodiaea in two separate seasons, providing a different name for each. On the basis of Steward’s (1930, 1933) ethnographic work and various early European accounts, Lawton et al. (1976) argued that two staple root crops, nahavita and tūpūsi1, were cultivated in the Owens Valley using ditch irrigation. As discussed by Lawton et al. (1976), botanical identifications of nahavita and tūpūsi1 have been wrought with confusion, as Steward originally described tūpūsi1 (harvested in the fall) as having a small “bulb” (likely Brodiaea capitata) and nahavita as “having a number of bulbs,” identifying it as spike rush (Eleocharis sp.) (Lawton et al. 1976:33; Steward 1933:245–247). On the basis of the fact that spike rush does not produce tubers or bulbs, and the assumption that wild-hyacinth (Brodiaea) is “not a fall plant,” Lawton et al. [1976:33] suggested that Steward’s identifications were wrong:

Such a description [for nahavita] appears better suited to the wild-hyacinth, or blue dicks. … This was the species Steward identified as tūpūsi1, sometimes called ‘grass-nuts’ or ‘nut-grass’ by laymen. … Wild-hyacinth blooms in the spring with violet flowers and probably would have been harvested in late May or early June. … Steward’s tūpūsi1 or taboose grass was also clearly misidentified, since his plant list showed it as gathered in the fall after the dams were destroyed. … Since wild-hyacinth (Steward’s tūpūsi1) is not a fall plant, it was necessary to reconsider this identification.

Lawton et al. (1976:33–36) provided a detailed analysis of the probable botanical identifications for nahavita and tūpūsi1 based on early European descriptions, ethnographic, and linguistic work, arguing that nahavita most likely refers to Brodiaea, harvested around June, and tūpūsi1 (harvested in the fall) most likely refers to yellow nut-grass (Cyperus esculentus), a member of the sedge family that produces small edible tubers. Although Lawton et al. were likely correct in identifying yellow nut-grass as an important food cultivated by the Owens Valley Paiute, and its connection to the term tūpūsi1, they acknowledged some ambiguity as several early accounts in addition to Steward’s clearly identified tūpūsi1 as Brodiaea. Kerr’s unpublished ethnobotanical notes from the 1930s, compiled by DeDecker in Lawton et al. (1976:34), identified “te-posie’ as tubers used for food” and “his notes on Owens Valley plant names also listed tupa si as the name for wild-hyacinth.” Furthermore, Fowler’s linguistic analysis of the term tūpūsi1 (personal communication in Lawton et al. 1976:34) suggests that tūpūsi1 is “really a ‘food name’ rather than a plant name… [and] the semantic focus among the Northern Paiute is on the product, rather than the plant.” If the term tūpūsi1 refers to any plant that produces a “tuber” or other edible geophyte, perhaps it is no mistake that Brodiaea was included in the early plant lists identified as tūpūsi1 and harvested in the fall along with yellow nut-grass.

Steward’s (1930:245–247) original description of tūpūsi1 “having a small bulb” and nahavita “having a number of bulbs” may reference two different plants (Brodiaea s.l. and C. esculentus) as suggested by Lawton et al. (1976). The descriptions may alternatively be applicable to the same plant (Brodiaea) in different seasons. As described in more detail below, the reference to nahavita’s numerous “bulbs” in the spring may refer to the numerous cormlets produced by parent corms of Brodiaea during the late winter–early spring months prior to flowering (Figure 2:C; Anderson and Rowney 1999:236). The cormlets and parent corms are just as numerous in midsummer–early fall, yet by this time the cormlets have grown in size and can be detached relatively easily from the parent corm through the process of digging, giving the appearance of a single “bulb” as described by Steward. Given the ambiguity over whether tūpūsi1 refers to a specific plant or the “product” of various geophytic
plants during the fall, it is conceivable that both
terms *nahavita* and *tupiisi* refer to *Brodiaea*
harvested in different seasons, similar to the Karuk
practice described by Harrington (1930).

**A Year in the Life of Brodiaea Corms**

The seasonal morphological characteristics de-
scribed below are all based on field observations
and growth experiments with blue dicks collected
on Santa Cruz Island between 2009 and 2014,
although they should be broadly applicable to all
species within the *Brodiaea* complex. Scientific
research on the life cycle of *Brodiaea* corms be-

Winter: December 21–March 20

Beginning in the early winter months and into
close spring, underground corms undergo signif-
cicant change. The parent corm begins to wither
from its base, using its reserved starches to de-
velop a new corm on top, giving the appearance
that the corm is dividing in two (Figure 2:A)
(Keator 1968; Rimbach 1902; Smith 1930). As
the growth of a new corm on top progresses, the
old corm becomes progressively more withered
as it transfers its energy to the new developing
corm (Figure 2:A–B). Eventually the old corm
withers entirely, including the remnant withered
adventitious roots, yet remains attached to the
new corm at its base (Figure 2:C, 4:B; see also
Schlising and Chamberlain 2006; Smith 1930).
As the “dividing” corm nears its final stages,
cormlets (also known as cormels or offsets) are
formed from axillary buds around the base of the
new corm (Figure 2:C; see Hoover 1940; Schlis-
ing and Chamberlain 2006:322; Smith 1930). The
number of cormlets produced generally depends
on the size of the mother corm (which increases
with age), sometimes numbering over 15 per plant
(Han et al. 1991; Keator 1968), and is genus de-
pendent, with *Dichelostemma* consistently pro-
ducing more than *Triteleia*, which usually produce
only one or two cormlets each year (Han 2001;
Schlising and Chamberlain 2006). Unless de-
tached via mechanical means such as digging,
the cormlets remain attached to the parent corm
and are protected by the fibrous outer coating
(Figure 4:A) until the following winter when the
parent corm divides again.

Cormlets formed during the previous year also
undergo significant change the winter after they
were first produced. Each cormlet develops a
contractile root (Figure 2:D), the primary function
of which is to pull the cormlet deeper into the
ground and away from the parent corm (Schlising
and Chamberlain 2006). Each small cormlet
shrinks in size, using most of its energy to produce
the large contractile root, measuring upward of
20 cm long and 3–4 mm wide (Keator 1968; Rim-
bach 1902; Smith 1930:921). Rather than tasting
starchy like the corm itself, the raw contractile
root is high in water content, slightly sweet, and
crunchy in texture (author’s personal observa-
tion). Once the cormlets have moved lower into the soil, the contractile root is resorbed, and the cormlet grows until it is large enough to flower, usually in the second year, dependent on favorable environmental conditions (Dafni et al. 1981). Contractile roots are produced by cormlets only in their first year, and never by a parent corm.

**Spring: March 21–June 21**

As the dividing corms reach their final stages, the plants begin to produce flower stalks. *Brodiaea* typically flowers in spring, between late March and late May or early June in the Santa Barbara Channel region (Junak et al. 1995). Each plant produces between one and five flower stalks, each as much as 50 cm tall and with a cluster of flowers at the end, usually ranging from blue to purple in color (Figure 3), although some species produce white (*T. hyacinthina*) or even red (*D. ida-maia*) flowers. The springtime flowering highlights the extraordinary abundance of blue dicks on the Channel Islands, turning large swaths of grasslands blue. After flowering, the dried flower stalks can remain upright in areas not subject to high winds or mechanical breakage, a reminder of their presence throughout the dry summer months.

During flowering and after going to seed, the surfaces of parent corms are smooth when the outer fibrous coating is removed (Figure 4:B–C). The previous year’s withered corm remains attached to the base of the parent corm (Figure 4:B) and is removed prior to consumption (Figure 4:C). Corms eaten during this time of year tend to be very starchy and stick to the teeth, even after roasting (author’s personal observation), and are a likely culprit behind high dental caries rates seen in island populations (Walker and Erlandson 1986). The apparent higher levels of carbohydrates in corms during this time of year, however, may have been important for island populations with access to abundant protein (i.e., shellfish, sea mammals, birds, fish), and future research into the seasonal changes of corm nutritional properties is warranted.

**Summer: June 22–September 22**

During summer, *Brodiaea* corms enter a dormant period, an adaptation to the seasonal drought conditions experienced in Mediterranean climates (Dafni et al. 1981; Schlising and Chamberlain 2006; Smith 1930). The flower stalks and leaves die back after the flowers have gone to seed, concentrating the plant’s energy into the underground corm. The dry summers of the Santa Barbara Channel region typically last from late June through late September, during which time there are no significant changes in corm morphology, with corms exhibiting smooth sides (Figure 4:B–C). During summer, plants may receive considerable moisture from fog drip, however, especially in upland areas.

**Fall: September 23–December 20**

The emergence from dormancy usually occurs during fall, when the corms begin to produce new leaf shoots and adventitious roots ahead of fall and winter rains (Schlising and Chamberlain 2006). These adventitious roots anchor the corm more securely in the ground and provide nutrients to the corm from the surrounding soil, allowing cormlets to grow larger as well. The timing of the emergence from dormancy in any given year may vary slightly between plant populations located in highland versus lowland settings on the Channel Islands, and possibly elsewhere in California as well. Highland locations on the islands are consistently subjected to greater amounts of precipitation than lower elevations (Fischer and Still 2007:7; Glassow et al. 2008), which may allow for higher overall corm productivity as well as emergence from dormancy slightly earlier in highland settings. Corms collected from the same highland location (Centinela, Santa Cruz Island; Figure 1) and same month in different years show that adventitious roots were fully formed on October 8, 2011, while they were just emerging on October 27, 2012. Newly emerging adventitious roots, which occur only around the basal margin of the corm, appear first as peaklike features (Figure 5:A–B) and continue to grow outward (Figure 5:C). Given the range in climatic fluctuations throughout the Holocene, the timing of adventitious root growth likely fluctuated through time, possibly ranging from September through November. Nevertheless, adventitious roots are formed after summer dormancy, and before division occurs in winter. On the basis of my field
observations, corms eaten during this period are noticeably less starchy and slightly sweeter than those eaten in spring or summer, as the stored starches in the corm are used for adventitious root growth.

Some botanical literature suggests a second dormancy period in *Brodiaea* during the winter months (Smith 1930:920). As with summer dormancy patterns, variation in timing and duration of winter dormancy may depend on regional environmental conditions. Santa Cruz Island rarely experiences freezing temperatures, which may reduce the advantage of a long winter dormancy in southern Alta and Baja California. Nevertheless, *Brodiaea* corms do not appear to experience much morphological change after the formation of adventitious roots, until January when the cycle begins again with the formation of replacement corm and cormlets.

**Discussion**

The annual life cycle of *Brodiaea* corms is important for understanding their potential as a food resource, determining season of harvest for archaeological specimens, and interpreting ethnographic descriptions of *Brodiaea* harvest. Although there are undoubtedly changes in nutritional properties of corms throughout various stages of its annual cycle, including variation in starches, the corms, cormlets, and contractile roots are potentially edible year round. The corm is technically edible at any stage of development, although the withering old corm is slightly tough when forming the new corm on top in the winter. Geophytes in other regions of the world were similarly available in more than one season, although other resources were targeted at certain times of the year. For instance, the Hadza in northern Tanzania regarded “roots [as] available and edible throughout the year, although they are mainly eaten during the main rains and again during the late dry” seasons (Vincent 1985:135).

Anderson and Rowney (1999) conducted experiments on blue dicks over a three-year period, investigating the sustainability of various harvesting regimes, ranging from 50 percent to 100 percent harvest, and replanting or not replanting cormlets. They found that blue dicks are highly resilient, with no significant difference between plots harvested at 50 percent versus 100 percent when the cormlets were replanted (Anderson and Rowney 1999:238). These harvesting experiments were conducted after the flowering and seed stages, as has been most commonly recorded ethnographically. However, on the basis of the life cycle of corms, harvesting in other seasons is not only feasible but also should have no adverse effect on overall plant population compared with harvesting only once after seeding. A possible exception might be harvesting contractile roots in the winter. Overharvesting contractile roots could diminish the cormlet population, and therefore the overall long-term plant population.

**Storage Potential of Brodiaea Corms**

Seasonality may be inferred from other types of archaeobotanical remains, but the problem of storage complicates the determination of the season a site was occupied. Small seeds collected during the spring or summer are often stored for long periods of time, especially through the winter, making it difficult to assign occupation of a site to a particular season (Anderson 2005; Timbrook 2007). Geophytes may also be stored once harvested, but they are often baked, roasted, or dried prior to storage (Anderson 2005:295–296; Prouty 1995). Ethnographic information from the Chumash area, and the islands in particular, describing roasting large quantities of *Brodiaea* corms in roasting pits may indicate preparation for storage after cooking. Fernando Librado reported to Harrington that “the cacomite ... they roast in pits, then take it out and spread it to dry, and then when dry, one or two days later, they take it and gather it and put it in a dish and rub it between their hands and then winnow it in an abalone a little at a time” (Hudson and Blackburn 1983:213). Cooking the corms prior to storage effectively kills them, inhibiting further growth (i.e. adventitious root formation). Without cooking, drying blue dick corms is difficult as they are particularly well adapted to surviving dry conditions (author’s personal observation).

Carbonized archaeobotanical corms with morphological features that occur only in the fall, therefore, suggest one of two scenarios, if corms were stored at all. First, although not consistent with the ethnographic description provided above, it is possible that *Brodiaea* corms were harvested
only in the spring and stored long term in an uncooked, undried state, with adventitious root formation occurring during the fall regardless of storage conditions. In this case, adventitious root growth identified on archaeobotanical corms would only indicate the use of stored corms during the fall, rather than the harvest itself. Alternatively, Brodiaea corms were harvested, roasted, and prepared for storage as described by Librado above, without storing uncooked corms. In this case, adventitious root features on archaeobotanical corms would directly indicate a fall harvest. Archaeologically, adventitious roots formed below ground versus those formed on corms stored in an uncooked state cannot be distinguished. Nonetheless, adventitious roots on archaeobotanical corms indicate the use of Brodiaea during the fall.

Archaeological Evidence of Brodiaea Use in the Santa Barbara Channel Region

Although limited paleobotanical work has been conducted in the Santa Barbara Channel area, the carbonized remains of Brodiaea have been identified on two of the northern Channel Islands (Gill 2013). Carbonized corm fragments identified in multiple strata of a trans-Holocene sequence at Daisy Cave (CA-SMI-261) on San Miguel Island, point to the importance of Brodiaea on the islands for the last 10,000 years (Reddy and Erlandson 2012). Martin and Popper (2001) also reported carbonized corms from Middle, Transitional, and Late Period deposits on Santa Cruz Island. The Diablo Valdez site (CA-SCRI-619/620), however, located in the highlands on the north side of Santa Cruz Island (Figure 1), has produced more carbonized corms than anywhere yet reported for southern California. These corms occur in nearly every stratum at two loci with occupations from 5700 cal B.P. through the historic period (A.D. 1782–1822; see Gill 2013).

Diablo Valdez is a large residential site associated with bedrock outcrops that include a rock shelter and bedrock mortars, surrounded by open grasslands and deep, densely wooded and well-watered canyons containing abundant oaks (Quercus spp.), cherry trees (Prunus sp.), and other plants. Situated at ~500 m asl adjacent to a perennial stream northwest of Diablo Peak, the site contains three loci with six bedrock mortars, a dense shell midden extending to 214 cm below surface, and five house depressions, with chipped stone debitage, projectile points, mortar fragments, donut stone fragments (digging stick weights), and shell beads noted on the surface. Excavations during the summer of 2011 revealed numerous domestic features, including hearths, areas of burned earth, postholes, several possible living surfaces, and multiple hearth-clearing pit features (Gill 2013). Two probable roasting pit features were identified, similar to those described by Fernando Librado for roasting cacomites on the islands (Timbrook 2007). Whole and fragmentary carbonized Brodiaea corms have been identified from nearly every stratum at both loci. Despite the prevalence of fish, sea mammal, bird, and shellfish remains, geophytes were clearly an important resource as well. The abundance of carbonized corms may also help explain the site’s location away from the coast, particularly if geophytes were more productive in highland areas receiving more summer fog precipitation than lowland coastal plains. While people occupied Diablo Valdez from 5700 cal B.P. through the Historic Period, radiocarbon dating shows that use of the site was most intensive between 5,000 and 2,000 years ago, with the two roasting pit features dating between 4770 and 4420 cal B.P. (Table 1). A roasting pit feature excavated at Locus 2, identified as Stratum 7 (~124–136 cm below surface), was most clearly defined. It measures over a meter across and consists of a shallow basin containing large burned rocks, a thin layer of charcoal at the base and between the rocks, with mottled ashy deposits throughout. Paleobotanical analysis of this feature is consistent with geophyte roasting pit features described elsewhere (Cheatham 1988; Peacock 2009), with abundant wood charcoal, few small seeds, and hundreds of whole and fragmentary carbonized corms.

Determining Seasonality of Carbonized Corms

Because the old corm is replaced every winter, the morphological characteristics described for each season are replaced annually as well. Thus, identifying adventitious roots or root scars on carbonized corms indicate a fall use, whereas smooth corms with no signs of such features must have been harvested after flowering in the late spring–early summer, but prior to adventitious
root formation in the fall.

The excellent preservation of a large quantity of whole, carbonized Brodiaea corms at Diablo Valdez provides an opportunity to investigate the season of harvest based on corm morphology. Overall, identification of the presence or absence of adventitious root growth was conducted conservatively. As a result, most carbonized corms cannot be conclusively assigned to one category or another. The positive identification of adventitious root scars and emerging roots is considerably easier than identifying their absence, particularly on small fragments. In addition, Early Period deposits comprise the majority of deposition at both loci, so the sample size of carbonized corms with identifiable features from this period is larger as well. Nevertheless, the archaeobotanical corms from Diablo Valdez indicate they were harvested before, during, and after the formation of adventitious roots, with raw counts and weights provided for each stratum and locus (Tables 1-2).

Figure 6 illustrates two different archaeobotanical corms that exhibit each stage of adventitious root formation, with the base of each corm shown. Smooth archaeobotanical corms indicate harvest after flowering but before adventitious root formation in fall (Figure 6:A). This corroborates ethnographic accounts that blue dick harvest took place in June, but it is also possible that they were harvested at any point during the summer dormant period. Corms with prominent peaklike features in a regular pattern around the basal margins indicate harvest at a time just as the adventitious roots were emerging, likely between September and October (Figure 6:B). These features must not be confused with surficial "bubbling" that sometimes occurs during carbonization, where the entire surface of the corm may be distorted by small, irregular bubbling. Corms with adventitious root scars, characterized by nearly circular holes in a regular pattern around the basal margin, indicate harvest after the adventitious roots are fully formed in the fall, but before the corm divides in the winter (Figure 6:C).

Raw counts and weights of carbonized corms and corm fragments from Unit 2 excavations are presented for locus 2 (Table 1) and locus 3 (Table 2). At each locus, Unit 2 was a .5X1-m unit excavated stratigraphically with sediments field screened over .32 cm mesh. All screen residuals were bagged, washed, and sorted in the laboratory. Corms and corm fragments recovered from Unit 1 (excavated primarily in arbitrary levels) and column samples are not presented here, as the Unit 2 data have the best stratigraphic control and abundance of whole or nearly whole corms. The proportion of corms and corm fragments assigned to one of the three stages of adventitious root formation is relatively low compared to the overall assemblage, largely because of preservation issues and the conservative approach taken in identifying these features. In many cases, however, adventitious root features were confidently identified on small fragments of carbonized corms, when the basal portion of the corm is recovered.

At Diablo Valdez, Brodiaea corms appear to have been harvested and/or used during various points throughout the year, including fall, rather than in a single late spring–early summer harvest. The largest sample of corms with adventitious root scars present, emerging, and absent occur in the well-preserved roasting pit feature (Stratum 7), indicating apparent reuse of the same feature over multiple seasons. These data also support botanical and ecological data that suggest blue dicks and other corms may have been an abundant and important food resource available on California’s Channel Islands during multiple seasons of the year.

Summary and Conclusions

I have shown that Brodiaea corms undergo seasonal morphological changes annually and that such changes can be identified archaeologically. The presence of adventitious roots on carbonized corms from Diablo Valdez is significant, demonstrating that corms were harvested during more than one season of an annual cycle. Although most ethnographic accounts suggest that harvest of Brodiaea was primarily a late spring–early summertime endeavor, the archaeological data presented here indicate harvest during the fall as well. Given the scant ethnographic data available supporting multiple seasons of harvest elsewhere in California, it is possible that more instances of a fall harvest for Brodiaea corms were recorded ethnographically, yet have not been recognized because archaeologists and ethnobotanists were
largely unaware of the specifics of corm biology when the aboveground plant parts are not visible. Knowing that the Karuk assigned two different names for the same plant harvested in different seasons, as recorded by Harrington (1930), further complicates potential inference from ethnobotanical literature, although more work in this area may be warranted.

There are still many unknown aspects of Brodiaea biology and phylogeny, but the seasonal morphological changes these corms undergo annually are clear. Edible corms occur worldwide—from Watsonia sp. in South Africa, Crocus sp. throughout Eurasia, and tara in Southeast Asia and Oceania—and may experience similar seasonal changes that can be identified archaeologically. Archaeobotanical corms, when well-preserved and recovered in sufficient quantities, may be excellent indicators of seasonality that have gone largely unrecognized. Given the growing evidence that geophytes and other plant foods were important in human diets around the world, a better understanding of seasonal morphological changes typical of various genera may provide valuable data on the ecology of our hominin ancestors and the seasonality of their occupations at specific sites.

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