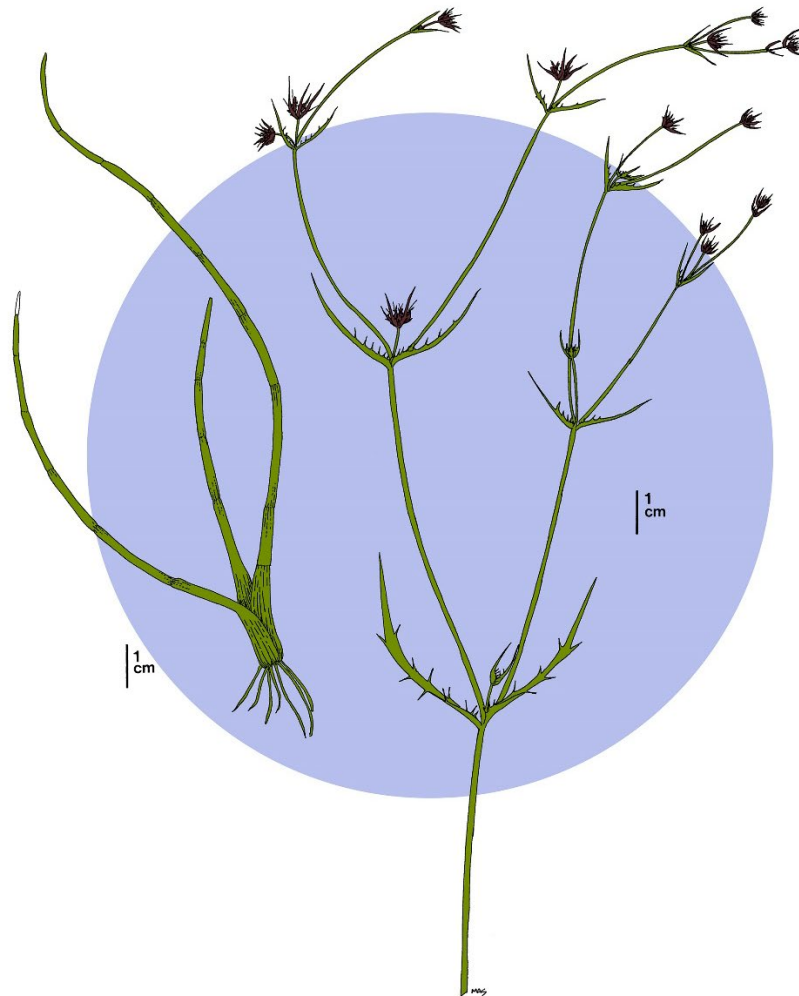


LOCH LOMOND ECOLOGICAL RESERVE ENDANGERED PLANT MONITORING PROTOCOL, 2015–2023 RESULTS, AND DISCUSSION



PREPARED BY THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
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INTRODUCTION

The California Department of Fish and Wildlife (CDFW) Loch Lomond Vernal Pool Ecological Reserve (Reserve) is in southern Lake County, California (Figure 1). The Reserve is in a large basin in the Mayacamas Mountains at an elevation of 854 m (2,800 ft) and is approximately 4.8 ha (12 ac). The Reserve was established by the Fish and Game Commission in 1993 to protect vernal pool habitat for three rare plant species: Loch Lomond button-celery (*Eryngium constancei*; state and federally endangered), few-flowered navarretia (*Navarretia leucocephala* subsp. *pauciflora*; state threatened and federally endangered), and many-flowered navarretia (*Navarretia leucocephala* subsp. *plieantha*; state and federally endangered). Other vernal pool endemic plant species that occur at the Reserve include rayless goldfields (*Lasthenia glaberrima*), toothed downingia (*Downingia cuspidata*), two-horned downingia (*Downingia bicornuta*), tricolor monkeyflower (*Diplacus tricolor*), and annual hair grass (*Deschampsia danthonioides*). Invasive pennyroyal (*Mentha pulegium*) is also present at the Reserve and is encroaching into the vernal pool.

The Loch Lomond vernal pool is a volcanic ash flow vernal pool (Keeler-Wolf et al. 1998; USFWS 2005; CNDDDB 2024), and the underlying substrate is composed of an impervious bedrock layer of volcanic origin (USFWS 2005). The vernal pool occupies a large portion of the Reserve, and direct precipitation is a major source of water for the vernal pool (Eakins 1994). Runoff from the adjacent uplands also contributes water to the vernal pool but has been reduced by two manmade features: (1) a dirt road on the north end of the property that redirects runoff towards Cole Creek to the north of the vernal pool, and (2) a drainage ditch immediately east of the vernal pool and parallel to Highway 175 that is maintained by the California Department of Transportation (Eakins 1994). The vernal pool is surrounded by mixed coniferous forest that is dominated by pacific Ponderosa pine (*Pinus ponderosa* var. *pacifica*), Douglas fir (*Pseudotsuga menziesii* var. *menziesii*), and California black oak (*Quercus kelloggii*), with an understory of manzanita (*Arctostaphylos* spp.) and deer brush (*Ceanothus integerrimus* var. *macrothyrsus*).

The Reserve was previously part of a mountain resort and was used primarily during the warm season for recreational activities such as softball, cycling, and horseback riding. At this time it was not protected by a fence and was vulnerable to off-road vehicle use, which left scars and ruts in the vernal pool (Eakins 1994). The Reserve is now protected by a wooden post and rail fence around the perimeter to limit access.

This monitoring plan should be implemented by CDFW staff at the Reserve. The purpose of the monitoring plan is to monitor the status of the Loch Lomond

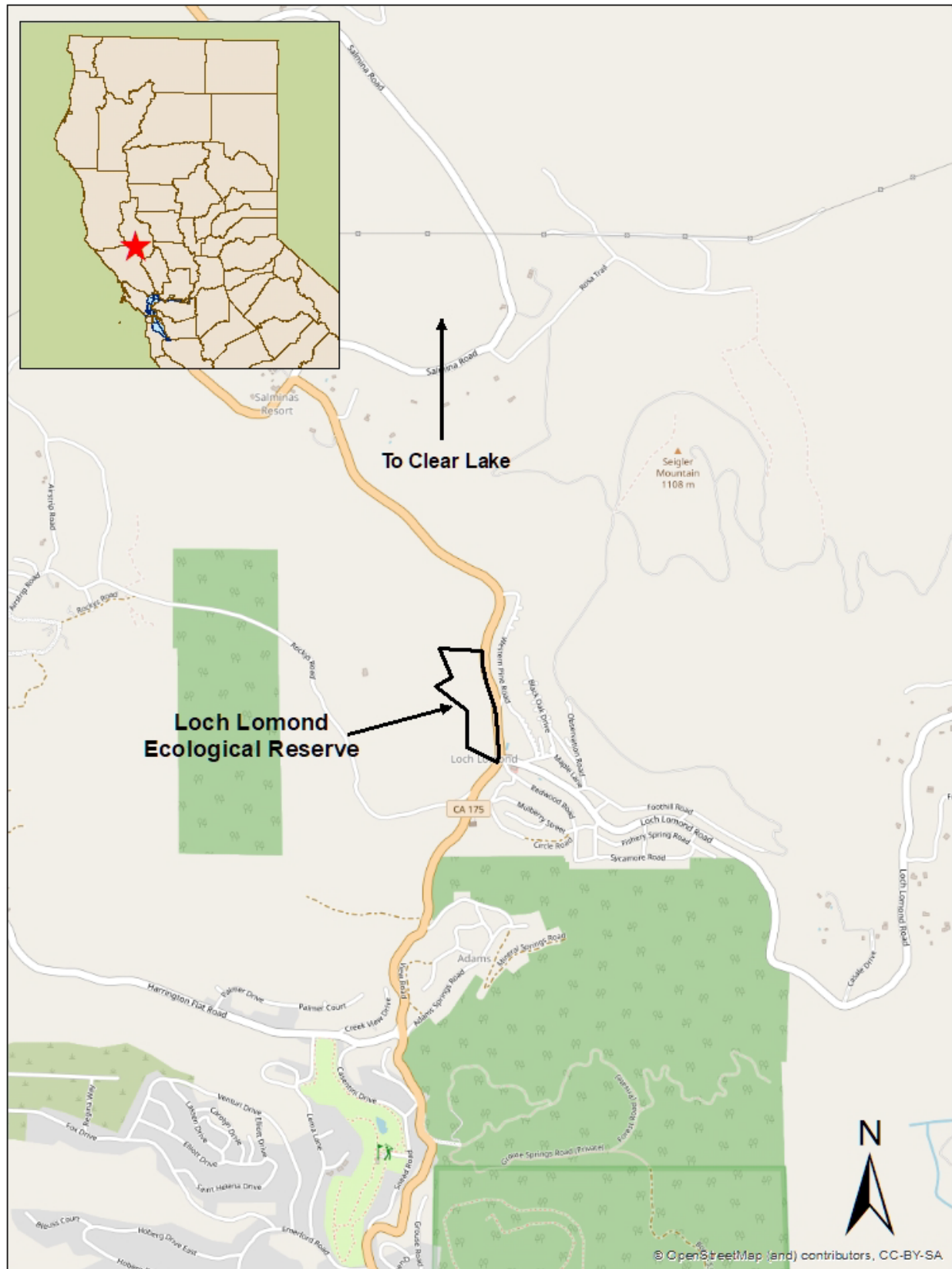


Figure 1. Loch Lomond Ecological Reserve Vicinity Map.

button-celery, many-flowered navarretia, and few-flowered navarretia populations at the Reserve, and to identify and alleviate threats, such as the encroachment of invasive species (e.g., pennyroyal) or from other factors such as breaches in the fencing. This work is important because alleviating threats early can prevent them from becoming prohibitively expensive to address later. The monitoring plan provides background information on the monitoring approach; detailed instructions on how to collect both qualitative and quantitative data on populations of Loch Lomond button-celery, many-flowered navarretia, few-flowered navarretia, pennyroyal, and other plant species; and management implications of potential results. The Monitoring Plan is intended to provide a foundation for adaptive management of the endangered plants at the Reserve, but it is not intended to be so rigid as to preclude adaptive management and flexibility in the future. The monitoring consists of three parts:

1. Spring/summer nested frequency monitoring of plants in the vernal pool on the Reserve;
2. Photomonitoring of the Reserve; and
3. Regular inspection of the post and rail fence surrounding the pool.

In developing this monitoring plan, we also conducted a hand weeding experiment from 2021 to 2023, where pennyroyal was manually removed from six experimental plots that also contained Loch Lomond button-celery. Percent cover of pennyroyal and Loch Lomond button-celery was estimated before and after treatment to assess the effectiveness of hand weeding as a management tool.

SPECIES DESCRIPTIONS

LOCH LOMOND BUTTON-CELERY

Loch Lomond button-celery is a perennial herb in the carrot family (Apiaceae) that only grows in vernal pools. The plants are covered in downy hairs and have slender, loosely branched stems 20–30 cm (7.9–11.8 in) tall that are decumbent to ascending (Sheikh 1983; Preston et al. 2023). There is little known about the reproductive ecology or life history of Loch Lomond button celery. However, certain features are common to species in the genus *Eryngium*, and its life history is presumably similar to that of other *Eryngium* species that occur in vernal pools, such as Vasey's coyote-thistle (*Eryngium vaseyi*) and Great Valley coyote-thistle (*Eryngium castrense*). Seeds likely germinate after the onset of winter rains, and the plants produce hollow, linear, tubular leaves either from germinating seeds or from a perennial rootstock in the late winter or early spring, when the pools are inundated with water (Sheikh 1978; Witham 2006). The hollow leaves stick up out of the water when the pools are full and transport air to the plants' roots (Witham 2006; Jepson Prairie Docent Program 2012). As the water in the vernal

pools evaporates in the spring and summer, the plants produce solid, broad, spiny terrestrial leaves (USFWS 2005; Witham 2006; Jepson Prairie Docent Program 2012).

Loch Lomond button-celery typically flowers from April to July (Preston et al. 2023) after the water has evaporated from the pools, and produces flower heads containing 5–7 tiny flowers with white to purple petals that are approximately 1 mm (0.04 in) long (Keeler-Wolf et al. 1998; USFWS 2009a, 2023b). The fruits are ovoid, and 1.6–2.2 mm long (Sheikh 1983), consist of a pair of one-seeded segments (Sheikh 1978), and typically develop July to August (USFWS 2005). There is no available information on pollinators or seed dispersal agents for Loch Lomond button-celery (USFWS 2005), but Sheikh (1978) reports that the seeds of *Eryngium* spp. are shed by mid-November, and their dispersal is assisted by the action of animals, wind, and flowing water.

The California Natural Diversity Database (CNDDDB) lists four occurrences of Loch Lomond button-celery. Three of these occurrences are in Lake County, and one occurrence is in Sonoma County (CNDDDB 2024). The population at the Reserve is the only occurrence on protected land (USFWS 2009a; CNDDDB 2024). Even though this population is protected, it is still threatened by invasion of non-native plant species, changes in hydrology, routine highway maintenance, trash dumping, vehicle trespass, and trampling (USFWS 2023b; CNDDDB 2024). Potential threats to the other populations include agricultural conversion, development, trash dumping, erosion, and changes in hydrology from road runoff, drainage ditches, culverts, and larger-scale alterations from commercial development or timber harvesting (USFWS 2009a; CNDDDB 2024).

FEW-FLOWERED NAVARRETIA

Few-flowered navarretia is a low-growing annual herb in the phlox family (Polemoniaceae) that grows to 1–4 cm (0.4–1.6 in) tall and is twice as wide due to branches originating near the base of the stem (USFWS 2008; USFWS 2023a). Few-flowered navarretia forms low mats and produces small pale blue or white flowers in heads that typically appear from May to June (Johnson 2013c). Each flower head is approximately 4–10 mm (0.16–0.39 in) wide and generally contains 2–20 flowers (USFWS 2005; Johnson 2013b, c). The fruit of few-flowered navarretia is a papery capsule that contains one or two reddish-brown seeds that stick together until water washes them apart (Day 1993). Little is known about the life history and demography of few-flowered navarretia, but like many vernal pool annuals, the seeds germinate underwater (Crampton 1954) and plants flower after the pools dry (Day 1993). Seeds do not disperse far from the parent plant because they have a gelatinous coating and stick together when the fruit ruptures (Crampton 1954; Day 1993; Johnson 2013a). The flowers are likely insect-pollinated, and honeybees (Apidae) have been observed visiting the closely related subspecies, many-flowered navarretia, described

below (CDFW observation). In addition, species of *Navarretia* with similar flowers that occur outside of vernal pools are pollinated by a variety of bees and bee flies (family Bombyliidae) (Grant and Grant 1965).

Few-flowered *navarretia* is dependent upon vernal pools for survival and its life history is closely linked to vernal pool hydrology (USFWS 2008, 2023a). This species is found only in vernal pools with volcanic substrate, specifically Northern Basalt Flow and Northern Volcanic Ashflow Vernal Pools (USFWS 2008). It is only found in Lake and Napa counties in the Lake-Napa Vernal Pool Region (USFWS 2005). Population sizes fluctuate widely among years (CNDDDB 2024), as is typical of annual plant species.

The CNDDDB reports ten occurrences of few-flowered *navarretia* (CNDDDB 2024). One occurrence in Napa County is protected by a conservation easement, and the occurrence at the Reserve is also protected. The other eight reported occurrences are on privately-owned land, or the landowners and precise locations are unknown, and the populations are assumed to be unprotected from development. Few-flowered *navarretia* populations are also threatened by alterations in hydrology, effects from road maintenance activities, agricultural land conversion, off-road vehicle use, grazing, feral pigs, recreational use, road/trail construction and maintenance, competition from invasive plant species, climate change, having few occurrences, and risk of localized stochastic (chance) extirpations (USFWS 2008, 2023a; CNDDDB 2024). Even though the population at the Reserve is protected, it is still threatened by invasion of non-native plant species, routine highway maintenance, trash dumping, vehicle trespass, and trampling (CNDDDB 2024).

MANY-FLOWERED NAVARRETIA

Many-flowered *navarretia* is closely related to few-flowered *navarretia*, described above. It forms mats 5–20 cm (2.0–7.9 in) across and 1–3 cm (0.4–1.2 in) high (USFWS 2005). Many-flowered *navarretia* typically has twice as many flowers per head as few-flowered *navarretia* and has more highly branched outer bracts subtending the flower heads (USFWS 2023c). Flower heads are approximately 1.5–2.0 cm (0.6–0.8 in) across and contain between 10 and 60 small pale blue flowers (Johnson 2013d; USFWS 2023c). Similar to few-flowered *navarretia*, the fruit of many-flowered *navarretia* is a papery capsule that breaks open only when wet, but contains as many as three seeds (USFWS 2023c).

The life history of many-flowered *navarretia* is likely similar to that of few-flowered *navarretia*, although neither subspecies has been studied intensively. Many-flowered *navarretia* is found only on substrates of volcanic origin and is dependent on vernal pools, vernal lakes, and swales for survival, and its life history is closely linked to the hydrology of these wetlands (USFWS 2009b, 2023c).

The CNDDDB reports eight occurrences of many-flowered navarretia (CNDDDB 2024). Two occurrences are located in Sonoma County, and the remaining occurrences are reported from Lake County. Only two occurrences, including the occurrence at the Reserve, are protected within reserves (USFWS 2023c; CNDDDB 2024). Threats to many-flowered navarretia include alterations in hydrology, competition from invasive plant species, grazing, foot traffic/trampling, residential development, erosion, off-road vehicle use, road/trail construction and maintenance, and climate change (USFWS 2023c; CNDDDB 2024). Threats to many-flowered navarretia at the Reserve include invasion of non-native plant species, routine highway maintenance, trash dumping, vehicle trespass, and trampling (CNDDDB 2024).

Some populations of *Navarretia* consist of individuals with characteristics that are intermediate between many-flowered and few-flowered navarretia and cannot be assigned definitively to either subspecies (Day 1997; USFWS 2023c). The *Navarretia* plants at the Reserve appear to be intermediates between these two subspecies, exhibiting characteristics of both taxa (Day 1997). Specimens keyed by department staff more closely resembled many-flowered navarretia based on the branching pattern of the bracts subtending the flower heads, but the same specimens also exhibited characteristics of few-flowered navarretia. Therefore, based on our observations and previous observations by Day (1997) we consider the plants at the Reserve as intermediates between many-flowered and few-flowered navarretia and do not discern between the two subspecies in this protocol and discussion. Both subspecies are collectively referred to as “navarretia” for the remainder of this report.

PENNYROYAL

Pennyroyal is a low-growing spreading to slender, upright perennial plant in the mint family (Lamiaceae) that grows approximately 10–90 cm (4–35 in) tall (Warner 2000; Tucker 2012). The plant has a powerful and pungent minty odor and is toxic to humans and livestock when ingested (Warner 2000; Tucker 2012). Pennyroyal flowers in July through October, and the flowers are lavender to violet and are clustered in dense whorls (circles) encircling the stems at the upper nodes (Warner 2000; Tucker 2012). The stems are covered in short hairs, are often branched, and are usually square in cross-section. The leaves are opposite, gray-green, and ovate to elliptic or oblong with rounded tips, and are approximately 1–3 cm (0.4–1.2 in) long and 0.5–2 cm (0.2–0.8 in) wide with smooth or finely serrated margins (Warner 2000; DiTomaso and Healy 2007). Fruits consist of four nutlets, each containing one small brown seed, that are enclosed by the sepals, which are fused together to form a tubular bell-shaped calyx (collective term for sepals) (Warner 2000; DiTomaso and Healy 2007).

Pennyroyal reproduces by seed and vegetatively from rhizomes (elongate, horizontal, underground stems) or stolons (thin, elongate stems lying flat on the

ground) (Warner 2000; DiTomaso and Healy 2007). The plants usually die back in the fall and resprout from rhizomes in the spring. Seeds and vegetative material are dispersed by water and/or animals, contributing to its successful spread and establishment on the landscape (Warner 2000). The calyx, which contains the nutlets, is covered in short hairs, making it well adapted to dispersal by sticking to animal fur or wool (Warner 2000).

Pennyroyal is native to Europe (DiTomaso and Healy 2007; Tucker 2012) and is considered a moderately invasive weed by the California Invasive Plant Council, but its ecological impacts are not well documented (Warner 2000). It grows in pastures, roadsides and various disturbed sites, and is also invading wetland habitats including seeps, vernal pools and swales, marshes, ditches, and stream edges (Warner 2000; DiTomaso and Healy 2007), and is abundant in the vernal pool and wetland areas at the Reserve.

THREE-PART MONITORING PROTOCOL

This protocol should be implemented by CDFW staff at the Reserve to facilitate the adaptive management of Loch Lomond button-celery and navarretia. The monitoring should be conducted when Loch Lomond button-celery, navarretia, and pennyroyal are evident and easily identifiable and after the vernal pool dries, likely in late June or early July. The monitoring protocol can be completed by three people in one field day, and consists of the following three components:

1. Monitoring frequency of Loch Lomond button-celery, pennyroyal, and navarretia within Macroplot A using systematic random sampling.
2. Taking photographs at specific locations.
3. Regular inspection of the post and rail fence surrounding the pool.

BEFORE GOING INTO THE FIELD

Reserve a date in June or July to conduct the monitoring. The date should be chosen based on the precipitation and weather conditions for the year. For example, in a dryer than normal year, the monitoring should be scheduled earlier in the season, such as mid-June. In wetter years, the monitoring can be scheduled later in the season, such as in late June to early July.

Three people should plan to do the monitoring, and it should only take one day to complete. At least one of the monitors should be able to positively identify the species being monitored, and all monitors should familiarize themselves with the species being monitored, the Reserve, this monitoring protocol, and the data that has been previously collected.

Before going into the field, read this protocol, print out the nested frequency datasheet and the photomonitoring log, identify quadrats to sample using

systematic random sampling, and fill in the appropriate quadrat locations on the nested frequency data sheets (see Appendix A). When Macroplot A was set up in 2015 the short edges (north and south edges) were divided into 13 segments (3 meters in each segment), and the long edges (east and west edges) were divided into 23 segments (3 meters in each segment), creating 299 3 m x 3 m areas that were each sampled from every year (Figure 2). To systematically sample one 1 m² frequency quadrat within each of the 299 section areas, we used the following methodology. Each year, the transects running north-south were placed three meters apart along the east-west axis, determined by a random start at 0, 1, or 2 meters from the origin in the northeast corner. Then, for each of these transects, a 1 m² area was sampled every three meters, determined by a random start at 0, 1, or 2 meters from the northern edge of Macroplot A. These new random starts were generated for each of the 13 north-south transects. See Figure 2 for an example of this configuration, keeping in mind that the 1 m² plots sampled within each of the 299 areas will shift from year to year.

EQUIPMENT

- PVC quadrats (see Figure 3, below)
 - 1.0 m x 1.0 m square
 - 0.5 m x 0.5 m elbow piece
 - 0.25 m x 0.25 m elbow piece
- 2 meter tapes, at least 50 m in length
- 1 meter tape, at least 75 m in length
- Screwdrivers, stakes, or other tools for pinning meter tapes to the ground
- Monitoring camera (dSLR or similar style)
- Tripod
- Pin flags (at least 50)
- Clipboard and data sheets
 - Nested frequency datasheets
 - Photomonitoring logs
 - Examples of each of the photomonitoring photos to aid in lining up photographs in the field
- Field notebook and pencil
- Compass
- A sub-meter GPS receiver with the appropriate maps and geodatabase set up ahead of time and downloaded to the Field Maps app on a mobile device as an offline map

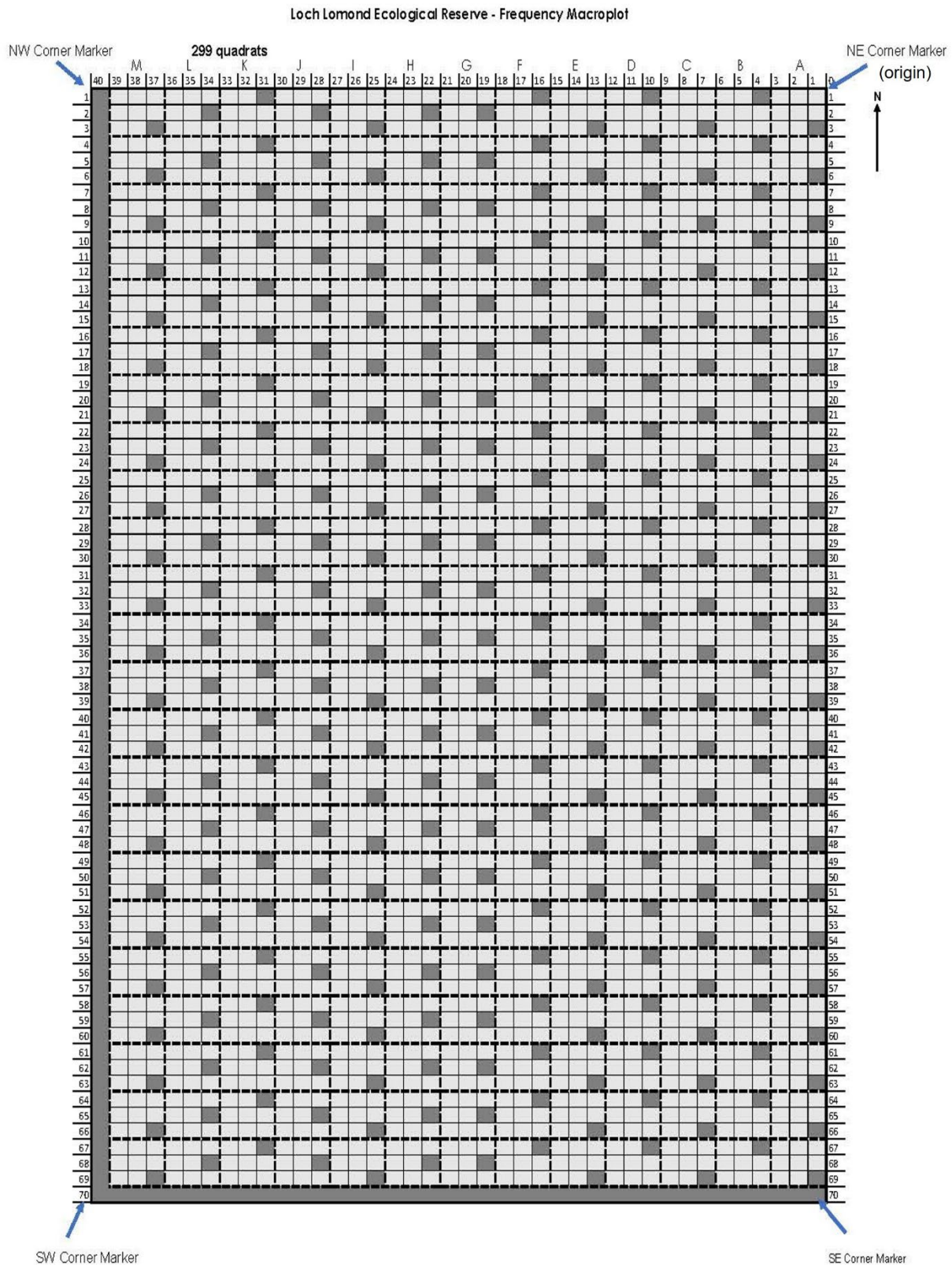


Figure 2. Quadrats sampled in 2016 (1 m x 1 m) within each 3 m x 3 m grid cell.

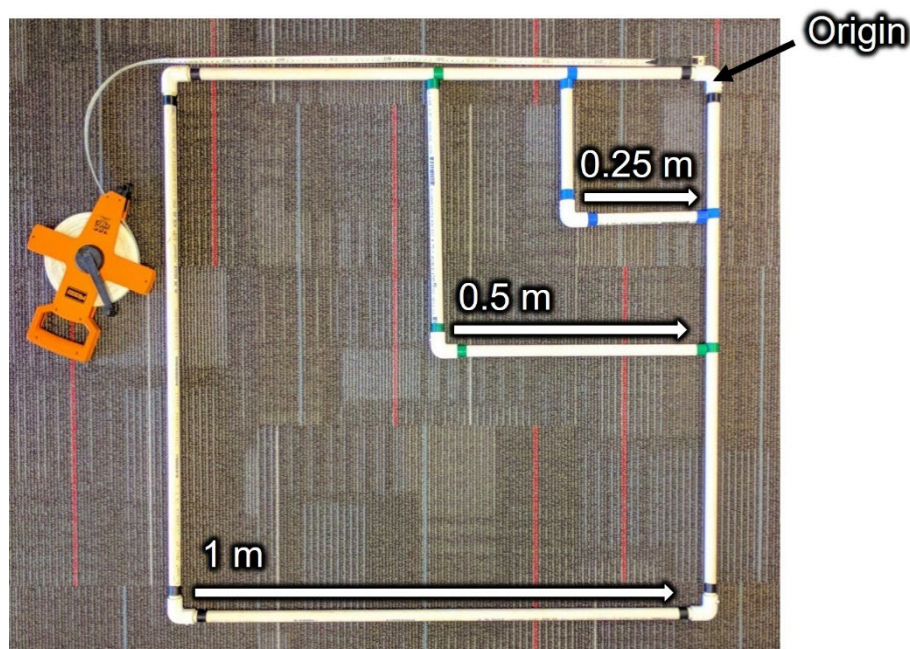


Figure 3. Nested frequency quadrats.

ACCESSING THE SITE

Along Highway 175, there is a small pullout on the east side of the access point to the Reserve that can accommodate two to three vehicles (38.866391, -122.719281).

COLLECTING FREQUENCY DATA

Macroplot A was deliberately placed to include portions of the Loch Lomond button-celery, navarretia, and pennyroyal populations at the Reserve. The macroplot is located within a 40 m x 70 m rectangle in the vernal pool (Figure 4) that is marked with rebar and PVC pipe hammered into the ground at each of the four corners as semi-permanent monuments. Aluminum tags have also been attached to the monuments labeling each corner. The exact location of Macroplot A is available from CDFW's Native Plant Program. The actual dimensions of Macroplot A are 39 m x 69 m, with the origin located at the northeast monument (see Figure 2). Use the two shorter meter tapes (at least 50 m long) to establish the north and south baselines of Macroplot A. The end at the 0-meter mark of one of the meter tapes (at least 50 m long) should be staked at the rebar monument at the northeast corner of the Macroplot A and extended to the northwest corner of the macroplot (wrap the loose end of the tape around the rebar monument so that it stays in place). The monitors should repeat these steps with the second short meter tape (at least 50 m long), from the southeast corner of the macroplot to the southwest corner of the macroplot

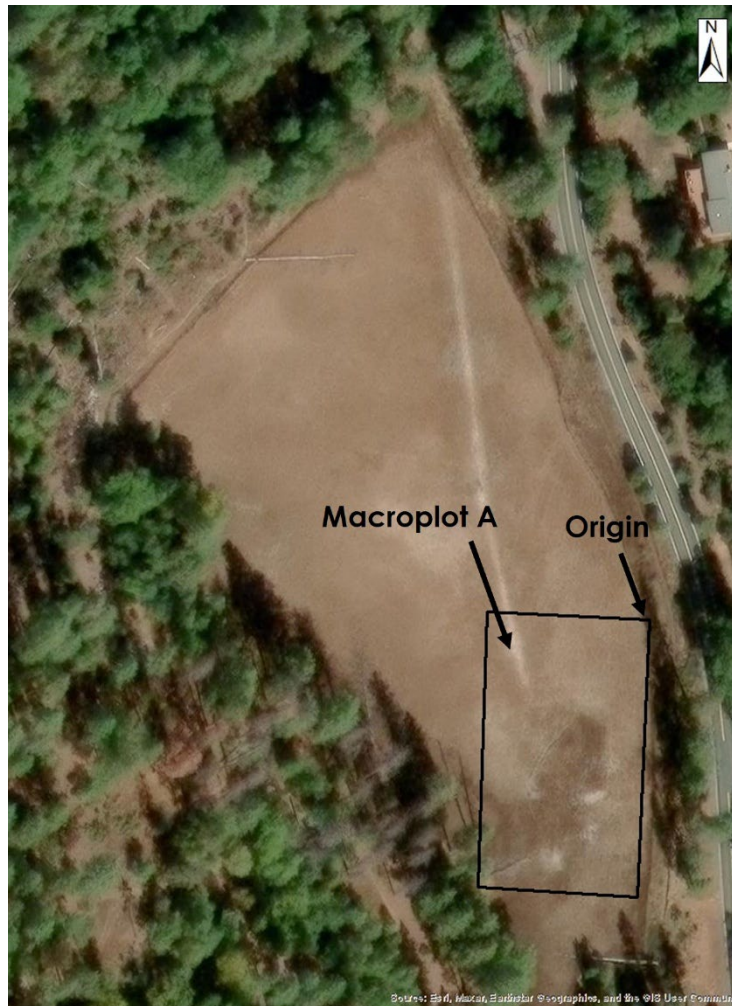


Figure 4. Location of Macroplot A in the vernal pool at Loch Lomond Ecological Reserve.

so that there are two parallel baselines. Monitors should make sure that the meter tapes are straight and taught, and it is very helpful if the side of the tape with the meter marks is facing up. One of the monitors should hold the components for the nested PVC quadrat frame and one of the monitors should hold the clipboard with the nested frequency datasheets. Monitors should do the following to collect the nested frequency monitoring data:

1. Working east to west, lay the long meter tape (at least 75 m long) so that it intersects both baselines at the appropriate meter mark for each transect identified on the nested frequency datasheets. For example, the first transect of the macroplot could begin one meter along the baseline from the northeast corner and be laid along the ground so that it crosses the other baseline at 1 meter from the southeast corner (See Figure 2). Use a screwdriver stuck in the ground or other object as the anchor point for the beginning of the meter tape with the 0-meter mark on the north

baseline. Make sure that the meter tape is taut and straight. Avoid trampling the northeast corner of the macroplot when laying meter tapes.

2. Lay the 1 m x 1 m PVC quadrat so that the quadrat origin corner falls on the point matching the data sheet and is closest to the macroplot origin. One edge of the quadrat should lay along the longer transect tape. The quadrat should always be laid so that the smallest of the nested quadrats (0.25 m x 0.25 m) is in the northeast corner of the frame (see Figure 3), closest to the origin of the quadrat. Lay down the 0.5 m x 0.5 m and 0.25 m x 0.25 m right-angle PVC inserts as needed. If the quadrat falls on a slope hold the quadrat frame in position horizontally as close as possible to the ground and imagine that the frame is projected straight down upon the ground.
3. Look for the target species being monitored within each of the quadrat frame sizes. Presence or absence of a species is based on whether it is rooted in or out of the quadrat, respectively. The following rules should be followed when looking for plants:
 - If the rooted portion of a plant is within the quadrat, then the plant is counted as being present in the quadrat. If the rooted portion of a plant is outside of the quadrat, then the plant is not counted as being in the quadrat.
 - If the rooted portion of a plant is only underneath the north or the east edge of the quadrat, then the plant is not counted as being in the quadrat. If the rooted portion of a plant is only underneath the south or the west edge of the quadrat, then the plant is counted as present in the quadrat.
 - Data should only be collected for plants that are determined to be from the current season's growth. Plant carcasses from the previous year should not be used to determine presence/absence.
4. Record presence/absence data on the appropriate datasheet for each of the species being monitored at each of the 299 quadrats. For each quadrat listed on the nested frequency datasheet, the monitors should record a 0, 1, 2 or 3 for each species as follows:
 - 0 – no plants of that species are rooted within the entire 1 m x 1 m PVC quadrat frame.
 - 1 – the species is rooted within the 0.25 m x 0.25 m section of the PVC quadrat frame.
 - 2 – the species is rooted within the 0.5 m x 0.5 m section of the PVC quadrat frame but not within the 0.25 m x 0.25 m section of the PVC quadrat frame.
 - 3 – the species is rooted within the 1 m x 1 m section of the PVC quadrat frame but not within the 0.25 m x 0.25 m or the 0.5 m x 0.5 m sections of the PVC quadrat frame.

A diagram of the four possible presence/absence categories is included on the datasheet.

PHOTOMONITORING

Photos should be taken at the Reserve whenever data is collected, and whenever you would like to quickly document the condition of the Reserve. The photopoints were established to capture the habitat conditions of the site and to document changes from year to year. Three monitoring photos are taken at each of five photopoints (described below), for a total of 15 photos. Detailed maps showing the photopoint locations are available from CDFW's Native Plant Program. To duplicate roughly the same field of view from year to year, the camera should be set to a focal length that is equivalent to approximately 27 mm on a "full frame" camera (e.g., 35 mm film camera or a Nikon "FX" camera), and the horizon should be approximately $\frac{1}{4}$ of the way down from the top of the frame. Previous monitoring photographs were taken using a Nikon "DX" camera set to a focal length of 18 mm, which is equivalent to 27 mm on a "full frame" camera. Before visiting the site, check the specifications for the digital camera to be used to confirm that photographs can be taken with the correct field of view. If the camera equipment to be used cannot duplicate this field of view (focal length of 27 mm on a "full frame" camera), the closest field of view possible should be used. The camera lens should be approximately 4.5 feet off the ground for all but one photopoint (Photopoint E) (for the original equipment, the tripod legs were fully extended but the camera was not telescoped any higher). The camera should be set to automatic with no flash. Prior to taking the first set of photos, it is helpful to indicate which photopoint you are at by taking a photo of the datasheet or a notebook with the photopoint identified. Repeat before each new photopoint. Take photos midday when possible to minimize shadows that may make comparisons across years more challenging. It is also helpful to consult examples of each of the photomonitoring photos to aid in lining up photographs in the field.

Photopoint A is located at the northeast monument of Macroplot A (38.86549, -122.71887). Three photos should be taken from this location in the following directions and identified by the following letters: (Aa) 180 degrees on a compass bearing (south); (Ab) 207 degrees; and (Ac) 270 degrees (west).

Photopoint B is located at the northwest monument of Macroplot A (38.865514, -122.71943). Three photos should be taken from this location in the following directions and identified by the following letters: (Ba) 90 degrees (east); (Bb) 152 degrees; and (Bc) 180 degrees (south).

Photopoint C is located at the southwest monument of Macroplot A (38.864891, -122.719451). Three photos should be taken from this location in the

following directions and identified by the following letters: (Ca) 0 degrees (north); (Cb) 30 degrees; and (Cc) 90 degrees (east).

Photopoint D is located at the southeast monument of Macroplot A (38.864840, -122.719001). Three photos should be taken from this location in the following directions and identified by the following letters: (Da) 270 degrees (west); (Db) 330 degrees; and (Dc) 356 degrees.

Photopoint E is located at the northeast corner of the Reserve at the corner of the perimeter fence (38.866679, -122.719652). The camera should be placed directly on the fence post to take these photos. Three photos should be taken from this location in the following directions and identified by the following letters: (Ea) 150 degrees; (Eb) 180 degrees (south); and (Ec) 226 degrees.

There should be a total of 15 photos for the photomonitoring of the Reserve. All monitoring photos should be saved to the project folder. Files should use the following naming convention: [uppercase letter of photopoint][lowercase letter of the photo][four digit year][two digit month][two digit day of the month]. For example, photo a of Photopoint A, taken on May 11, 2021, should be named "Aa20210511".

With the monitoring photos saved and sorted by file name, use a photo previewer program and the left and right arrow keys on the keyboard to compare monitoring photos with those taken during previous site visits to look for shifts in population size, disturbance, and other differences in habitat condition. Compare the photos to the distribution mapping.

FENCE INSPECTION

The perimeter fence surrounding the vernal pool should be inspected at least once annually by the Native Plant Program staff or the Northern Central Region staff. Inspections should occur every other year when frequency monitoring data is collected but should also occur in late spring or early summer during the years when no data collection occurs. If possible, a second inspection should occur each year during the fall or winter. Any damage to the fence should be noted and promptly reported to the Northern Central Region Land Staff and should be promptly repaired.

MAKING RECOMMENDATIONS

Review the data collected and compare results with the results from previous years. Think about any changes in management of the site that may benefit Loch Lomond button-celery or navarretia. Are there any actions that could be taken to increase the populations of these species or improve the vernal pool habitat? At a minimum, document your answers to the following questions:

- For each species, has the population increased, decreased, or remained about the same compared to last year and/or the previous ten years?
- What are the immediate and/or future threats to the populations of Loch Lomond button-celery and navarretia?
- What are the immediate and/or future threats to the vernal pool?
- If new management techniques were applied, how well did they work? What, if anything, would you modify?
- What would you change, if anything, to the current management?
- What recommendations, if any, do you have for the land manager?

Talk to the Reserve manager about the management of the site. **This is the most important part of adaptive management!**

HAND-WEEDING EXPERIMENT

In 2021, we initiated an experiment to investigate whether hand pulling invasive pennyroyal resulted in a decline in pennyroyal and/or an increase in Loch Lomond button-celery. Continuing the hand-weeding experiment, described below, would require one field day with three people, occurring after implementing the two-part monitoring protocol.

We established six paired plots at random within Macroplot A. Each plot was two meters by two meters, and control and treatment plots were adjacent to each other so that each set of paired plots was two meters by four meters. The paired plots were positioned in areas supporting both Loch Lomond button-celery and pennyroyal. The precise locations of the plots are available from CDFW's Native Plant Program. In 2021, 2022, and 2023 we estimated percent cover of Loch Lomond button-celery and pennyroyal within each plot before removing all invasive pennyroyal from the treatment plots by hand, with minimal soil disturbance. Cover was estimated within a one-square-meter quadrat centered in the plot and also within each of the four one-square-meter quadrats that are within the four-square-meter plot (Figure 5). Navarretia was not present in most of the plots, but we estimated its percent cover in the plots where it was observed. All hand-pulled pennyroyal was bagged and disposed of off-site.

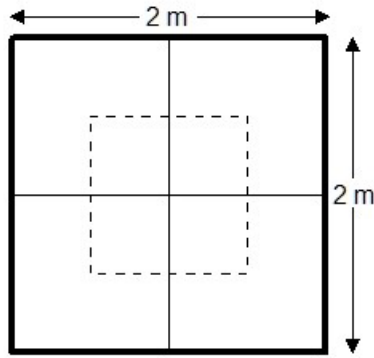


Figure 5. Example of using a centered 1 m x 1 m quadrat (dashed line) and four 1 m x 1 m quadrats (solid lines) to estimate percent cover in each plot. When using four 1 m x 1 m quadrats, percent cover was estimated in each of the four 1 m x 1 m quadrats within each plot and then averaged together to obtain the estimated percent cover of the entire plot.

SUMMARY OF RESULTS

CDFW staff visited the Reserve at least annually between 2015 and 2023 to conduct frequency monitoring and to take photographs of the Reserve at specific photopoint locations, and also visited the Reserve annually between 2021 and 2023 to implement the hand weeding experiment (Table 1). We provide a summary of the following information in this section:

- Annual frequency of Loch Lomond button-celery, pennyroyal, and navarretia in Macroplot A
- Monitoring photographs at specific photopoint locations
- Results of the hand-weeding experiment
- Mapping

Table 1. Dates of site visits.

Year	Day(s)	Purpose of visit(s)
2015	June 3, July 16	Monitoring setup, monitoring
2016	June 30, July 14	Monitoring
2017	July 3	Monitoring
2018	July 12	Monitoring
2019	July 3	Monitoring
2020	July 1, 2	Monitoring
2021	June 30, July 1	Monitoring, hand-weeding experiment set up and implementation
2022	June 28, 29	Monitoring, hand-weeding experiment implementation and data collection
2023	June 21, 22	Monitoring, hand-weeding experiment data collection

FREQUENCY MONITORING

Loch Lomond Button-Celery

Loch Lomond button-celery was abundant in Macroplot A every year from 2015 to 2023, but its frequency decreased overall during the monitoring period. Of the three nested frequency quadrat sizes, the 0.25 m x 0.25 m quadrat size was the most useful for monitoring Loch Lomond button-celery because its values had the largest range and the average estimated frequency value (69.3%) was closest to 50%, making this quadrat size the most sensitive for detecting upward and downward changes. The highest frequency of Loch Lomond button-celery at 0.25 m x 0.25 m between 2015 and 2023 was 80.3% in 2018, and the lowest was 53.9% in 2020 (Figure 6). We compared the frequency of Loch Lomond button-celery in each year to the starting frequency in 2015. A Chi-square test detected a significant decrease in frequency at 0.25 m x 0.25 m of Loch Lomond button-celery beginning in 2019 and continuing through 2023 (Table 2).

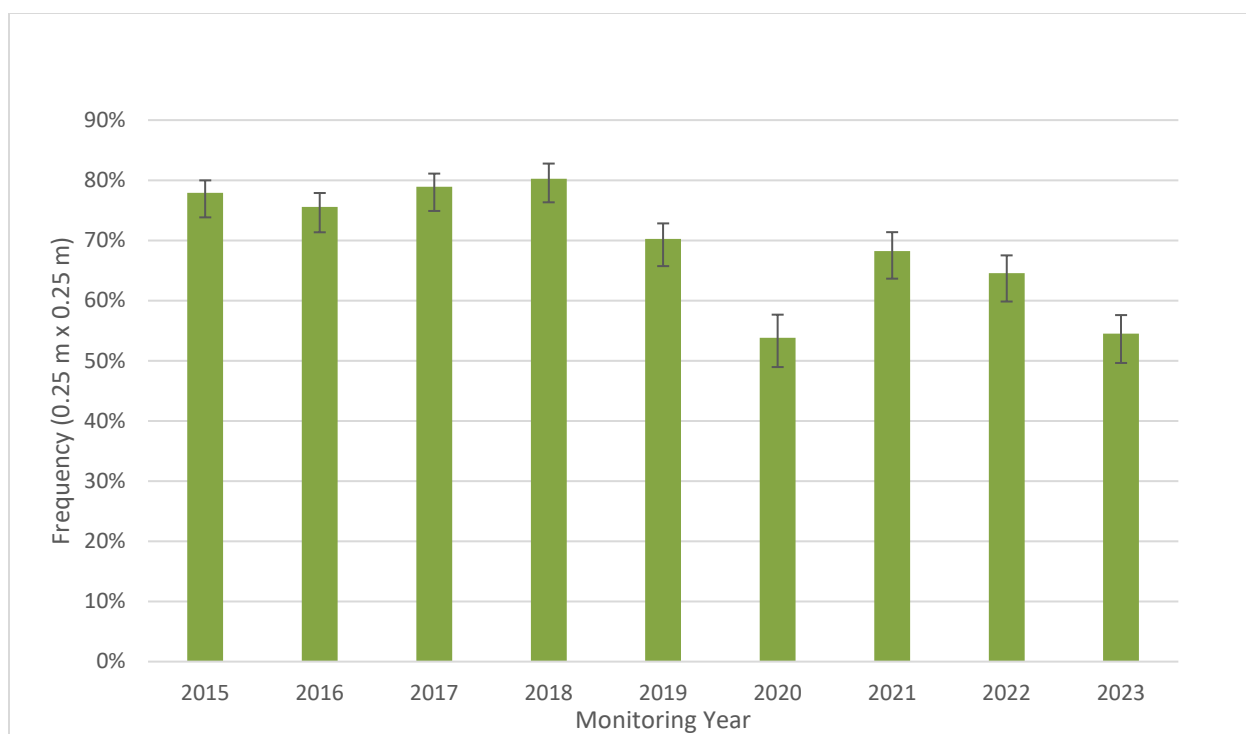


Figure 6. Frequency (0.25 m x 0.25 m) of Loch Lomond button-celery in Macroplot A (90% confidence), 2015–2023.

Table 2. Chi-square results for Loch Lomond button-celery each monitoring year as compared to 2015 in the 0.25 m x 0.25 m frequency quadrats.

Year	χ^2	df	N	p
2016	0.459	1	43,056	0.496
2017	0.089	1	43,056	0.766
2018	0.496	1	43,056	0.481
2019	4.607	1	43,056	0.032*
2020	38.570	1	43,056	<0.001*
2021	7.148	1	43,056	0.008*
2022	13.058	1	43,056	<0.001*
2023	36.631	1	43,056	<0.001*

*Significant p-value

Figure 7(a) shows the detections of Loch Lomond button-celery in a random 0.25 m x 0.25 m quadrat within a 3 m x 3 m area (grid cell) each year from 2015–2023. When compared to the detections of pennyroyal presented in Figure 7(b), it appears that over time, Loch Lomond detections decreased in some areas where pennyroyal increased, especially toward the middle and southern portions of Macroplot A. This suggests that pennyroyal is displacing Loch Lomond button-celery.

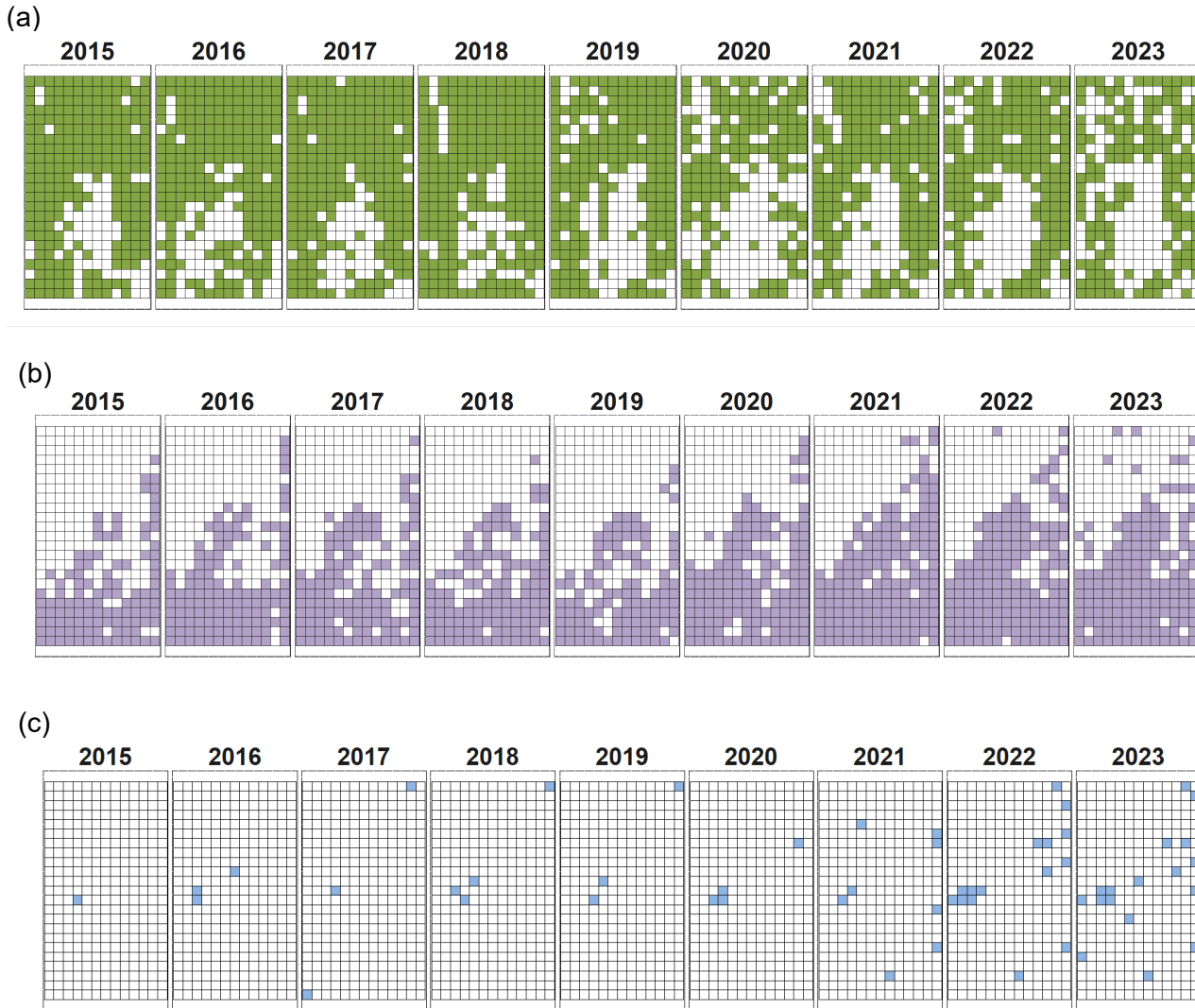


Figure 7. Detection of (a) Loch Lomond button-celery, (b) pennyroyal, and (c) navarretia in 3 m x 3 m grid cells. Detections were made by randomly sampling one 0.25 m x 0.25 m quadrat per grid cell in each year for Loch Lomond button-celery and pennyroyal, and by sampling one 1 m x 1 m quadrat per grid cell in each year for navarretia.

Using a simple linear regression to look at the possible effect of pennyroyal frequency on Loch Lomond button-celery frequency over eight years, we found that pennyroyal frequency had a significant negative effect on the frequency of Loch Lomond button-celery ($\beta = -0.938$, $p = 0.04$) (Figure 8). Even when we include total winter/spring (September–June) precipitation (Figure 9) to help explain the variation in Loch Lomond button-celery, pennyroyal still has a direct, negative effect on Loch Lomond button-celery, albeit marginal ($\beta = -0.992$, $p = 0.07$), which further supports our conclusion that the encroachment of pennyroyal is causing a reduction in Loch Lomond button-celery. We also found

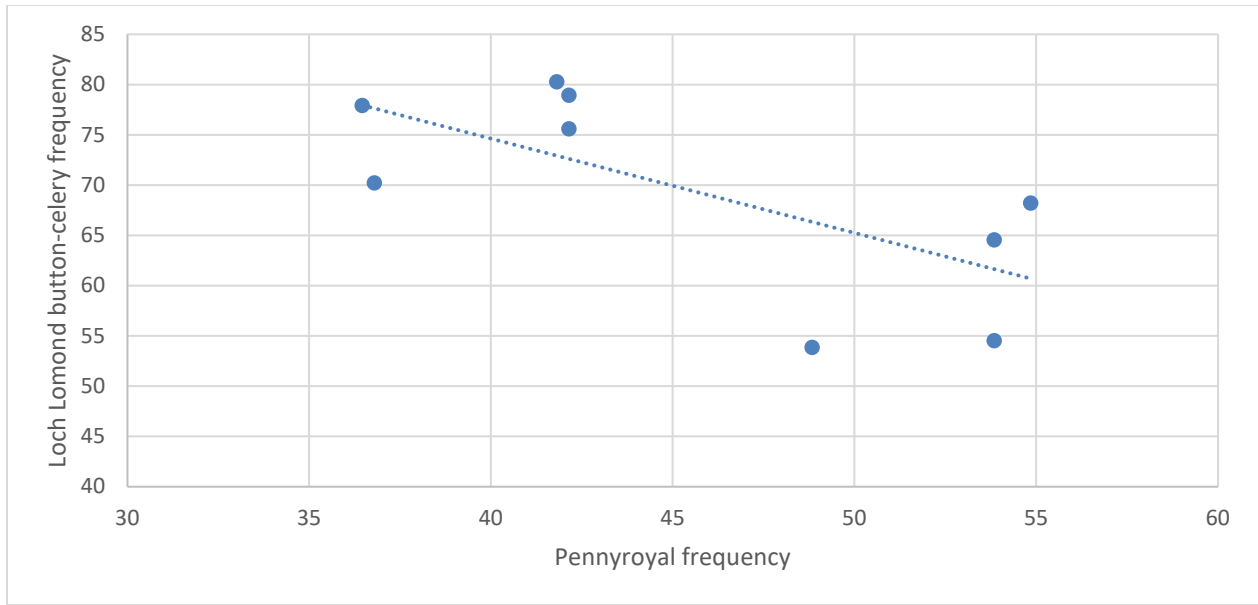


Figure 8. Effect of pennyroyal frequency on Loch Lomond button-celery frequency annually between 2015 and 2023 ($R^2 = 0.47$, $F(1,7) = 6.19$, $\beta = -0.938$, $p = 0.04$).

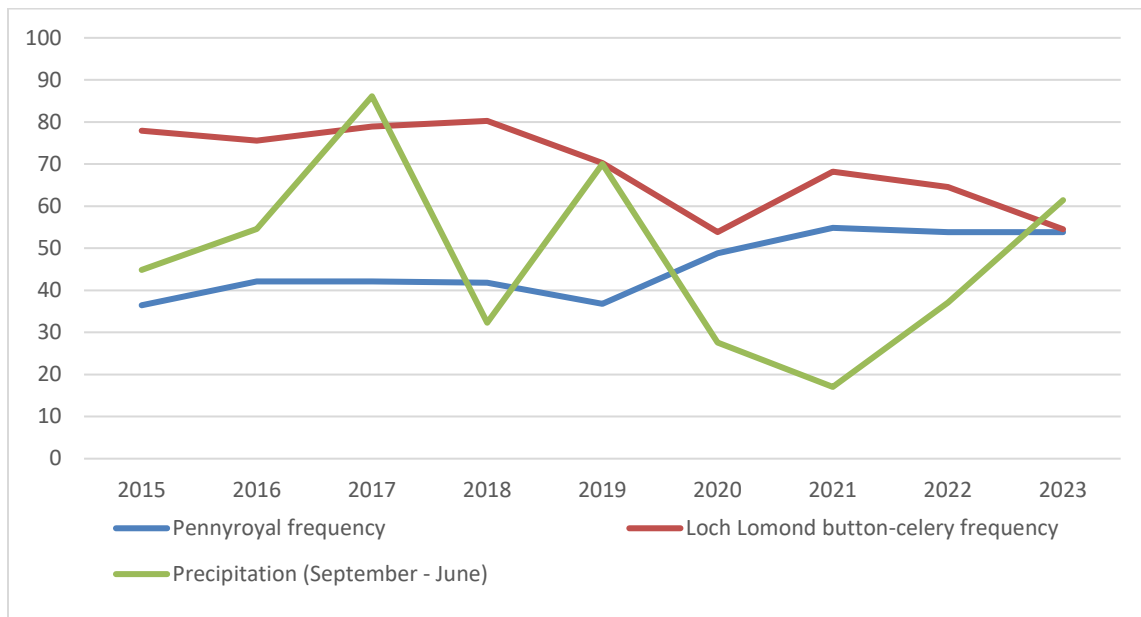


Figure 9. Cumulative September through June precipitation in inches (Prism Climate Group 2025), pennyroyal frequency, and Loch Lomond button-celery frequency by year, 2015–2023.

a moderate negative correlation between precipitation and pennyroyal frequency ($r = -0.46$), indicating that drier years are associated with an increased frequency of pennyroyal. We did not find a correlation between precipitation and Loch Lomond button-celery frequency ($r = 0.24$).

Pennyroyal

Pennyroyal was detected every year in Macroplot A, and its frequency increased overall from 2015 through 2023 (Figure 10). Of the three nested frequency quadrat sizes, the average estimated frequency values for the 0.25 m x 0.25 m quadrat and the 0.5 m x 0.5 m quadrat size were both similarly close to 50% (45.6% and 53.9%, respectively). The 0.25 m x 0.25 m quadrat size had a larger range of frequency values than the 0.5 m x 0.5 m quadrat size. The highest frequency (0.25 m x 0.25 m) detected was 54.9% in 2021, and the lowest was 36.5% in 2015. Results are presented for the smallest quadrat size (0.25 m x 0.25 m) for pennyroyal since this size had the greatest range of values and the average estimated frequency was close to 50%; thus, it was determined to have the optimal sensitivity for detecting changes in frequency values of pennyroyal. In addition, we chose the 0.25 m x 0.25 m quadrat size to be consistent with the quadrat size used for Loch Lomond button-celery.

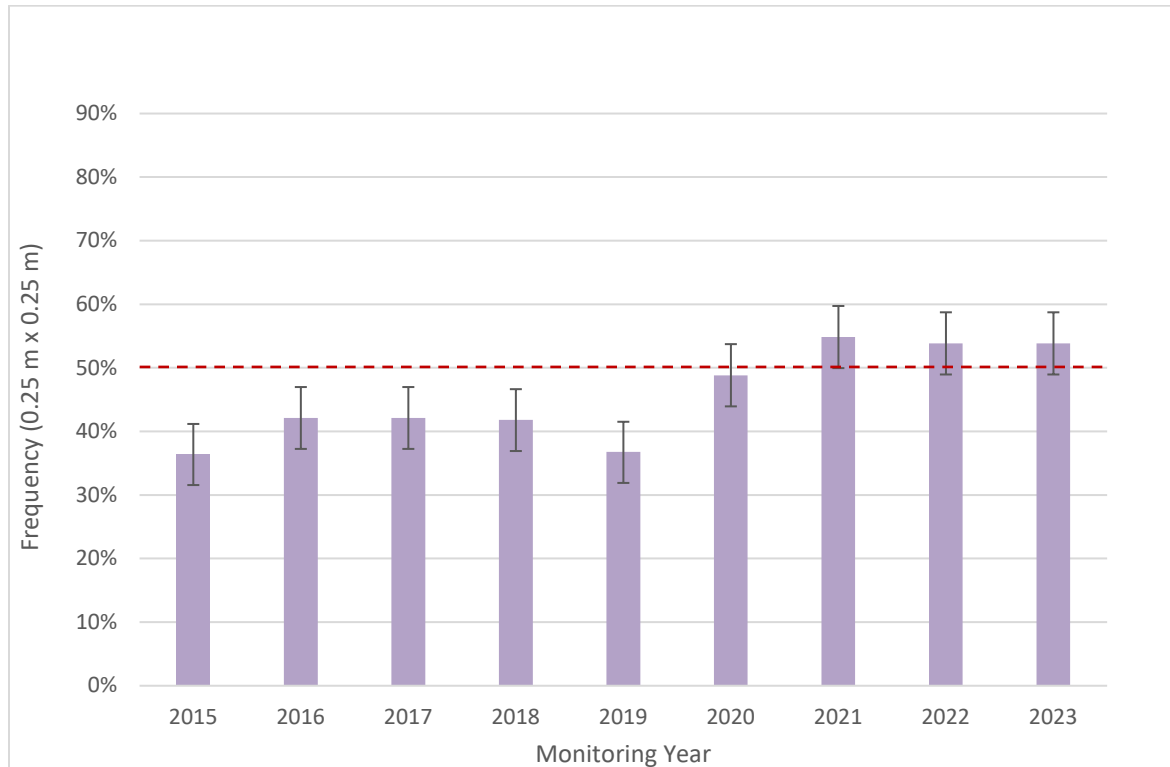


Figure 10. Frequency (0.25 m x 0.25 m) of pennyroyal in Macroplot A (90% confidence), 2015–2023. The horizontal line represents the 50% threshold identified in Management Objective 1.

We compared the frequency of pennyroyal in 2015 to each subsequent year through 2023. A Chi-square test detected a significant increase in frequency (0.25 m x 0.25 m) of Loch Lomond button-celery from 2015 beginning in 2020 and continuing through 2023 (Table 3).

Table 3. Chi-square results for pennyroyal each monitoring year as compared to 2015 in the 0.25 m x 0.25 m frequency quadrats.

Year	χ^2	df	N	p
2016	2.026	1	43,056	0.155
2017	2.026	1	43,056	0.155
2018	1.797	1	43,056	0.180
2019	0.007	1	43,056	0.932
2020	9.360	1	43,056	0.002*
2021	20.388	1	43,056	<0.001*
2022	18.259	1	43,056	<0.001*
2023	18.259	1	43,056	<0.001*

*Significant p-value

Figure 7(b) above shows the overall increase in detections of pennyroyal in a random 0.25 m x 0.25 m quadrat within a 3 m x 3 m area (grid cell) each year from 2015–2023.

Navarretia

The frequency of navarretia was very low in Macroplot A for all quadrat sizes in all years. Despite the low frequency of navarretia in the macroplot, we did detect a steady increase in its frequency for all quadrat sizes from 2015–2023. Of the three nested frequency quadrat sizes, the 1 m x 1 m quadrat size was the most appropriate for monitoring navarretia because it resulted in the highest values and the largest range of values, indicating it was the most sensitive for detecting change. Consequently, results are presented for the 1 m x 1 m quadrat size for navarretia (Figure 11). The lowest frequency for navarretia was 0.3% in 2015, and the highest frequency was 5.7% in 2023.

A Chi-square test detected a statistically significant increase in the frequency of navarretia in the 1 m x 1 m quadrat size beginning in 2021, and continuing through 2023, when compared to 2015 (Table 4).

Figure 7(c) above shows the spread of navarretia throughout the macroplot based on sampling of a random 1 m x 1 m quadrat within each 3 m x 3 m area (grid cell) each year from 2015–2023. The detections of navarretia increased overall from 2015–2023.

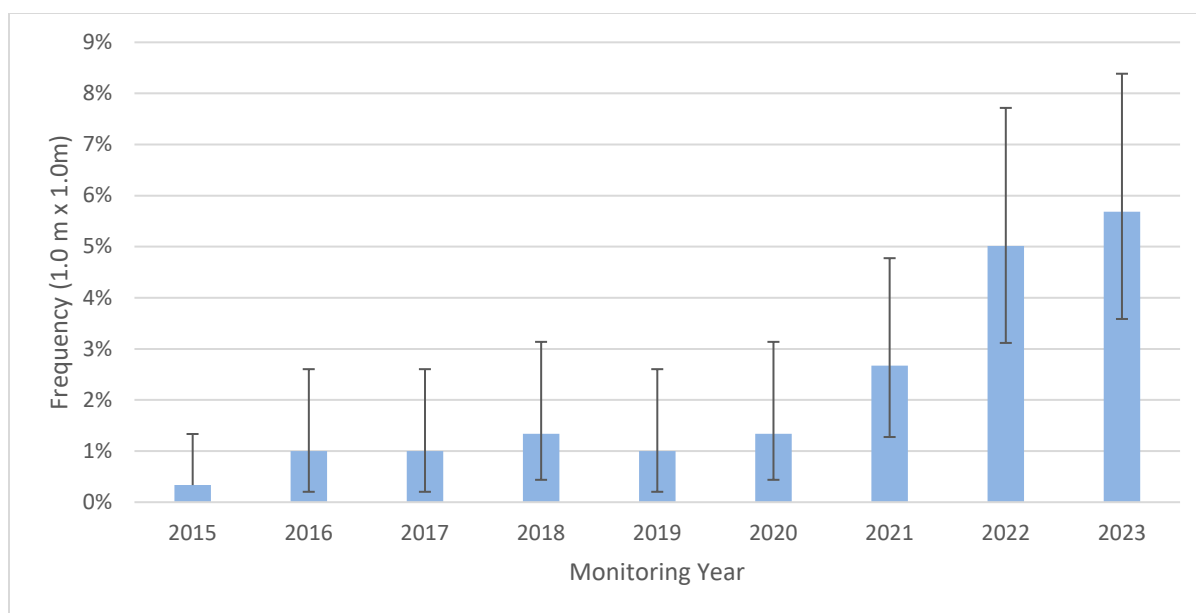


Figure 11. Frequency (1 m x 1 m) of navarretia in Macroplot A (90% confidence), 2015–2023.

Table 4. Chi-square results for navarretia each monitoring year as compared to 2015 in the 1 m x 1 m frequency quadrats.

Year	χ^2	df	N	p
2016	1.007	1	2,691	0.316
2017	1.007	1	2,691	0.316
2018	1.815	1	2,691	0.178
2019	1.007	1	2,691	0.316
2020	1.815	1	2,691	0.178
2021	5.528	1	2,691	0.019*
2022	12.587	1	2,691	<0.001*
2023	14.664	1	2,691	<0.001*

*Significant p-value

ANNUAL PHOTOMONITORING

Photos were taken at the five photopoints annually from 2015 through 2023. Photos from photopoints Bb and Bc are shown in Figures 12 and 13 and demonstrate the habitat conditions at the site in 2016, 2019, and 2023.

HAND WEEDING EXPERIMENT

The percent cover of Loch Lomond button-celery and pennyroyal was highly correlated between the single, centered quadrats and averages of the four quadrats ($r = 0.9$), so our summarized results are based only on the data from the centered quadrat. Figures 14 through 17 show the percent cover in the



Figure 12. Photopoint Bb showing habitat conditions on June 30, 2016 (top), July 3, 2019 (middle), and June 21, 2023 (bottom).



Figure 13. Photopoint Bc showing the habitat conditions on June 30, 2016 (top), July 3, 2019 (middle), and June 21, 2023 (bottom).

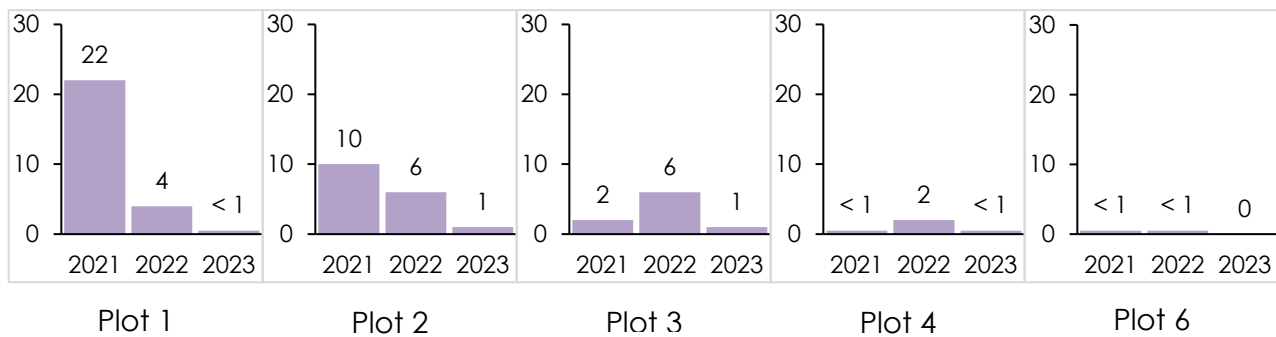


Figure 14. Estimated percent cover of pennyroyal in each treatment plot, 2021–2023. The year is on the x-axis and percent cover is on the y-axis.

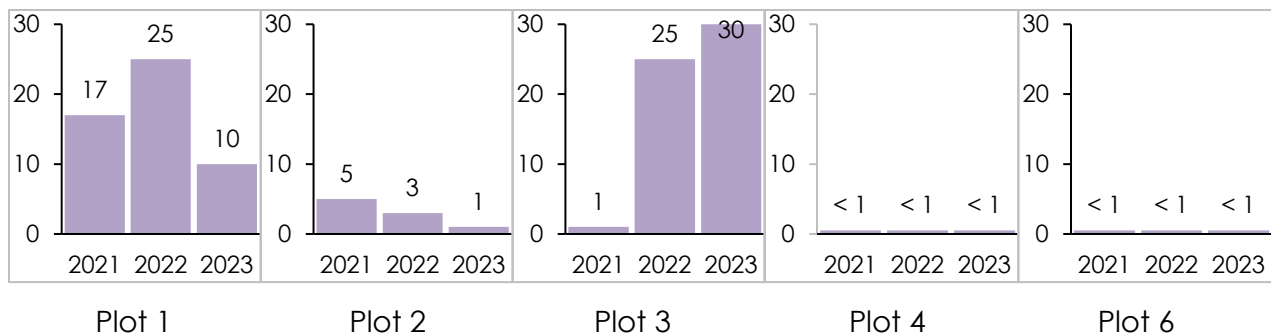


Figure 15. Estimated percent cover of pennyroyal in each control plot, 2021–2023. The year is on the x-axis and percent cover is on the y-axis.

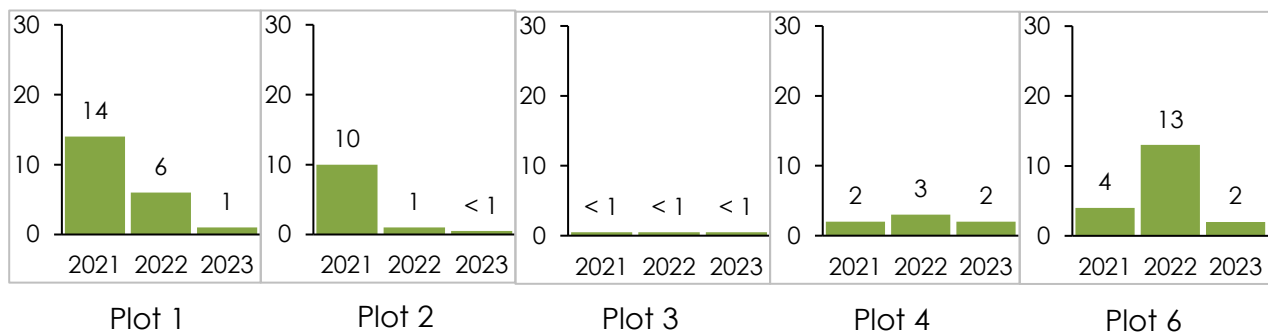


Figure 16. Estimated percent cover of Loch Lomond button-celery in each treatment plot 2021–2023. The year is on the x-axis and percent cover is on the y-axis.



Figure 17. Estimated percent cover of Loch Lomond button-celery in each control plot, 2021–2023. The year is on the x-axis and percent cover is on the y-axis.

pennyroyal and Loch Lomond button-celery in five pairs of treatment and control plots. From 2021 through 2023, the percent cover of pennyroyal declined in four treatment plots and remained the same in one plot. Treatment plots 1 and 2 had the highest estimated percent cover in 2021, and the percent cover declined substantially in these plots (Figure 14), confirming that hand removal of pennyroyal can be an effective management approach to reducing its cover. Loch Lomond button-celery, however, did not show a detectable increase in percent cover within the treatment plots where pennyroyal was removed, and Loch Lomond button-celery actually showed a detectable decrease from 2021 to 2023 in two of the treatment plots (Plots 1 and 2; Figure 16). Results are not presented for Plot 5 because pennyroyal was not present in the treatment plot in any year of the experiment and the plot was not subject to treatment (hand pulling). This was an oversight that was made during plot selection.

MAPPING

In 2018, we mapped the extent of the navarretia population at the Reserve. The majority of the population was concentrated in the northern portion of the vernal pool, along the west, north, and east edges. As discussed above, the navarretia plants at the Reserve appear to be intermediates between many-flowered and few-flowered navarretia, exhibiting characteristics of both taxa (CDFW Observation; Day 1997). Since the plants are considered intermediates between the two subspecies, we did not attempt to map the two subspecies separately.

In 2020, we mapped the extent of the pennyroyal population. Pennyroyal was dense around the edges of the vernal pool, especially in the deeper southern portion of the pool and along the eastern edge of the pool, adjacent to a roadside drainage ditch. The maps of navarretia and pennyroyal distribution are available from CDFW's Native Plant Program.

DISCUSSION AND INTERPRETATION OF RESULTS

Our frequency data indicate that there has been a significant increase in pennyroyal since we began monitoring in 2015. Pennyroyal is abundant around the edges of the vernal pool and appears to be encroaching further into the center of the pool (see 7(b) above). When comparing observations by year, it appears that pennyroyal detections increased in areas toward the center of the pool, and that Loch Lomond button-celery detections decreased in some of those areas where pennyroyal was newly detected. Population size of Loch Lomond button-celery is not expected to fluctuate substantially among years because it is a perennial species, and our observations provide strong support for the hypothesis that the Loch Lomond button-celery population is declining, in part due to pennyroyal encroachment. Since pennyroyal frequency is

continuing to increase, we are concerned about ongoing threats and declines in the Loch Lomond button-celery population at the Reserve.

The hand-weeding experiment resulted in a decrease in pennyroyal cover the following year in four of five treatment plots but did not result in a noticeable increase in Loch Lomond button-celery in any of the plots the very next year. Pennyroyal spreads easily by rhizome, and our removal treatments targeted aboveground biomass because we did not want to disturb the soil. Some of the roots and plant fragments left in the ground likely survived to the next season, so it may take several years of hand-weeding to reduce both above and below-ground competition from pennyroyal, and several years for Loch Lomond button-celery to respond to the reduced competition. Our main conclusion is that we were able to reduce pennyroyal cover in the treatment plots with the highest estimated cover, but two years of treatment at the scale we used may not be enough time to detect a significant increase in cover of Loch Lomond button-celery since it is a perennial species, and we do not know how long it may take for it to recolonize an area. It also does not spread vegetatively, so recolonization of the treatment plots relies in part on seeds successfully germinating and establishing. Additionally, Loch Lomond button-celery is a wiry plant that averaged less than five percent cover across years and plots, so detecting small changes in cover was difficult at the scale we used for data collection. Estimating percent cover is challenging to standardize between data collectors and between years, so it is possible that, when estimating such a small amount of cover, the measurement error may have been greater than the interannual variation in the percent cover of the species. Our recommended improvements to the study design include additional replicates in areas of dense pennyroyal, collecting measurements at scales smaller than 1 m², and using fine-scale presence/absence measurements rather than percent cover for increased accuracy.

ASSESSMENT OF THE MONITORING PROJECT

The monitoring project has successfully tracked population changes in several target species and has resulted in a nine-year baseline of frequency and photomonitoring data that can be easily collected again in the future. Our methods have resulted in knowledge of the current status, distribution, and trends of Loch Lomond button-celery, navarretia, and invasive pennyroyal at the Reserve.

The vegetation metric we selected to monitor the Reserve was frequency because CDFW is particularly interested in detecting changes in the spatial distribution of Loch Lomond button-celery and the encroachment of invasive pennyroyal. Our results have demonstrated that pennyroyal is an appropriate habitat component to monitor because it appears to have a negative effect on

Loch-Lomond button-celery. As the frequency of pennyroyal observed at the Reserve increases, our concern for Loch Lomond button-celery also increases.

Initially, this monitoring project was intended to monitor few-flowered navarretia and many-flowered navarretia; however, further study is needed to differentiate between the subspecies at the Reserve or to determine if the navarretia plants at the Reserve are intermediates between the two subspecies. In addition, Macroplot A was established in an area with scattered, infrequent navarretia plants and was, therefore, not placed ideally to monitor changes in navarretia frequency. However, we did detect an increase in frequency of navarretia in Macroplot A from 2015 to 2023, and mapping in 2018 and qualitative observations suggest that the navarretia has persisted outside of Macroplot A. Future monitoring efforts should add a component to monitor navarretia at the Reserve in areas outside of Macroplot A.

The monitoring photos taken in 2016 used an incorrect camera setting and were zoomed in closer than the baseline zoom settings outlined. This made image comparison with other years problematic. In addition, precise alignment of monitoring photos is necessary for direct comparison of specific areas of the ground over the years. Differences in perspective resulting from photographs taken with different cameras, from slightly different positions, or in slightly different directions may require correction with photo editing software such as Adobe Photoshop to facilitate comparisons. Because correcting the differences in perspective requires photo editing expertise and additional time, every effort should be made to standardize monitoring photos as much as possible in the field.

MANAGEMENT RECOMMENDATIONS

Management objectives and management implications for Loch Lomond button-celery at the Reserve are presented below with a discussion of what the management implications should be if the objective is not met or a threshold in the objective is crossed. Additional management recommendations are also included.

MANAGEMENT OBJECTIVE #1

Maintain a pennyroyal frequency of 50 percent or less at the 0.25 m x 0.25 m quadrat scale in Macroplot A at the Reserve in every year (this is a target/threshold type of management objective).

Management Implication #1: If any portion of the 90 percent confidence interval for pennyroyal exceeds 50 percent at the 0.25 m x 0.25 m scale in Macroplot A, CDFW shall develop and implement a weed management plan.

Recommendation: The 90 percent confidence interval for pennyroyal exceeded 50 percent in 2020 through 2023. The management implication has been triggered. CDFW staff should immediately implement a weed management project to reduce the pennyroyal infestation at the Reserve, while minimizing any impacts to Loch Lomond button-celery, navarretia, and other native plants.

OTHER RECOMMENDATIONS

- CDFW's Native Plant Program and/or the Northern Central Region should continue to prioritize monitoring of Loch Lomond Ecological Reserve using the monitoring protocol described in this document. Monitoring should be conducted at least every two years, and perimeter fence inspection should occur at least annually.
- Studies should be designed and implemented to determine if the navarretia plants at the Reserve are many-flowered navarretia, few-flowered navarretia, or intermediates between the two subspecies. In addition to morphological investigations, a genetics study should be implemented to help make this determination.
- Future monitoring should add a component to monitor navarretia at the Reserve in areas outside of Macroplot A.
- CDFW should re-map the distribution of Loch Lomond button-celery, navarretia, and pennyroyal at the Reserve every five years.

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APPENDIX A – NESTED FREQUENCY MONITORING DATA SHEETS

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Field Personnel:

Randomly Select a Transect Start	0m	1m	2m
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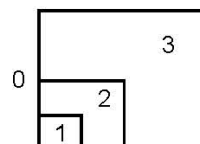
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Date:

Field Personnel:

Nested Quadrat Codes
0 Species absent
1 Species present within 0.25 x 0.25 m area
2 Species present within 0.5 x 0.5 m area
3 Species present within 1 x 1 m area



Randomly Select a Transect Start	0m	1m	2m
----------------------------------	----	----	----

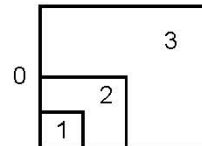
[illegible]

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Date:

Field Personnel:

Nested Quadrat Codes
0 Species absent
1 Species present within 0.25 x 0.25 m area
2 Species present within 0.5 x 0.5 m area
3 Species present within 1 x 1 m area



Randomly Select a Transect Start	0m	1m	2m
----------------------------------	----	----	----

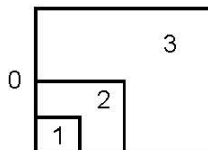
[illegible]

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Date:

Field Personnel:

0	Species absent
1	Species present within 0.25 x 0.25 m area
2	Species present within 0.5 x 0.5 m area
3	Species present within 1 x 1 m area



Randomly Select a Transect Start

0m	1m	2m
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Nested Quadrat Code

[illegible]