

Lupine Direct Seeding Experiment Preliminary Proposal

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Background

Creekside Science has successfully obtained funding from the Disney Butterfly Conservation Initiative and launched a regional, interagency conservation effort to support lupine diversification and habitat enhancement for the Mission blue butterfly (MBB). We have enlisted and received support from multiple partners including: San Mateo County Parks Department (SMCP), the Golden Gate National Recreation Area (GOGA), the Golden Gate National Parks Conservancy (GGNPC), San Francisco Recreation and Parks Department (SFRPD) and the San Francisco Public Utilities Commission (SFPUC). In cooperation with these partners, we are proceeding with our efforts to address known habitat enhancement challenges through updated host plant mapping, lupine seed amplification and experimental direct seeding strategies.

Milestones achieved to date:

- 1) Construction of lupine seed amplification boxes was completed at the Creekside Conservation Growing Facility (CCGF) that meets rigorous pathogen-free standards.
- 2) Permits were secured and lupine seed received from SMCP (85 *Lupinus formosus* seeds) and SFRPD (125 *Lupinus albifrons* seeds). Additional seed was received from GOGA (90 *Lupinus albifrons* seeds) in summer 2018.
- 3) Lupine propagation is underway at the CCGF. As of June 2018, 47 *Lupinus albifrons* and 28 *Lupinus formosus* plants were growing at the CCGF. Seed collection from first generation of *Lupinus formosus* has commenced.
- 4) Permits were secured from partner agencies and wild seed was collected from all three lupine species from SMCP in summer 2018.
- 5) Permits were secured and seed rain plots, traps and wildlife cameras installed at San Bruno Mountain (SMCP) and Oakwood Valley (GOGA) reference sites. Field data collection from seed rain plots was completed in August 2018.
- 6) Permits were secured and updated lupine maps and census were completed at Twin Peaks (SFRPD).
- 7) Mid-term report for the Disney Butterfly Conservation Initiative was submitted.

By the end of 2018, we expect accomplish the following milestones:

- 1) Seed collection from first generation of lupines propagated at the CCGF will continue through summer 2018 and fall/winter propagation of newly obtained seed will commence.
- 2) Seed rain plots, traps and wildlife cameras will be removed from Owl Canyon and Oakwood Valley by early September, 2018.
- 3) Seed rain data from reference sites will be analyzed to develop natural seed rain estimates.
- 4) Preliminary direct seeding experimental design will be completed (including seeding rate, seed and ground treatments, number of plots and locations) and permit requests will be submitted.
- 5) Results from Twin Peaks census and maps will be analyzed to update estimates of the MBB population at this site.

Proposed Experiments

Lupine diversification and host plant expansion is key to MBB recovery. However, propagation and survival of planted lupines, particularly *Lupinus formosus*, is a labor-intensive challenge. Furthermore, direct seeding, though recommended in the MBB Recovery Plan (USFWS, 1984), has generally been disregarded as a viable strategy for lupine population expansion. This study seeks to alleviate known limitations of direct seeding including: (1) seed scarcity and (2) lack of effective field seeding protocols.

In order to address the first issue, seed amplification for all three lupine species is now underway at the CCGF and will continue through 2020. In a parallel effort, GOGA is currently amplifying *Lupinus formosus* seed and is beginning amplification of *Lupinus albifrons* seed at Hedgerow Farms. We anticipate producing sufficient seed through our combined efforts to initiate direct seeding trials in fall/winter of 2019.

In order to establish effective field seeding protocols, we endeavored to document natural seed production of *Lupinus formosus* in reference sites at Owl Canyon (SMCP) and Oakwood Valley (GOGA). From June through August of 2018, five seed rain plots/traps and a wildlife camera were monitored at each site on a weekly basis. Data collection included tracking lupine phenology, counting inflorescences, fruits, seeds per fruit, seeds per trap, herbivory evidence and measuring lupine density. Lupines were censused and mapped at each site. Photographic data from wildlife cameras captured evidence of lupine herbivory and additional photographs documented impacts of lupine seed predators. Analysis of 2018 data will provide estimates of natural seed production rates, which will be used to determine experimental seeding rates in the fall/winter 2019 field seeding trials.

Once sufficient seed has been produced and natural seeding rates have been estimated, we propose to begin direct seeding trials at restoration sites on San Bruno Mountain and one or two locations within GOGA (likely Milagra Ridge, Sweeny Ridge and/or the Marin Headlands). Factors influencing seedling recruitment include: seed rain, predation, depth, dormancy and seed bank (Fig. 1). The experiments proposed below seek to maximize seedling recruitment based on these factors. The final numbers of treatments, sites and replicates will be refined depending on how much seed is available for experimentation. The final quantity of seed required for each treatment will be determined by the amount of seed successfully produced at the CCGF and the quantity of seed GOGA is able to contribute from the Hedgerow Farms amplification effort. We anticipate these trials will begin in fall/winter 2019, although the Passive Recruitment Experiment could be installed as early as fall/winter 2018, as the treatments do not include the addition of lupine seed.

Passive Recruitment Experiment

Effective direct seeding hinges on understanding natural seed bank dynamics (Figure 1). A passive recruitment experiment can inform strategies for lupine population enhancement that depend on ground treatments that stimulate the existing seed bank, without the application of additional seed to the site. This experiment could take place as early as fall/winter 2018, if site selection and permits were fast-tracked. Otherwise, this experiment would initiate in fall/winter 2019. Ideal locations for passive recruitment plots would be within 2m (Magnusson 2006) or downslope of existing lupines, in spots likely to contain a dormant lupine seed bank, but do not currently contain lupines or other rare plants. Preferably, this experiment would include five plots of each of the following four treatments (for a total of 20 x 1m² treatment plots):

- Control (no treatment)
- Disturbance A (scrub removal)
- Disturbance B (scraping)
- Disturbance C (scrub removal and scraping)

Direct Seeding Experiment

Results from carefully conducted direct seeding trials will help establish effective field protocols that efficiently utilize limited seed, maximize recruitment and improve techniques for expansion and diversification of lupine populations. Seed bank size and seedling recruitment of wild lupines are influenced mainly by three factors that affect seed demography: (1) post-dispersal seed predation by granivores, such as rodents, (2) seed viability, and (3) seed dormancy (Maron & Simms 1997). The following experimental treatments seek to improve recruitment by protecting seed from above-ground predators (burial), preferentially selecting healthy seed for experiments and overcoming seed dormancy (pre-germination treatments). Ideal locations for direct seeding plots would include sites that have already been prioritized for lupine expansion (similar soils, vegetation, aspect, etc.), occur within or adjacent to existing lupine patches, but do not currently contain lupines or other rare plants. Preferably, this experiment would include the following treatments:

- Control
- Ground disturbance treatments: scraping, scrub removal
- Above-ground predator protection: seed burial to 1cm depth, 2cm depth
- Germination treatment: no treatment, scarification plus soaking
- Seeding density: high, medium, low rates

Exact plot design and treatment levels will be determined by seed availability and experimental site conditions.

Future Tasks

- 1) Finalize experimental design and secure permits, 2018/2019
- 2) Collect seeds from the CCGF, Hedgerow Farms and field sites, summer 2019
- 3) Select sites and install plots, fall/winter 2019
- 4) Measure recruitment of seedlings and count established plants and for at least three years after initial experiment (Halpern, 2005), spring 2019, 2020 and 2021 (or for as many seasons as possible)
- 5) If feasible, scale up seeding for a second year experiment, fall 2020

Assistance Requested:

- Provide documentation or results from any existing seeding trials
- Identify appropriate sites for direct seeding trials
- Help with permitting field experiments
- Aid installing experimental plots and application of field treatments
- Provide additional seed from augmentation efforts or field collection
- Provide media support in the form of engaging video, photos and press to provide to Disney and their donors
- Help monitor experimental plots for at least one season after initial project funding expires in 2020

Big Picture Considerations (AKA: How do we manage on the landscape level to get self-sustaining populations?)

- In grasslands, where do lupines already exist? Where are similar sites with no lupines that can be prioritized for establishment?
- On an unoccupied bare slope site, can we establish 1 lupine per sq meter?
- What seeding rate is needed? What seed treatment? Site treatment?
- What planting pattern is best for patch establishment (ex: planting at top of slope, seed disperses downhill.)
- What scrub management, soil disturbance is sufficient for stimulating natural recruitment?

- Examine population dynamics over 5-10 years scale.
- Focus on understanding site selection and be realistic about where lupines can be planted.
- Eventually re-write the MBB recovery plan.
- Shift away from active restoration to habitat management.

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graph TD
    Input1[Input] --> Dispersal[DISPERSAL]
    Dispersal --> Output1[Output]
    Dispersal <--> BudBank[BUD BANK]
    BudBank <--> VegProp[VEGETATIVE PROPAGATION]
    VegProp --> Veg[VEGETATION]
    Veg --> VegProp
    Veg --> SeedProd[SEED PRODUCTION]
    SeedProd --> Dispersal
    SeedProd --> Pred1[PREDATION]
    Pred1 --> AbovegroundBank[ABOVEGROUND SEED BANK]
    AbovegroundBank --> Dispersal
    AbovegroundBank --> SeedRain[SEED RAIN dispersal]
    Dispersal --> SeedRain
    SeedRain --> Input2[Input]
    SeedRain --> Output2[Output]
    SeedRain --> Germination[GERMINATION]
    Germination --> SeedlingBank[SEEDLING BANK]
    Germination --> SaplingBank[SAPLING BANK]
    Germination --> Veg
    SeedlingBank --> Veg
    SaplingBank --> Veg
    Fire[Fire] --> SeedRain
    Wind[Wind] --> SeedRain
    Water[Water] --> SeedRain
    Animals[Animals] --> SeedRain
    Mechanical[Mechanical] --> SeedRain
    Passive[Passive] --> SeedRain
    Light[Light] --> Germination
    Temperature[Temperature] --> Germination
    Water2[Water] --> Germination
    Oxygen[Oxygen] --> Germination
    Fire2[Fire] --> Germination
    Mechanical2[Mechanical] --> Germination
    Chemical[Chemical] --> Germination
    Germination --> SoilSeedBank[SOIL SEED BANK]
    SoilSeedBank --> Pred2[PREDATION]
    Pred2 --> FailedGermination[FAILED GERMINATION]
    FailedGermination --> PhysDeath[PHYSIOLOGICAL DEATH]
    SoilSeedBank --> Pathogens[PATHOGENS]
    Pathogens --> PhysDeath
    SoilSeedBank --> DeepBurial[DEEP BURIAL]
    DeepBurial --> PhysDeath
    PhysDeath --> Input3[Input]
    PhysDeath --> Output3[Output]
  
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The flowchart illustrates the life cycle of a plant seed, showing the progression from dispersal to vegetative propagation, seed production, predation, aboveground seed bank, seed rain (dispersal), germination, and the soil seed bank, including various inputs and outputs.

Top Section:

- DISPERSAL** (Input/Output) is connected to **BUD BANK** and **VEGETATIVE PROPAGATION**.
- BUD BANK** and **VEGETATIVE PROPAGATION** are connected to **VEGETATION**.
- VEGETATION** is connected to **SEED PRODUCTION** and **VEGETATIVE PROPAGATION**.
- SEED PRODUCTION** is connected to **DISPERSAL** and **PREDATION**.
- PREDATION** is connected to **ABOVEGROUND SEED BANK**.
- ABOVEGROUND SEED BANK** is connected to **DISPERSAL** and **SEED RAIN (dispersal)**.
- SEED RAIN (dispersal)** (Input/Output) is connected to **SEEDLING BANK**, **SAPLING BANK**, and **GERMINATION**.
- SEEDLING BANK** and **SAPLING BANK** are connected to **VEGETATION**.
- GERMINATION** is connected to **VEGETATION** and **SOIL SEED BANK**.

Bottom Section:

- SOIL SEED BANK** (hatched box) is connected to **PREDATION**, **FAILED GERMINATION**, **PATHOGENS**, and **DEEP BURIAL**.
- PREDATION** is connected to **FAILED GERMINATION**.
- FAILED GERMINATION** is connected to **PHYSIOLOGICAL DEATH**.
- PATHOGENS** is connected to **PHYSIOLOGICAL DEATH**.
- DEEP BURIAL** is connected to **PHYSIOLOGICAL DEATH**.
- PHYSIOLOGICAL DEATH** (Input/Output) is connected to **SOIL SEED BANK**.

Inputs and Outputs:

- DISPERSAL** (Input/Output)
- SEED RAIN (dispersal)** (Input/Output)
- PHYSIOLOGICAL DEATH** (Input/Output)

Factors Affecting Germination:

- Fire, Wind, Water, Animals, Mechanical, Passive** (affecting **SEED RAIN (dispersal)**)
- Light, Temperature, Water, Oxygen, Fire, Mechanical, Chemical** (affecting **GERMINATION**)
- Physical, Animal** (affecting **DEEP BURIAL**)

United States Fish and Wildlife Service (USFWS). 1984. Recovery Plan: San Bruno elfin and Mission blue butterflies. Portland, OR. 81pp.