Striking a balance: Selecting strategy levels for a startup invasive *Limonium* project based on eradication stage and budget

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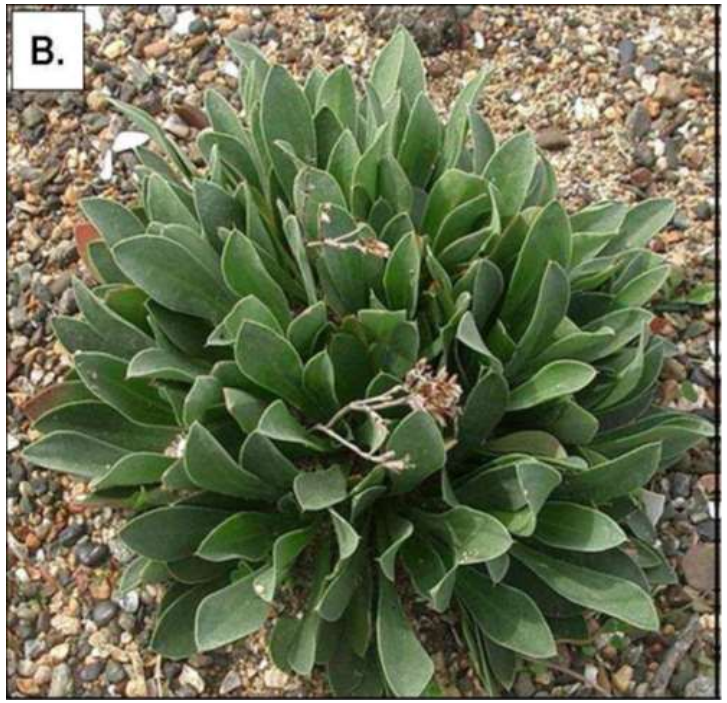
Limonium ramosissimum (LIRA; Algerian sea lavender) in the San Francisco Estuary

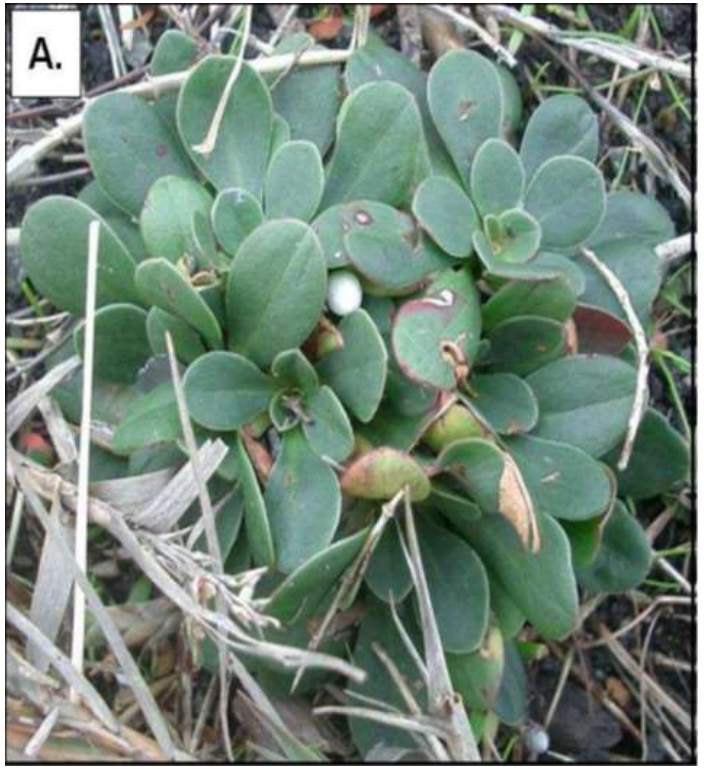


From Archbald & Boyer 2014

- First discovered in the San Francisco Estuary in 2006-2007 (Sanchez Marsh in San Mateo County, just south of SFO)
- Leaves 80-100 mm x 15-20 mm (LxW)
- Basal rosette that produces branching inflorescences (30-50 cm)
- Flowering spikelets with purple corollas (petals)

Can grow as a dense substratum *beneath* native veg

Limonium duriusculum (LIDU; European sea lavender) in the San Francisco Estuary



From Archbald & Boyer 2014

- First discovered in the San Francisco Estuary in 2006-2007 (Strawberry Marsh/ Richardson Bay in Marin County)

- Leaves 30-40 mm x 5-9 mm (LxW)
- Basal rosette that produces branching inflorescences (30-50 cm)
- Flowering spikelets with purple corollas (petals)

- Only 1 infestation detected outside Marin area of introduction (Belmont Slough, likely independent not spread)

Limonium species in San Francisco Estuary

Non-native *Limonium ramosissimum* (left) & Native *Limonium californicum* (right)

Both species are bolting

Limonium species in San Francisco Estuary

Native *Limonium californicum* playing well with other marsh plants at Ideal Marsh

Limonium species in San Francisco Estuary

Non-native *Limonium ramosissimum* forming a monoculture at Ideal Marsh

Thriving in areas of natural disturbance THEN dominating and excluding natives

Research into Invasive *Limonium*

- Two students, Gavin Archbald and Kerstin Kalchmayr, in Katharyn Boyer's Lab at San Francisco State University (SFSU)
- In the San Francisco Estuary, LIRA grows most vigorously (and produces the most seed) in the high marsh and the estuarine-terrestrial transition zone
- LIRA primarily established in **disturbed** high marsh (both natural and human-induced disturbance)
- Vast majority found above Mean High Water (MHW)
- Estimated **36,000 to 130,000 seeds per m^2**, increasing with tidal elevation
- Fortunately **LIRA cannot hybridize with our native LICA** (Boyer pers. comm.)
- Displaces native *Limonium californicum*, *Frankenia salina* (alkali heath), *Grindelia stricta* (gumplant), saltgrass (*Distichlis spicata*), *and Sarcocornia pacifica* (perennial pickleweed)

Research into Invasive *Limonium*

- 15,655 m^2 (3.9 acres) found throughout the Estuary by 2008
- Kalchmayr revisited sites: 113% increase by 2015 to 32,002 m^2 (7.9 acres)
- LIRA was also found in an additional 45 locations
- Several documented cases of mistaken identity/accidental seeding for restoration also helped spread the invader to Far South Bay including Don Edwards National Wildlife Refuge
- **Carpets of short rosettes of LIRA/LIDU cannot provide our native wildlife comparable vertical plant structure for refugia from predators, especially at high tides when most vulnerable**
- Destroys habitat for two federally-endangered species, the California Ridgway's rail and salt marsh harvest mouse

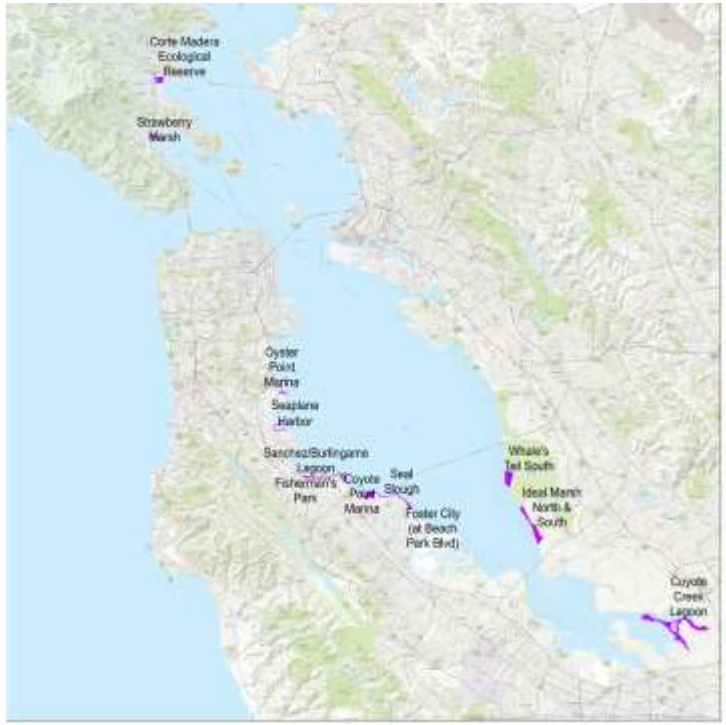
Data-Driven Prioritization of Targets

- SFSU research was critical in the **decision to take action**
- LIRA was identified by USFWS as one of three "Highest Concern" plant species in the South San Francisco Bay Weed Management Plan
- Cited as an ideal opportunity for an early detection/rapid response (ED/RR)
- Previous control efforts (mostly volunteer) were localized around the Estuary: CuriOdyssey (Coyote Point), Marin Audubon Society, Friends of Five Creeks, USFWS, Save the Bay, Kathy Boyer/SFSU, Bay Area Early Detection Network (BAEDN), Greens at Work
- A coordinated Estuary-wide response to invasive *Limonium* was needed
- With manual removal so effective, local stewards can push to eradication once the scale is reduced to a manageable level

NFWF Grants to Cal-IPC

- Initial small grant in 2015 to the California Invasive Plant Council (Cal-IPC) from National Fish & Wildlife Foundation (NFWF)
- 1st grant primarily funded pilot treatment of invasive LIRA/LIDU, as well as development of a Marsh Vulnerability Index for potential site prioritization around San Francisco Estuary
- Cal-IPC contracted with Drew Kerr for project management and field supervision of treatment crews, Solitude Lake Management (formerly Aquatic Environments) for treatment, and Olofson Environmental for mapping
- 2nd NFWF grant awarded October 2017
- $200,000 to ramp up from 15 pilot sites to begin a coordinated response to the infestation around the Estuary for the 2018-2019 seasons

2016-2017 Pilot *Limonium* Treatment Strategies



- 15 tidal marsh sites treated during the two-year pilot under the 1st NFWF grant
- Most sites at least partially mapped by Kalchmayr (2015) **Key savings for our grant $$**
- Selected mostly large infestations with easy access near the epicenter of LIRA in the Estuary (SFO area)
- More work accomplished per $ (▼mobilization costs)
- Balanced by including largest sites in the limited infestation in Marin County (reduce outliers from North Bay & **tap into volunteer network for future**)

Sanchez Marsh (presumed original introduction site)

Typical monoculture of established LIRA (left) & LIRA growing out of cracks in paved path (below)

Foster City

LIRA on the now-rare oyster shell beach of Foster City at various stages of establishment, from monoculture to new outliers

Ideal Marsh South

Ideal Marsh shows the potential of the invader once it reaches intact tidal marsh, with LIRA successfully established at marsh plain elevation, imposing a greater impact on the interior of the marsh, mainly reducing habitat along channel banks and high marsh ecotone

Ideal Marsh South

Expansion of LIRA into monocultures along infested channel banks threatens to exclude *Grindelia stricta*, a key habitat feature for endangered Ridgway's rail and salt marsh harvest mice, along with other marsh plants that provide high quality refugia from predators during extreme high tides

Belmont Slough Mouth – Largest Site in Estuary

13,323 net m^2 (3.3 net acres) when treatment began in 2017; highly disturbed area adjacent to salt marsh

Knockin' it Back during the Pilot Years

- 15 pilot sites treated 2016-2017 contained 38,454m^2 (9.5 net acres)
- At the start of the 2nd NFWF grant (Spring 2018), the net area within these sites had already been **reduced 75% to 9,375m^2 (2.3 net acres)**
- Photo of initial treatment at Oyster Point; typical LIRA infestation at epicenter on San Francisco Peninsula, ringing the edge of disturbed wetland for miles along marinas and riprap shoreline; little biotic resistance to invasion

Key Lesson from Two-Year Pilot

- Key lesson we learned from the two pilot years: LIRA is a tough plant to kill!
- Possibly due to a combination of a thick leaf cuticle (limiting herbicide uptake) and a stout tap root (allowing the plants to bounce back from their reserves)
- Much of this LIRA plant is brown post-treatment, but it escaped death
- Within 3 months, new green growth emerged & it is actually bolting

Variability of *Limonium* Treatment

- Efficacy highly variable, even within sites and tidal elevations

- In general, most sites had a net reduction of around 40-50% after a single treatment in Year 1, with some areas much better.

Variability of *Limonium* Treatment

- Efficacy tended to be very good at higher elevations

- Positive news for long-term eradication prognosis since Archbald & Boyer found these areas to be the big seed producers

Pilot *Limonium* Treatment

Treated LIRA mats often sprout from the side and between dead ones (mature plants, not seedlings recruiting on top)

Branching structure may explain (partitioning ?)

Herbicide Selection

- Test plots at two sites during pilot
- Combination of 3% imazapyr (Polaris) and 2% glyphosate (Roundup Custom) was the most effective (Liberate surfactant 1%)

- Center of photo showing imazapyr only; not as effective (green plants) compared with the standard combo with glyphosate (surrounding). Although imazapyr-only did inhibit flowering

- Capstone (triclopyr and aminopyralid) at 3% has showed good results in areas above Mean High Water (limited applications 2019)

Key Lesson from Two-Year Pilot

- While there are lots of brown LIRA leaves in this photo one month post-treatment, many are yellow or red and have shown to bounce back to some degree
- BUT two same-year applications spaced approximately 6-8 weeks apart greatly improved our reductions on an annual basis
- Round 2 treatment may increase efficacy from 40% up to 80%+ in one season by weakening LIRA's reserves just a bit more
- Normally just treating a small portion of a plant with signs of life; green plants may have been missed

Lessons from Pilot Transferred to 2018-2019 *Limonium* Treatment Seasons

- Started treatment two months earlier than 2016 (mid March vs. late May)
  - Herbicide efficacy good early in phenology, but after spring temperatures begin to rise and stimulate more seedbank recruitment
- At most sites, efficacy from a single application is not sufficient to achieve an eradication trajectory
- **Round 2 treatment 6-8 weeks after initial yields <u>much higher mortality on mature plants</u> & catches misses as well as new seedbank recruitment**
- Treating sites ahead of flowering ensures minimal seed production
  - At $100k per year for entire Estuary, budget still too limited to conduct Round 2 treatment on all sites, but even if some plants survive, the majority don't flower after application
- June/July surveys provide higher detection (inflorescences emerging from under native veg)

2nd NFWF Grant: 2018-2019 Mapping & Treatment

- **Year 3 (2018)** the project team mapped all pilot sites
  - Measure progress from 2016-2017
  - More thorough detection better defined scope
- Focused new site mapping to again maximize LIRA reductions and economies of scale
- Began to radiate out from epicenter and other known moderate-to-large infestations

- **Year 4 (2019)** focused limited grant $ on treatment
- Only mapped new sites (no follow-up inventory from 2018)
- Created a duplicate 2018 data set to use on rugged GPS tablets to inform treatment (often same footprint)

Invasive *Limonium* Site Status 2019

Invasive *Limonium* Site Status 2019

- 86 infestation sites identified by project team
- 53 sites (62%) mapped and treated (from 1-4 seasons)
- 19 sites mapped but not yet treated
- 14 sites identified but not yet mapped/treated (mostly nascent infestations scattered over the large marshes of South Bay)
- Leveraging synergies with the Invasive *Spartina* Project; created system to track new observations of LIRA during annual *Spartina* mapping

Invasive *Limonium* Site Status 2019

- Total net area of all mapped sites at their peak is 67,391m^2 (16.7 net acres)
- 53 treated sites represent 64,489m^2 (15.9 net acres), or 96% of the total peak area of mapped sites
- 19 sites that have been mapped but not yet treated contain 2,902m^2 (0.7 net acres) or 4%
- "Peak"= area mapped 2015-2019 before any Cal-IPC treatment. Several sites previously received manual removal, mostly from volunteer groups.
  Actual "peak" ~ 1-2% higher

Invasive *Limonium* Reductions Pilot Sites 2016-2018

Reductions at some key pilot sites. As described previously, we invested in treatment in 2019 so the most recent mapping for these sites is 2018. All have subsequently been treated 2X.

Site	Year Treatment Initiated	Peak (net m^2)	2018 (net m^2)	% reduction
Sanchez Marsh	2016	5,436	111	97.9%
Coyote Point	2016	3,674	278	92.4%
Coyote Creek Lagoon	2016	1,642	233	85.8%
Oyster Point	2016	3,510	729	79.2%
Belmont Slough mouth	2017	13,323	4,280	67.8%

Once a reduction of 80-85% is achieved, annual reductions normally slow; the slow asymptotic approach to local eradication requires exhausting the seedbank and LIRA matures quickly.

LIDU Invading Rare Plant Population

Carpet of flowering rosettes of LIDU growing amongst the rare native *Chloropyron maritimum* ssp. *palustre* at Strawberry Marsh in 2016

Conduct **manual removal** in early March before *Chloropyron* (an annual hemi-parasite) emerges from seedbank, allowing us to avoid impacts to the rare plant

Testing Alternatives – Propane Flaming

Backpack with clean H_2O + fire extinguisher

Equipment borrowed from Marin County Parks

Testing Alternatives – Propane Flaming

- Most effective on small plants and seedlings
- Tedious and time-intensive task
- Appears to be more cost effective than manual removal of 1000's of seedlings
- More costly than herbicide application
- Good follow-up method

Testing Alternatives – Propane Flaming

- Within a few weeks of a spring 2019 propane flaming of LIRA & LIDU, two native plants were growing vigorously from perennial roots: saltgrass (*Distichlis spicata*) & alkali heath (*Frankenia salina*)

- Efficacy on the *Limonium* appeared quite good except on the largest plants; jury is still out until the following year

Scary Upland Invasive Potential of LIRA

Well established in landscaping far above tides

Surrounding a pool in Sausalito adjacent to houseboats

Thank You!

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