Assessing Spatio-temporal Changes of Invasive Algerian Sea Lavender (*Limonium ramosissimum)* in San Francisco Bay Wetlands

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Introduction

Limonium ramosissimum (LIRA) is a native of Western Mediterranean coastal marshes and was first recorded growing in San Francisco Bay wetlands in 2007. Early concerns prompted immediate research to describe the species' life history and behavioral traits to help inform management strategies.

These early studies provided essential baseline information on LIRA's ability to invade and impact San Francisco Bay salt marshes (Archbald and Boyer, 2014a and b; Cleave 2012). However, as these studies were conducted over a short-term period they provided only a limited view into the ecological behavior of the species whose effects can change dramatically over time (Strayer et al. 2006). This study lengthens the view of LIRA's increasing presence.

Study Objectives:
In this study we return to the study sites established 7 years ago to assess:
1. Changes in abundance and distribution of LIRA populations throughout the Bay-Area.
2. Changes to species composition and soil properties.

Methods

This study repeats the 2008-2010 methodology of Archbald and Boyer (2014a).

Bay-wide mapping:
Our study resurveyed and remapped 16 of the 20 locations previously mapped by Archbald and Boyer (2014a)(Figure 1). LIRA population patches were mapped using a handheld Trimble GeoXH GPS. At each of the patches, percent cover of LIRA was ocularly estimated. GPS data were post processed in Trimble Pathfinder Office, and ArcMap 10.2.2 was used to extract area and percent cover data from the polygon layers. Changes in area and percent cover were examined.

Mensurate surveys:
Mensurate surveys were conducted at three established study sites in San Mateo County (Figure 2) in August 2015 to determine LIRA's impacts on species composition and soil properties. Archbald and Boyer (2014a) established 30 survey plots at each of the study sites. At each site 15 survey plots were placed inside LIRA patches and 15 survey plots were placed outside LIRA patches (Figure 3). These plots were relocated. One meter square quadrats were used to evaluate species percent cover within the plots. Further work on soil properties to determine changes in soil moisture and salinity are currently underway.

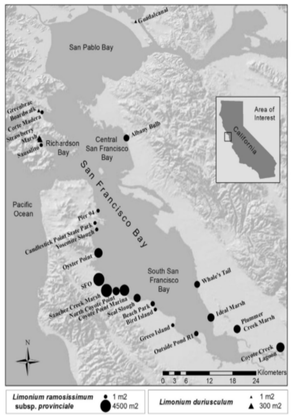

Figure 1: Relative size and location of known LIRA populations as of 2010. (*L. durisculum* populations also shown) (Archbald and Boyer 2014a)

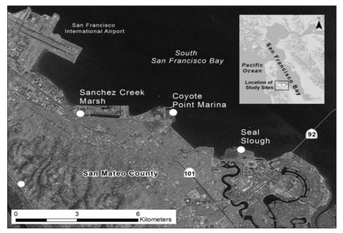

Figure 2: The three study sites established by Archbald and Boyer (2014a) in 2008

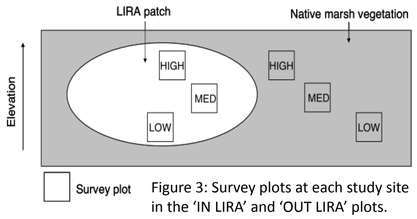

Figure 3: Survey plots at each study site in the 'IN LIRA' and 'OUT LIRA' plots. (Archbald and Boyer 2014a)

Preliminary Results

Mapping Results:
Paired t-tests were used for this preliminary analysis. Bay-wide LIRA populations were shown to have significantly increased since the 2008-10 survey from ~15,000 m^2 to ~30,000 m^2 in 2015 ($p \leq 0.05$) (Figure 4A&B). Along with total area, the number of patches containing LIRA as well as its percent cover also increased . We found an almost doubling of total LIRA area in the mapped sites when compared to the previous survey.

At Yosemite Slough, which recently in 2013 underwent tidal marsh restoration, the increase was dramatic, from 5m^2 mapped in 2008 to 1360m^2 in 2015. Locations such as Pier 94 and Albany Bulb experienced relatively smaller population increases likely due to frequent weeding efforts by local non-profits.

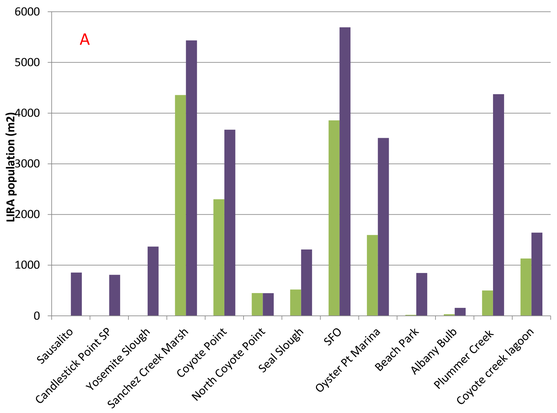

Figure 4A and B: LIRA population size at 16 Bay-wide locations between 2008-2010 and 2015.

Mensurate surveys:
Only differences between the 'IN LIRA' plots versus. 'OUT LIRA' plots were currently analyzed. Further multivariate analysis examining the relationship between species and sites are pending.

From the years 2008 to 2015 LIRA decreased in mean percent cover in the 'IN LIRA' plots except at Seal Slough where an increase was observed. The increase at Seal Slough, however, was not significant. The decrease in LIRA at Sanchez Creek Marsh and Coyote Point Marina were significant ($p \leq .05$) (Figure 5).

From the years 2008 to 2015 LIRA significantly increased in mean percent cover in 'OUT LIRA' plots at all three study sites (Figure 5).

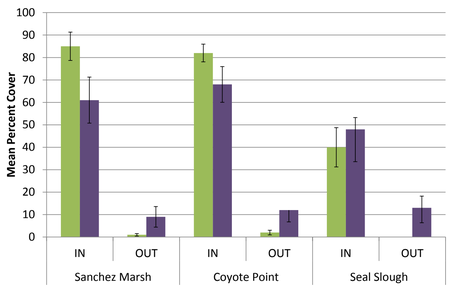

Figure 5: LIRA mean percent cover 'In' vs 'Out' plots at 3 study sites

Dominant co-occurring native species such as *Salicornia pacifica* (SAPA), *Distichlis spicata* (DISP) and *Jaumea carnosa* (JACA) all decreased in percent cover in the 'IN LIRA' and 'OUT LIRA' plots at Sanchez Marsh and Seal Slough. At Coyote Point, DISP and JACA showed a slight increase in both the 'IN LIRA' and 'OUT LIRA' although this was not significant. (Figure 6A,B,C)

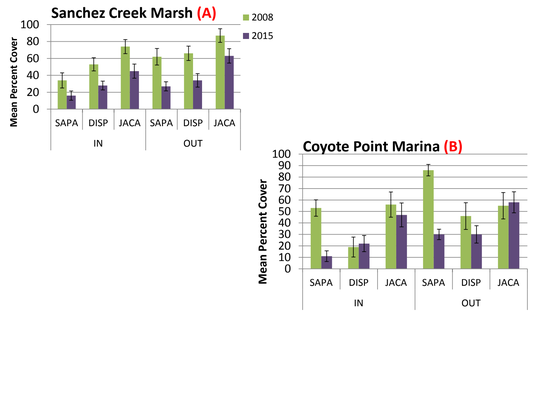

Figure 6 A,B,C: Native species mean percent cover at the 3 study sites in 'In' vs 'Out' plots.

Limonium ramosissimum
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Discussion

Over the last 7 years LIRA populations throughout San Francisco Bay have significantly increased in size and density. As observed by Archbald and Boyer (2014a), LIRA does well in disturbed sites especially where wetland restoration efforts have taken place. Newly restored sites are increasingly vulnerable to LIRA invasion. Ongoing weeding efforts at smaller sites have shown to be effective in curbing population explosions.

Vegetation surveys showed that LIRA increased in density in plots that had not been invaded in an earlier survey. Native species decreased where LIRA was previously present and increasing. However, as all species were observed to be decreasing in previously invaded plots it is highly likely that the current extreme drought may have had some influence on native species abundance and distribution. It is possible that LIRA may be more adaptive to extreme drought conditions compared to native species. An additional vegetation survey will take place in Marsh 2016 to give further insights into the above conclusions.

Conclusion

LIRA is an aggressive invasive species in Bay Area wetlands and should be targeted for removal to prevent damage to native species.

This study is currently underway, future results will include soil analyses as well as multivariate analyses to learn more about LIRA in Bay Area wetlands.

Works cited:

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