Adaptive Restoration of Tijuana Estuary

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Based on research and field work conducted with dozens of collaborators

Tijuana Estuary's salt marsh diversity is threatened; 30 years of data on the natural salt marsh show that species lost in 1984 have not recovered, despite multiple restoration efforts.

1974-76: The diverse salt marsh
Salicornia bigelovii and *Suaeda esteroa* were widespread and abundant
Salicornia virginica not superdominant; no pure *Sv* plots

1984: The depauperate salt marsh
Salicornia bigelovii and *Suaeda esteroa* virtually extirpated
Salicornia virginica superdominant;

1994-2004: Incompletely recovering marsh
Salicornia bigelovii and *Suaeda esteroa* still missing
Ambitious reseeding experiments did not recover them

Other alarming trends, 1989-2004
Spartina foliosa is being replaced by *Salicornia virginica* in the low marsh
Dominance is now high
S.virginica has much higher cover than in 1974
Jaumea carnosa also has higher cover than in 1974

Why? The marsh has changed since 1974

1944-74: Long period without catastrophes
1983: Sea storm filled channels with sand
1984: Mouth closed for 8 mo.
1985: Tidal flushing restored
1978ff: Flooding and sedimentation events; marsh-plain elevating and salinizing

Efforts to restore lost diversity:

1984: Excavation of sediments; mouth reopened; tidal flushing restored
Twice: Reintroductions of *Sb* & *Se* to natural marsh
1997: Tidal Linkage site excavated (~1.25 ac)
2000: Friendship Marsh excavated (20 ac)

The Tidal Linkage did not recover *Suaeda esteroa* or *S. bigelovii*
The Friendship Marsh did not recover *Suaeda esteroa*, but *S. bigelovii* is (briefly) abundant
[Loss at Tidal Linkage suggests it won't persist.]

Conclusions from 30 years of sampling and restoring Tijuana Estuary:

•The salt marsh has lost diversity.
•*Sb* & *Se* still threatened; *Sv* & *Jc* are superdominant.
•Sedimentation elevates and salinizes the marsh plain.
•Restoration efforts have expanded salt marsh area but not recovered short-lived species to 1974 levels

We understand the degradation, but recovering losses has been a puzzle…..

How adaptive restoration has helped Tijuana Estuary

Retracing our steps:
- We needed to restore diverse salt marsh vegetation.
- There were no guidelines.
- How to begin?
  - Select reference sites;
  - Develop a species list;
  - Set up an experiment
- Start simple and small scale
- Plant each species in plots; provide unplanted control plots.
- Replicate treatments (8 species and control x 5 = 45 plots).
- Evaluate outcomes (number surviving, growth).
- Relate results to treatment (planted vs. unplanted plots).

Knowledge for future phases
- No need to plant species that recruit without help. *[Salicornia virginica]*
- Introduce those that do not recruit on their own. [7 of 8 tested; Lindig-Cisneros & Zedler 2001]

But which can establish well from seed vs. plugs?
- Follow recruitment of seedlings;
- Sow seeds of those that recruit *[S. bigelovii, Suaeda esteroa;* Lindig-Cisneros & Zedler 2001*];*
- Plant plugs of those that don't.

But how densely should they be planted?
- Compare 10 cm, 30 cm, 90 cm
- Tight clusters have higher survival.(O'Brien and Zedler In press)

Do species-rich clusters persist?
- Long-term assessment shows that readily recruiting, short-lived species drop out.

Are specific microsites needed?
- Compare depressions, mounds, and flat areas
- Some species persist only where dominants are subdued, e.g., in waterlogged depressions
- It's not sufficient to plant a site; consider contouring site to create key microsites

Can we accelerate establishment and vegetative growth?
- Other preparations can improve survival, growth
- Some species grow best near creeks; others with soil amendments (O'Brien & Zedler In press)

Composition might need adjustment over time
- Test ways to control invasives; introduce key animals

Knowledge improves with experiments;
- Adaptive restoration solves puzzles, but new problems continue to arise….

Formalizing adaptive restoration:
1. Identify and prioritize key unknowns
2. Phase the project
3. Address top unknown(s) in Phase-1 experiment
4. Use knowledge from phase 1 in Phase-2 restoration
5. Address additional unknowns in next-phase experiments
6. Repeat 4-5 and scale up over time

Contrast **adaptive approach** with **trial and error**

With trial and error,
- If the target is missed; you don't know why, so you might repeat the error
- If you hit the target, you don't know why, so you might not be able to repeat the outcome

With adaptive restoration,
- Efforts that hit the target are linked to the measures that were taken
- Efforts that miss the target can be ascribed to other measures taken

Further reading, especially about restoration at Tijuana Estuary:

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