Monitoring a Living Shoreline in San Francisco Bay

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Common goals of living shorelines projects

- Restore habitat-forming species
- Successful establishment of target species
- Habitat use by other species

- Provide physical benefits to shorelines
SF Bay Living Shorelines Project

Multi-Habitat, Multi-Objective

- Restore two habitat forming species
- Refine restoration techniques
- Monitor use by invertebrates, fish, birds
- Determine benefit of two species
- Determine physical benefits

- Apply lessons learned to larger projects
Native Olympia Oysters
*Ostrea lurida*

- Filter feeders
- Habitat builders
- Food source

Eelgrass
*Zostera marina*

- Traps sediments, reduces erosion, sequesters carbon
- Builds habitat
- Foraging area for birds & marine mammals
Design basics of large-scale project
Smaller-scale test of “Baycrete” substrates
Oyster Settlement Substrates

Large plots: 10 x 32m
Series of shell bag mounds

“Baycrete” small scale substrates
Reef Balls
Reef Ball Stacks
Oyster Blocks
Layer Cake
Project Design, San Rafael (TNC) site

Lagoon

Mudflat

Shell bag mound

Eelgrass

Shell bag mound + eelgrass

Control

SF Bay

~250 m

Layer cake

Reef ball stack

Reef ball

Oyster block

Detail:
Larger scale experiment
32 m x 10 m

Eelgrass vegetative shoots

Shell bag mounds

Detail:
Substrate experiment
30 m x 1 m
San Rafael (TNC)

Larger control site

Photos, S. Kiriakopolos
8 Major Objectives

To measure success:

• Pilot-scale, experimental approach
• BACI design
• Robust monitoring plan
• Funding for 5 years of monitoring
• Multidisciplinary team
8 Project Objectives

1. Establish target species

2. Compare restoration approaches
   - Restore separately or combo?
   - Best oyster substrate?
   - Best tidal elevation?
   - Eelgrass transplants or seeds?
   - Best donor site?
Oyster establishment

Small quadrats
Small shell bags
Recruitment tiles
- Density
- Size
- Survival
- Recruitment
- Cover of sessile species
No apparent benefit from eelgrass
Oyster recruitment variable
Which substrate elements are best?

- Greater surface area
- Greater protection from heat stress
- More horizontal surfaces
Best tidal elevation

Densities one year after construction (Nov 2013)

High +45 cm MLLW
Mid +30 cm
Low +12 cm
Elevation effect decreases over time
Over time, space competition may be greater at lower tidal elevations.
Eelgrass monitoring

- Quarterly
- Count shoots
- Measure longest
- Collect samples for epifauna/epiphytes
Eelgrass establishment

- Initial transplanting, seed buoys failed
- Replanting successful ~3 years
- Die off winter 2015-16
  Possible explanations:
  Increased wave action or turbidity during El Nino?
  Large algal bloom?
  Canada Geese?

Deeper plants survived

- Second Replanting 2016
Eelgrass establishment

- Eelgrass-only plot better density and height
- Difference by donor sites
Data informed 2nd replanting

After 3 months, shoreward side of reef: much higher shoot numbers

![Graph showing total number of vegetative shoots by location.](image)

- **Initial number planted**
- **Total number of vegetative shoots**
  - Alone: ~50
  - Bayward of reef: ~10
  - Shoreward of reef: ~400
Project Objectives

3. Did we enhance habitat?
4. Does treatment type matter?
   - Invertebrates
   - Fish
   - Birds
Invertebrates: methods
Fish: methods

- **acoustic tagging**
  array of 69-kilohertz receivers to detect tagged fish

- **trapping**
  spring and summer minnow and oval 24 hrs
Fish: methods

- seining quarterly
- 1 shoreside, 2 bayside transects
Birds: methods

- Area divided into zones
- Monthly
- Bird density, behavior
- High, low tides
- Benthic cores fall & spring
Invertebrate effects: more shrimp and rock crabs

C = Control
E = Eelgrass
E+O = Eelgrass + Oyster
O = Oyster
P = Pre-treatment
Structure affects invertebrate communities

- Distinct communities by treatment type
- Combo has greatest richness
Infaunal invertebrates

- Invertebrate densities and biomass increased in all treatments
- Amphipods, polychaetes
- # of unique invertebrate taxa increased in treatments, from 14-22 taxa
Fish response

- **acoustic monitoring:**
  - few individuals detected
  - site too shallow
  - white sturgeon, green sturgeon, leopard shark, steelhead smolt, striped bass
  - indication some lingered/repeat visits
Fish response

- trapping: trend > black surfperch, bay pipefish in eelgrass
- seining: rapid recruitment of pipefish to eelgrass; more pipefish, shiner surfperch, saddleback gunnel to combo plots
Increased avian richness

- Wading birds, Forster’s Terns and Black Oystercatchers
Increase in wading birds
All birds – more foraging at reefs

On oyster reefs:
- Forage: 70%
- Rest/Roost: 15%
- Preen/Comfort: 13%
- Swim/Walk: 1%
- Sleep: 1%

Off reefs:
- Forage: 53%
- Rest/Roost: 18%
- Preen/Comfort: 12%
- Swim/Walk: 11%
- Sleep: 3%
Project Objectives

6. Physical effects
- Wave attenuation
- Sedimentation
- Subsidence of structures

Continuous Ambient WQ

Acoustic Doppler Current Profiler

Total station
Physical changes

- Fewer, smaller waves shoreward of treatment plot
- Wave modeling indicates reef extracts 30% more energy
- However most energy lost on broad offshore mudflat
Subsidence and Sediment Accretion
Lessons learned to date

- Use shell bags to maximize native oyster recruitment
- Co-locate eelgrass and oyster reefs to maximize invert/fish use
- Plan for accretion
- Large structures may benefit shorelines
- Oyster/eelgrass habitats benefit many other species
Lessons learned to date

- Oyster, eelgrass populations are dynamic
- Expect different stressors, results
- Start small at new sites
- Long term monitoring is critical!
more info: sfbaylivingshorelines.org