Hard Infrastructure
Impacts to Shorelines and Wetlands

- Dredging, placement of fill, construction of structures
- Loss of habitat values and species
- Impacts to natural processes, often increases in erosion, high maintenance costs
- Worsening impacts w/ sea level rise, increased storm surge, flashier system

Potential Benefits
Nature-Based Infrastructure

- Enhanced habitat values- functions and services
- Increased species support and connectivity
- Erosion control and shoreline protection
- Climate adaptation and habitat resilience
- Cost effective, higher sustainability, less maintenance
Policy Support and Permitting

- President’s Climate Action Plan:
  - Improve natural defenses
  - Protect biodiversity
  - Conserve natural resources in the face of climate change
  - Manage public/private lands to store carbon
- ACOE Dec 2013- requires SLR consideration

- State of CA Safeguarding CA Plan
- State Coastal Commission LCP updates, SLR
- State Coastal Conservancy CC Priorities and SLR Guidance
- SF Bay BCDC policies- fill, SLR
Maryland Living Shorelines Protection Act

• 580 acres of shoreline- Chesapeake, Atlantic
• preferred method of shoreline protection
• state public policy- protect natural habitat and shoreline processes
• have to demonstrate that it’s not feasible before constructing bulkhead

States with Programmatic Permits- *partial list*

• Maryland
• Virginia
• South Carolina
• Alabama
• Mississippi
Regional Climate Adaptation Recommendations
1. Restore estuary-watershed connections.
2. Design complexity and connectivity into the Baylands landscape.
3. Restore and conserve complete tidal wetlands systems.
4. Plan for the Baylands to migrate.
5. Actively recover, conserve, and monitor wildlife populations.
6. Invest in planning, policy, research and monitoring.

SF Bay Living Shorelines Project
- Intertidal and subtidal connectivity
- Native Olympia Oysters and eelgrass
- Biological and physical goals
Transition Zones on Both Edges

Upland transition

Subtidal transition

Wetland edges: sand bars, shell beds, kelp and eelgrass fringe, rocky intertidal
Complete tidal wetland system
Multi-Habitat, Multi-Objective

- SF Bay Subtidal Habitat Goals
- Pilot scale, experimental approach
- Monitor biological use and physical benefits
- Pilot climate change adaptation
- Apply lessons learned to larger projects
Native Olympia Oysters: *Ostrea lurida*

- Small: usually 1.5 – 2”
- Planktonic larvae, settle on hard substrate
- Filter feeders, water quality
- Heterogeneity = increased niche space
- Food source for other invertebrates, birds, fish

Eelgrass: *Zostera marina*

- Rooted, flowering plant
- Spreads clonally and by seed
- Traps sediments, reduces erosion, sequesters carbon
- Builds habitat: epifauna, infauna, fish (e.g., pipefish)
- Foraging area for birds & marine mammals
<table>
<thead>
<tr>
<th>Ecosystem Functions</th>
<th>Ecosystem Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>enhance habitat for fish and wildlife</td>
<td>sediment accretion</td>
</tr>
<tr>
<td>increase food resources</td>
<td>wave attenuation</td>
</tr>
<tr>
<td>rearing/nesting support</td>
<td>minimize shoreline erosion</td>
</tr>
<tr>
<td>improve linkages and connectivity between habitat types</td>
<td>promote potential physical synergistic effects between habitats</td>
</tr>
<tr>
<td>assess interactions between habitat types that influence restoration success</td>
<td>test alternatives to traditional shoreline armoring</td>
</tr>
</tbody>
</table>
Project location

San Rafael (TNC)

Hayward (ELER)
Design basics of large-scale project

Mudflat

SF Bay

Shell bag mound

Eelgrass

Shell bag mound + eelgrass

Control

~250 m
Smaller-scale test of “Baycrete” substrates
Project Design, San Rafael (TNC) site

Detail:
Larger scale experiment
32 m x 10 m

Eelgrass vegetative shoots
Shell bag mounds

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

Inset Map

Oyster Treatment

Eelgrass Treatment

Eelgrass + Oyster Treatment

Legend
- Treatment Plots
- Control Plots

Treatments
- Eelgrass
- Shell Bag Mound

Oyster Structures
- Layer Cake
- Oyster Blocks
- Oyster Ball Stack
- Reef Ball

Plot Control Treatment

1:1,250
1 inch = 32 meters

Photos, S. Kiriakopolos
Construction
Construction Prep: Pacific Oyster Shell Bags

Photos, M. Latta
Preliminary results - San Rafael
- < 3.8 million oysters at height of recruitment
- Currently ~750,000 oysters
  - Survival rates, annual recruitment fluctuations
  - Food resource for many species

Photos, S. Kiriakopolos
Establishment of oysters

SHELL BAGS: ESTIMATED TOTAL # OYSTERS TNC

<table>
<thead>
<tr>
<th>Month</th>
<th>Oyster</th>
<th>Oyster &amp; Eelgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2012</td>
<td>1,728,000</td>
<td>1,486,000</td>
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<tr>
<td>April 2013</td>
<td>826,964</td>
<td>894,410</td>
</tr>
<tr>
<td>July 2013</td>
<td>1,078,272</td>
<td>964,000</td>
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<tr>
<td>November 2013</td>
<td>1,597,920</td>
<td>1,261,440</td>
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<tr>
<td>April 2014</td>
<td>608,256</td>
<td>649,728</td>
</tr>
<tr>
<td>July 2014</td>
<td>601,344</td>
<td>615,168</td>
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<tr>
<td>November 2014</td>
<td>435,456</td>
<td>422,532</td>
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<tr>
<td>April 2015</td>
<td>349,056</td>
<td>494,532</td>
</tr>
<tr>
<td>July 2015</td>
<td>349,056</td>
<td>494,532</td>
</tr>
</tbody>
</table>
Comparison of treatments

Shell bag units have the most oysters, layer cakes the least

- Greater surface area
- Greater protection from heat stress
- More horizontal surfaces
TNC: # oysters on elements by elevation

![Graph showing the number of oysters on elements by elevation for different time periods: November 2012 (North), April 2013 (North), July 2013 (North), November 2013 (North), April 2014 (North), July 2014 (North), November 2014 (North), April 2015 (North), July 2015 (North). The graph includes categories for Layer Cake, Oyster Ball Stack, Oyster Block, and Reef Balls.]
Eelgrass Densities

- Planted density $= 576$

![Bar chart showing eelgrass densities over different seasons:
- Fall 2014: EG, EO
- Winter 2015: EG
- Spring 2015: EG, EO
- Summer 2015: EG, EO

Vegetative and flowering eelgrass densities are depicted with blue and green bars respectively.

Planted density $= 576$
Preliminary results - San Rafael
So much life out there

Photos, S. Kiriakopolos
Native fish and invertebrates associated with physical structure

- Juvenile Dungeness Crabs
- Bay Shrimp
- Red Crabs
- CA Rock Crabs
- Bay Pipefish

White Sturgeon, Leopard sharks, and Steelhead

-- repeat visits to reefs
(acoustic receivers detecting tagged fish)

Photos, S. Kiriakopolos
Preliminary results - San Rafael
Many species reproducing

Gravid shrimp

Goby eggs on oyster shell

Oysters brooding

Brooding rates of 25% from year-one oysters

Nudibranch egg casings

Photos, S. Kiriakopolos
Preliminary results - Birds

- Wading birds and Black Oystercatchers increased significantly
- Suggests increased fish foraging opportunities
- In the sediments: # of unique invertebrate taxa increased, from 14-22 taxa
Black Oystercatcher behavior on TNC reefs

- Mean proportion of time spent in various behaviors
- 47% of time spent in foraging behaviors (shades of purple)
Preliminary results - Physical changes

15 cm sediment accretion along reefs

24 cm in center

Total station

Acoustic Doppler Current Profiler

Wave energy

- most energy lost on broad mudflat
- but reef extracts 30-50% more at MSL water levels

Continuous Ambient WQ
Settlement and Sediment Accretion

San Rafael: Sedimentation and Oyster Habitat Availability

- Elements Placed
- Space available (8 weeks after start of project)
- Accretion inside units
- Accretion adjacent to units
- Approximate Pre-Project Ground Surface
- Space available for oysters inside reef (11 months)
- Space available for oysters on outside of reef (11 months)
Phase Two - Integrated Restoration
Climate Adaptation requires Multi-Objective Approaches

Shoreline Protection with Biological and Physical Goals

Design to address Sea level rise and erosion

Additional Pilot Projects needed – BMP’s and Design Criteria

Increased capacity needed
  • design
  • permitting
  • implementation

Policy changes- bay fill, thoughtful experimentation

Marilyn Latta, Project Manager
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www.sfbaylivingshorelines.org