Beach Replenishment with High-Fines Sediments: Using Before-After Control-Impact Approaches to Monitor Beach Habitats

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Coastal Sediment Management: the Problem in California

- Reduction in Sand Reaching the Coast
  - Retention of sediments by dams
  - Urbanization – reduced loads & peak flows
  - Removal of sediment from watersheds as waste product
  - Reduced coastal bluff erosion

➢ Need for a Management Strategy

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Coastal Sediment Management Workgroup

- Collaborative Effort Led by USACE and the California Natural Resource Agency
  - Incorporation of Regional Sediment Management approach
  - Maximize Beneficial Reuse of sediment through optimization of supply/need imbalances
  - When possible, incorporate or augment natural processes

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Sediment Management: the Fate of Fines

- Association with Contaminants, Nutrients
- Turbidity Impacts
- Compatibility with Disposal Site Characteristics
- Constraint: the 80:20 ‘Rule of Thumb’
- Limited Quantitative Understanding of the Fate of Fines in the Environment

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Objective: A Comparison:

"Natural" Placement

Direct Placement

- What are the Pathways of Fine Sediment in the Nearshore?
- Are there Biological Impacts as a result of DP?

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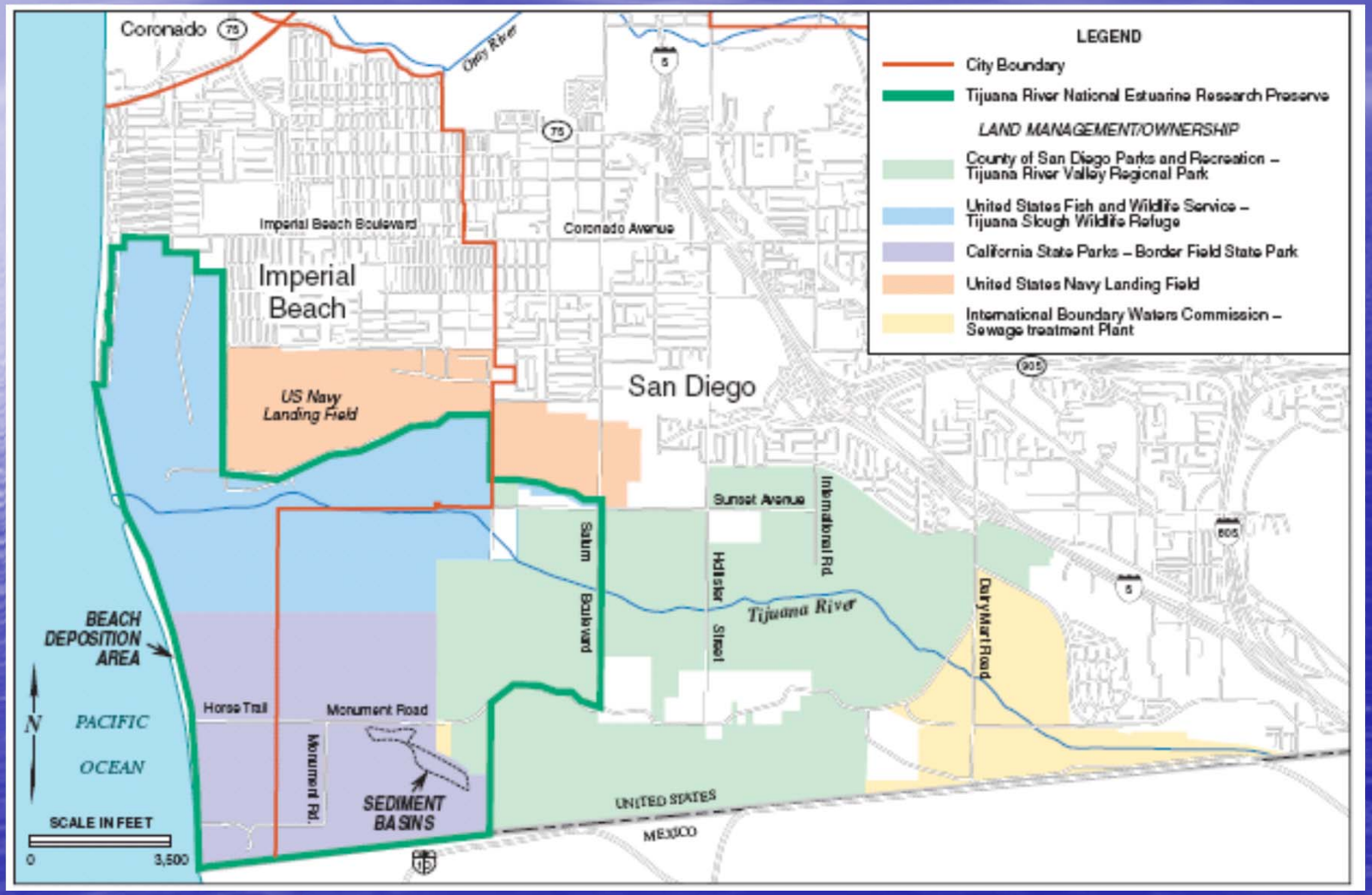
Tijuana River Watershed



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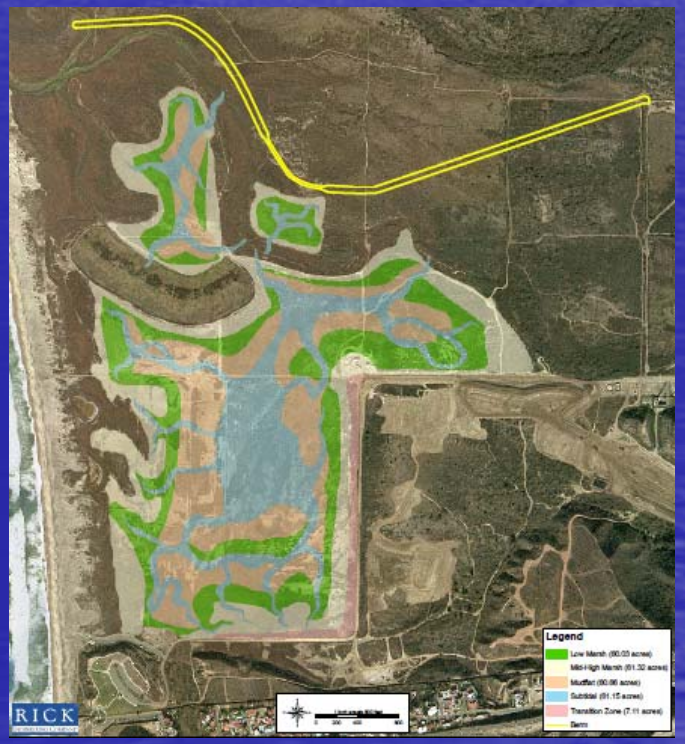
Sources of Fines

- Tijuana River Discharge
- Border Canyon Flows (Smuggler's Gulch, Yogurt Canyon)
- Goat Canyon (with retention basins)
- Tijuana River Tidal Restoration Program



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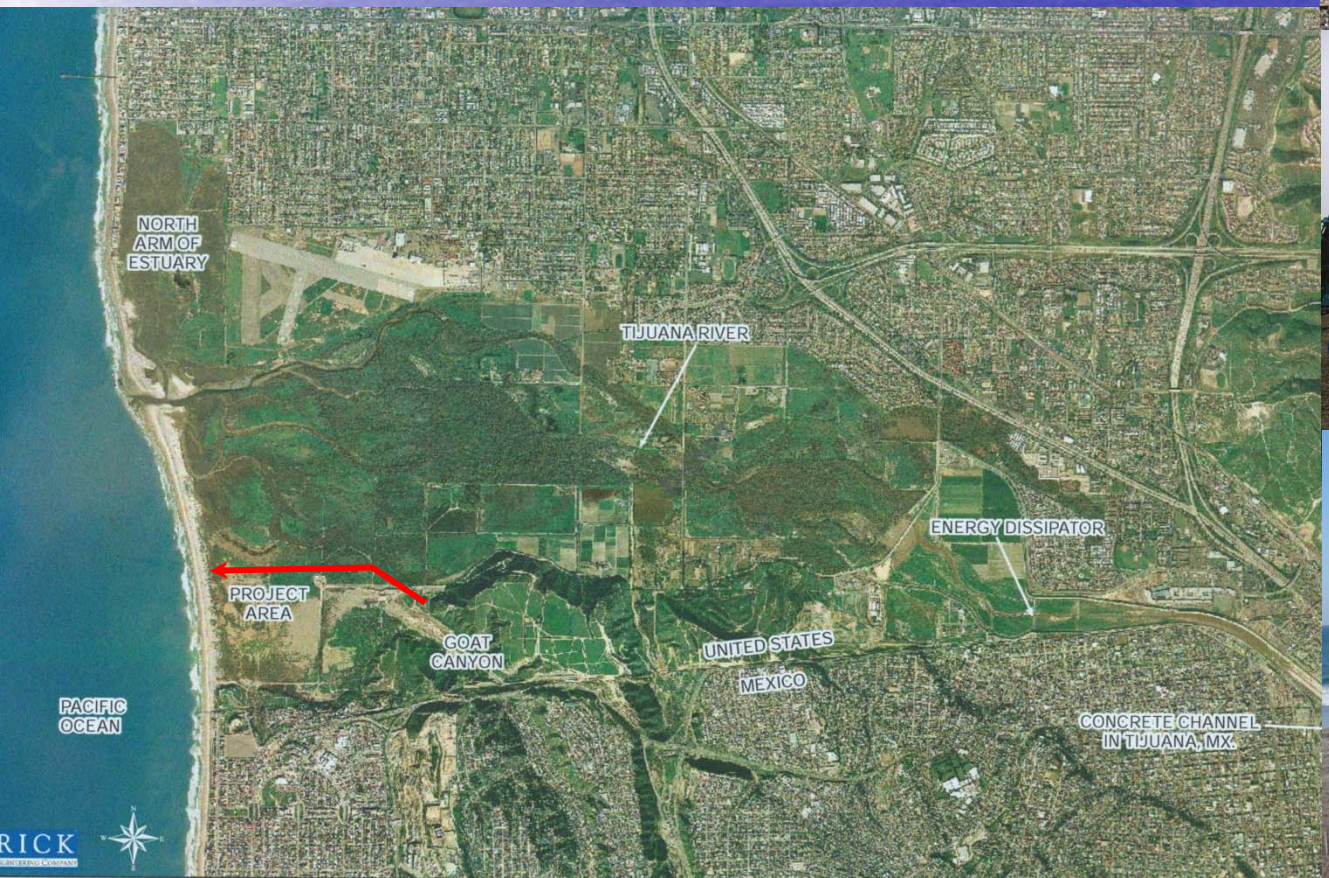
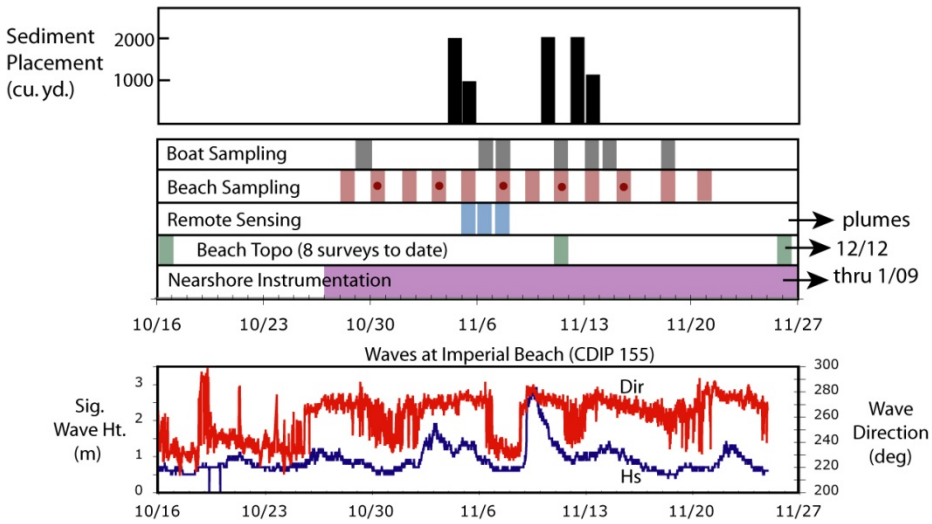
Goat Canyon

- ~30,000 cy/yr
- Clean sediment, sorted for trash & debris
- ~45 percent fines

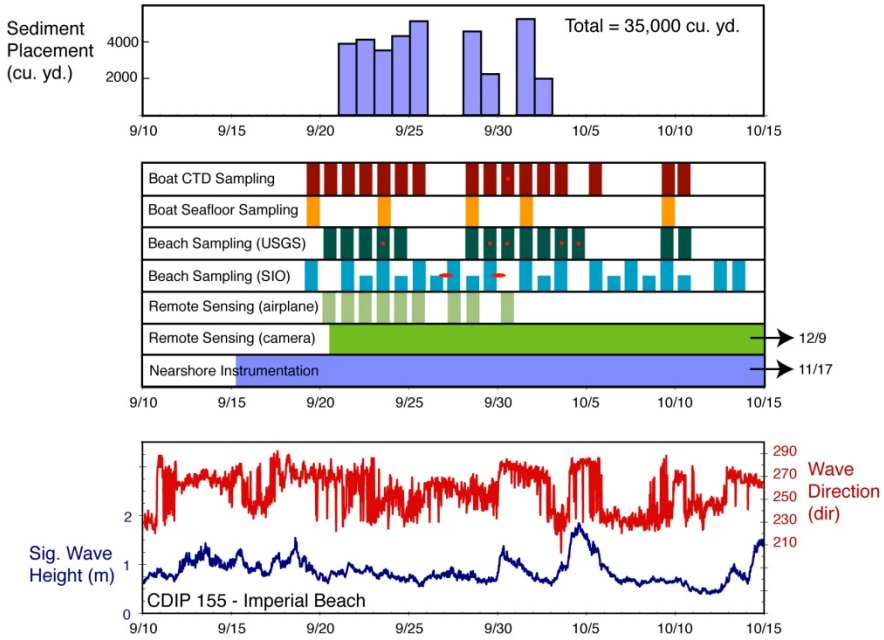


Project Implementation Schedule

2008 10,000 cubic yards



2009 35,000 cubic yards



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Biological Monitoring Objectives

- Is the benthic macroinvertebrate fauna affected by sediment placement activities in the intertidal?
  (Abundance & Biomass)
- Are shorebirds affected by project activities?
  (Abundance & Behavior)
- Are offshore sand dollar beds affected by the sediment placement?
  (Size-Frequency Distribution, Bed Dimensions)
- Is magnitude of placement event important?
  (Phase I [2008] – 10,000 cy, Phase II [2009] – 35,000 cy)

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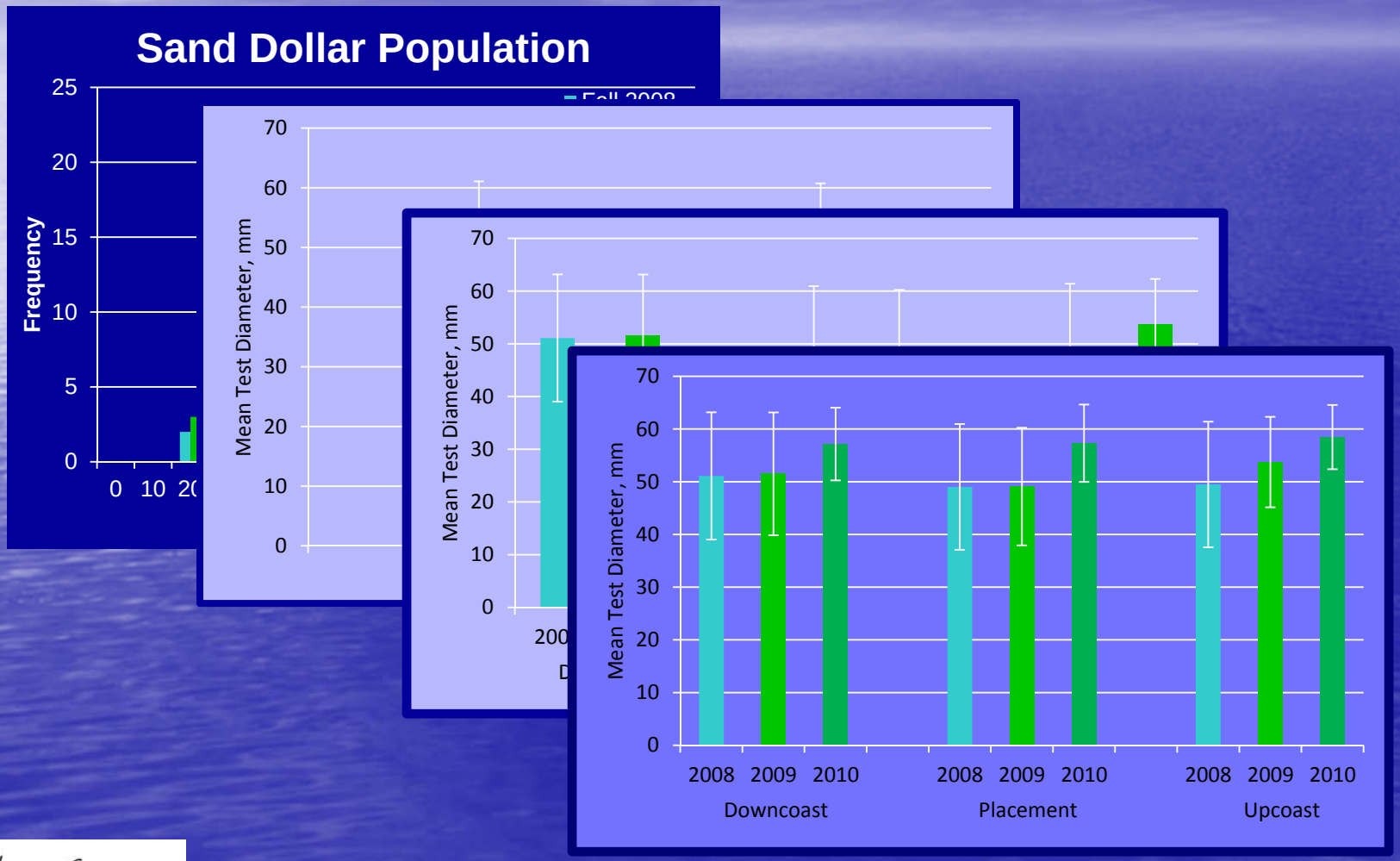
Is Change Evidence of an Effect?



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Before-After Control-Impact (BACI) Analyses

- Advance planning of experimental design is critical for proper data analysis
- Use of Analysis of Variance to determine statistical significance
- Evaluation of factor interaction term to determine whether an effect is due to the hypothesized impact

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Monitoring Locations

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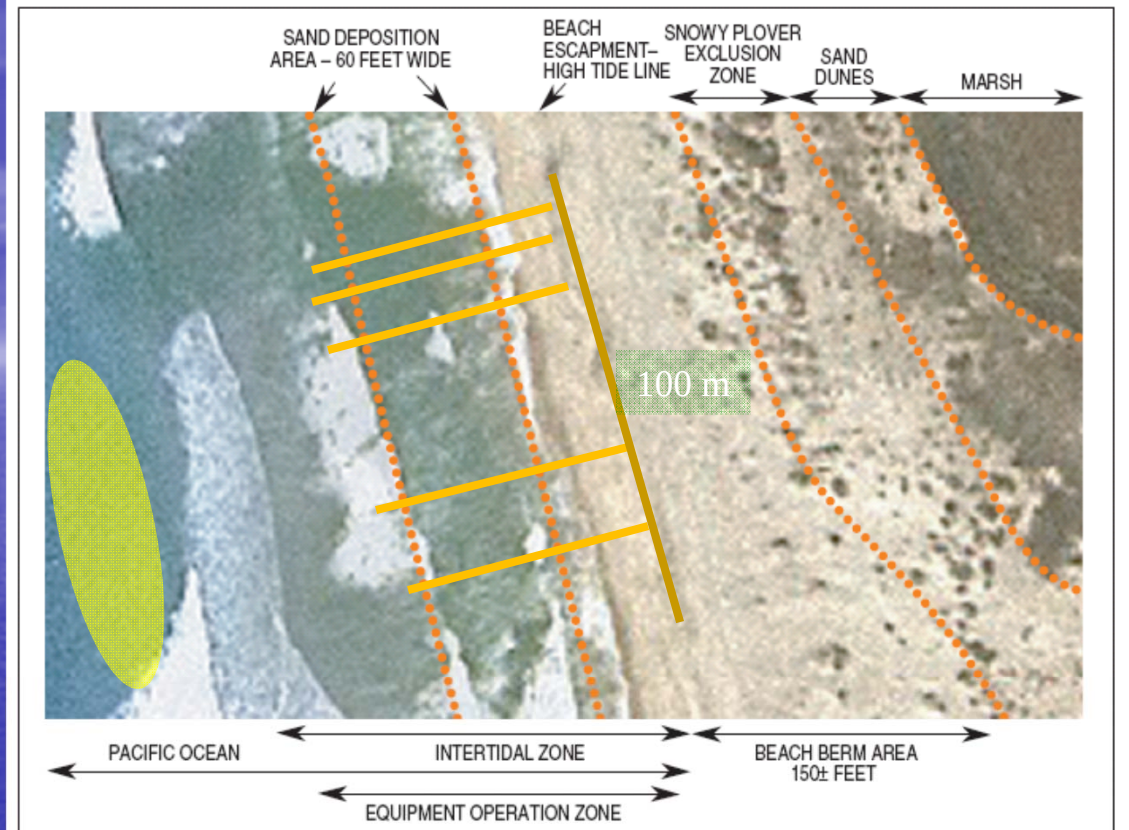
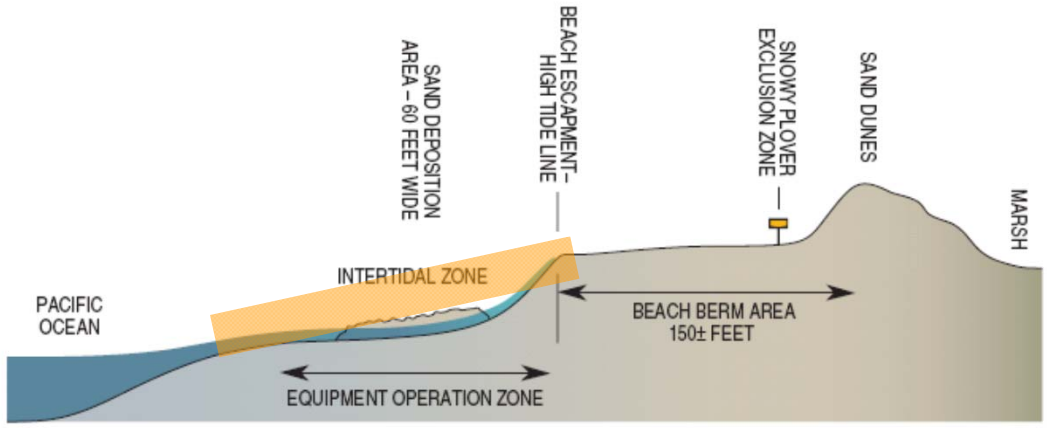


Note: Beach width is variable; aerial photograph is for illustrative purposes only.



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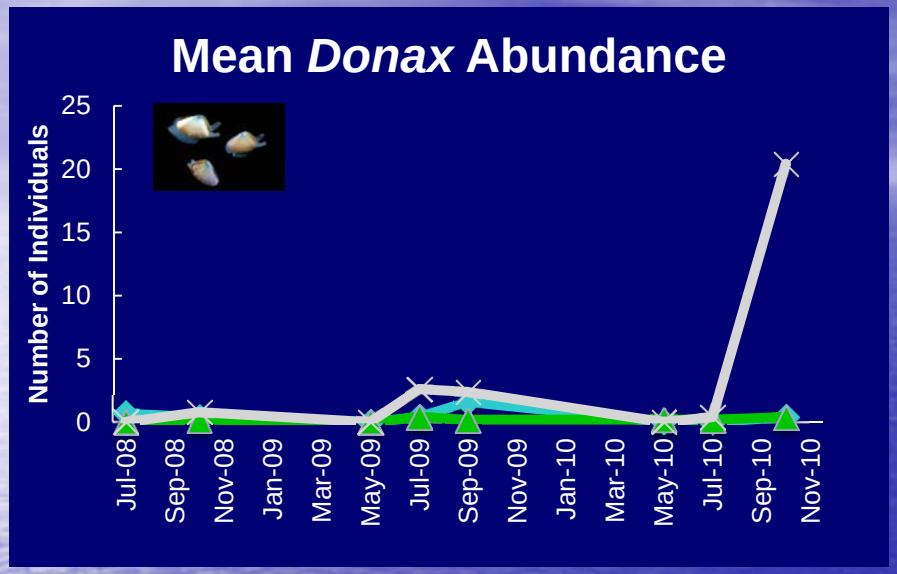
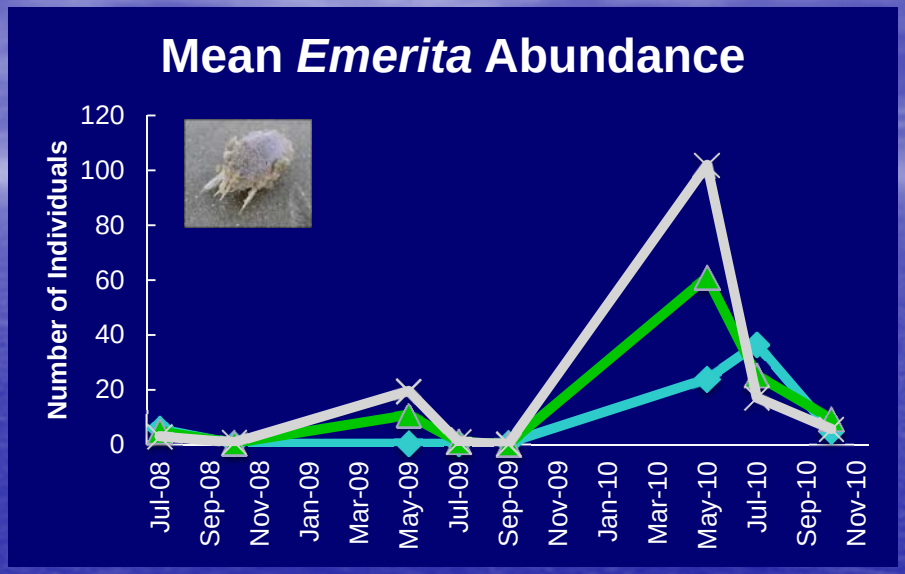
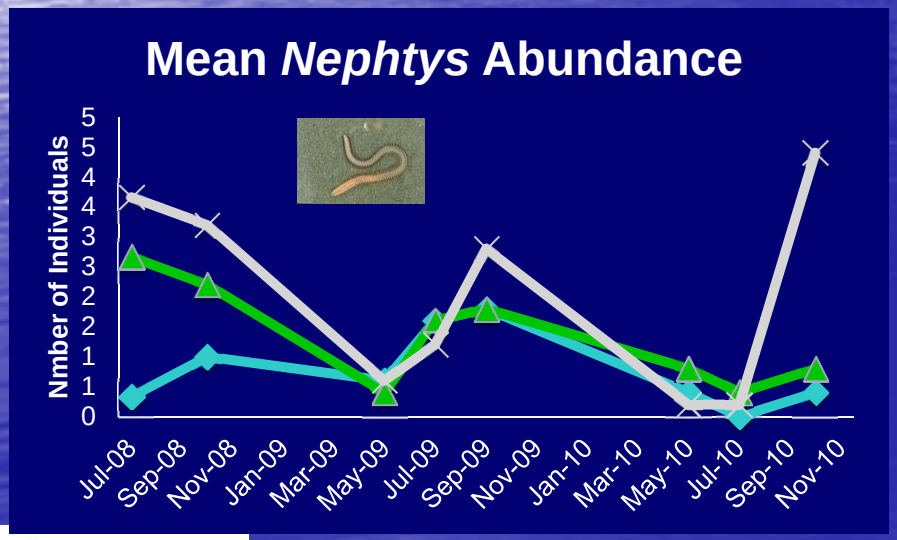
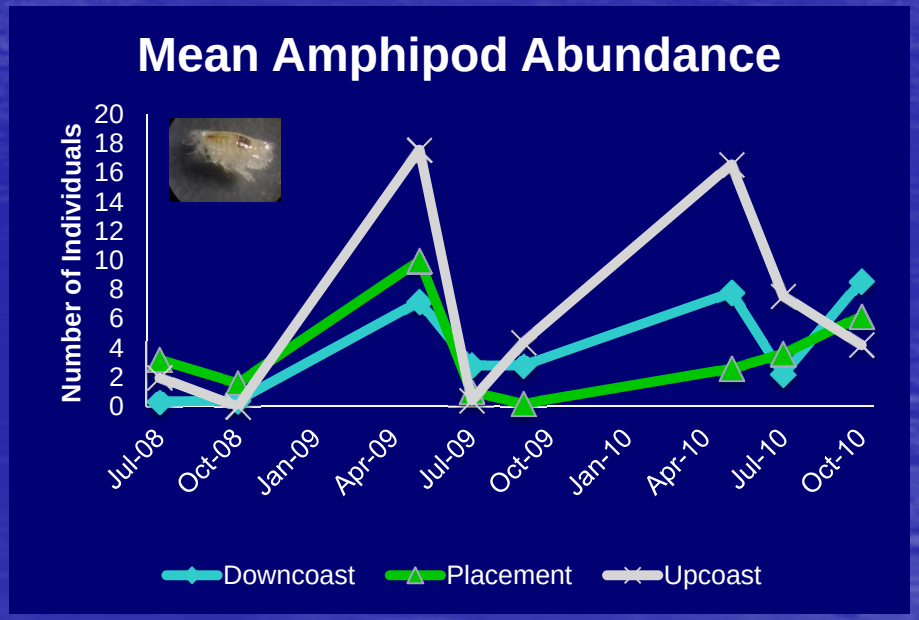
Intertidal Macroinvertebrates









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BACI Interpretation

		Placement Site		
		Population Decline	**Population Static**	**Population Growth**
Control Site	**Population Decline**	If BACI Significant, Potential Impact	If BACI Significant, No Impact	If BACI Significant, No Impact
	Population Static	If BACI Significant, Impact	No BACI Significance	If BACI Significant, No Impact
	Population Growth	If BACI Significant, Impact	If BACI Significant, Potential Impact	If BACI Significant, No Impact

Note: Population in this context refers to both abundance and biomass measurements.

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BACI Results – Abundance at Finer Scales

(BFSP Beach Sites Only)

		Placment vs. Upcoast		Placement vs. Downcoast	
Season	**Taxon**	**08-09**	**09-10**	**08-09**	**09-10**
Spring	*Donax*	-	NS	-	NS
	Neanthes	-	NS	-	NS
	Emerita	-	NS	-	NS
	Amphipods	-	NS	-	NS
Summer	*Donax*	Static	Static	NS	NS
	Neanthes	NS	NS	NS	NS
	Emerita	NS	NS	NS	NS
	Amphipods	NS	NS	NS	NS
Fall	*Donax*	NS	Static	NS	NS
	Neanthes	NS	NS	NS	NS
	Emerita	NS	NS	NS	NS
	Amphipods	Decline	NS	Decline	Increase

Results of interaction factor significance for two-factor ANOVAs (location & year), n varies, α=0.05

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BACI Results – Biomass at Finer Scales

(BFSP Beach Sites Only)

		Placement vs. Upcoast		Placement vs. Downcoast	
Season	**Taxon**	**08-09**	**09-10**	**08-09**	**09-10**
Spring	*Donax*	-	NS	-	NS
	Neanthes	-	NS	-	NS
	Emerita	-	NS	-	NS
	Amphipods	-	NS	-	NS
Summer	*Donax*	NS	NS	NS	NS
	Neanthes	NS	NS	NS	NS
	Emerita	NS	NS	NS	NS
	Amphipods	NS	NS	NS	NS
Fall	*Donax*	NS	Increase	NS	NS
	Neanthes	NS	NS	NS	NS
	Emerita	NS	NS	NS	NS
	Amphipods	Decline	Increase	Decline	Increase

Results of interaction factor significance for two-factor ANOVAs (location & year), n varies, α=0.05

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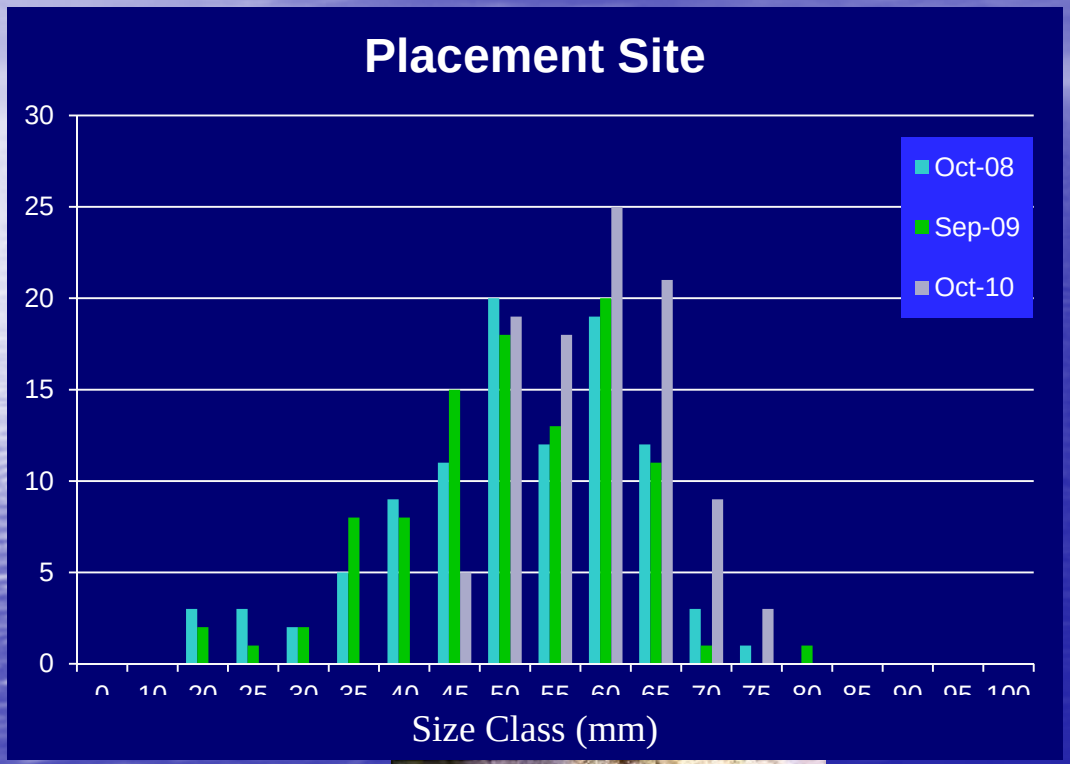
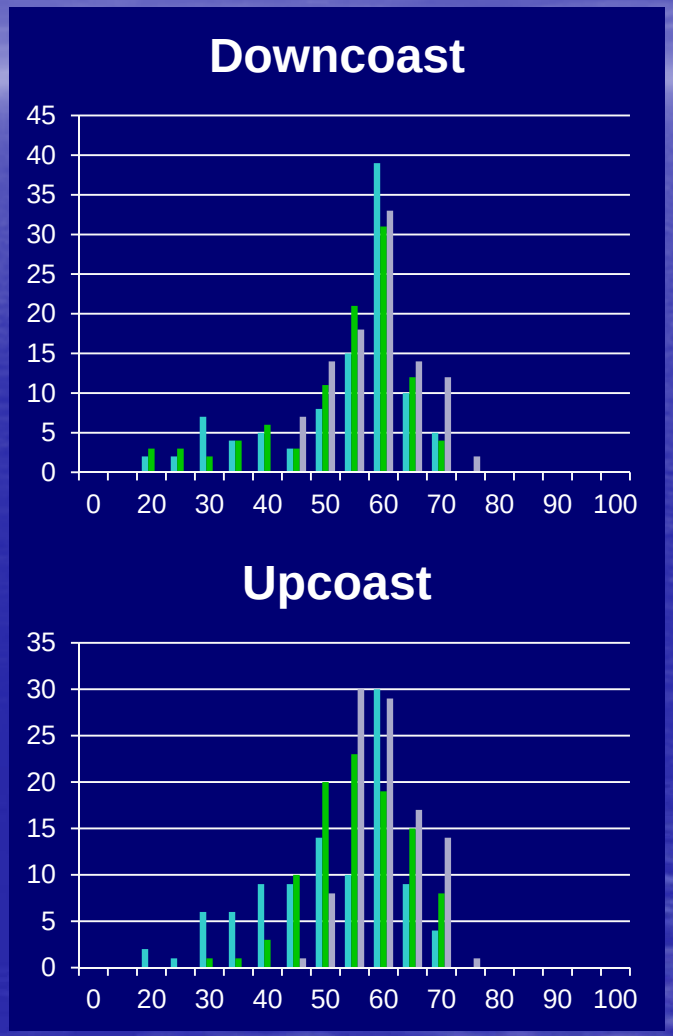
Sand Dollar Population Data





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Pismo Clam Abundance (Live, in Cores)

	Summer 2008	Fall 2008	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010
Silver Strand	3		3	3	1	1		
Upcoast		1		2				
Placement			1					
Downcoast		1	3				1	

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Shorebird Impacts

- Snowy Plovers: Qualitatively Monitored
- No changes noted with regard to either behavior or abundance in comparison to pre-project activity levels

(Patton Report, 2008)

R. Patton

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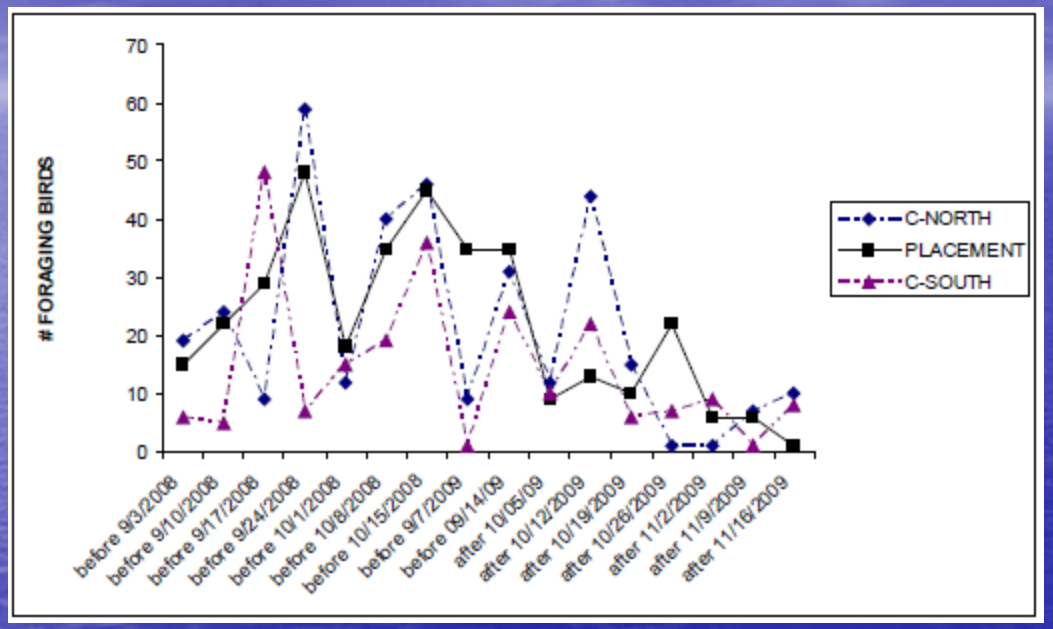
Shorebird Impacts



- Shorebird Foraging: Repeated Measures BACI Design
- ANOVA interaction terms were not significant; therefore no evidence of an impact (Bolland 2010)

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Conclusions

Biological Resources do not appear to be affected by the project:

1. Subtidal communities studied appear to be resilient to the addition of fines (within the limitations of the scope of the project);
2. Observed differences in population attributes varied seasonally, from year-to-year, and on broad spatial scales;
3. When fine-scale population differences were observed, project impacts were unlikely the source of such variation;
4. Changes in beach fauna were attributable to forces such as: recovery/recolonization, high natural variability and resilience of the sandy intertidal community;
5. Shorebirds did not appear to be impacted by project activities.
6. *Dendraster* and Pismo clam populations did not appear to be negatively affected by the project.

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Future Directions

Context of project within regulatory arena:

1. This project was considered by several regulatory agencies as a pilot project;
2. Regulators were clear from the outset of the project that regardless of the results, applicability of this monitoring program would be limited to similar projects (magnitude & type);
3. In California, the CSMW is actively coordinating efforts to serve as a hub of information with regard to sediment management options available to project proponents.

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CSMW Activities

- CSMW efforts include assistance for regional permitting programs and management plans;
- Plans incorporate the framework for use of available sediment for nourishment.
- Among the efforts of CSMW is the compilation of biological data relating to sediment placement in coastal environments; a Biological Impacts Report is currently being finalized which includes a thorough science-based review of environmental sensitivities of various habitat types.
  http://www.cdbw.ca.gov/csmw
- Turbidity remains a challenge in terms of magnitude, duration, and seasonality of impact

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Thank You! Questions?

Project Partners

- **Government Agencies:**
  - California Coastal Conservancy
  - California Ocean Protection Council (OPC)
  - U.S. Geological Survey (USGS)
  - California Department of Boating and Waterways (DBW)
  - U.S. Army Corps of Engineers
  - California Sediment Management Workgroup (CSMW)
  - California State Parks - Border Field S.P.
  - NOAA Tijuana Estuary National Research Reserve
  - U.S. Environmental Protection Agency (EPA)
  - San Diego Regional Water Quality Control Board (RWQCB)
  - California Coastal Commission
  - U.S. Fish and Wildlife

- **Academic Partners/Collaborators**
  - Scripps Institute of Oceanography (SIO)
  - University of California, Santa Cruz (UCSC)

- **Private Sector and Non-Profits**:
  - Moffatt & Nichol Engineers
  - Southwest Wetlands Interpretive Association (SWIA)
  - Nordby Biological Consulting
  - AMEC
  - Diamond Lane Contractors
  - Ocean Imaging Corp.
  - CoastalCOMS
  - Deltares

When Not to Use BACI/Caveats

- What level of effort is required to test the hypothesis?
- Control Attributes – is the control truly representative & accomplish the goal of a control?
- Statistical considerations–wariness with regard to α, multiple comparisons, erroneous conclusions
- Budgetary Considerations

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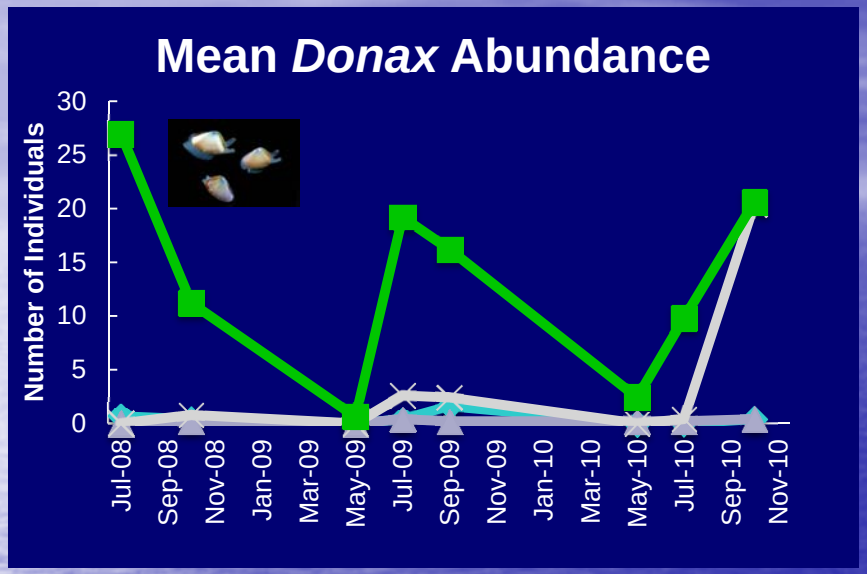
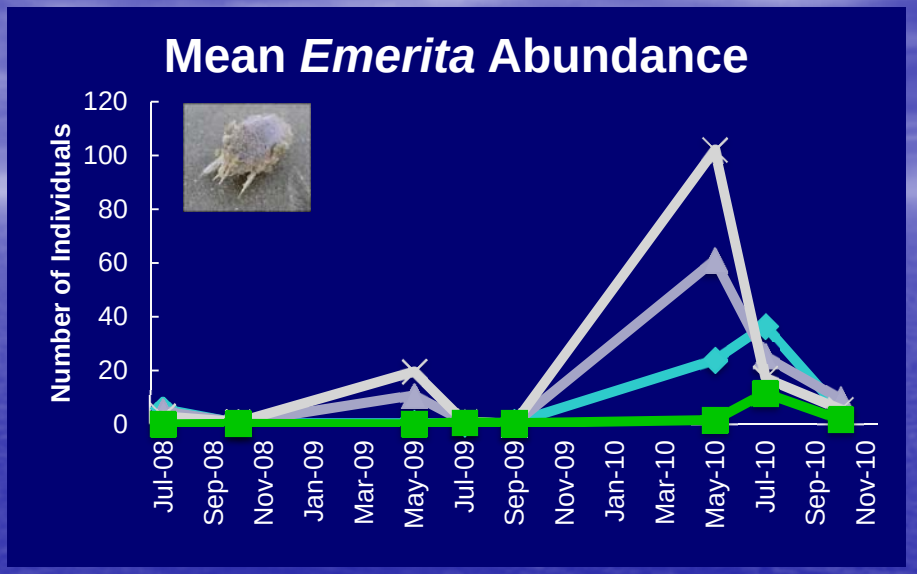
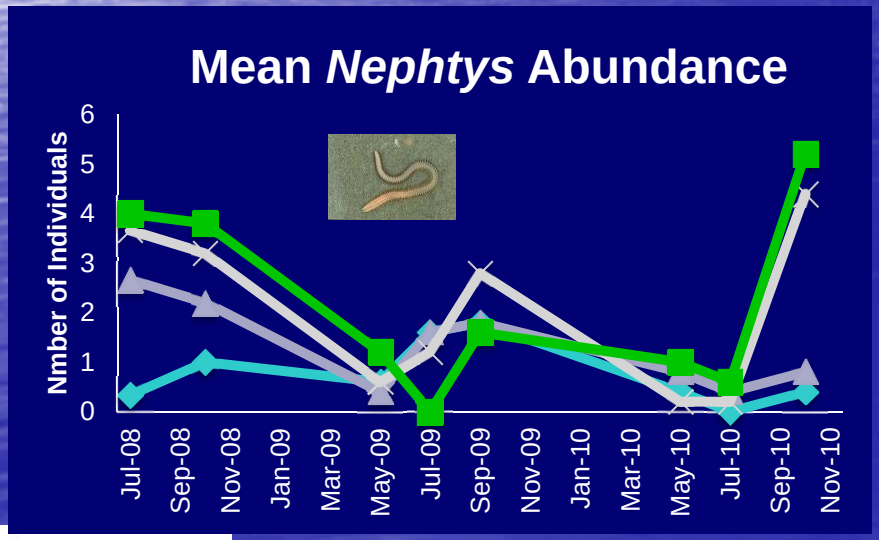
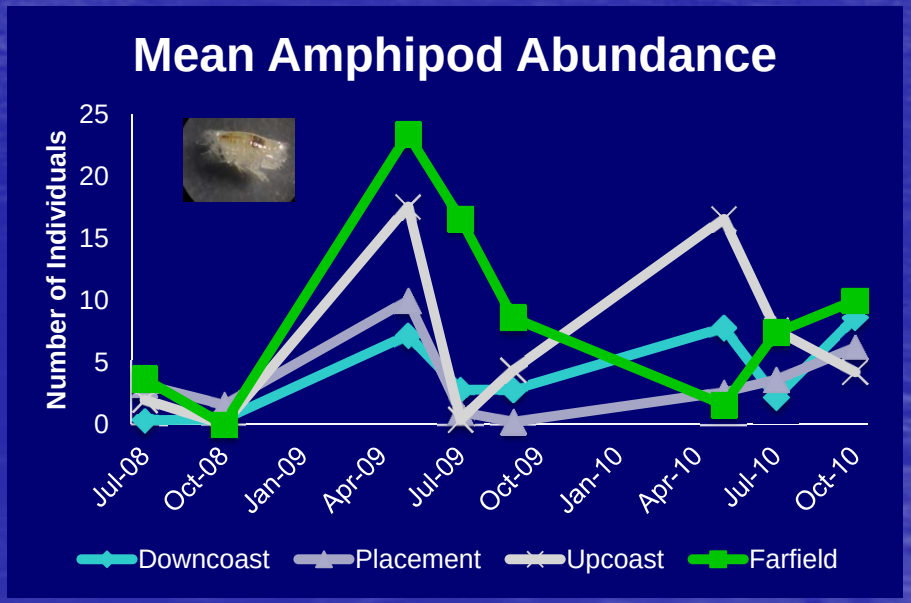
Intertidal Macroinvertebrates









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Before-After Control-Impact Analyses (Abundance Data, All Locations)

Season	Taxon	All Years	2008-2009	2009-2010
Spring	*Donax*	-	-	Difference
	Neanthes	-	-	NS
	Emerita	-	-	NS
	Amphipods	-	-	Difference
Summer	*Donax*	NS	NS	Difference
	Neanthes	Difference	Difference	NS
	Emerita	NS	NS	Difference
	Amphipods	Difference	Difference	Difference
Fall	*Donax*	Difference	NS	Difference
	Neanthes	Difference	NS	Difference
	Emerita	NS	NS	NS
	Amphipods	NS	Difference	NS

Results of interaction factor significance for two-factor ANOVAs (location & year), n varies, α=0.05, NS=not significant

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Before-After Control-Impact Analyses (Biomass Data, All Locations)

Season	Taxon	All Years	2008-2009	2009-2010
Spring	*Donax*	-	-	Difference
	Neanthes	-	-	NS
	Emerita	-	-	Difference
	Amphipods	-	-	Difference
Summer	*Donax*	NS	NS	NS
	Neanthes	NS	NS	NS
	Emerita	Difference	Difference	Difference
	Amphipods	NS	NS	Difference
Fall	*Donax*	Difference	NS	Difference
	Neanthes	NS	NS	NS
	Emerita	NS	NS	NS
	Amphipods	Difference	Difference	Difference

Results of interaction factor significance for two-factor ANOVAs (location & year), n varies, α=0.05

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