Tidal Marsh Research

USGS San Francisco Bay Estuary Field Station

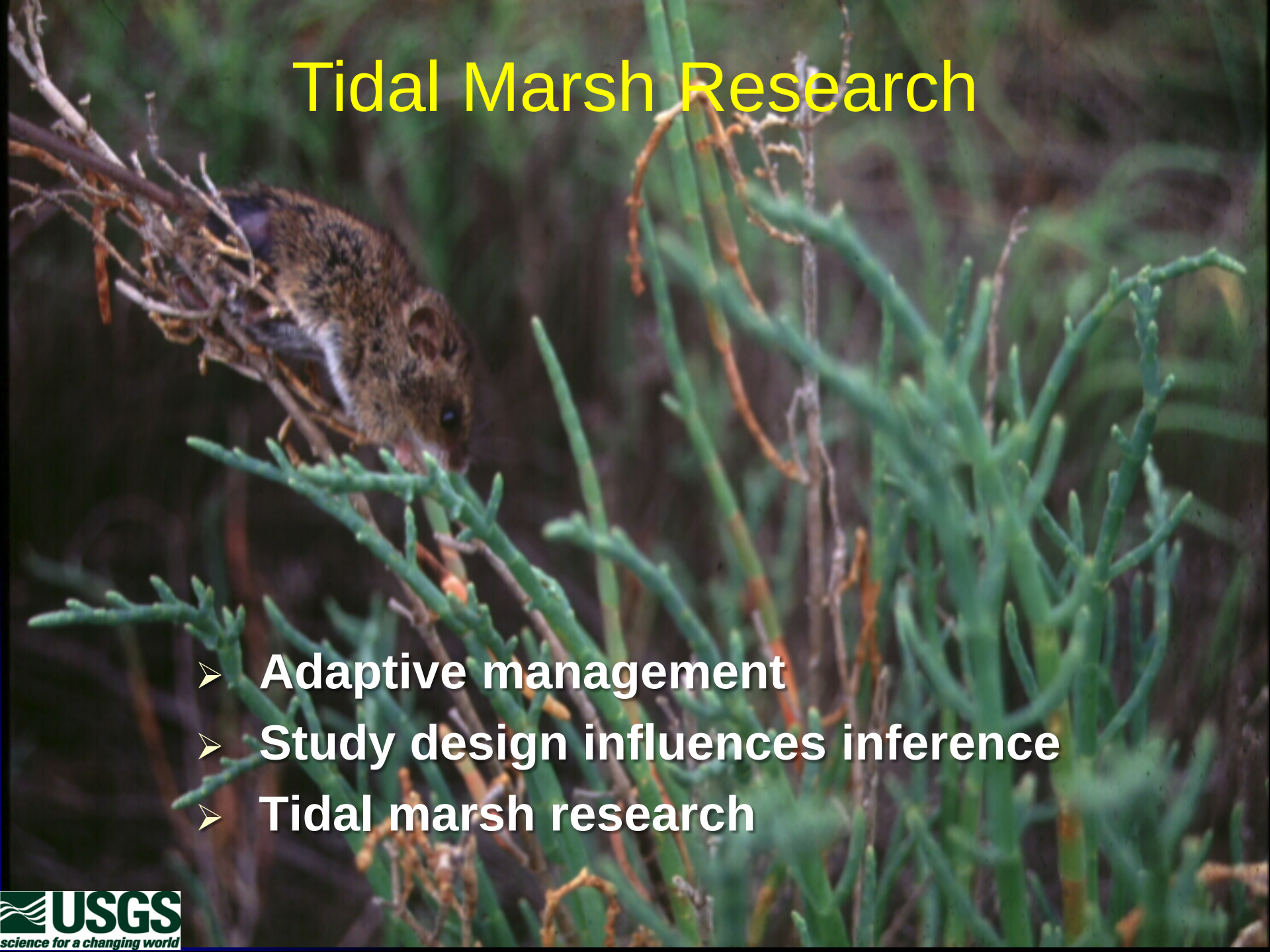
John Takekawa, Isa Woo, Susan De La Cruz, Lacy Smith

Primary Co-Investigators:

Karen Thorne, Mike Cassaza, USFWS, CA Dept. Fish and Wildlife, Nisqually Indian Tribe (Puget Sound)

Many, many Collaborators

Tidal Marsh Research



- Adaptive management
- Study design influences inference
- Tidal marsh research

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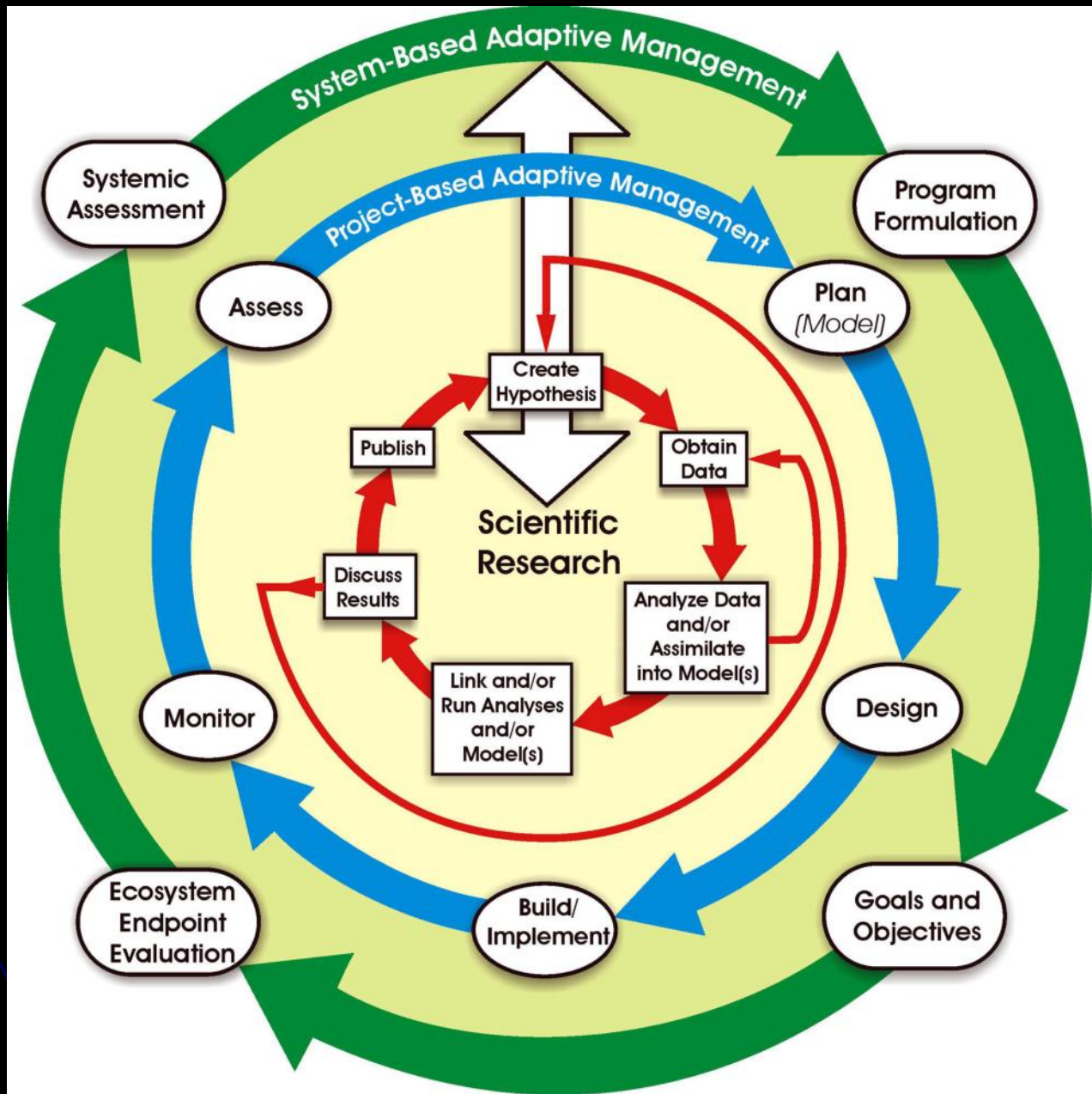
Adaptive Management Framework

Within AM, monitoring program includes science at the core to address restoration questions to inform management at project and system scales



Daraio, J. A. and L. J. Weber. Science-based adaptive management in large river restoration. Unpublished report. University of Iowa, Iowa City. Iowa

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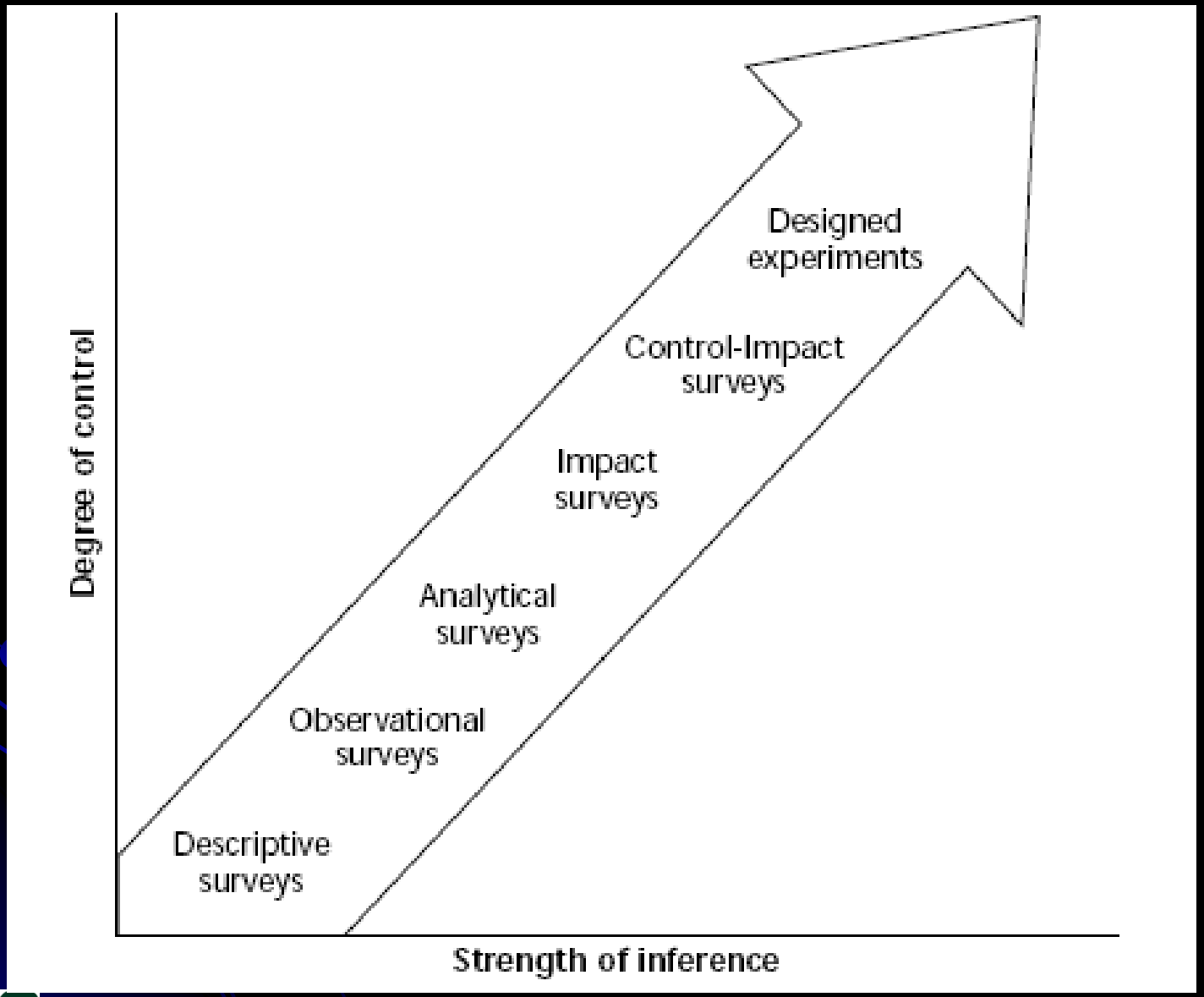
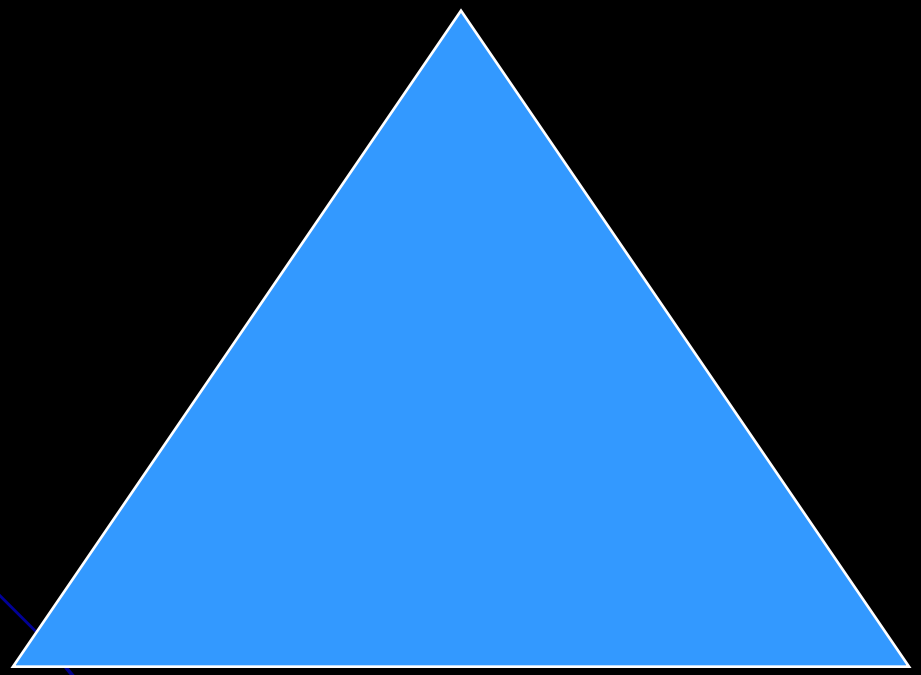
Relationship between type of study design and strength of inference



Sit, V. and B. Taylor (editors). 1998. Statistical Methods for Adaptive Management Studies. Res. Br., B.C. Min. For., Res. Br., Victoria, BC, Land Manage. Handbook. No. 42.

Tradeoffs and Compromise

Strength of inference

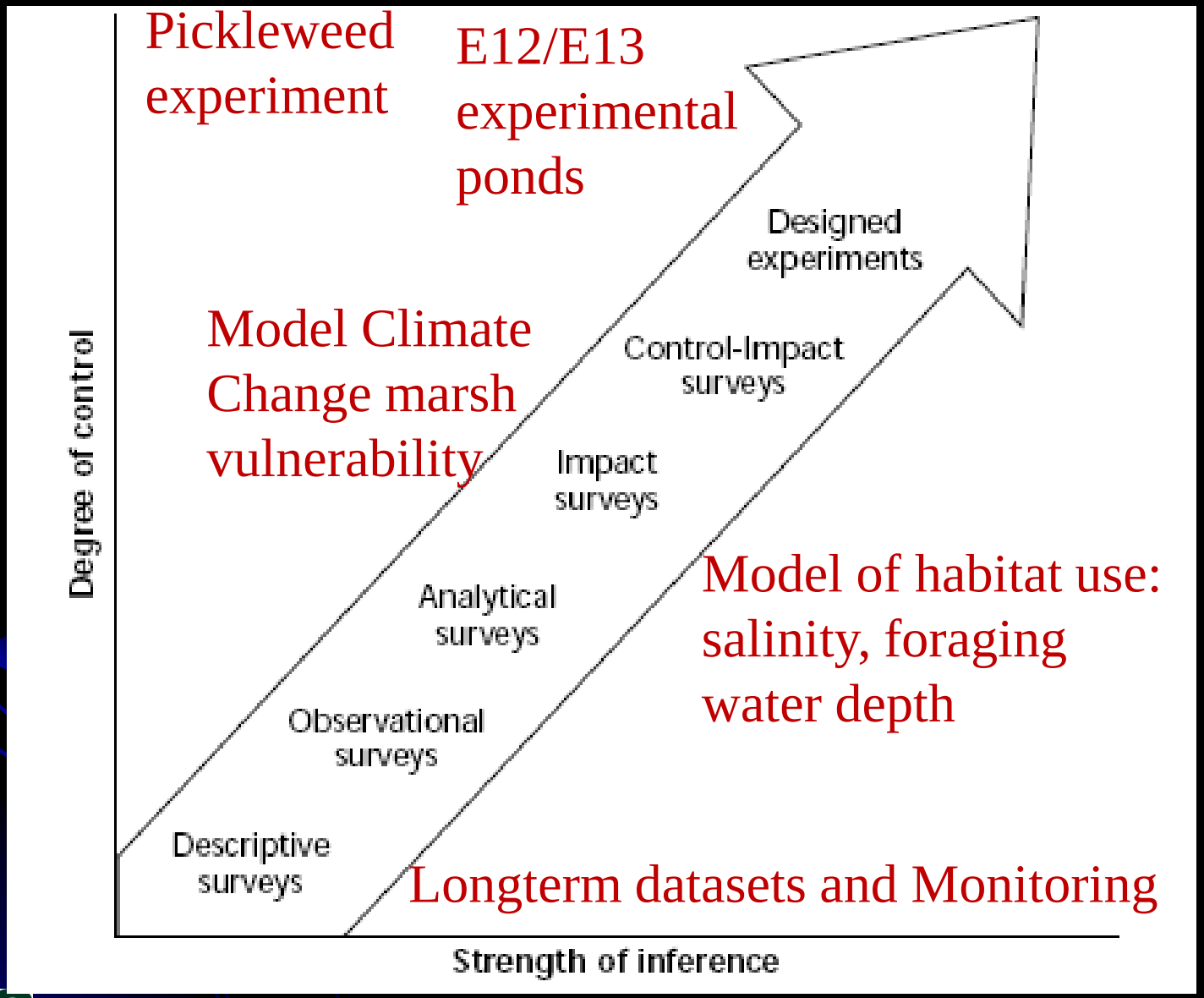


Intensity : degree of control

Cost

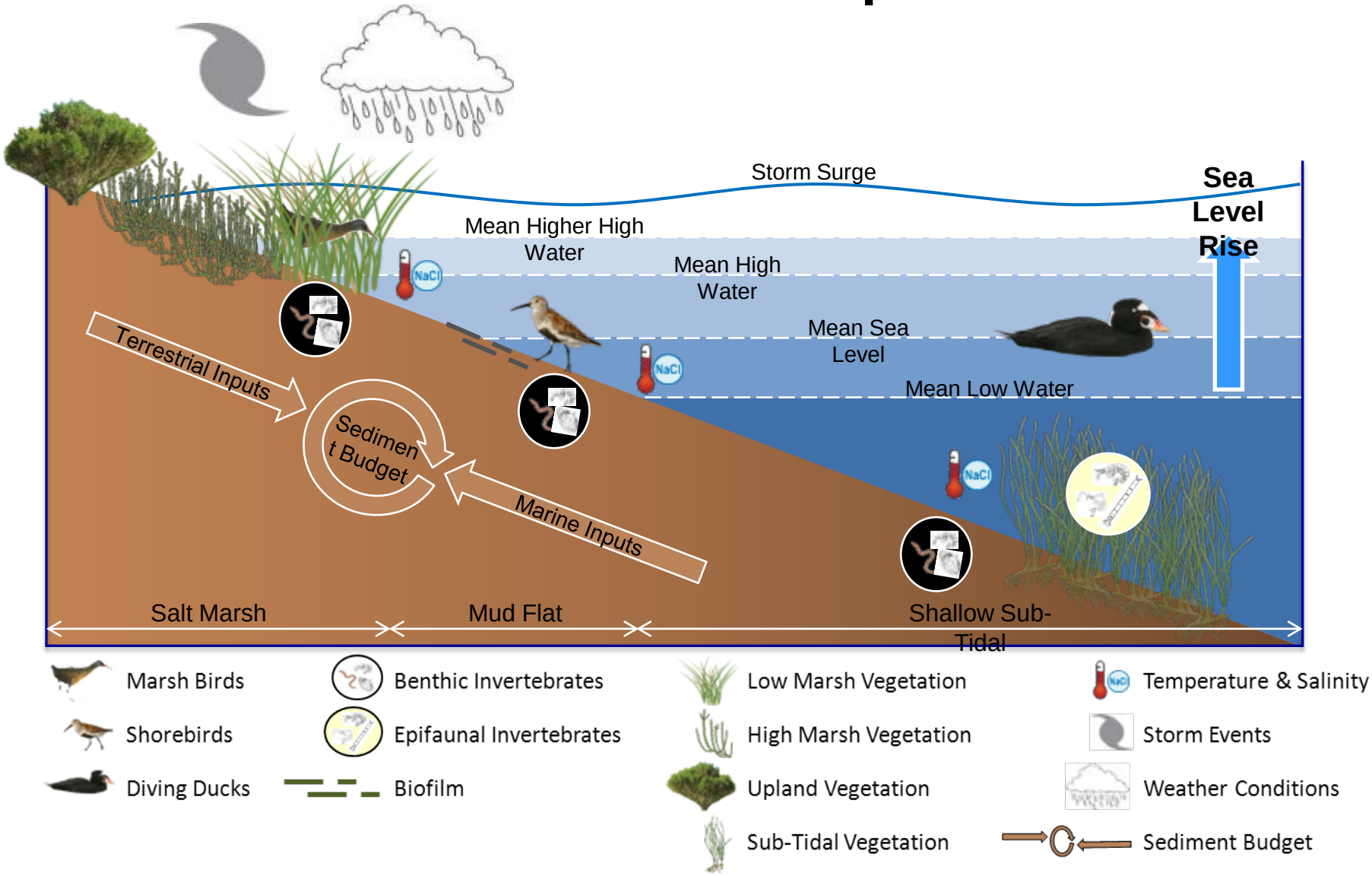
Modified from: Integrating the Nations Environmental Monitoring and Research Networks

Relationship between type of study design and strength of inference



Sit, V. and B. Taylor (editors). 1998. Statistical Methods for Adaptive Management Studies. Res. Br., B.C. Min. For., Res. Br., Victoria, BC, Land Manage. Handbook. No. 42.

Tidal Marsh Conceptual Model



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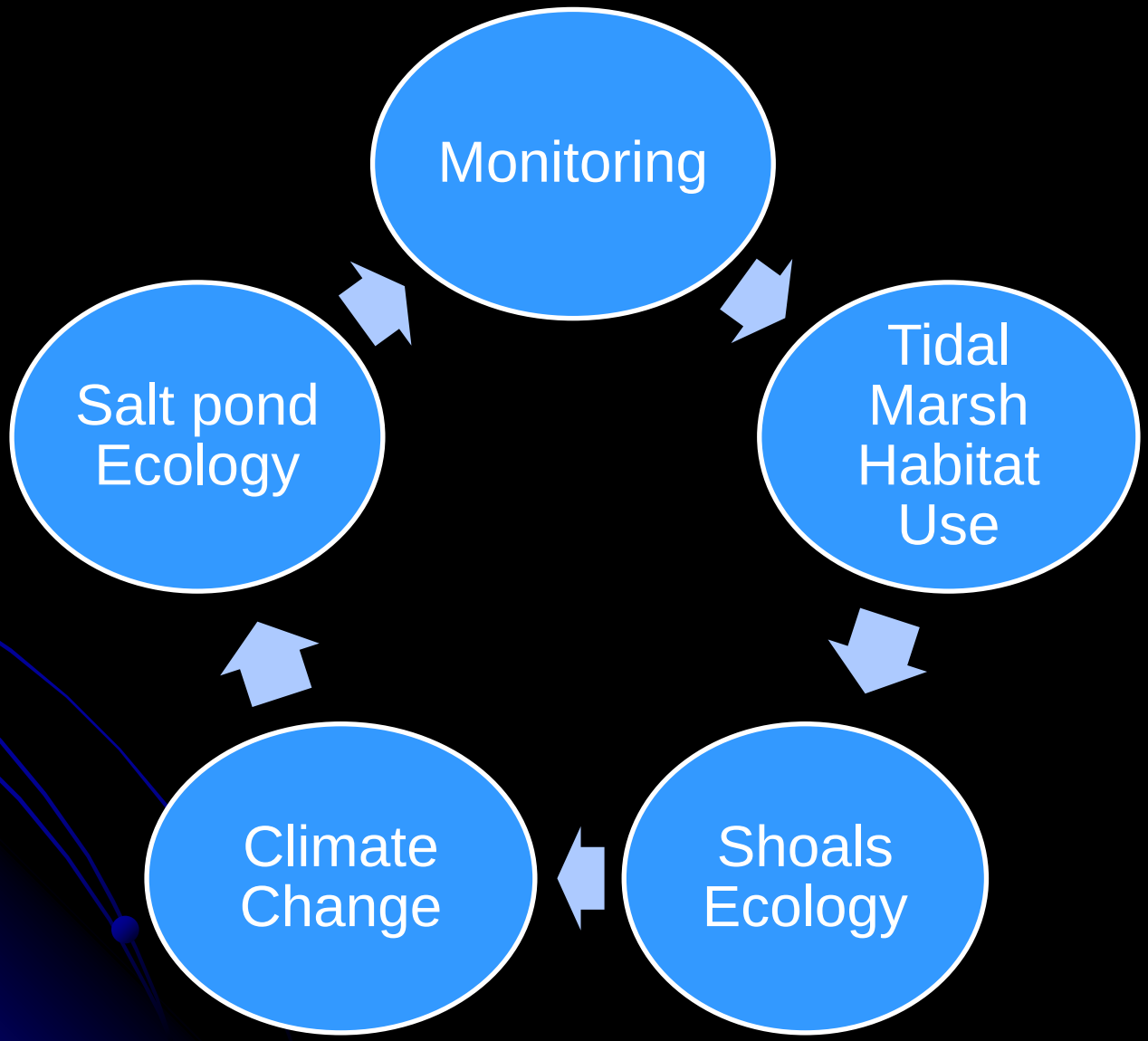
Tidal Marsh Research



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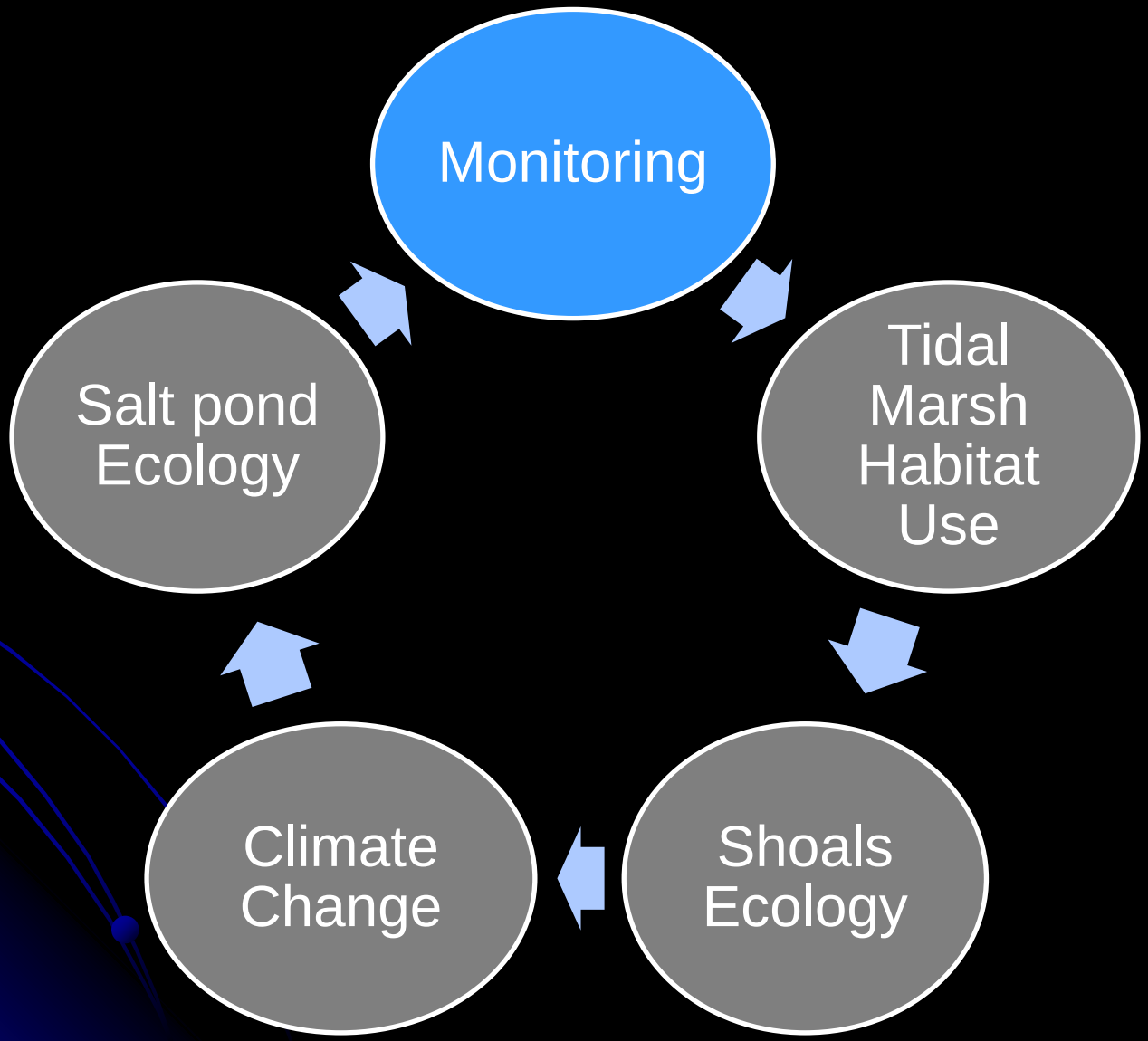

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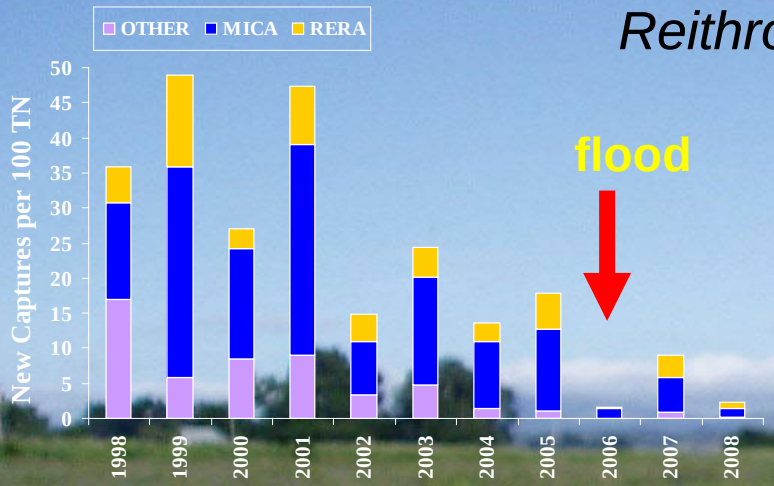
Salt Marsh Harvest Mouse

Reithrodontomys raviventris



- **Endangered and Endemic to SFB**
- **Only mammal *species* in the world endemic to tidal marshes**
- **Focal species for Tidal Marsh Recovery Plan (USFWS)**
- **Longterm monitoring datasets (i.e., Tolay Creek Watershed)**
- **Marsh indicator species: connectivity, habitat structure, CC**
- **Currently partnering with CDFW, UCD, USFWS for research**

Takekawa, J.Y., I. Woo, H. Spautz, N. Nur, J. L. Grenier, K. Malamud-Roam, J. C. Norby, A. Cohen, F. Malamud-Roam, S. E. Wainwright-DeLa Cruz. 2006. Environmental threats to tidal marsh vertebrates of the San Francisco Bay Estuary. Studies in Avian Biology 32: 176-197

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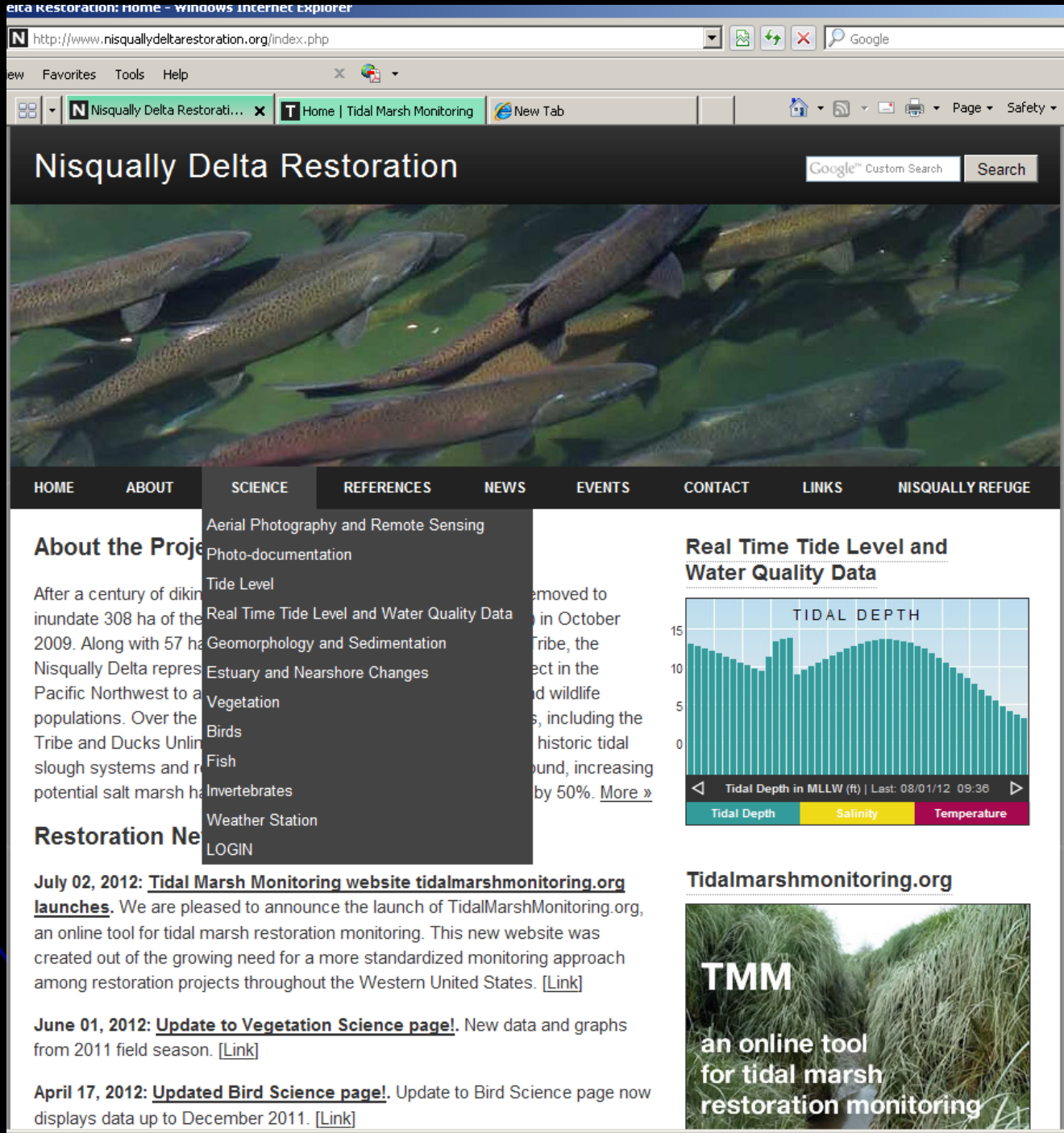
Nisqually Delta Restorations, the largest estuarine restoration in the Pacific Northwest.

Oline data portal for monitoring data and summaries.



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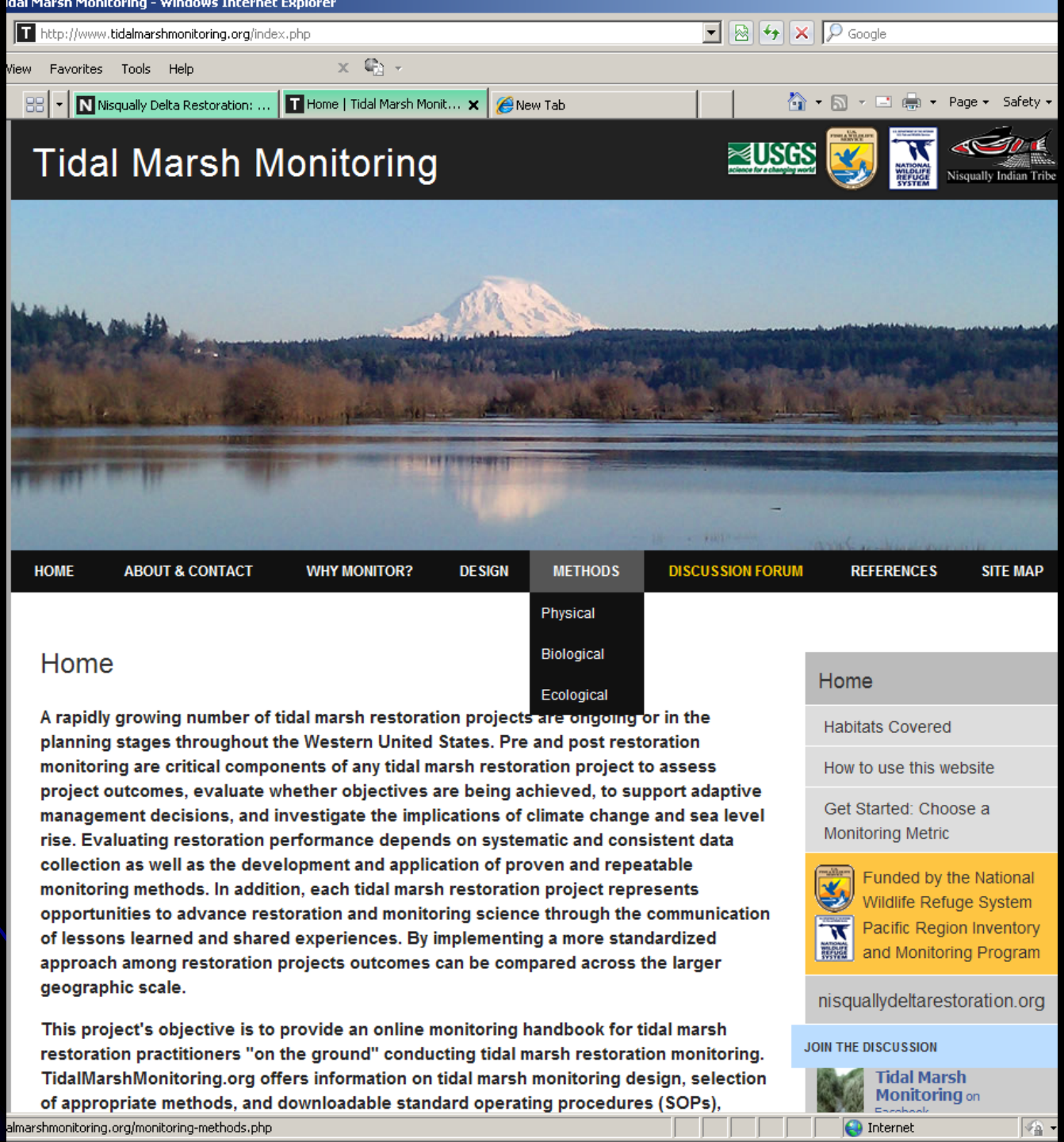
Tidal Marsh Monitoring

An online, practitioner's guide to monitoring methods in tidal marshes

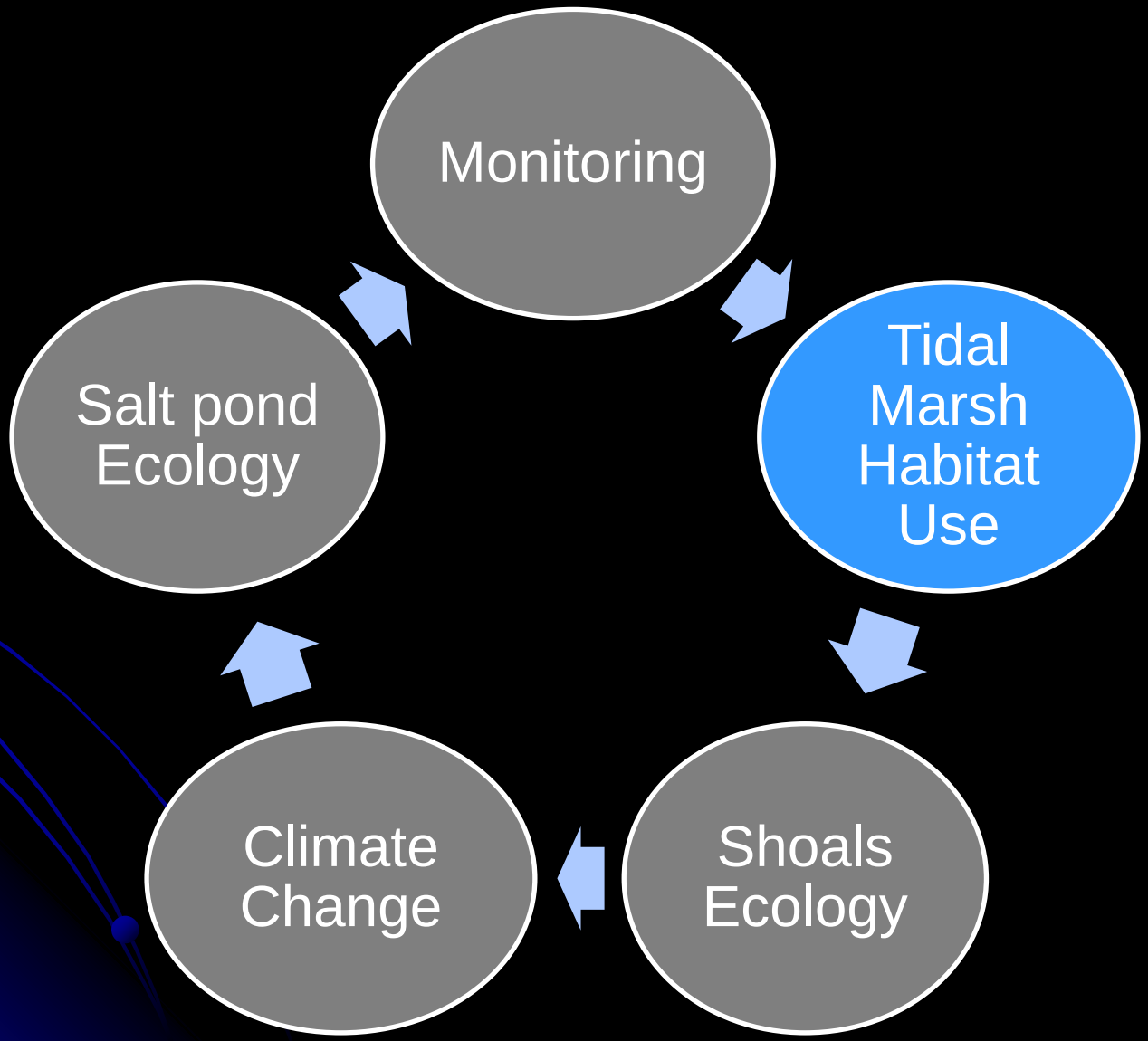
45% return rate



Partners and Collaborators

- Funded by EPA, ESRP, FWS, USGS, and internships (Students in Support of Native American Relations,Youth interns, Evergreen)
- Nisqually National Wildlife Refuge
  - J. E. Takekawa, D. Roster, J. Barham,M. Bailey
- Nisqually Indian Tribe
  - J. Dorner, C. Ellings, F. Leischner, J. Cutler and S. Hodgson
- Nisqually River Foundation: J. Hall
- Ducks Unlimited: D. Golner, S. Liske and P. Schulte
- Avian Design: C. Fox
- USGS Patuxent Wildlife Research Center: G. Guntenspergen, J. Lynch and J. Olker
- USGS Pacific Coastal and Marine Geology: E. Grossman,, R. Kayen and D. Finlayson
- USGS Western Fisheries Research Center: S. Rubin, K. Larsen and A. Lind-Null
- USGS Washington Water Science Center: R. Dinicola, C. Curran
- Washington Department of Fish and Wildlife: M. Hayes
- Nisqually Reach Nature Center: D. Hull

Tidal Marsh Research



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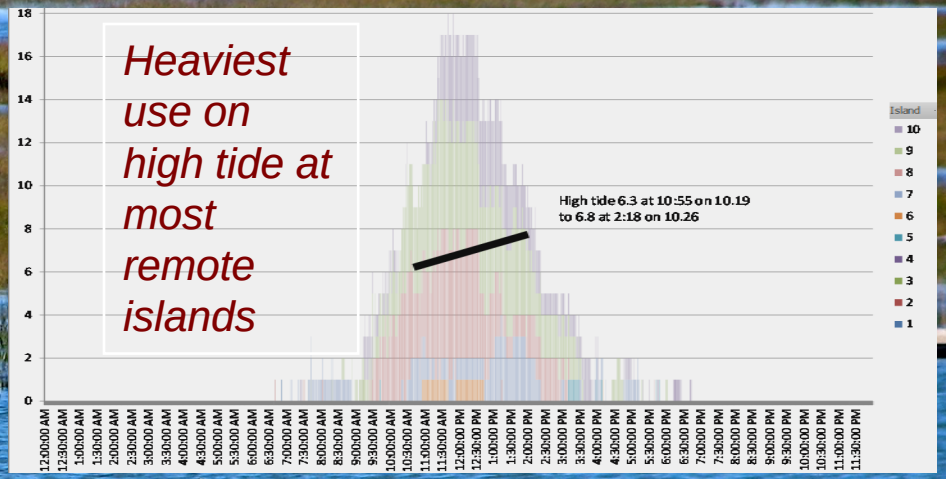
Clapper Rail – *high tide refugia*
Arrowhead Marsh artificial islands



Overton, Takekawa, Cassaza, et al.

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California Black Rail:

Habitat Use, Methylmercury, Foodwebs, Genetics

- California Threatened species
- Populations in decline
- Secretive, habitat use not well known
- ~80% of subspecies resides in SFB
- In SFB, tidal marsh obligate

•Girard, P., J. Y. Takekawa, S. R. Beissinger. 2010. Uncloaking a cryptic, threatened rail with molecular markers: origins, connectivity and demography of a recently-discovered population

•Tsao, D. C., J. Y. Takekawa, I. Woo, J. Yee, and J. Evens. 2009. Home range, habitat selection and movements of California Black Rails at tidal marshes at San Francisco Bay, California. The Condor 111(4): 599-610.

•Tsao, D., K. Miles, J. Y. Takekawa, and I. Woo. 2008. Potential effects of mercury on threatened California black rails. Archives of Environmental Contamination and Toxicology Online First 10.1007/s00244-008-9188-4

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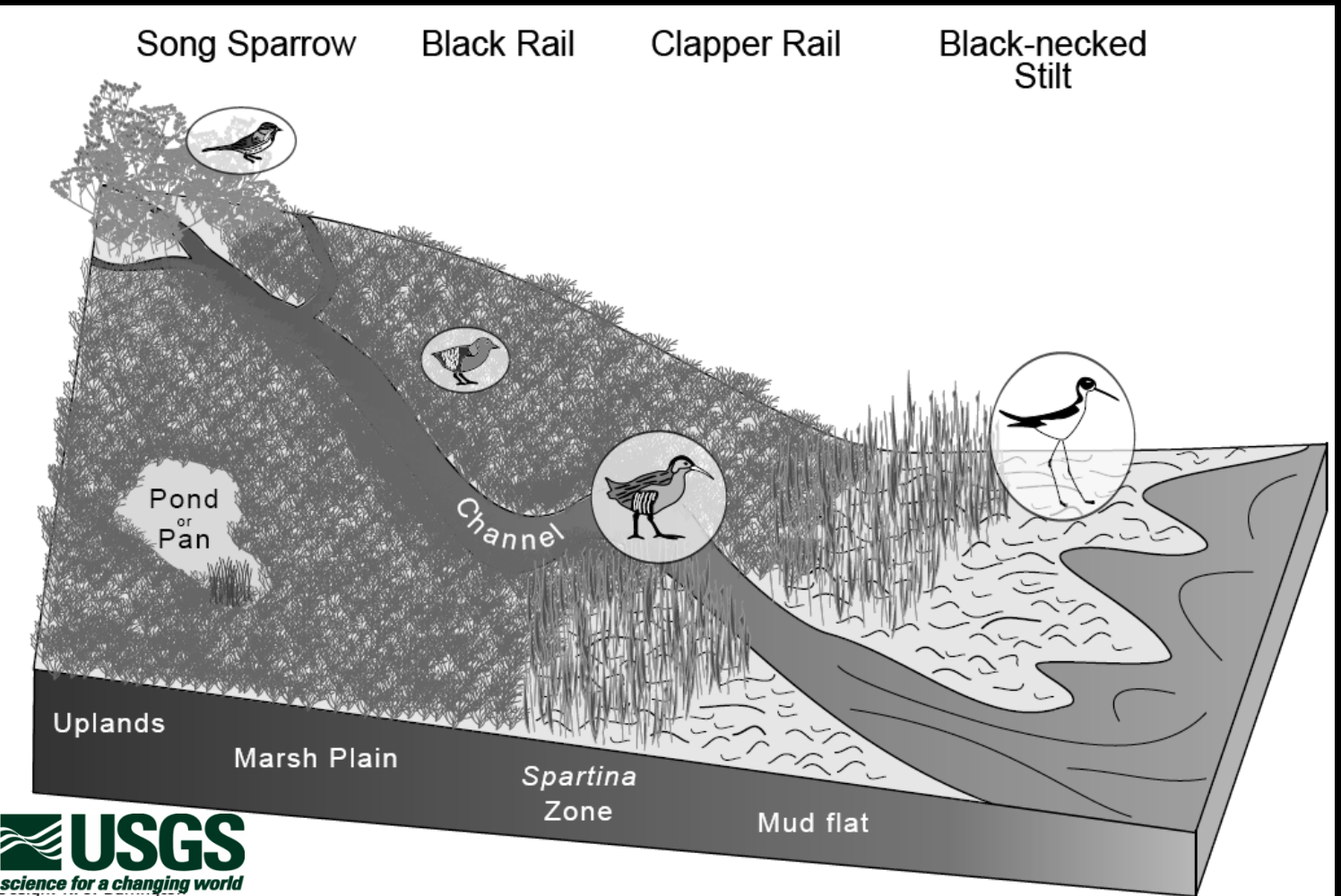
Bird communities in tidal marshes:

effects of fragmentation, disturbance, and sea level rise on population viability.



Takekawa, J. Y. T., I. Woo, K. M. Thorne, K. J. Buffington, N. Nur, M. Casazza, J. Ackerman. 2012. Chapter 13: Bird communities: effects of fragmentation, disturbance, and sea level rise on population viability. IN (Palaima, A. Ed). Ecology of San Francisco Bay. UC Press

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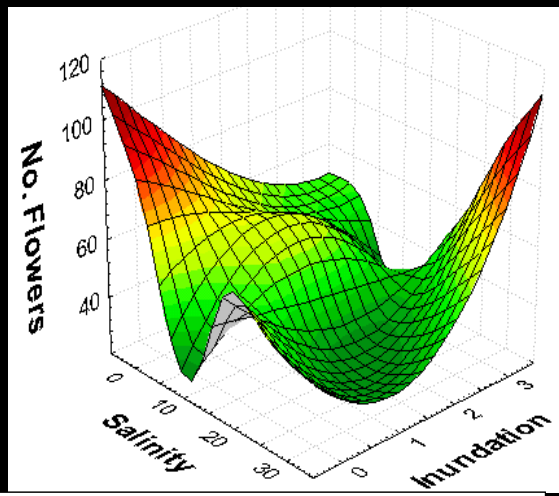
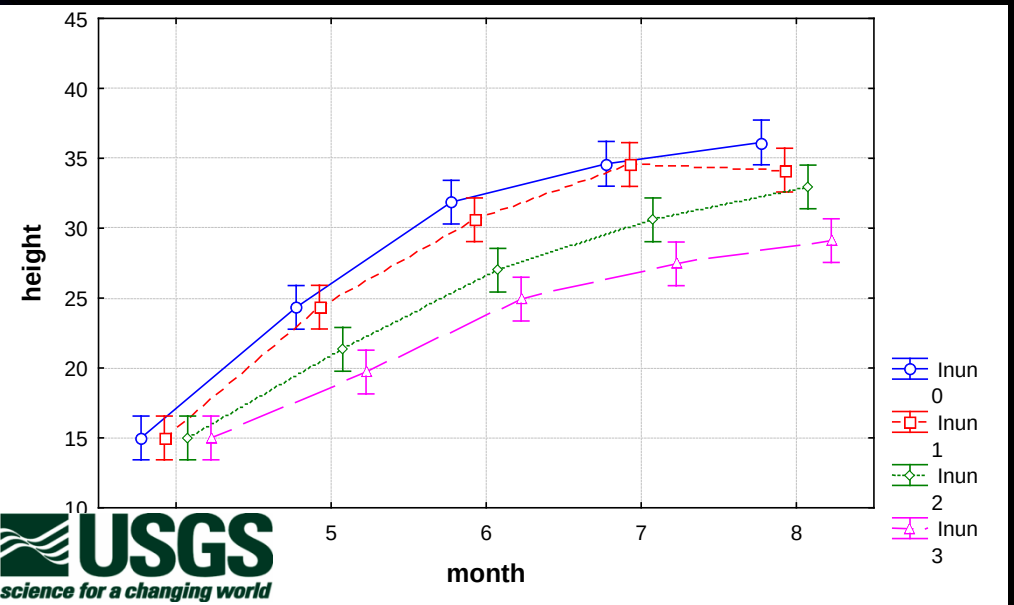
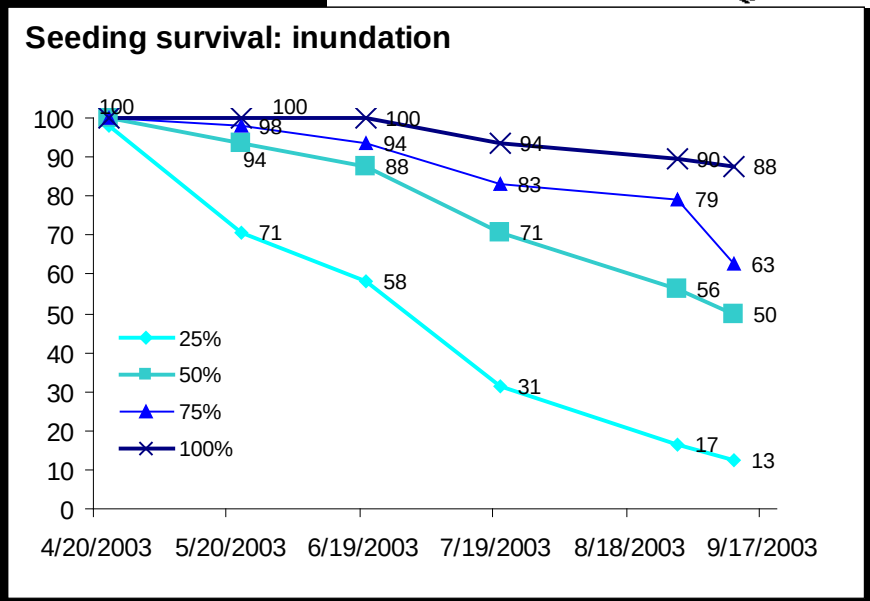
Experimental manipulation of inundation and salinity levels

effects on the survival, growth, and reproductive capacity of common pickleweed

Woo, I. and J. Y. Takekawa. 2012. Will inundation and salinity levels associated with projected sea level rise reduce the survival, growth, and reproductive capacity of *Sarcocornia pacifica* (pickleweed)? Aquatic Botany 102:8-14.







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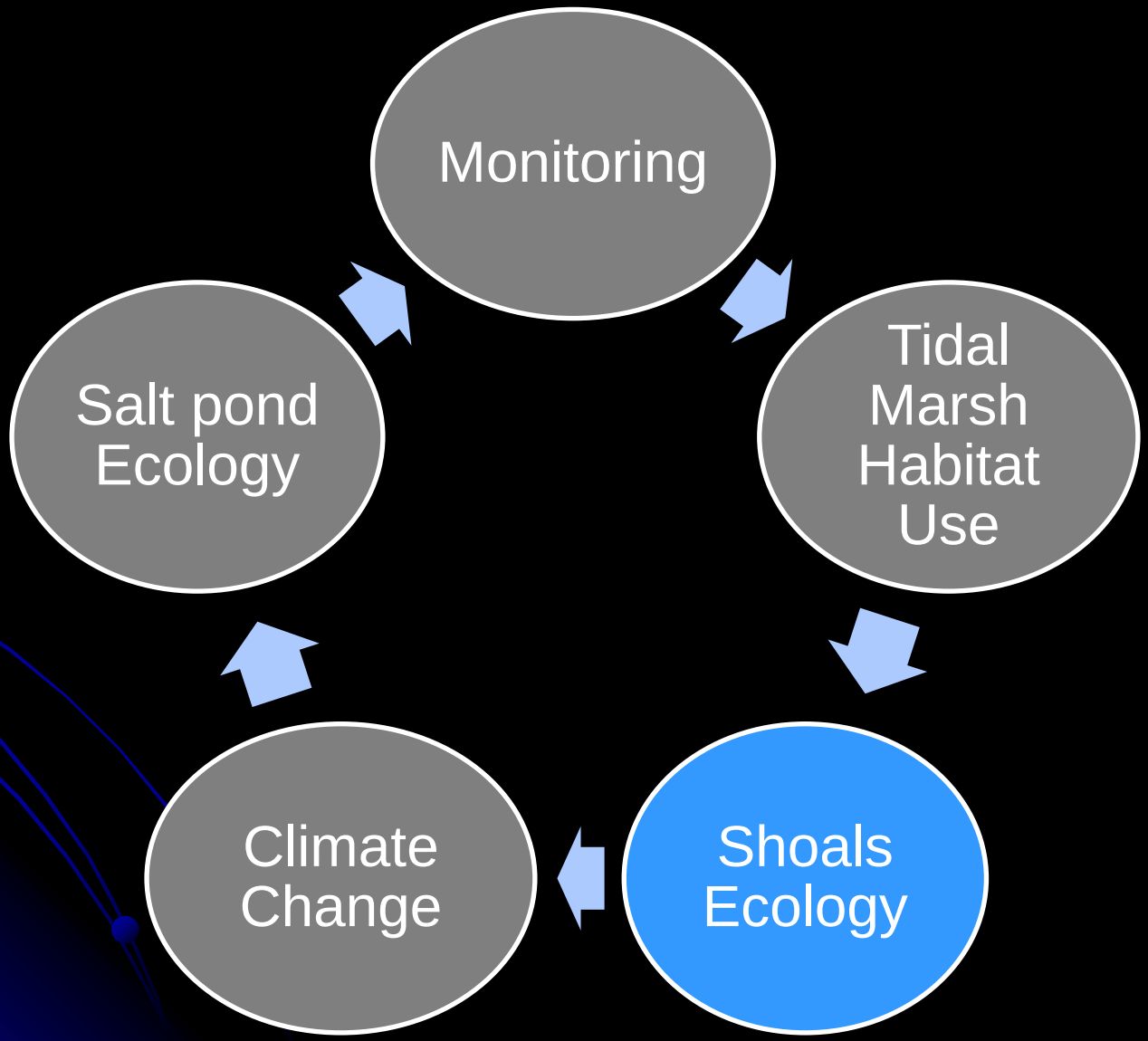
Tidal Marsh Research



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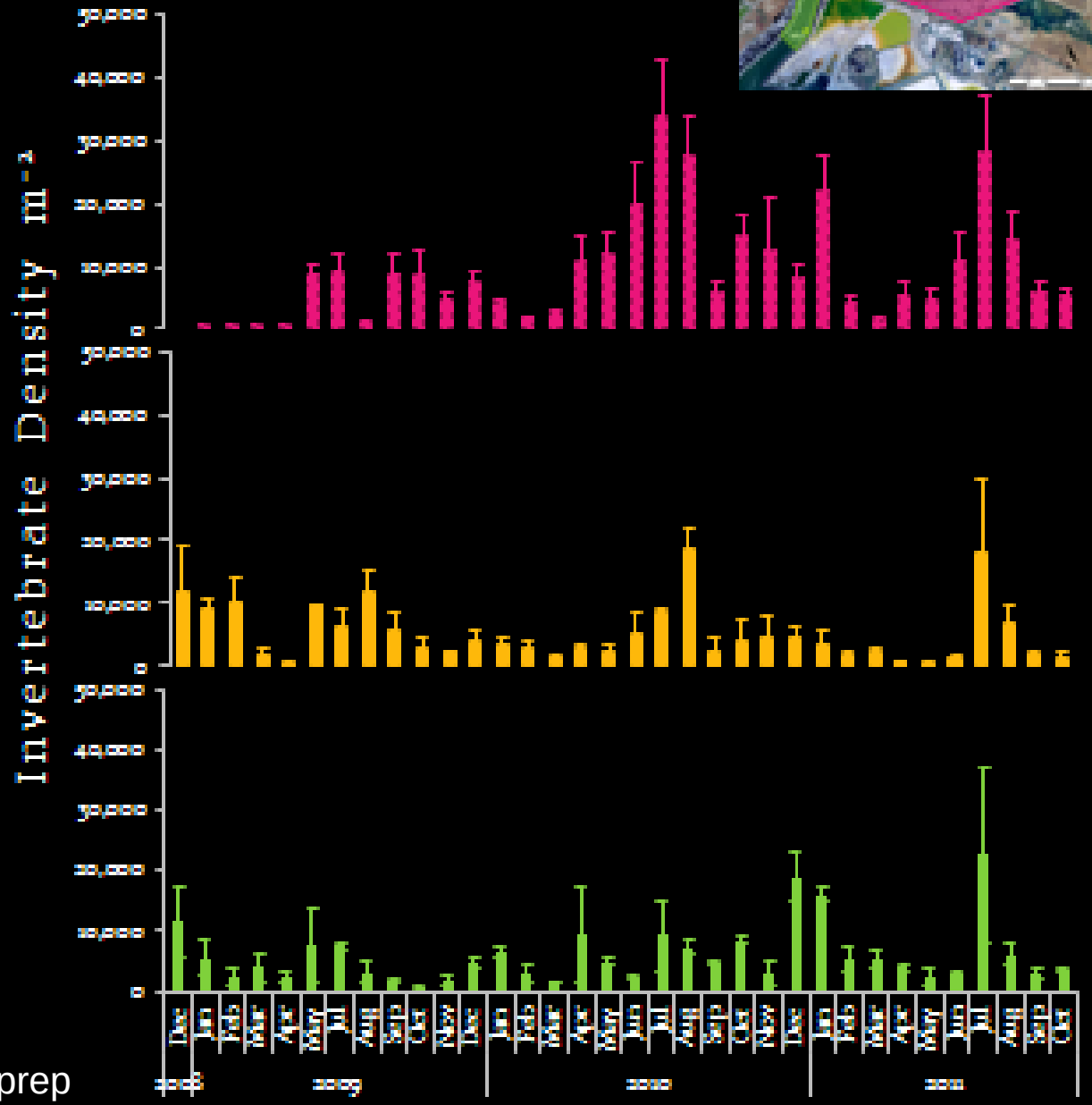
Invert Colonization Following Restoration

- Ponds 9 & 10 (Former Salt Pond)
- Source populations:
  - Fagan Slough (2 locations)
  - Napa River (2 locations)
- Monthly sampling:
  - Dec 2008 – Oct 2011

Presentations from Woo, I, A. Smith and J. Y.Takekawa in prep

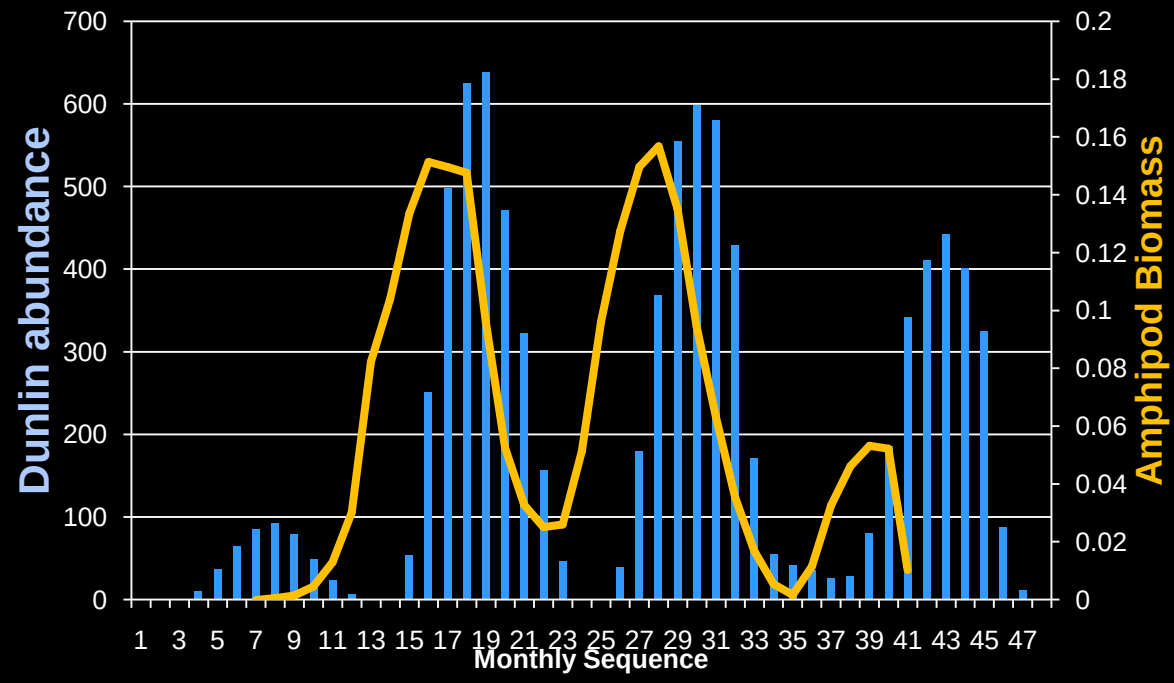
Total Invertebrate Density m^{-2}

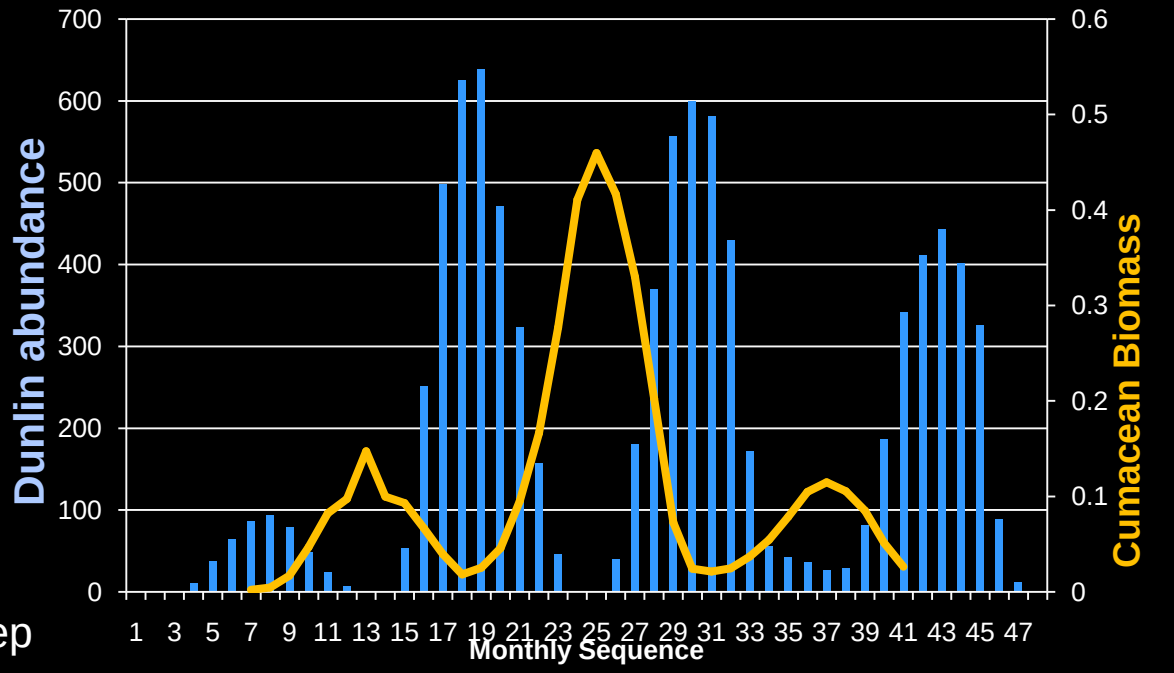
- Restored Pond
  - Colonization
    - First colonization observed 7 months after breach (May 2009).
- Fagan Slough
  - Seasonal patterns
    - Density peaks in summer months.
- Napa River
  - Seasonal patterns
    - Density peaks in spring and winter



Takekawa et al in prep

Relationship of Dunlin abundance to invertebrate taxa biomass



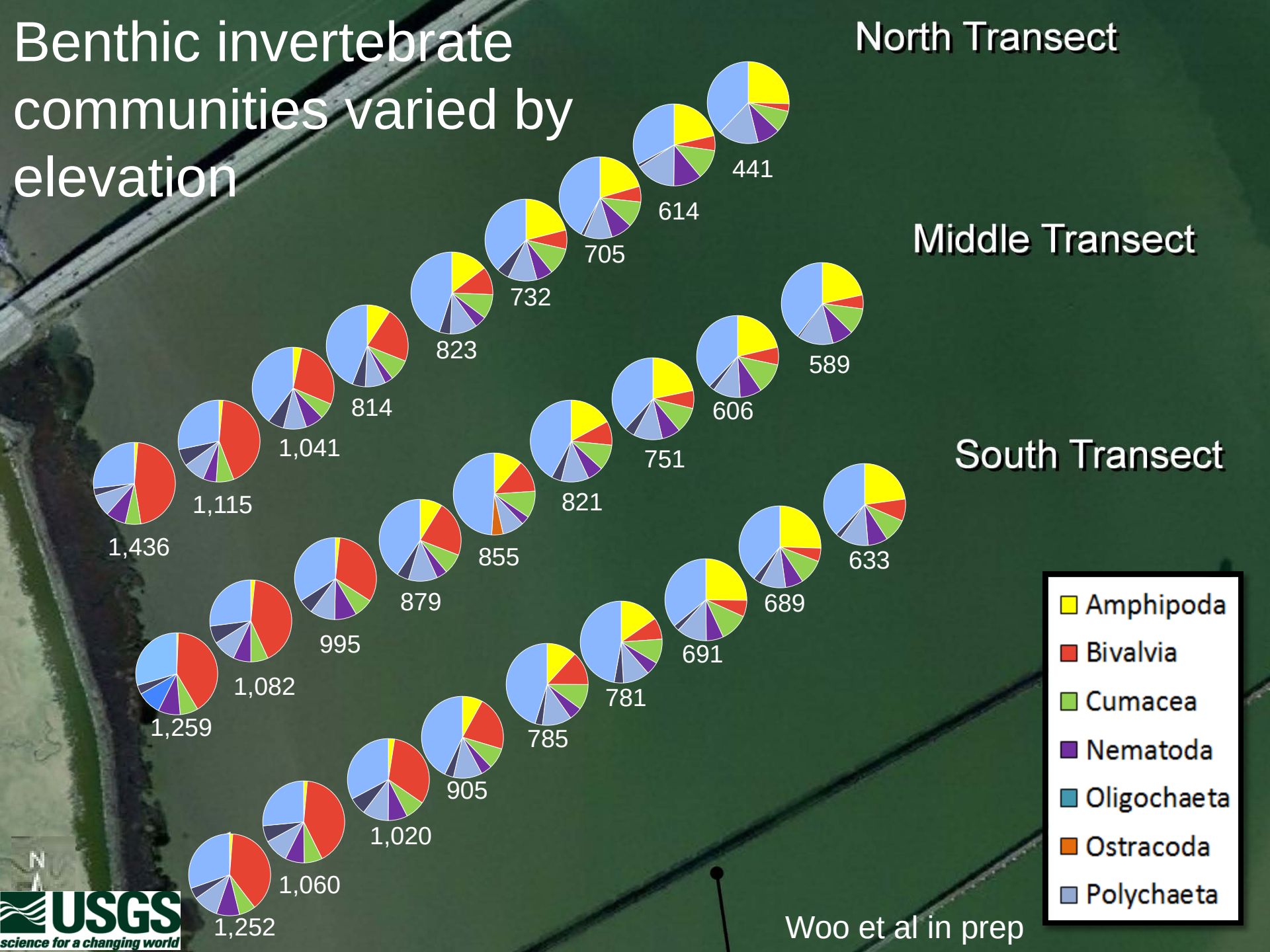


Takekawa et al in prep

Dumbarton Shoals

- Benthic macroinvertebrate prey varied by month and by elevation

Benthic invertebrate communities varied by elevation



Woo et al in prep

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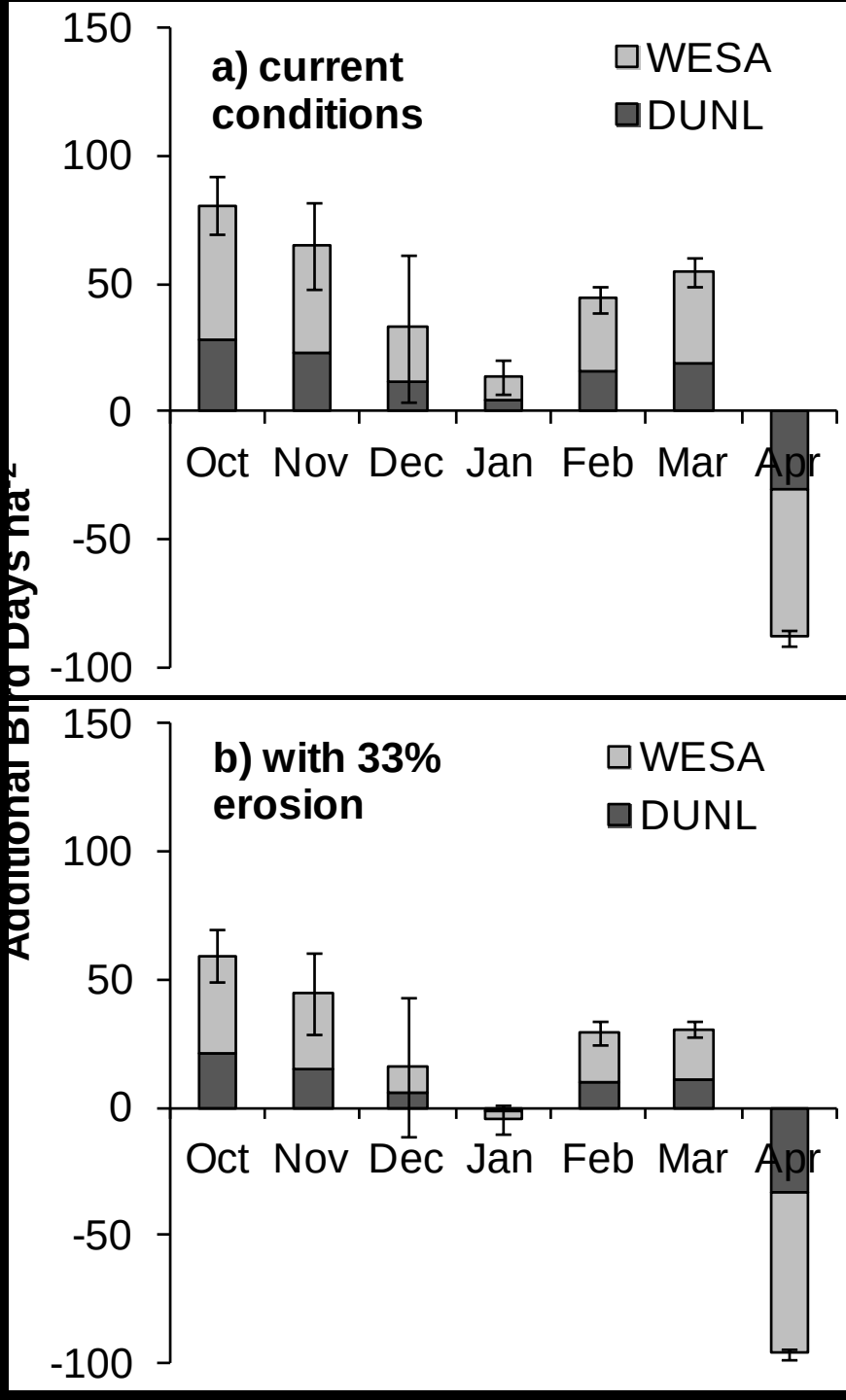
Shorebird Carrying Capacity



Rocha, A.,R. I. Woo, J. Y. Takekawa, J. D. Davis, J. R. Lovvorn. Temporal Variation of Small Shorebird Carrying Capacity on an Estuarine Mudflat. Report in draft for manuscript

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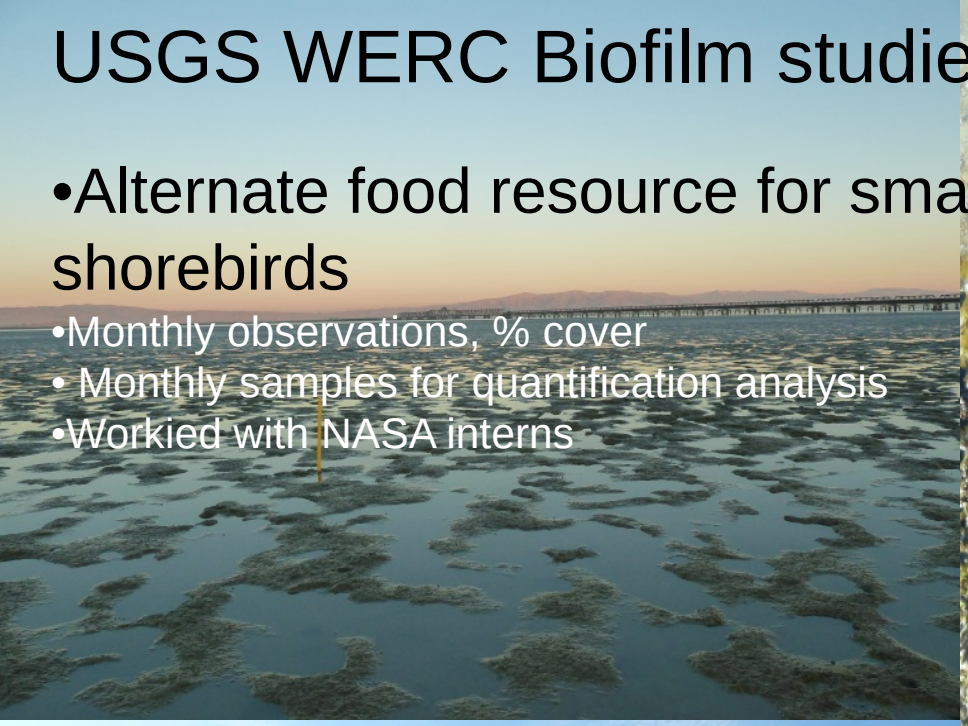
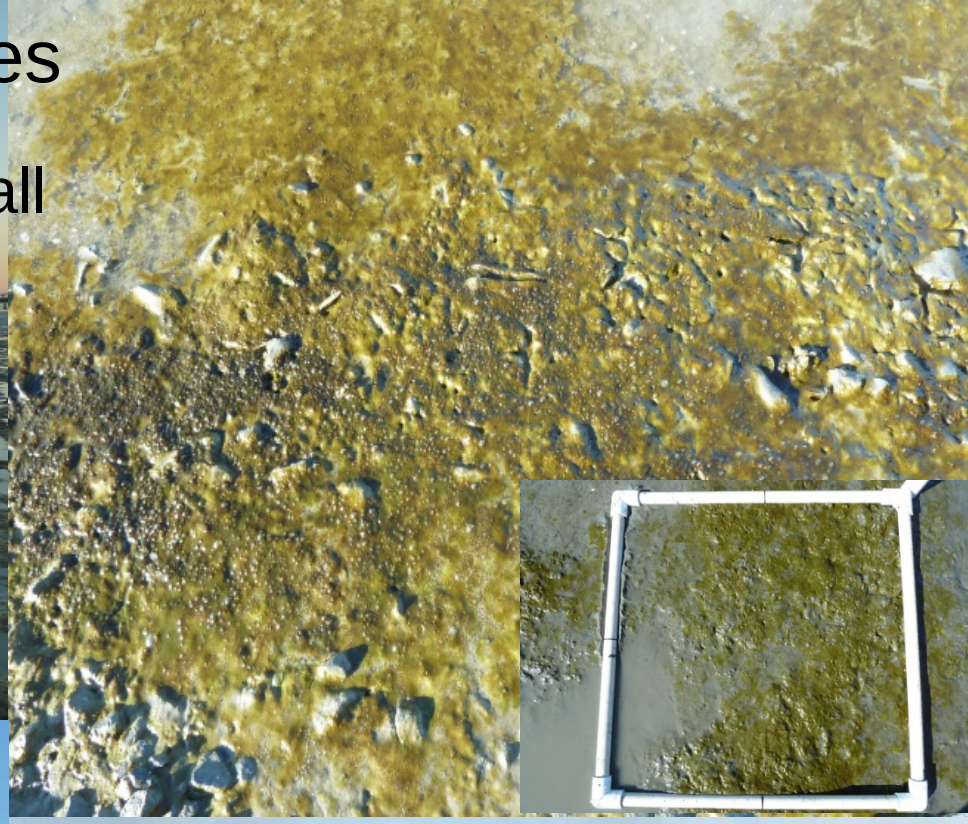
USGS WERC Biofilm studies

- Alternate food resource for small shorebirds
  - Monthly observations, % cover
  - Monthly samples for quantification analysis
  - Worked with NASA interns





NASA DEVELOP interns at Dumbarton Shoals collecting spectral reflectance data

Partners & Collaborators

- USGS Priority Ecosystem Studies, SF Bay Program
- USGS, CAWSC, CMG – D. Shellenbarger, D. Schoellhamer, B. Jaffe, A. Foxgrover
- California Department of Fish and Game – Karen Taylor, Tom Huffman, Mike Sipes, Larry Wyckoff, Stacy Martinelli
- USFWS (San Francisco Bay and San Pablo Bay Refuges– A. Morkill, D. Brubaker, E. Mruz
- Wildlife Conservation Board - Bonnie Turner, Tony Chappelle
- Ducks Unlimited – Renee Spenst, Steve Carroll, Austin Payne, Russell Lowgren, Fritz Reid,
- State Coastal Conservancy – Amy Hutzel, Nadine Hitchcock, Betsy Wilson
- SF Bay Joint Venture - Beth Huning, Christina Sloop
- GAIA Consulting, Inc. - Susanne von Rosenberg
- Endangered Species Permits – S.Osborn (CDFG) and D. Kelley (USFWO)
- University of Wyoming– J. Lovvorn

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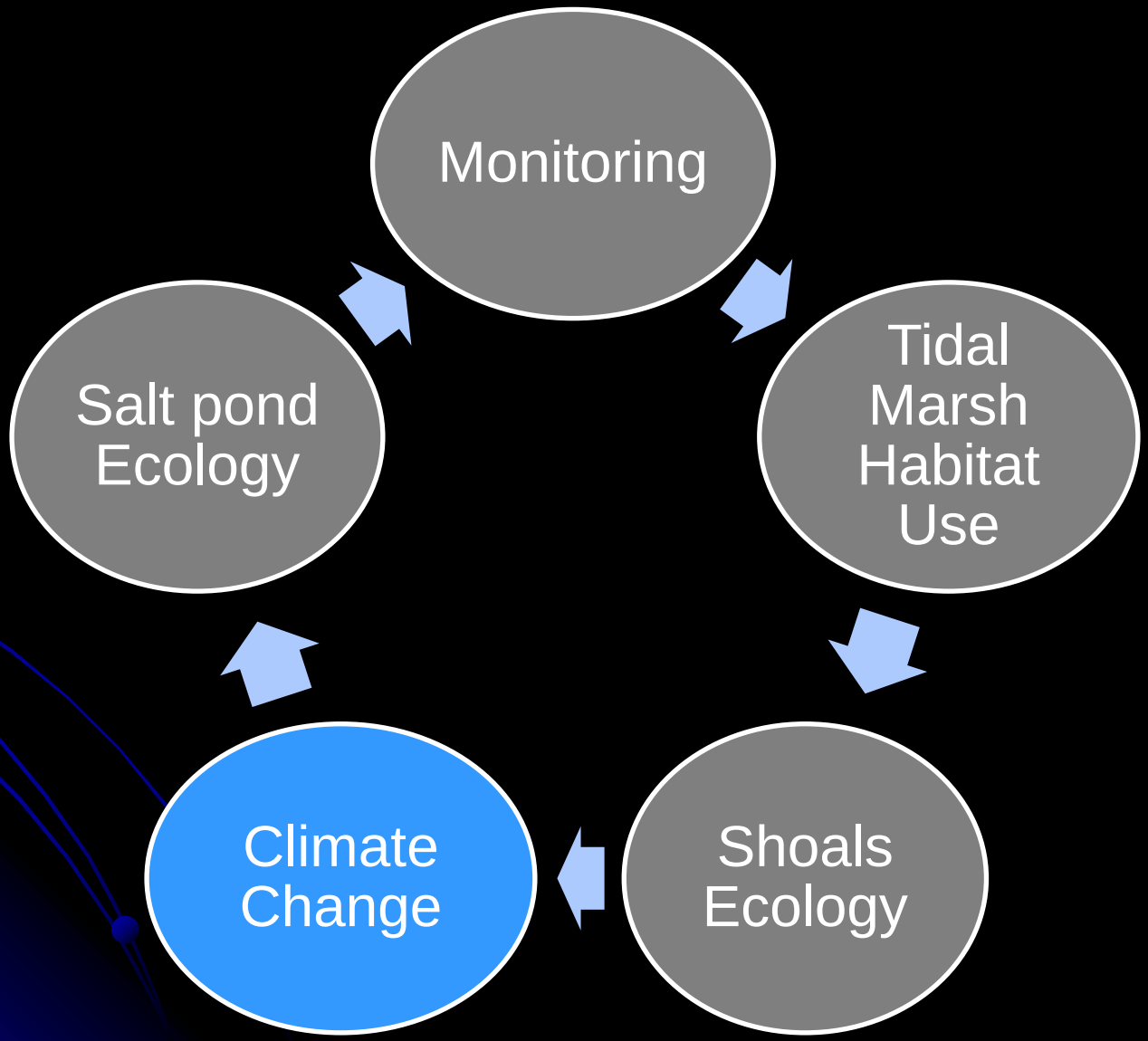
Tidal Marsh Research



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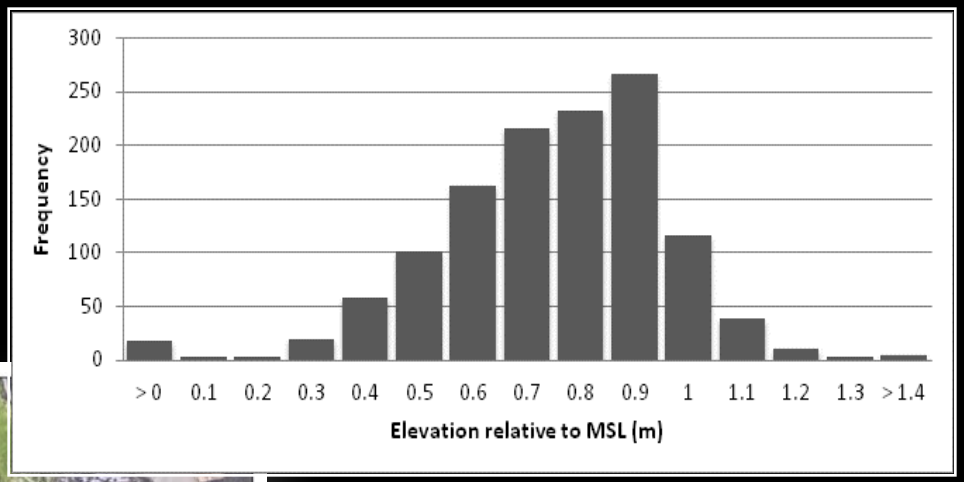
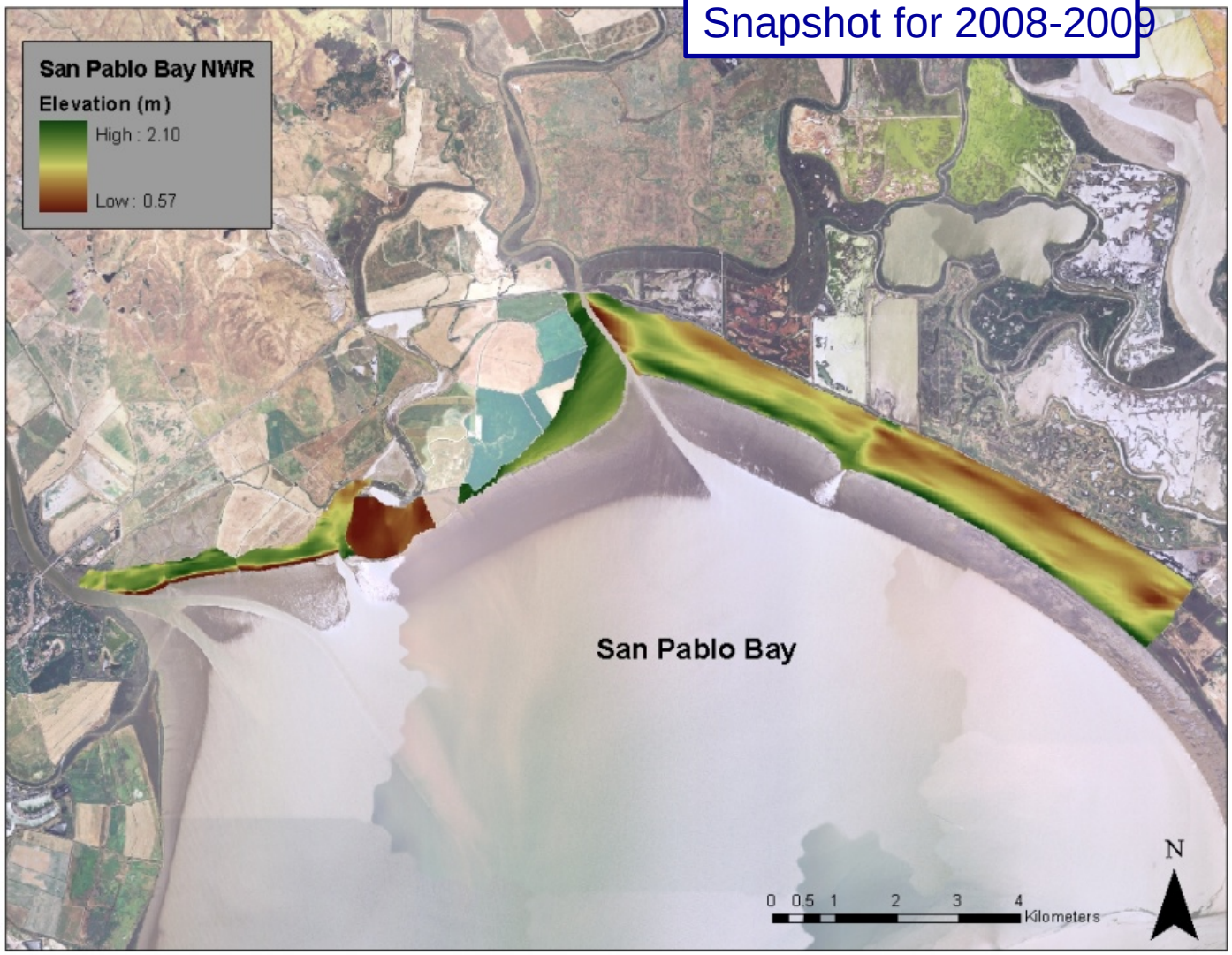
Goal: Develop high resolution elevation model

Data: Elevation Data



- Field data collected in 1995 and 2008-2009.
- 1700 elevation points collected.
- 68% within 1.6 – 2.0 m

Elevation Model for San Pablo Bay NWR



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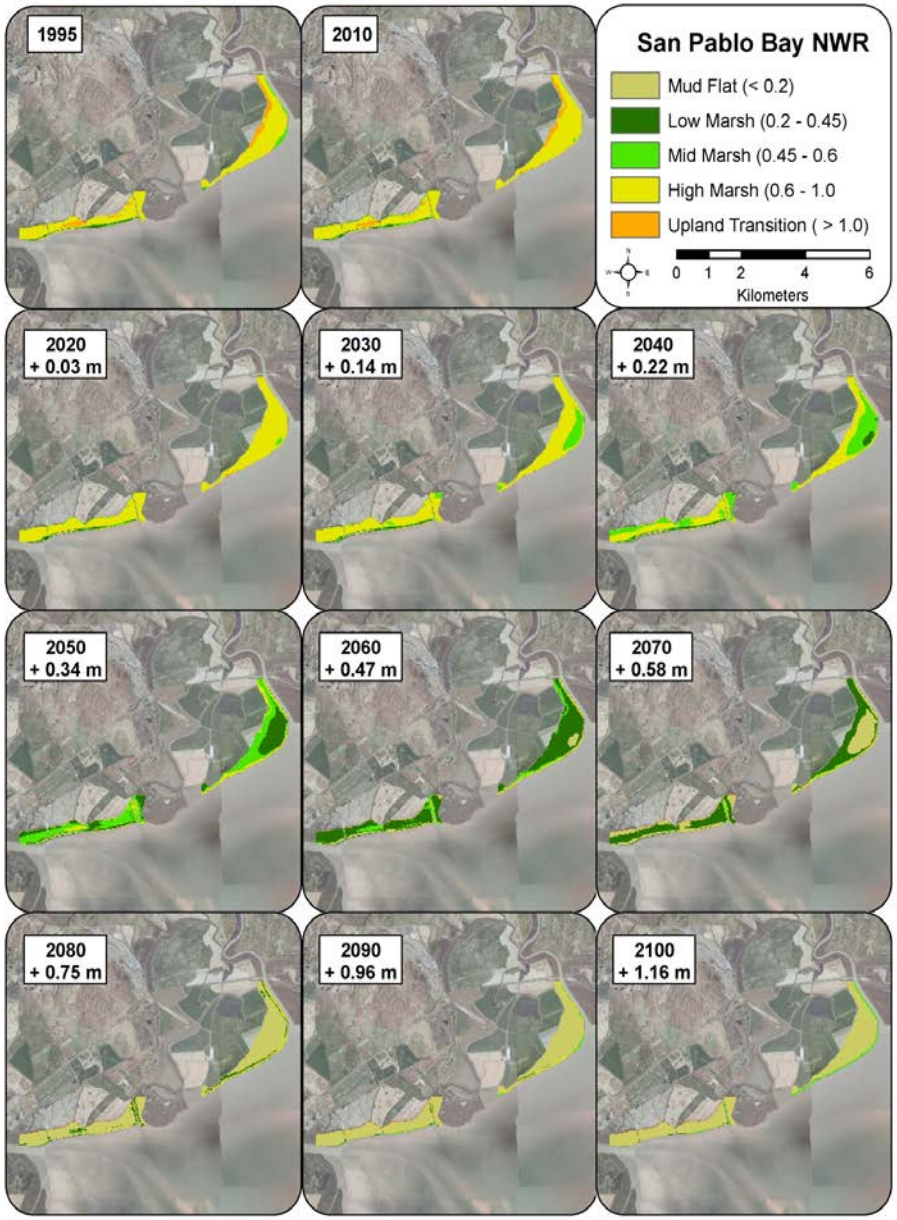
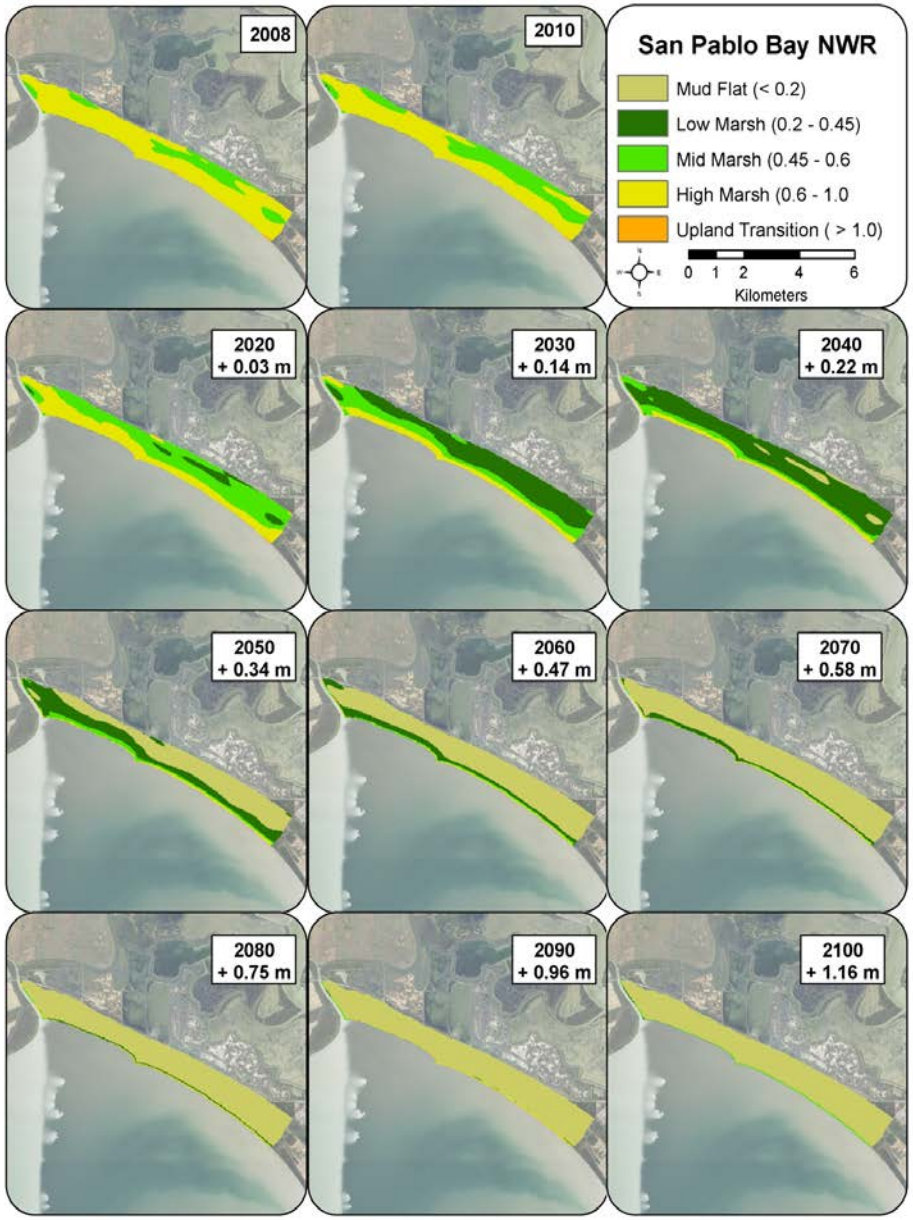
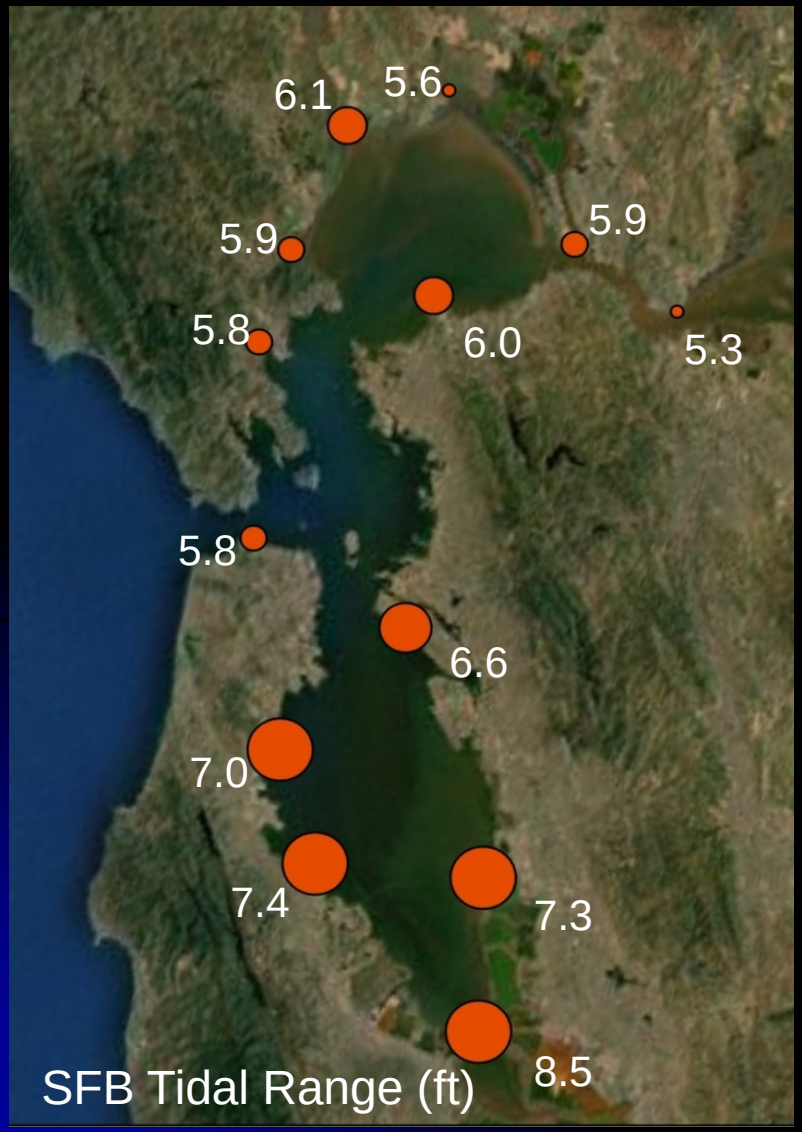
San Pablo Bay NWR plant community results



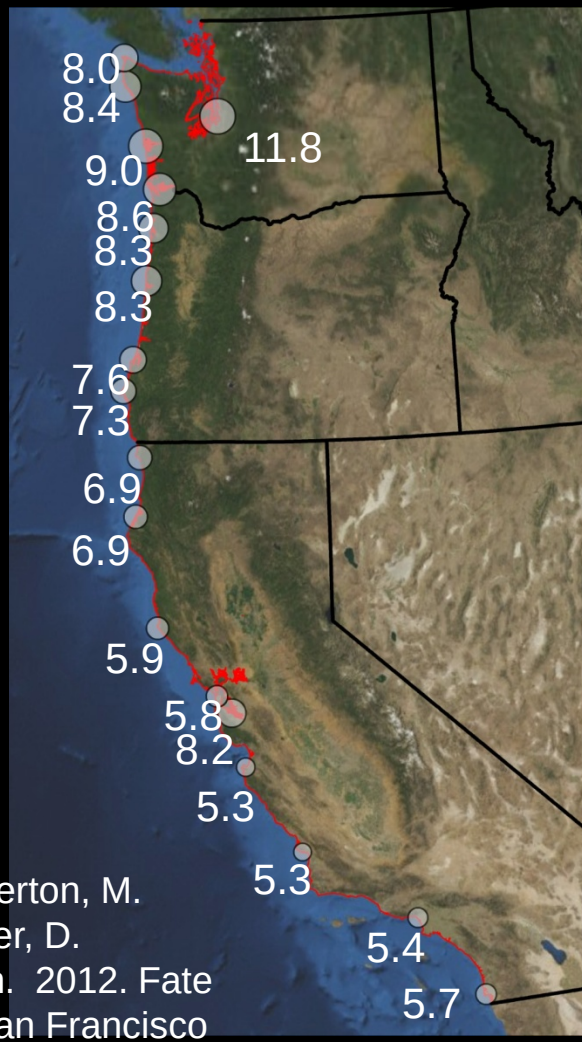


Vulnerability of tidal marshes to Climate Change: Elevation, sediment, hydrology, vegetation



Expansion to SFB marshes

Expansion to US West Coast Marshes



Takekawa, J., K. Thorne, C. Overton, M. Casazza, K. Swanson, J. Drexler, D. Schoellhamer and K. Buffington. 2012. Fate of endangered species in the San Francisco Bay salt marshes with sea-level rise. USGS . Open-File Report http://pubs.usgs.gov

Web outreach: www.werc.usgs.gov/SFBaySLR

About the Project

Executive Summary

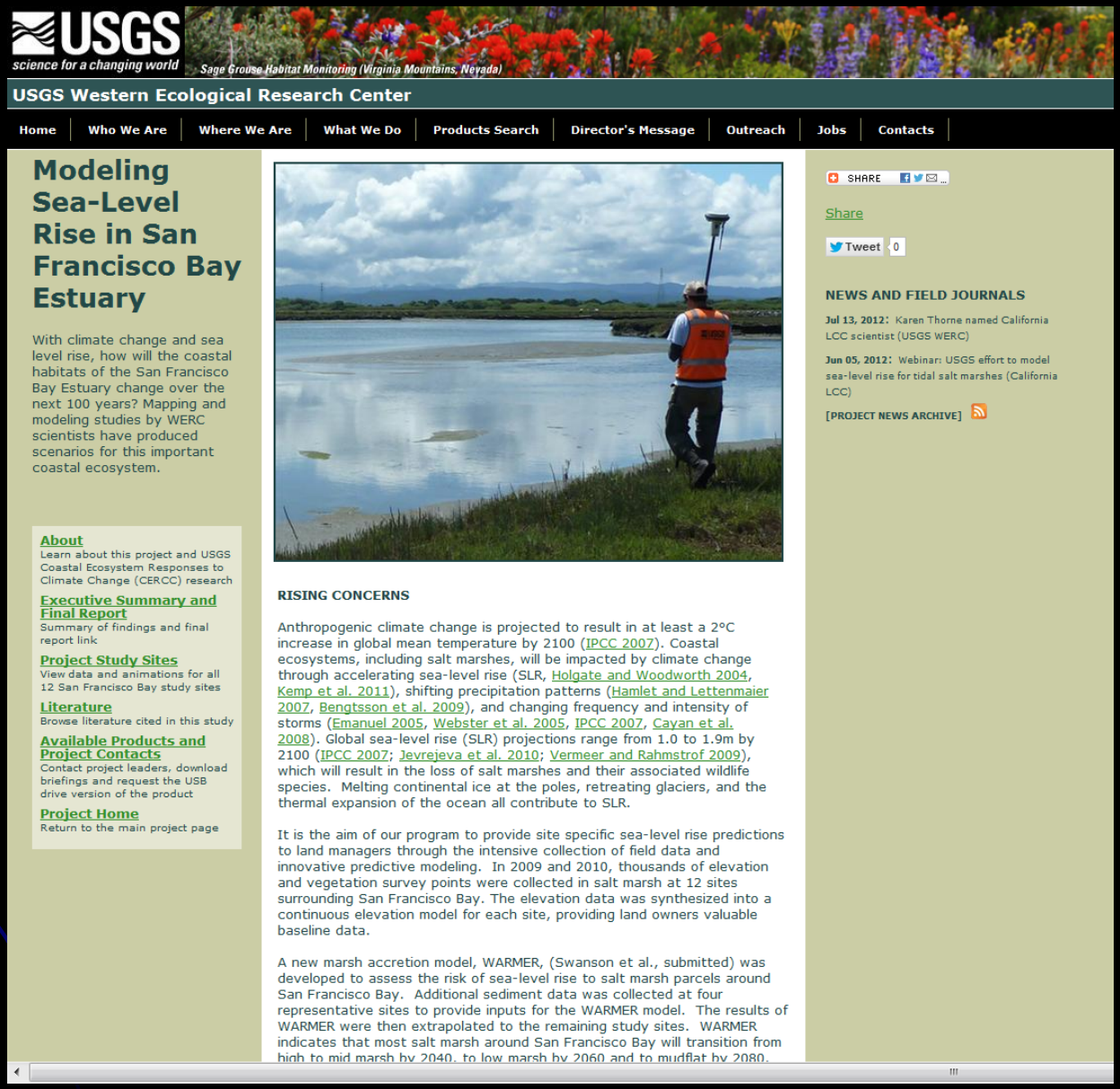
Draft Final Report

Results by Site

Literature

Products and Contacts

www.werc.usgs.gov/SFBaySLR



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Climate Change Partners/Collaborators

USGS Climate Change Program
USGS National Climate Change and Wildlife Science Center
California LCC
North Pacific LCC
U.S. Fish & Wildlife Service I & M Program
U.S. Fish & Wildlife Service – Recovery Branch
U.S. Fish & Wildlife Service – Refuges: SFBNWR, SDNWR
NOAA NERR – China Camp SP, Tijuana Estuary
USGS Western Ecological Research Center
USGS California Water Science Center
USGS Native American Internship Program
California Department of Fish & Game
East Bay Regional Parks
University of California, Davis

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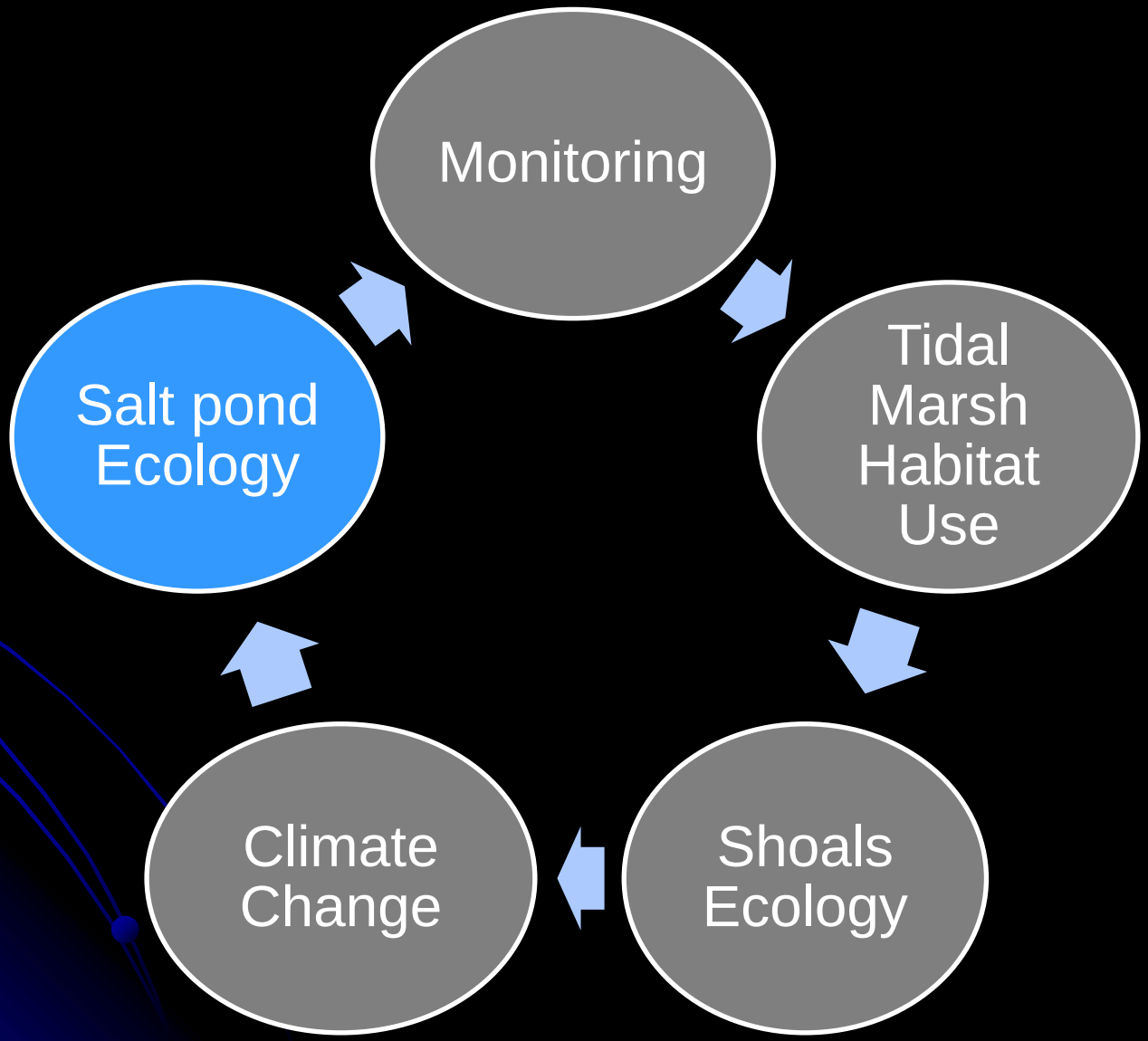

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Salt Pond Program

Year	Project	Partners

Salt Pond Program

Year	Project	Partners
• 1999-2013	North Bay Salt Ponds	CDFW (Karen Taylor), UC Davis (Jim Hobbs) CAWSC (Greg Shellenbarger, Dave Schoellhamer)

Brand et al. 2012. Trajectory of early tidal marsh restoration: elevation, sedimentation and colonization of breached salt ponds in the northern San Francisco Bay. Ecological Engineering 42: 19-29.

Takekawa et al. 2009. Dietary flexibility in three representative waterbirds across salinity and depth gradients in salt ponds of San Francisco Bay. Hydrobiologia 626:155–168.

Salt Pond Program

Year	Project	Partners
1999-2013	North Bay Salt Ponds	CDFW (Karen Taylor), UC Davis (Jim Hobbs) CAWSC (Greg Shellenbarger, Dave Schoellhamer)
2002-2013	South Bay Salt Pond Surveys	Don Edwards NWR (C. Strong, E. Mruz)

Athearn et al. 2012. Variability in habitat value of commercial salt production ponds: implications for waterbird management and tidal marsh restoration planning. Hydrobiologia 697: 139-155.

Demers et al. 2010. Space use and habitat selection of migrant and resident American avocets in San Francisco Bay. Condor 112: 511-520.

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• 2002-2013	South Bay Salt Pond Surveys	Don Edwards NWR (C. Strong, E. Mruz)
• 2002-2011	South Bay Water Quality	NRP (Jim Kuwabara, Brent Topping) CAWSC (Greg Shellenbarger, Dave Schoellhamer)

Shellenbarger et al. 2008. Dissolved oxygen in Guadalupe Slough and Pond A3W, South San Francisco Bay, California, August and September 2007: U.S. Geological Survey Open-File Report 2008–1097, 26 pp.

Takekawa et al. 2006. Trophic structure and avian communities across a salinity gradient in evaporation ponds of the San Francisco Bay estuary. Hydrobiologia 567: 307-327.

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2002-2011	South Bay Water Quality	NRP (Jim Kuwabara, Brent Topping) CAWSC (Greg Shellenbarger, Dave Schoellhamer)
2009-2013	Pond A3W Water Quality	NRP (J. Kuwabara, B. Topping, Jim Cloern) CAWSC (G. Shellenbarger)

Salt Pond Program

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2002-2011	South Bay Water Quality	NRP (Jim Kuwabara, Brent Topping) CAWSC (Greg Shellenbarger, Dave Schoellhamer)
2009-2013	Pond A3W Water Quality	NRP (J. Kuwabara, B. Topping, Jim Cloern) CAWSC (G. Shellenbarger)
2008-2011	Shoals	CMG PSC (Bruce Jaffe, Amy Foxgrover) NRP (Jan Thompson)

Salt Pond Program

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2013-2014	Eden Landing Scaup	CDFW (J. Krause), Trustee Council for Cosco Busan oil spill

South Bay Salt Pond Surveys

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2. Our 10-year dataset provides important insights into bird response to initial restoration and pond management

3. We must continue monitoring to understand future bird response to habitat changes and to help guide the future restoration decisions

Salt Pond Survey Data

Salt Pond Survey Data

1. Waterbirds

Salt Pond Survey Data

1. Waterbirds
2. Elevation & water depth

Salt Pond Survey Data

1. Waterbirds
2. Elevation & water depth
3. Water quality

Salt Pond Survey Data

1. Waterbirds
2. Elevation & water depth
3. Water quality
4. Invertebrates

Salt Pond Survey Data

1. Waterbirds
2. Elevation & water depth
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4. Invertebrates
5. Vegetation

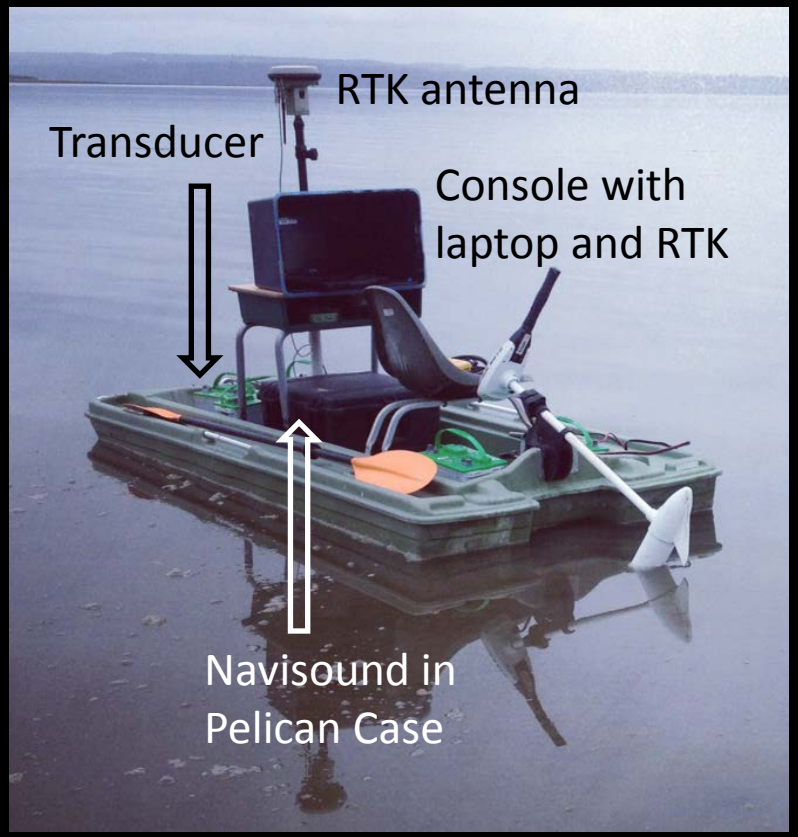
Waterbirds

Salt Pond Waterbird Counts

- Monthly counts at high tide
- Recorded
  - Species
  - Abundance
  - Spatial location
  - Behavior: roosting or foraging

Elevation & Water Depth

- Real Time Kinematics GPS in combination with Reson Navisound echosounder
- LiDAR
- Staff gages read monthly



Athearn et al. 2010, Takekawa et al. 2010

Water Quality

- Surveyed monthly
- 1-3 locations per pond
- Parameters
  - pH
  - Dissolved oxygen
  - Temperature
  - Salinity
- Focused studies with deployed meters

Citations here

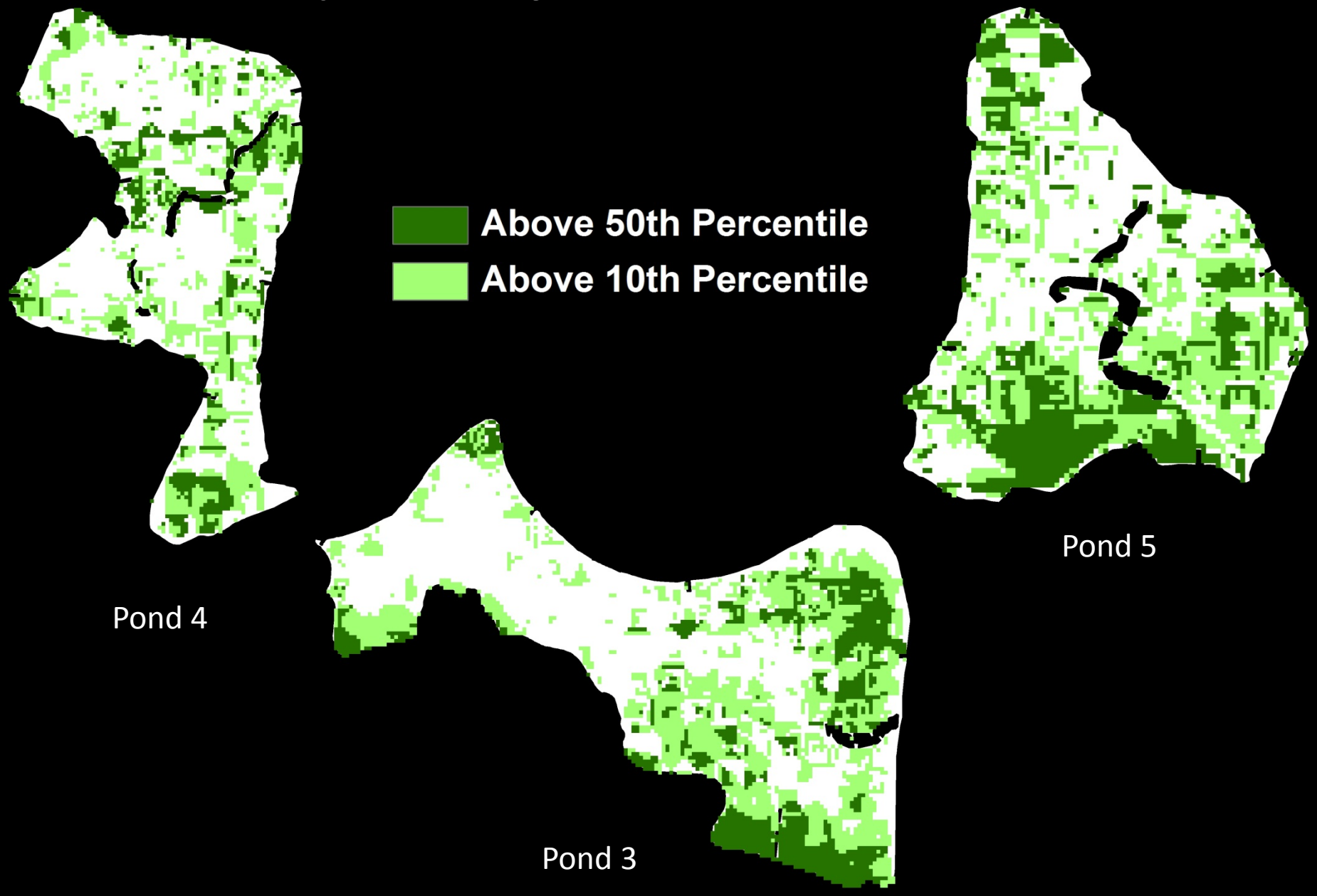
Invertebrates

- Samples collected by boat during high tide
- Sieve through 0.5 mm screen
- Stained with Rose Bengal dye, preserved in 95% ethanol
- Prey sorted into taxonomic categories

Vegetation

- 2-5 RTK GPS locations taken per *Spartina* patch in the ponds
- Colonization occurred at this elevation or lower

Spartina foliosa Elevation



Scales of Analysis

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Spatial

1. Islands
2. Grids
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4. Complexes
5. Adjacent Shoals

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4. Years

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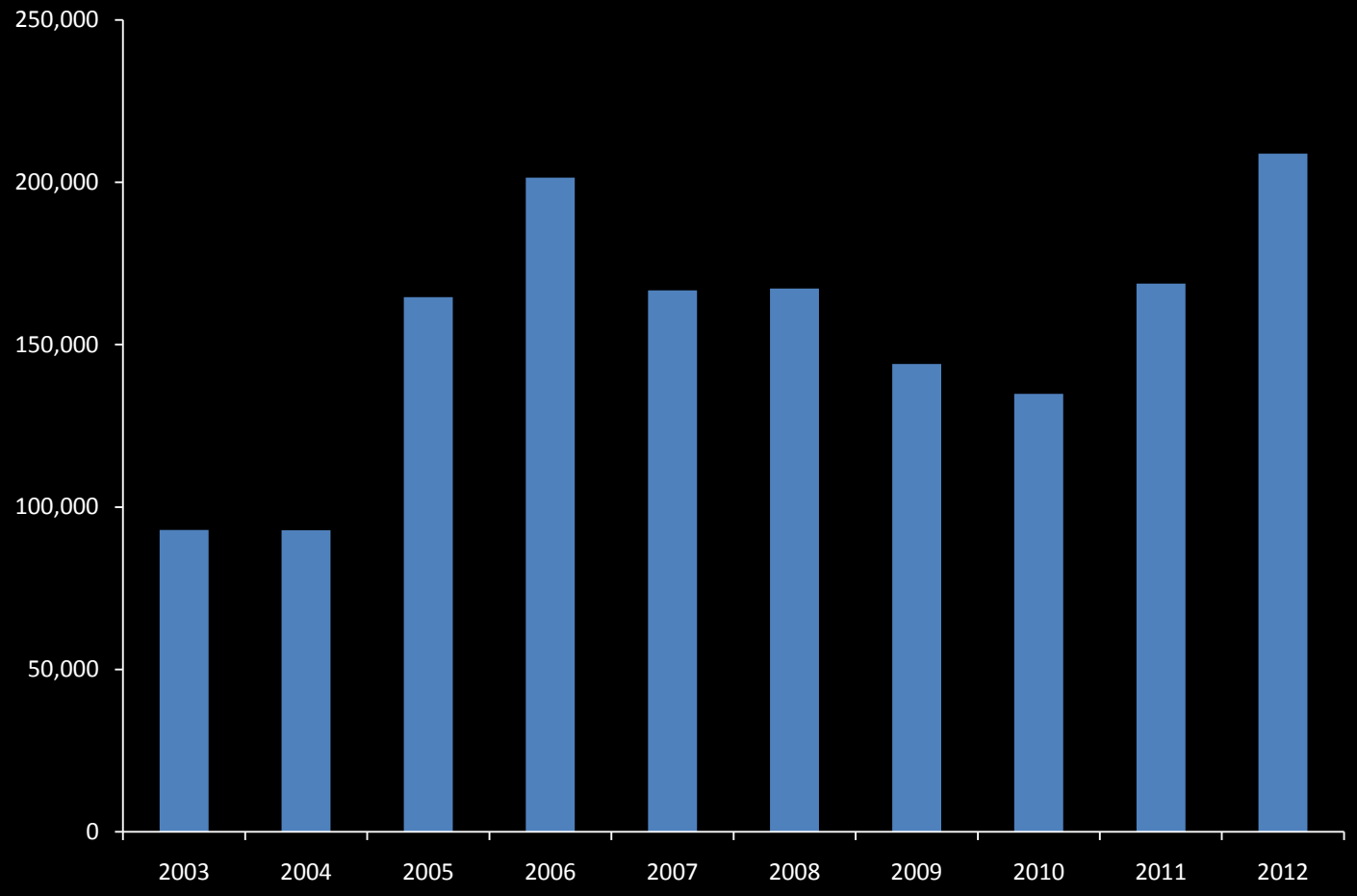
Birds

1. Species
2. Guilds

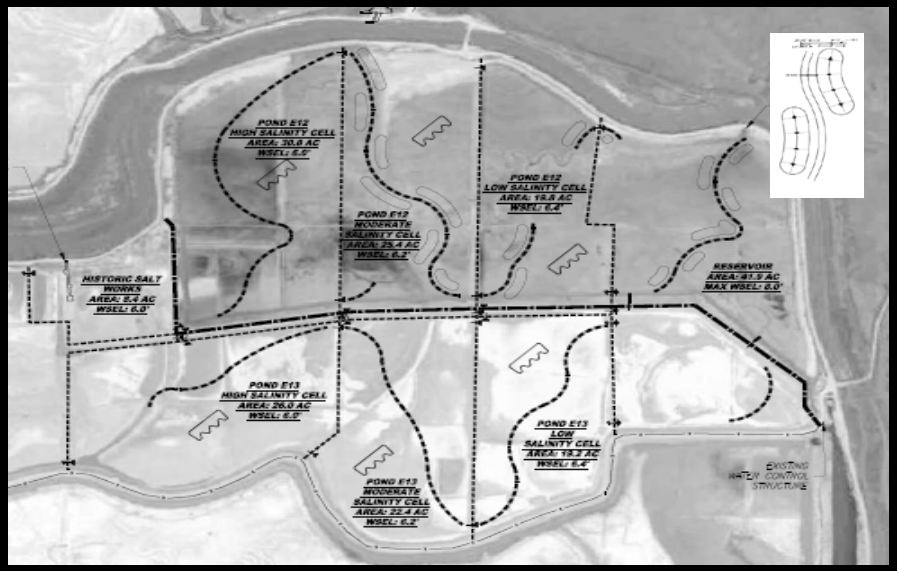
Long Term Data

Mean Winter Waterbird Abundance in South Bay



Focused Research

- Eden Landing E12/E13
  - Experimental ponds
  - Varying water depth
  - Varying salinity
  - Islands
  - Shorebird response



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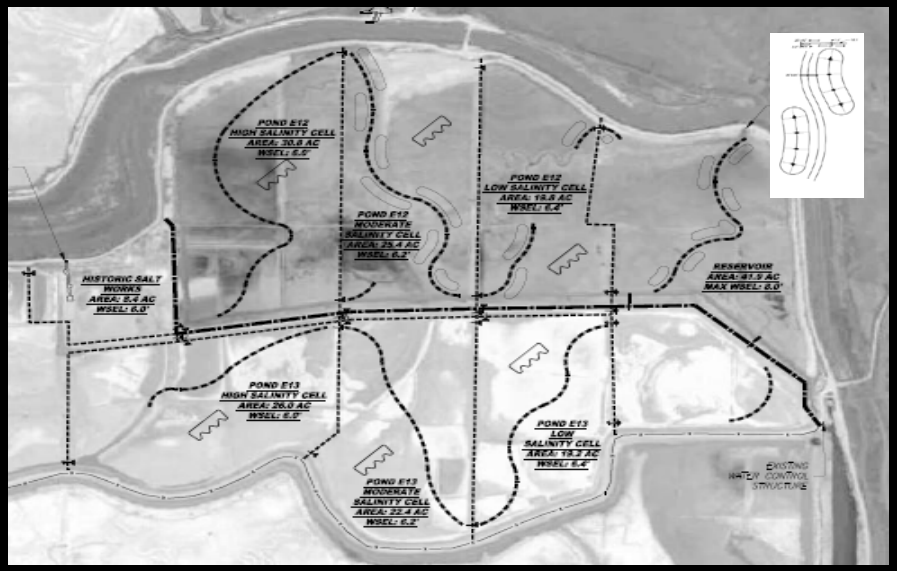
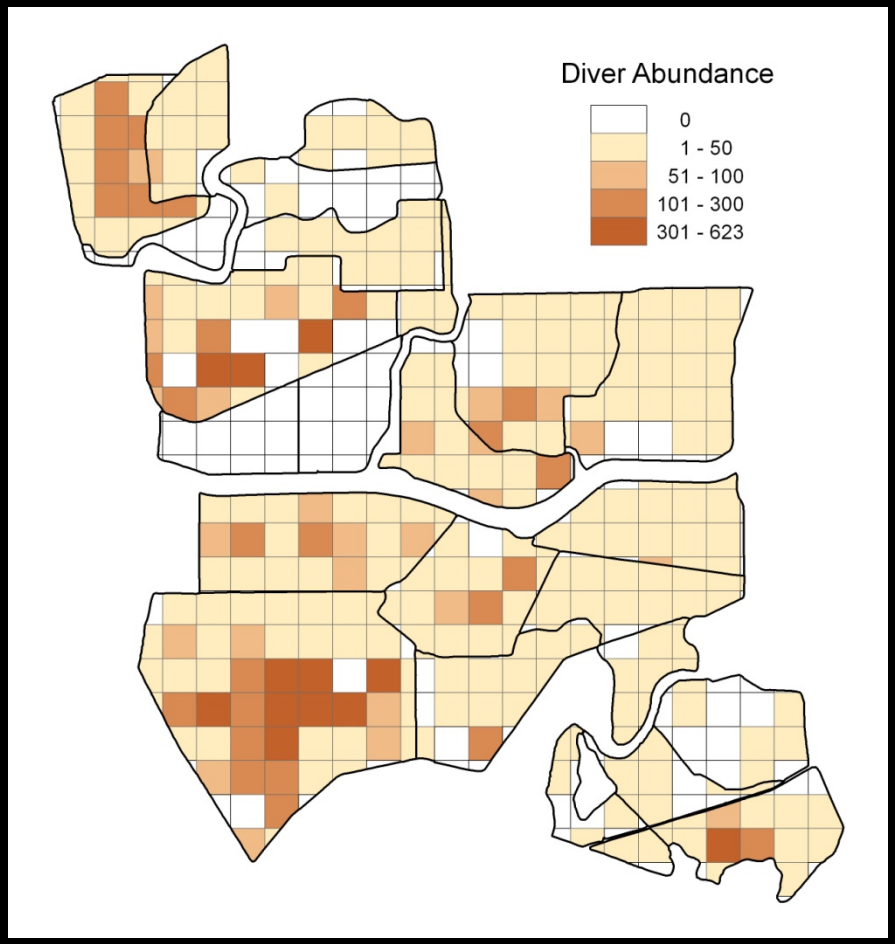


- Eden Landing Diving Ducks
  - Habitat preferences
  - Managing for ducks in winter and snowy plovers in summer

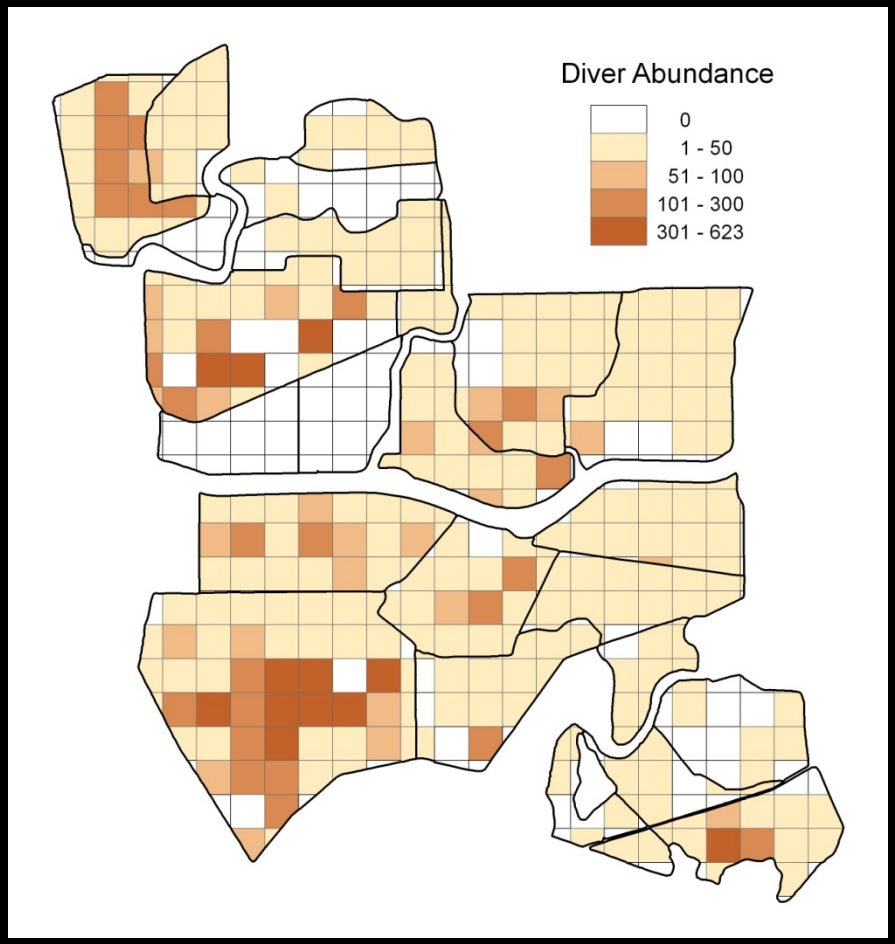
Eden Landing Diving Ducks 2009

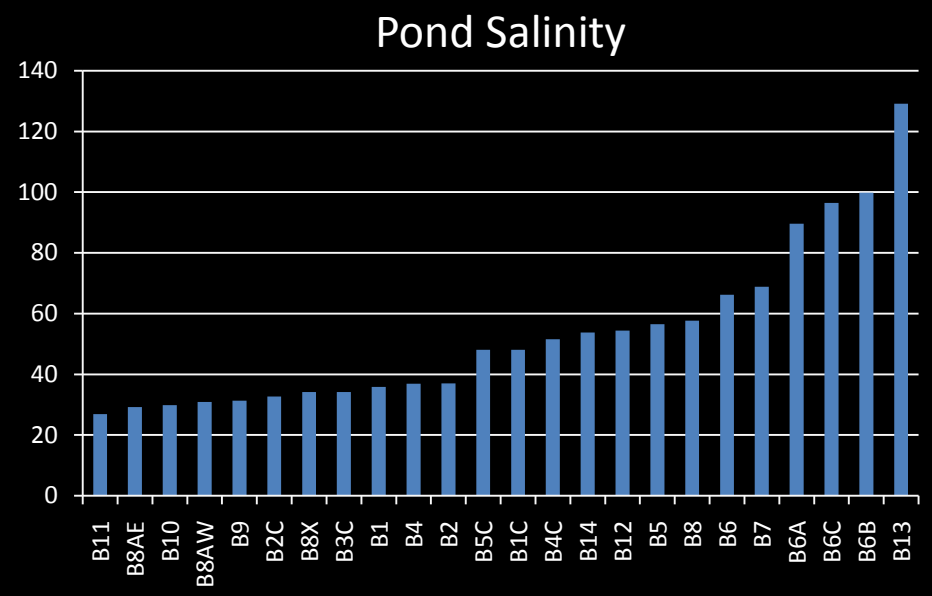
Eden Landing Diving Ducks 2009



Scaup:	2,797
Ruddy Duck:	3,499
Bufflehead:	985
Canvasback:	164
Com. Goldeneye:	269

Eden Landing Diving Ducks 2009





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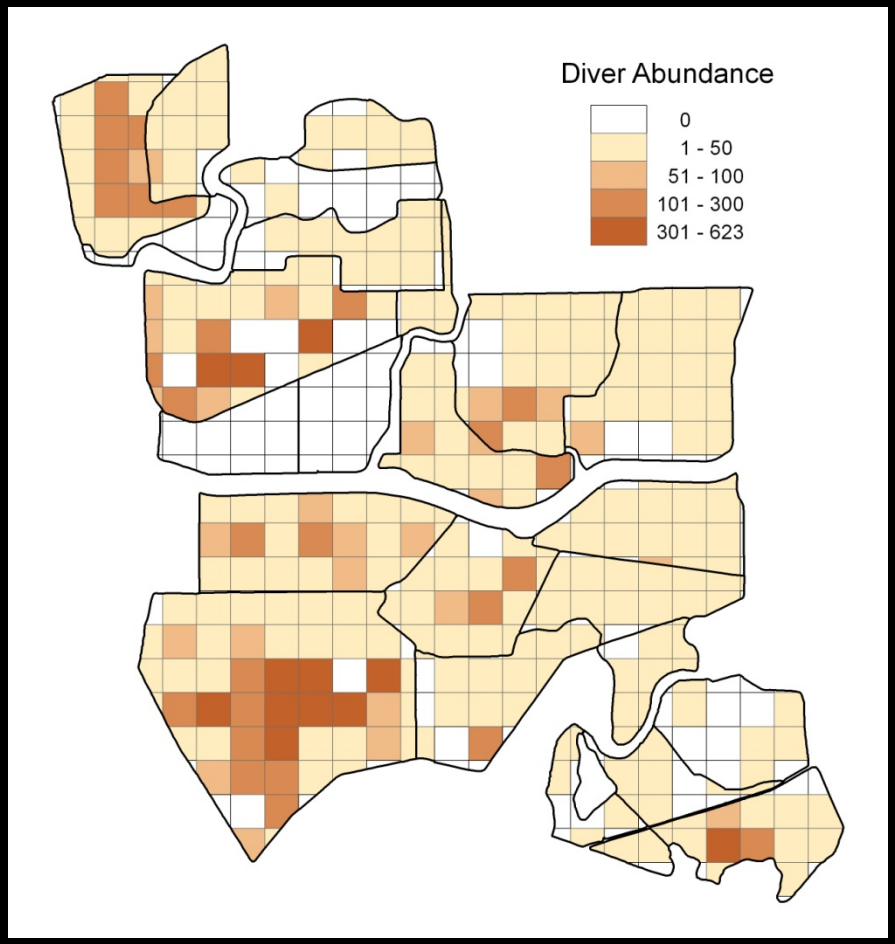

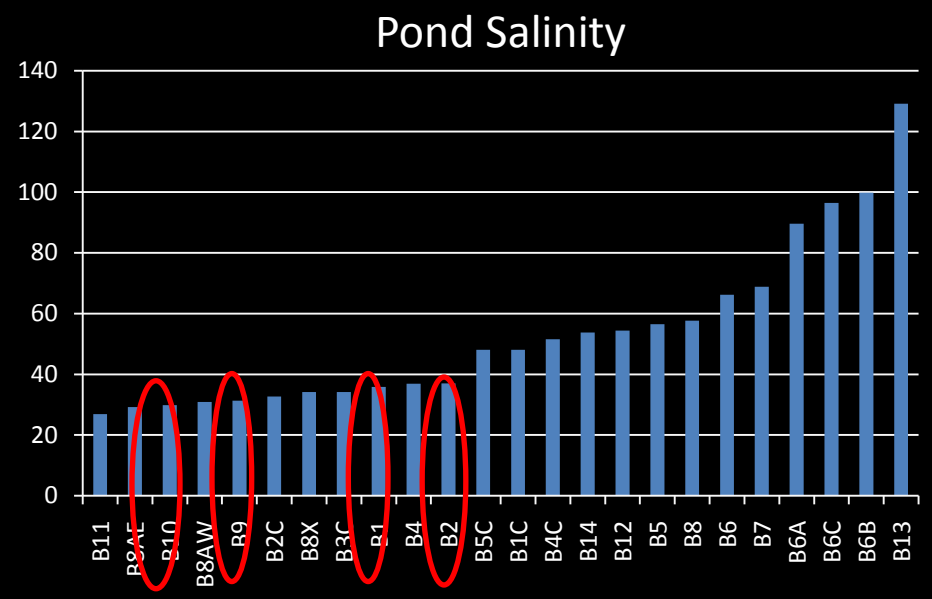

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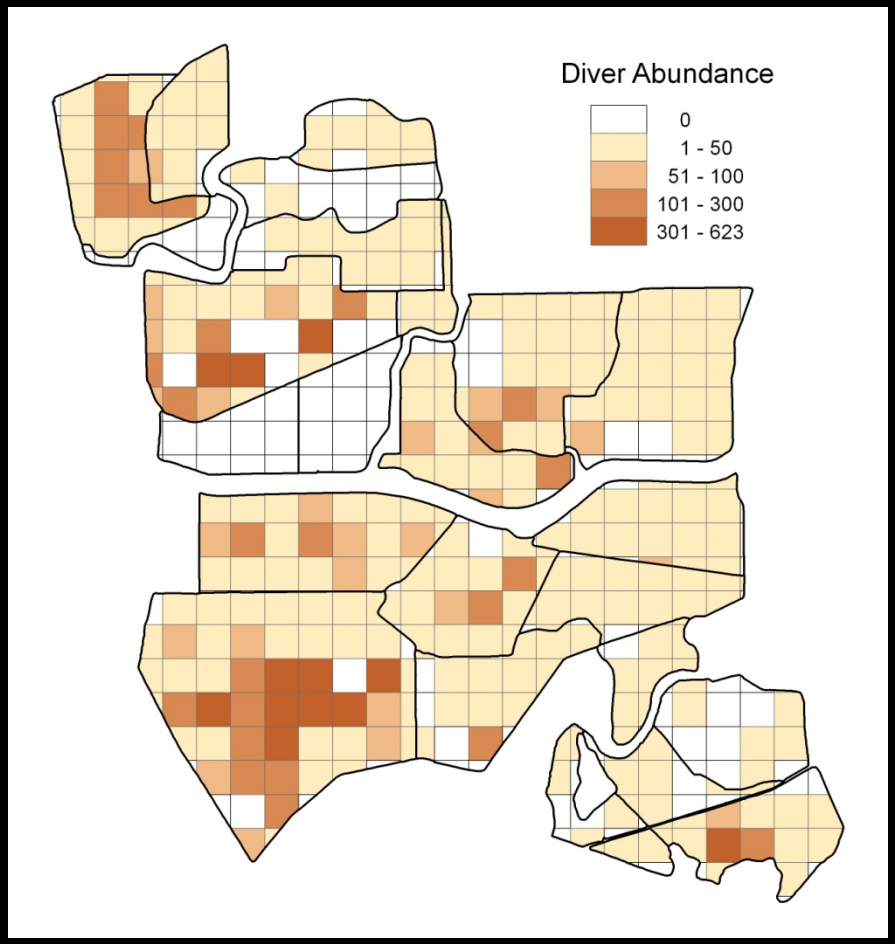

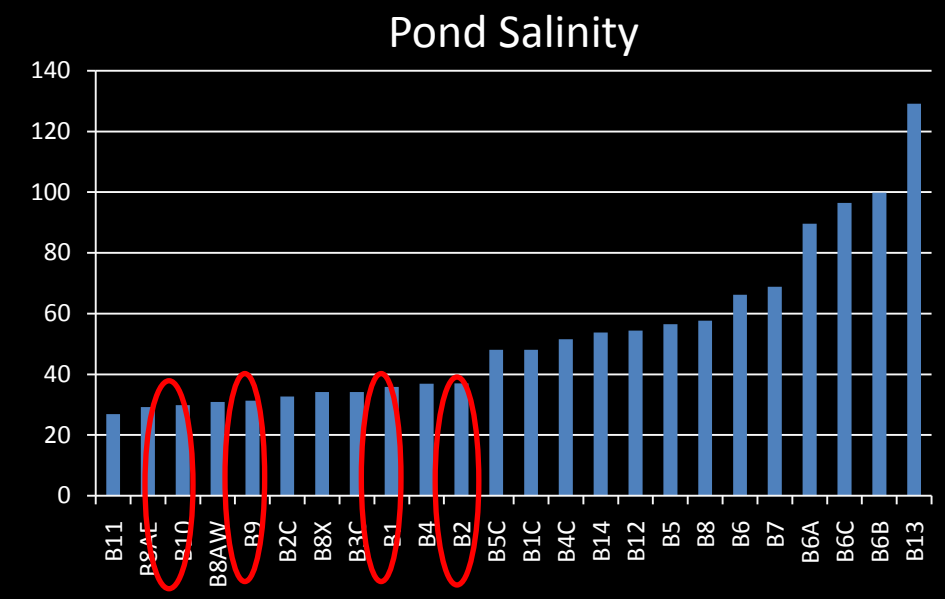

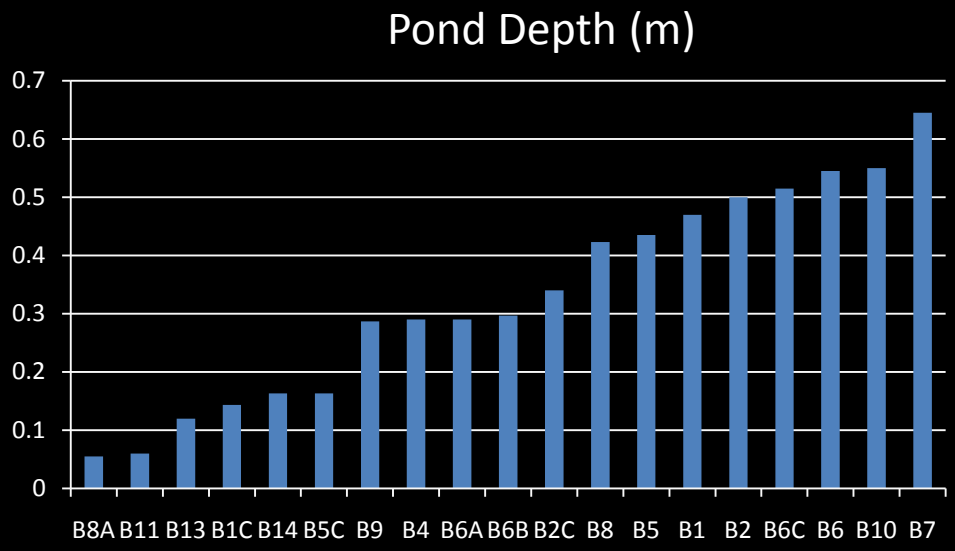

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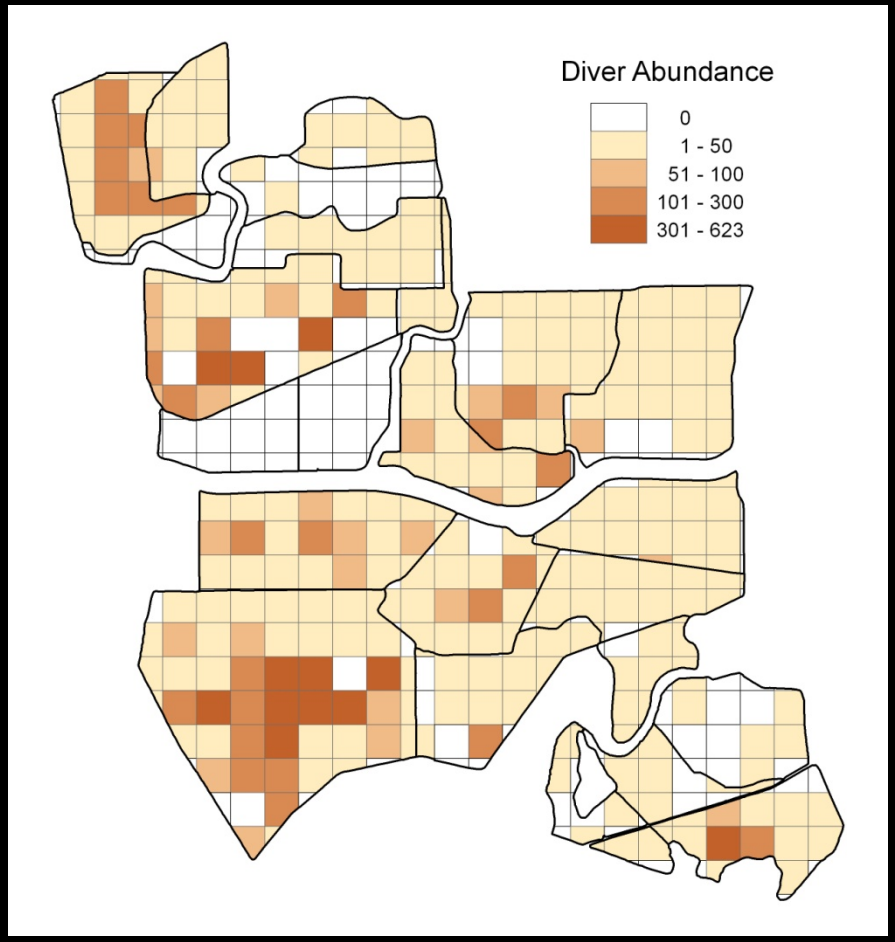

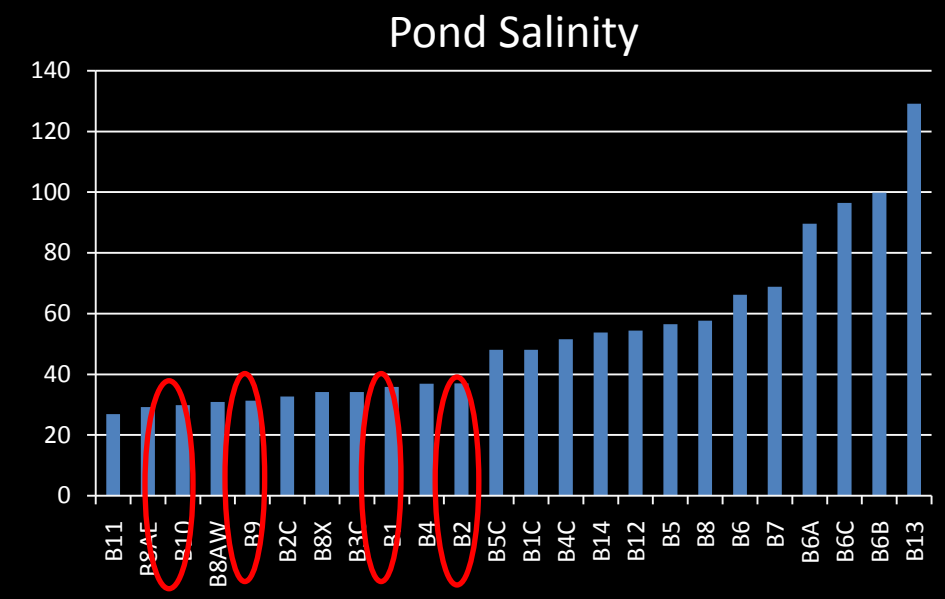

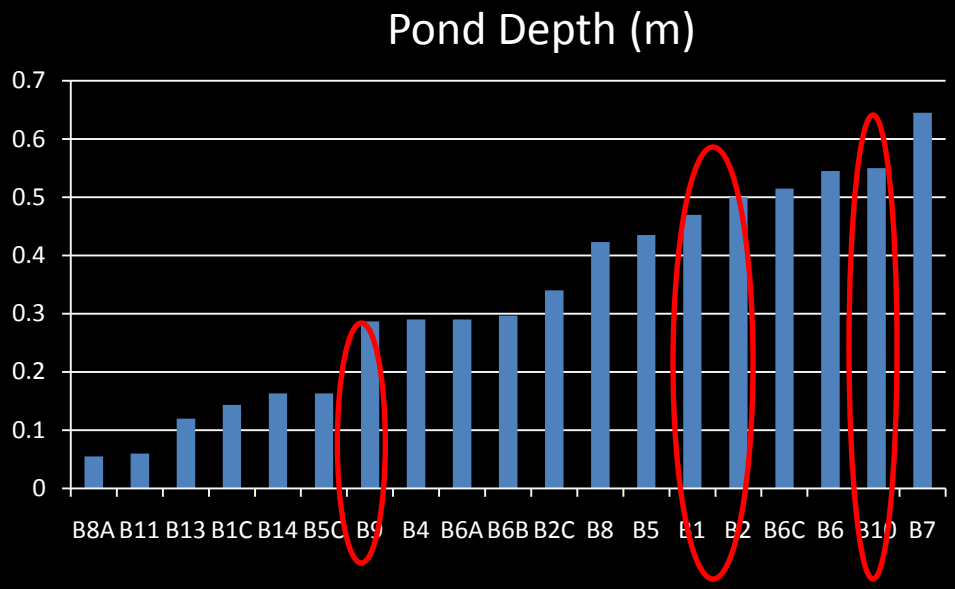

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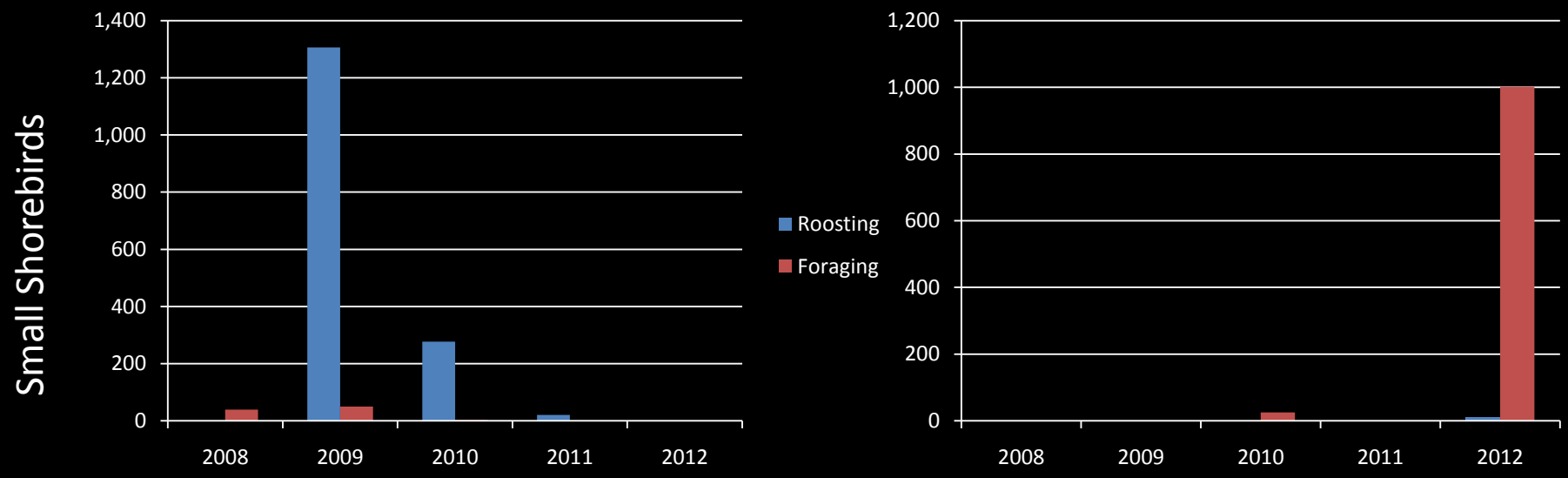
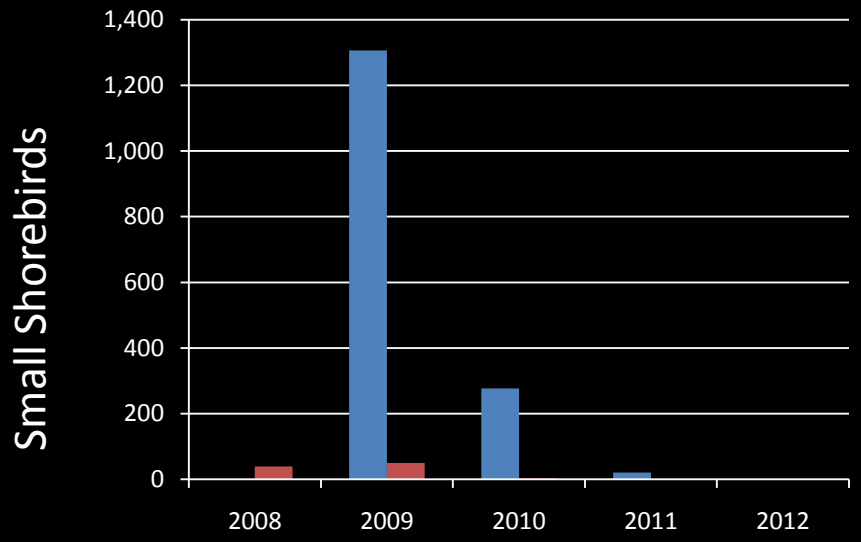
Alviso Pond A6



Alviso Pond A6

Winter High Tide



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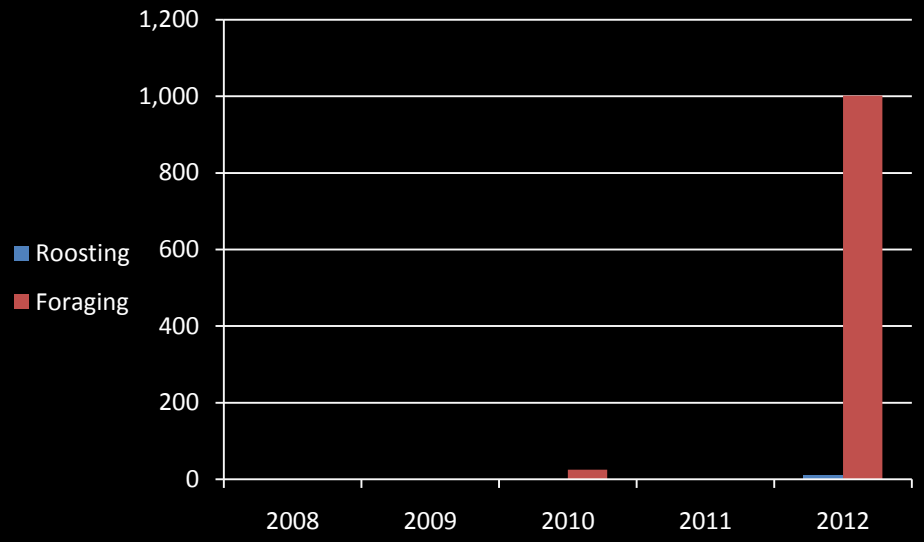
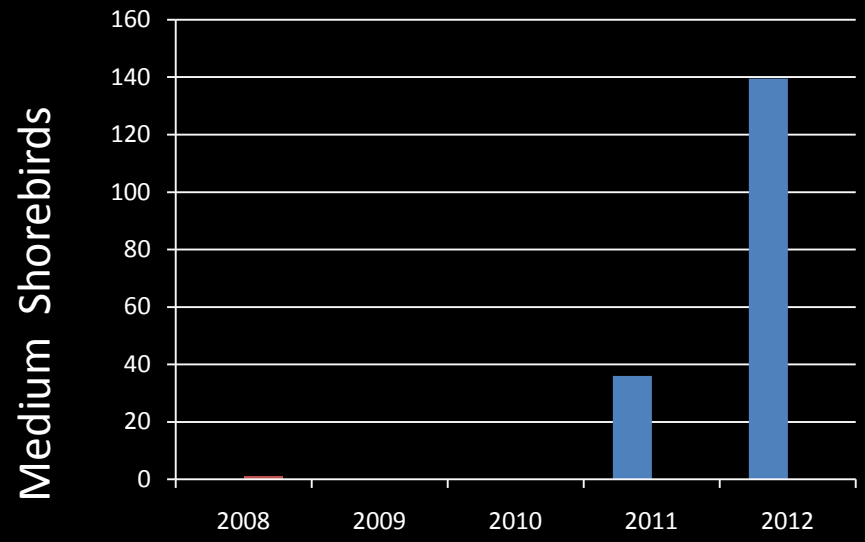
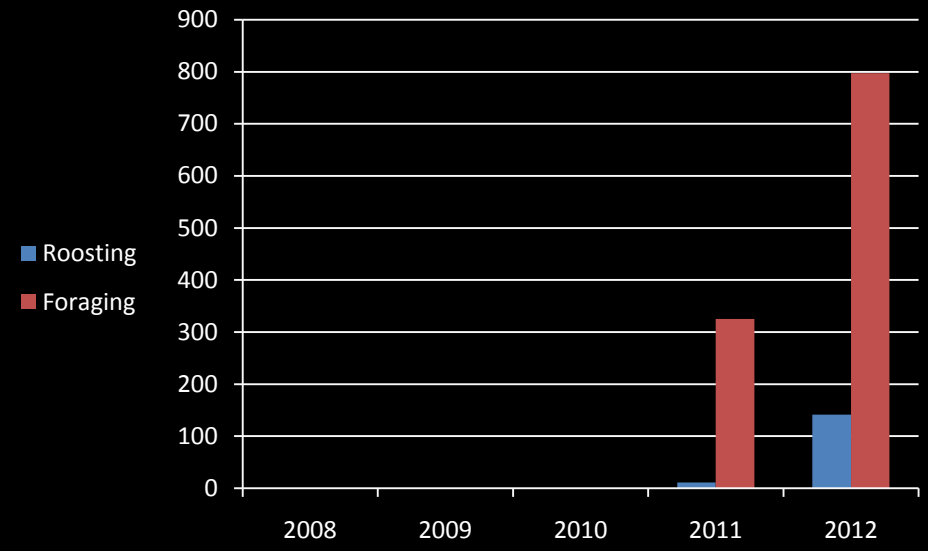


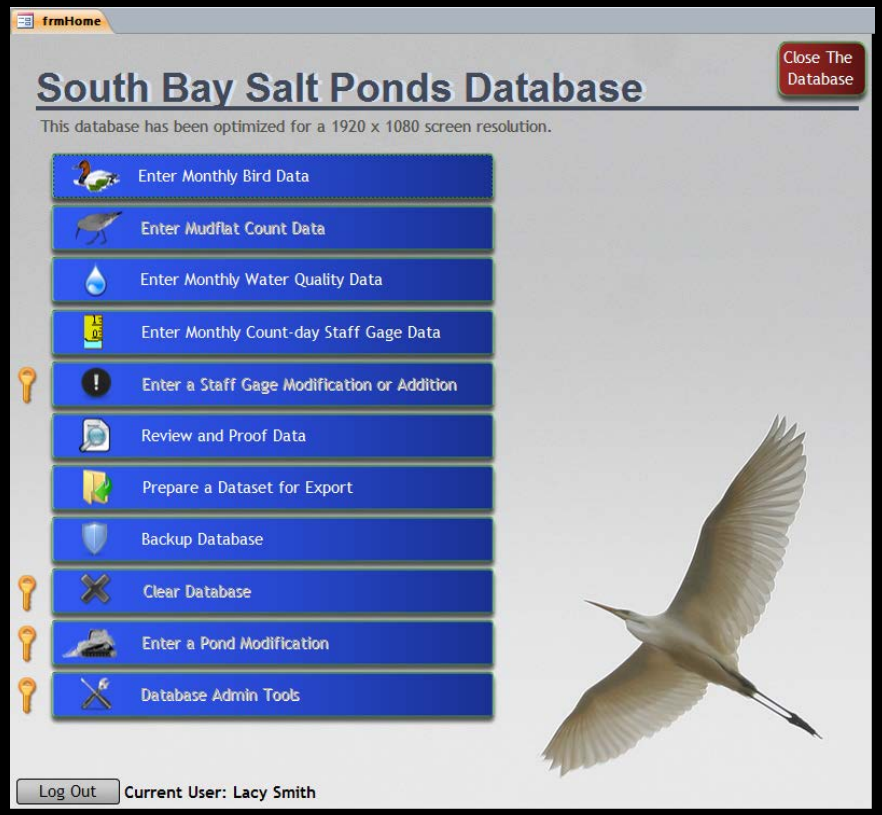


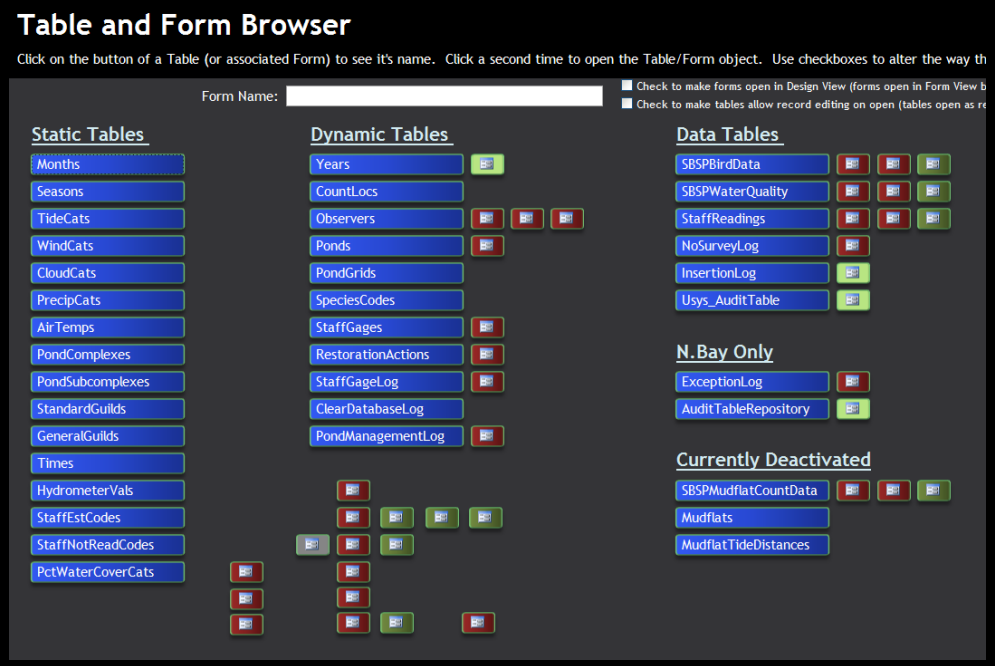


Data Analysis & Communication

1. Access database
2. Reporting
3. Publications
4. Working groups
5. Websites

Salt Pond Database





Salt Pond Database

frmHome | frmDataExport | tblOutput_qryFWSSummary_Species

MonthYear	CountDate	Season	Pond	PondAcres	TideCat	Total Of Sum	SpeciesRichi	AGWT	AMAV	AMBI	AMCO	AMCR
10/1/2002	10/24/2002	Fall	B3C	167	High	1191	12	60	16	0	0	
10/1/2002	10/24/2002	Fall	B4C	178	High	1678	9	0	0	0	0	
10/1/2002	10/24/2002	Fall	B5	167	High	105	9	0	0	0	0	
10/1/2002	10/24/2002	Fall	B5C	95	High	266	6	0	0	0	0	
10/1/2002	10/24/2002	Fall	B6	196	High	601	11	0	0	0	0	
10/1/2002	10/24/2002	Fall	B6C	84	High	35	4	0	0	0	0	
10/1/2002	10/25/2002	Fall	B1	298	High	990	13	0	0	0	0	
10/1/2002	10/25/2002	Fall	B10	216	High	393	15	14	18	0	0	
10/1/2002	10/25/2002	Fall	B10X	53	High	6	4	0	0	0	0	
10/1/2002	10/25/2002	Fall	B11	126	High	116	6	0	82	0	0	
10/1/2002	10/25/2002	Fall	B2	685	High	1768	14	0	0	0	0	
10/1/2002	10/25/2002	Fall	B4	195	High	293	13	0	0	0	0	
10/1/2002	10/25/2002	Fall	B7	218	High	207	9	0	0	0	0	
11/1/2002	11/18/2002	Fall	A19	269	High	35095	2	0	0	0	0	
11/1/2002	11/18/2002	Fall	A20	64	High	0	1	0	0	0	0	
11/1/2002	11/18/2002	Fall	A21	149	High	0	1	0	0	0	0	
11/1/2002	11/18/2002	Fall	A22	274	High	20	3	0	0	0	0	
11/1/2002	11/18/2002	Fall	A23	457	High	5587	2	0	0	0	0	
11/1/2002	11/18/2002	Fall	A5	646	High	2019	17	0	0	0	0	
11/1/2002	11/18/2002	Fall	A7	270	High	386	13	0	11	0	0	
11/1/2002	11/18/2002	Fall	A8	414	High	918	17	0	120	0	0	
11/1/2002	11/18/2002	Fall	B1	298	High	515	12	0	0	0	0	
11/1/2002	11/18/2002	Fall	B5	167	High	209	11	0	0	0	0	

Reporting

1. Brand, L. A., L. M. Smith, A. Smith, I. Woo, W. Chan, T. Graham, K. Taylor, and J. Y. Takekawa. 2012. Assessing early tidal marsh restoration at the Napa Plant Site Restoration Project within the Green Island Unit of the Napa-Sonoma Marshes Wildlife Area. Data Summary Report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 135 pp.

2. Mruz, E., M. Helton, L. A. Brand., S. Piotter, and J. Y. Takekawa. 2011. 2010 Self-monitoring program for Alviso Ponds within South San Francisco Bay Low Salinity Salt Ponds, Alameda, Santa Clara, and San Mateo Counties, California.

3. Brand, L. A., I. Woo, A. Smith, L. Smith, S. Moskal, and J. Y. Takekawa. 2011. Effects of regional wetland restoration on the Alviso Shoals of South San Francisco Bay: pre-restoration assessment of shorebird and invertebrate populations. Data Summary Report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 49 pp.

4. Takekawa, J. Y., L. M. Smith, and N. D. Athearn. 2009. Bathymetric surveys of salt ponds 3, 4, and 5 in the Napa-Sonoma Marshes, 2008-2009. Unpubl. Summary Report, U. S. Geological Survey, Vallejo, CA. 52 pp.

5. Shellenbarger, G. G., D. H. Schoellhamer, T. L. Morgan, J. Y. Takekawa, N. D. Athearn, and K. D. Henderson. 2008, Dissolved oxygen in Guadalupe Slough and Pond A3W, South San Francisco Bay, California, August and September 2007: U.S. Geological Survey Open-File Report 2008–1097, 26 p.

6. Takekawa, J. Y., A. K. Miles, N. D. Athearn, S. E. Spring, M. K. Saiki, F. Mejia, I. Woo, A. K. Schultz, and B. Hattenbach. 2006. Habitat Restoration Monitoring for the Napa-Sonoma Marsh Restoration Project, 2006. Unpubl. Prog. Rep., U. S. Geological Survey, Vallejo, CA. 113pp.

Publications

1. Athearn, N. D., J. Y. Takekawa, J. D. Bluso-Demers, J. M. Shinn, L. A. Brand, C. W. Robinson-Nilsen, and C. M. Strong. 2012. Variability in habitat value of commercial salt production ponds: implications for waterbird management and tidal marsh restoration planning. Hydrobiologia 697: 139-155.

2. Brand, L. A., L. M. Smith, J. Y. Takekawa, N. D. Athearn, K. Taylor, G. Shellenbarger, D.H. Schoellhamer, and R. Spenst. 2012. Trajectory of early tidal marsh restoration: elevation, sedimentation and colonization of breached salt ponds in the northern San Francisco Bay. Ecological Engineering 42: 19-29.

3. Athearn, N.D., J.Y. Takekawa, B. Jaffe, B.J. Hattenbach, and A.C. Foxgrover. 2010. Mapping elevations of tidal wetland restoration sites in San Francisco Bay: comparing accuracy of aerial LiDAR with a singlebeam echosounder. Journal of Coastal Research 26(2): 312-319.

4. Demers, S. A., J. Y. Takekawa, J. T. Ackerman, N. Warnock, and N. D. Athearn. 2010. Space use and habitat selection of migrant and resident American avocets in San Francisco Bay. Condor 112: 511-520.

5. Takekawa, J. Y., I. Woo, N. D. Athearn, S. Demers, R. J. Gardiner, W. M. Perry, N. K. Ganju, G. G. Shellenbarger, and D. H. Schoellhamer. 2010a. Measuring sediment accretion in early tidal marsh restoration. Wetl. Ecol. and Manage. 18: 297-305.

6. Mejia, F., M. K. Saiki, and J. Y. Takekawa. 2008. Relation between species assemblages of fishes and water quality in salt ponds and sloughs in South San Francisco Bay. Southwestern Naturalist 53: 335-345.

7. Hickey, C., N. Warnock, J. Y. Takekawa, and N. D. Athearn. 2007. Space use by black-necked stilts in the San Francisco Bay estuary. Ardea 95: 275-288.

8. Takekawa, J. Y., A. K. Miles, D. H. Schoellhamer, N. D. Athearn, M. K. Saiki, W. D. Duffy, S. Kleinschmidt, G. G. Shellenbarger, and C. A. Jannusch. 2006. Trophic structure and avian communities across a salinity gradient in evaporation ponds of the San Francisco Bay estuary. Hydrobiologia 567: 307-327.

9. Takekawa, J. Y., N. Warnock, G. Martinelli, A. K. Miles, and D. Tsao. 2002. Waterbird use of bayland wetlands in the San Francisco Bay estuary: movements of long-billed dowitchers during the winter. Waterbirds 25: 93-105.

Salt Pond Working Group

USGS
science for a changing world

CALIFORNIA DEPARTMENT OF
FISH and WILDLIFE

U.S.
FISH & WILDLIFE
SERVICE
DEPARTMENT OF THE INTERIOR

U.S. DEPARTMENT OF THE INTERIOR
U.S. Fish and Wildlife Service
NATIONAL
WILDLIFE
REFUGE
SYSTEM

SAN FRANCISCO BAY BIRD OBSERVATORY

Websites

www.napa-sonoma-marsh.org

Websites

Coastal Conservancy

US Army Corps of Engineers.

Napa Sonoma Marsh Restoration Project

- Overview
- Restoration Objectives
- Meetings
- Documents
- Related Efforts
- Links

New and Featured Items archive

- November 6, 2012 - The **next NSMRG meeting** is scheduled for Tuesday November 6, 2012 from 9:00 am to 4:00 pm at the Auditorium of the Harris State Building (1515 Clay Street, Oakland). Agenda
- Related Project: Napa Plant Site Restoration

www.southbayrestoration.org

Websites

South Bay Salt Pond Restoration Project

Restoring the Wild Heart of the South Bay

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Welcome to the largest tidal wetland restoration project on the west coast.

USGS volunteer tracks western sandpipers in restored pond

Watch videos

Track progress

Visit the ponds

New & Featured

Read the January 2013 newsletter.

Save the date! Tuesday, July 16 for the 2013 South Bay Science Symposium!

See Presentations from the November 2012 Stakeholder Forum meeting (and Citizens Committee 1974 photo of marsh at Charleston Slough)

Give your input on Phase 2 actions

Sign up for a free subscription to San Francisco Estuary Partnership's award-winning *Estuary News*.

www.werc.usgs.gov/southbayrestoration

Websites

Conclusions

Conclusions

1. Importance of long term data to assess impacts of management actions on bird distribution and abundance

2. From our data we have modeled habitat availability, carrying capacity, and have assessed waterbird use of salt ponds

3. Importance of continued monitoring to provide science support for managers

Athearn et al. 2011, 2012; Rowan et al. 2011; Warnock et al. 2002

Thank You