# Effects of sea-level rise and storms on salt marshes and endemic wildlife of San Francisco Bay

*Low Tide*

*High Tide*

*USGS Western Ecological Research Center, USGS National Climate Change & Wildlife Science Center, USGS California Water Science Center, FWS CALCC, FWS Inventory and Monitoring, FWS R8 Science Program, UC Davis*

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# Outline

- **SLR in SFB Tidal Marshes**
- Challenges at a Local Scale
- Consequences for Endemic Vertebrates
- Adaptive Management Options

# San Francisco Bay

- Over 8 million people
- >80% of historic tidal wetlands lost
- >90% of California's remaining coastal wetlands
- One of the world’s most invaded estuaries
- Endemic species affected by: fragmentation, predation, invasive species, pollution.

U.S. Fish & Wildlife Service

# Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California

**Salt Marsh Harvest Mouse**
***(Reithrodontomys raviventris)***

## $1.3B Recovery Plan

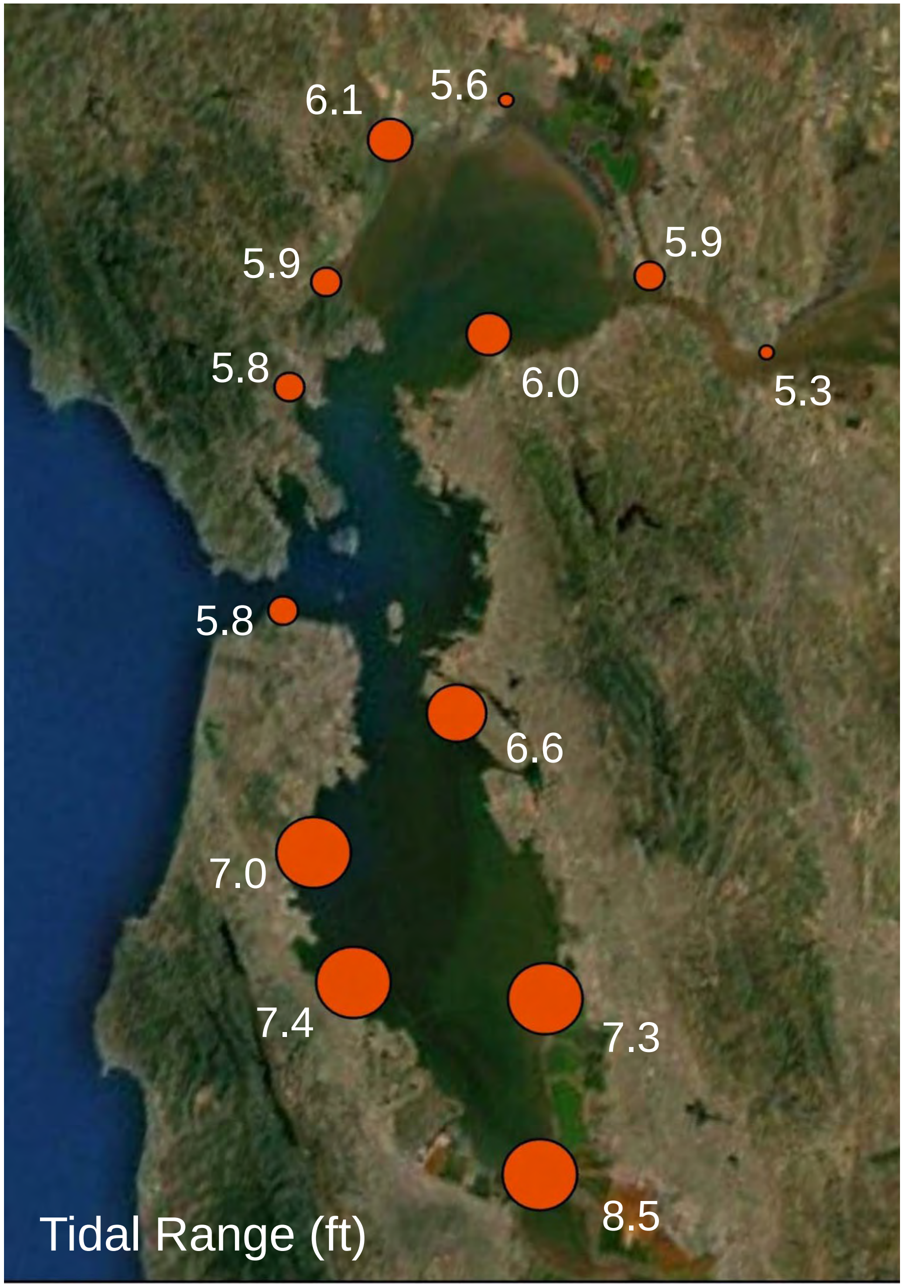
**California Black Rail**
**(*Laterallus jamaicensis*)**

**California Clapper Rail**
***(Rallus longirostris obsoletus)***

# SFB Estuary Variation in Tidal Range

Tidal Range 5.3-8.5 ft
(1.6-2.6 m)
Greater in South Bay

Suspended Sediment Concentration Range,
(30-70 mg/L)



# Climate Change Effects in SFB

1. Western snowpack decreased 10-40% since 1950 & will continue to decline (Barnett et al. 2008).
2. Runoff will be earlier & shorter (Diffenbaugh et al. 2008).
3. Water temperatures & salinity will increase (Malamud-Roam 2002, Cayan et al. 2005).
4. Sea level will rise 30-90 cm (Dettinger etal. 2003) & possibly to 1.9 m (Vermeer and Rahmsdorf 2010).
5. High & low tide events will be more extreme -- a 30 cm rise reduces storm events from 100 to 10 years.
6. 39-70% of intertidal habitats may become subtidal by 2100 (Galbraith et al., 2002).

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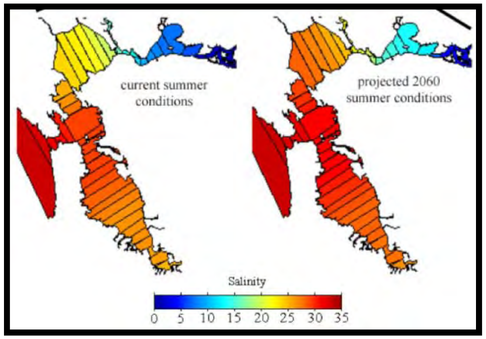
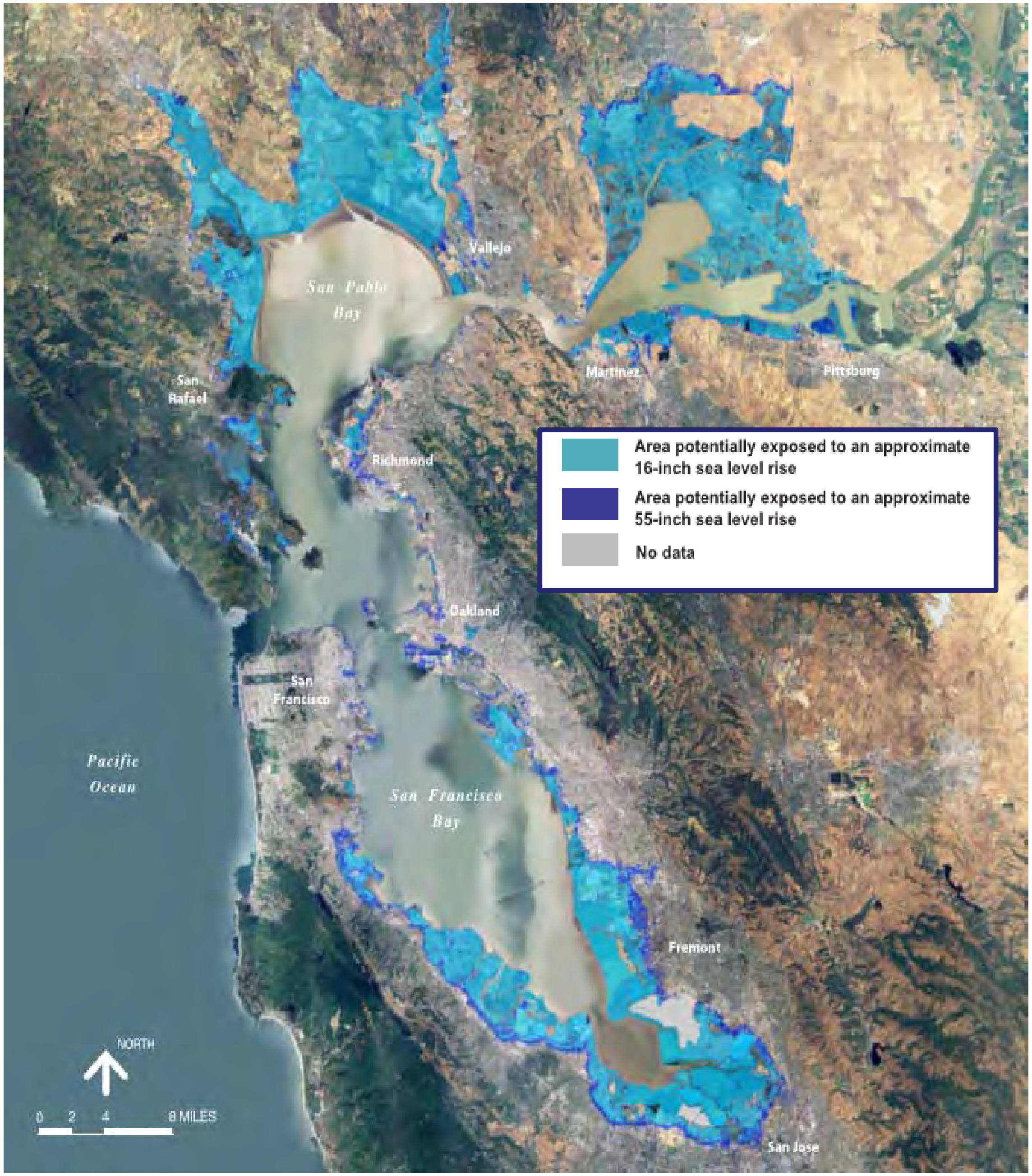
*salinity increase up-estuary (Cayan 2005)*



# SFB Extent of Inundation
## (40cm, 140cm SLR)

Projected area at risk of inundation under SLR scenarios




*(Knowles 2010, SFEWS)*

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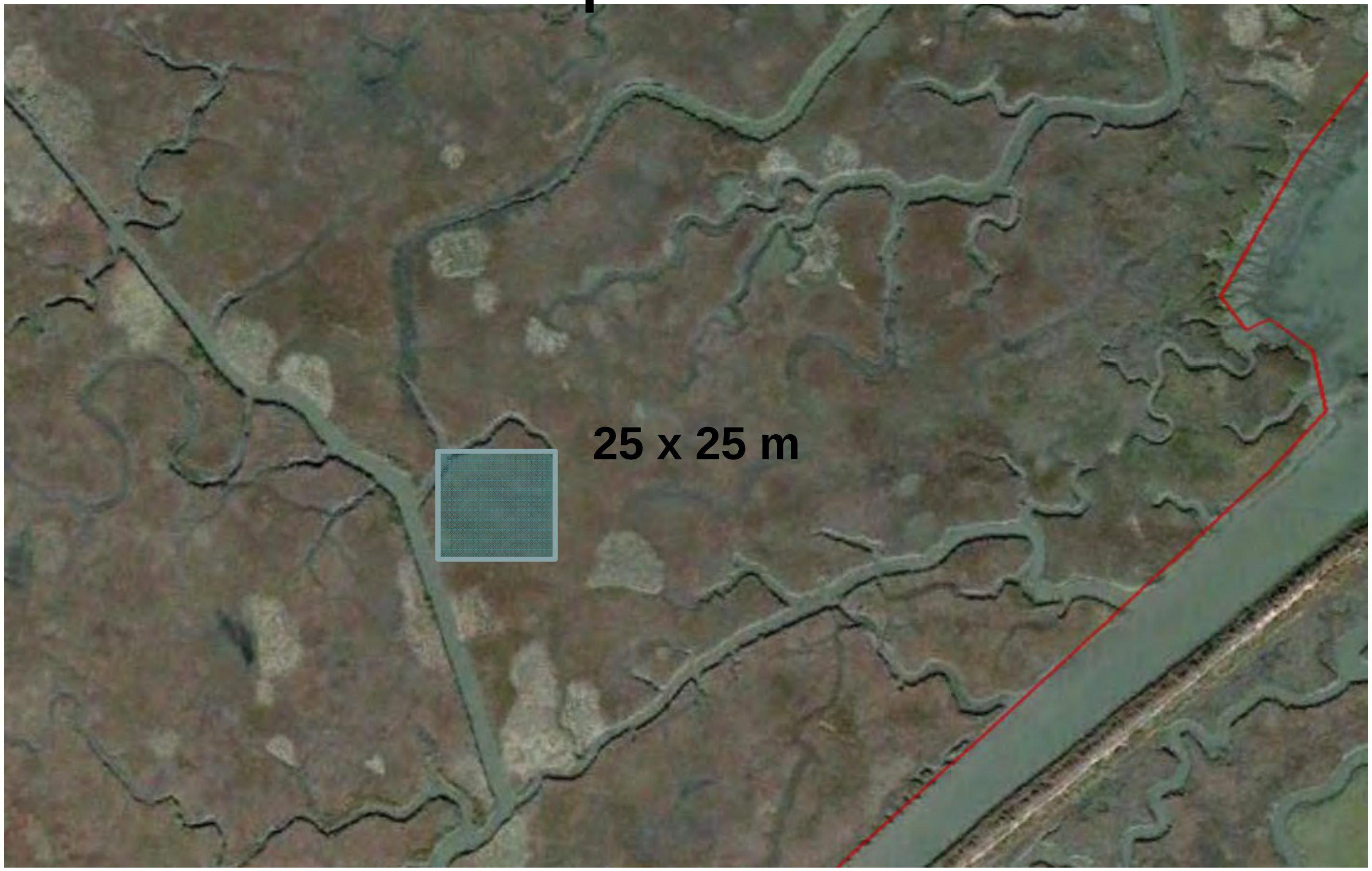
# Top-down Climate Models vs. Bottom-up Parcel Models

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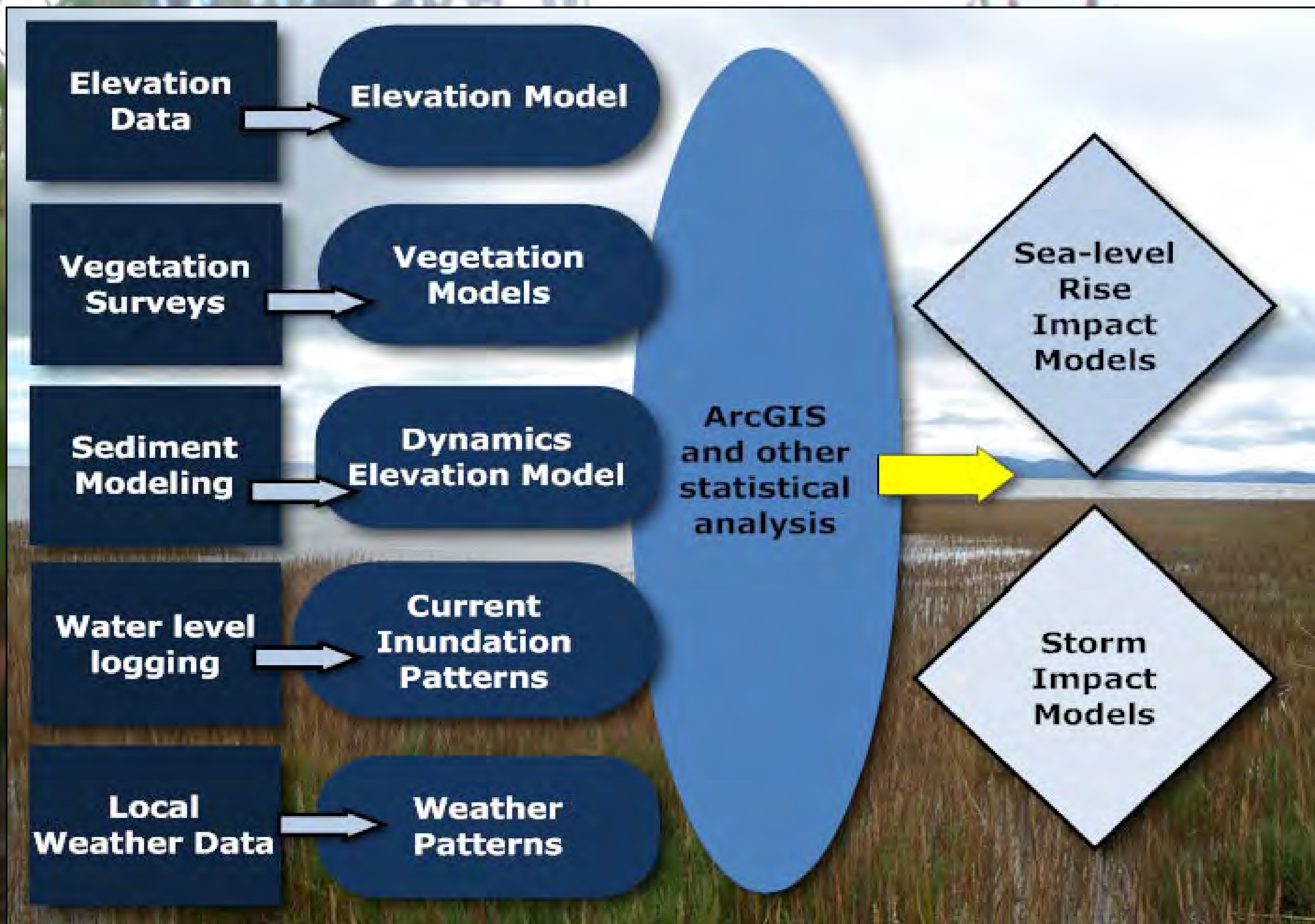
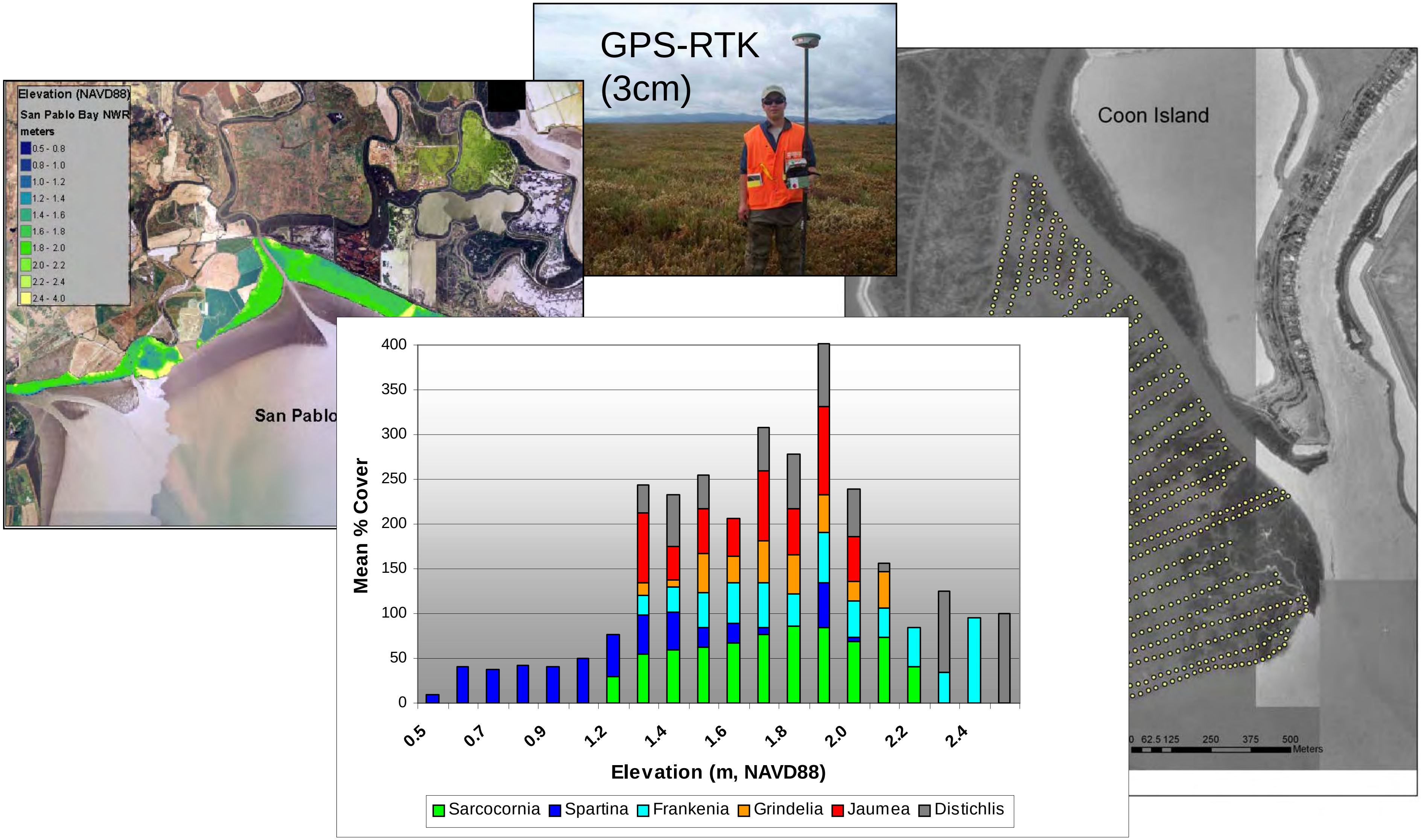
## *Research Objective: Investigate how sea-level rise and storms will alter Pacific coast tidal marshes*

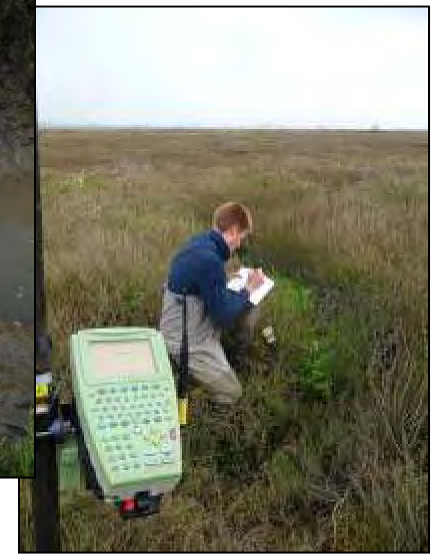


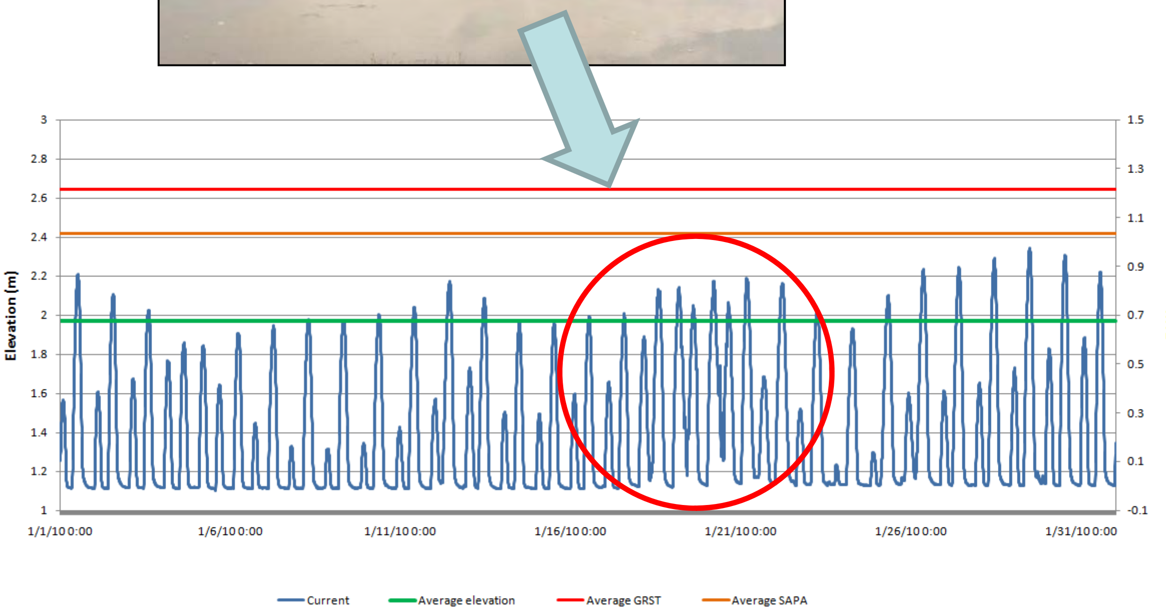
# Develop tidal marsh parcel-based high resolution elevation and plant models

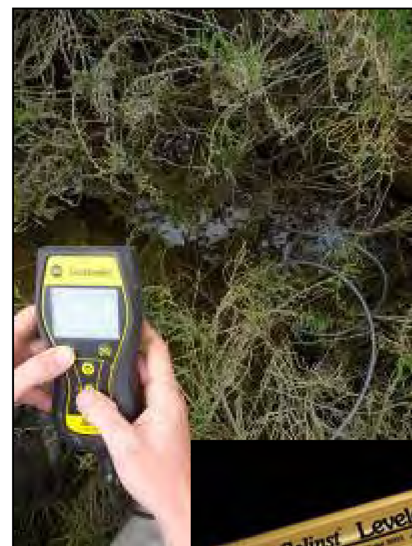


# Model Input

*Data: Water level monitoring*

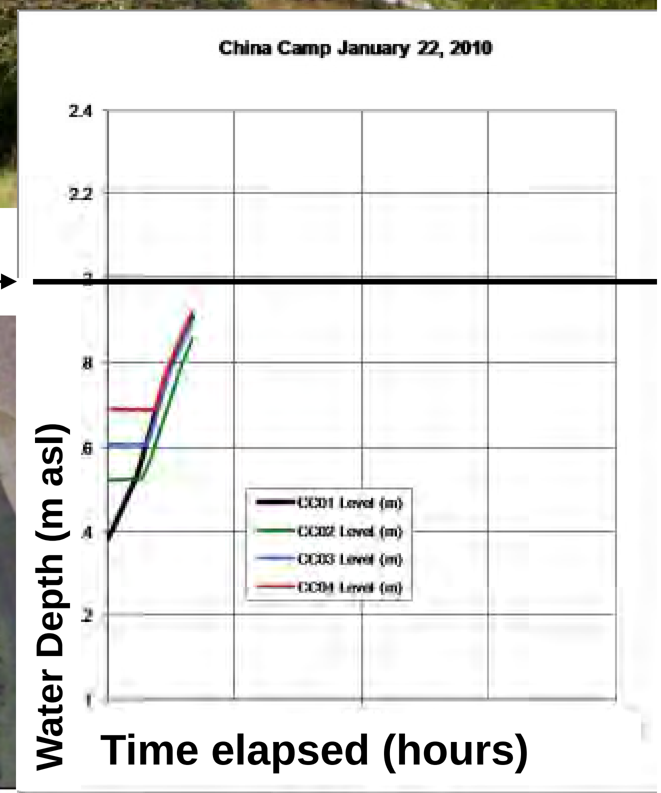


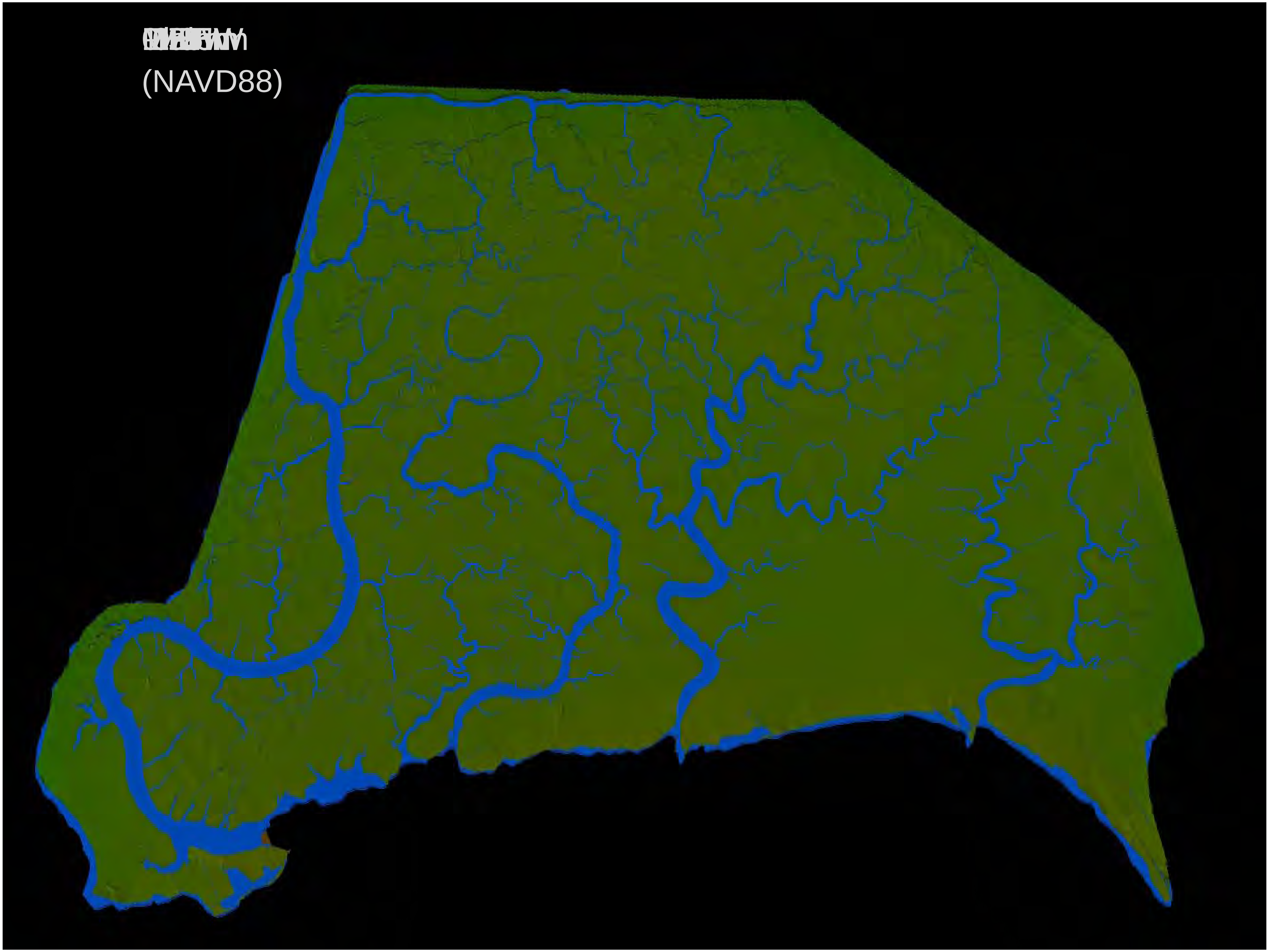


## *King Tide at China Camp*

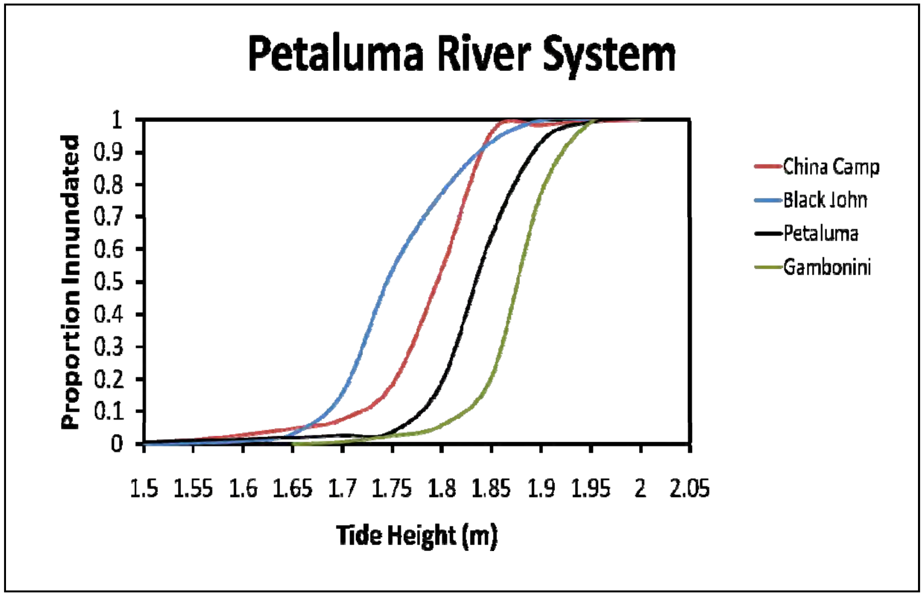
Marsh Plain (~2m NAVD88)



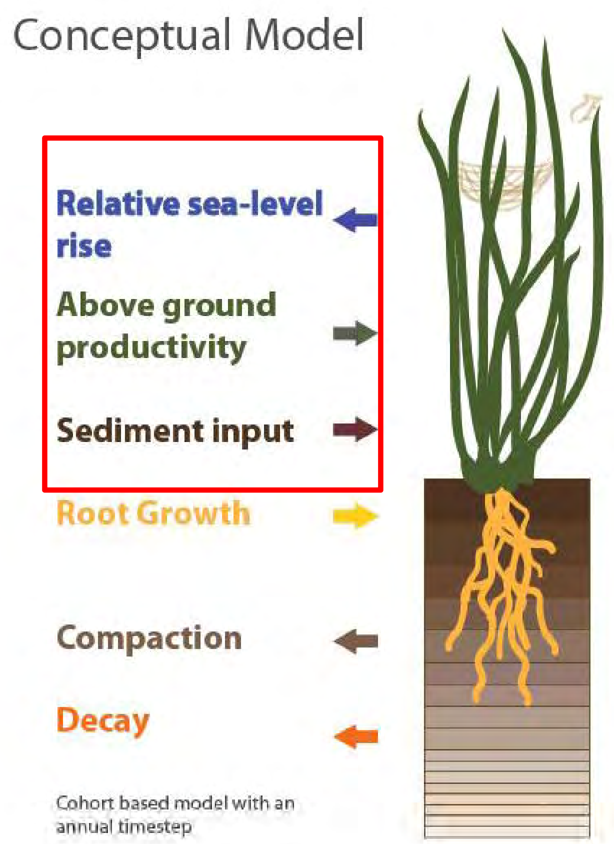

(NAVD88)

# Integrated Application

- Can we anticipate the fate of a given wetland?
  - Will the wetland drown?
- What is the final inundation pattern?
  - Which species may be adversely affected and why?
  - Can we determine shifts in dominant vegetation type?

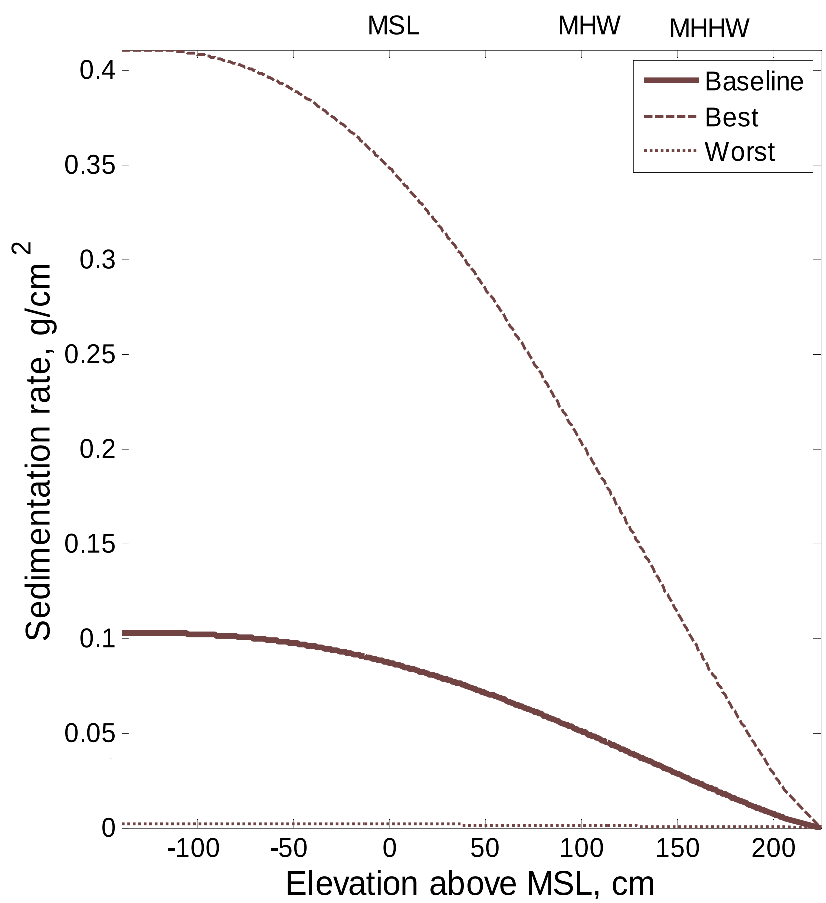



# Wetland Accretion Rate Model of Ecosystem Resilience *(Swanson etal., in prep.)*

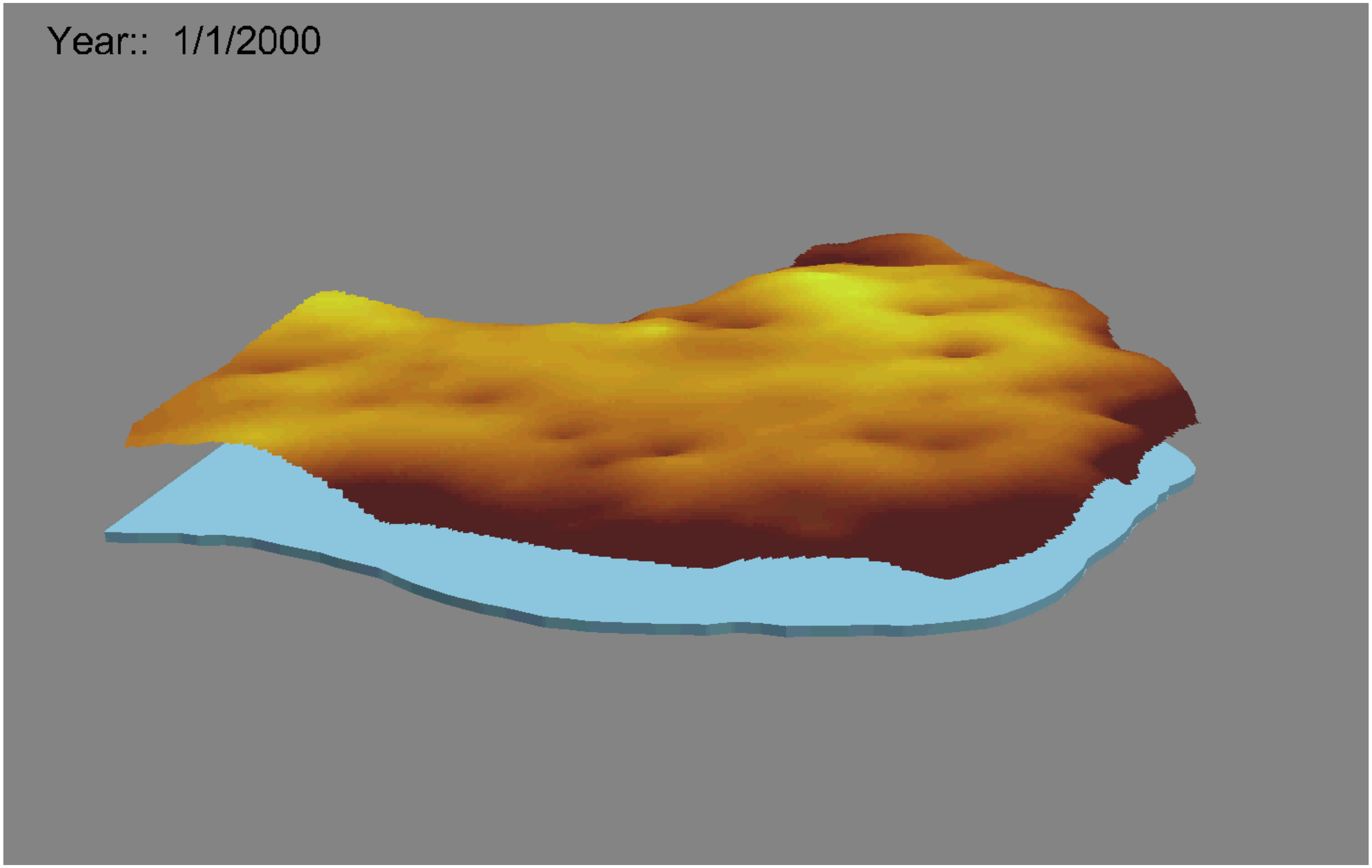



*(modified from Callaway et al. 1996)*

## Sediment Input



# Projected SLR Effects on Tidal Marshes
## (Digital Elevation Map – 120 ha Fagan Ecological Reserve)



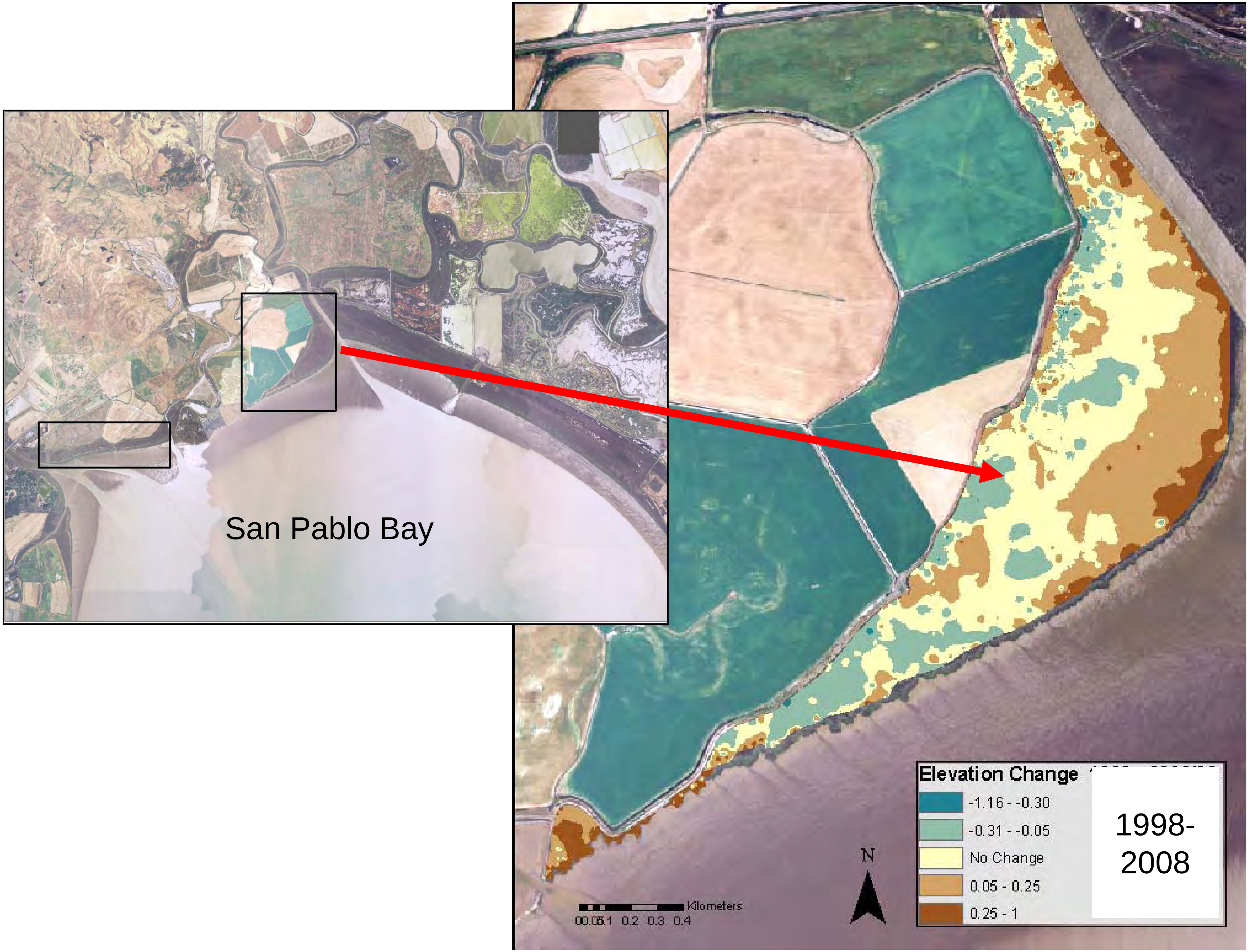
***Model Input***

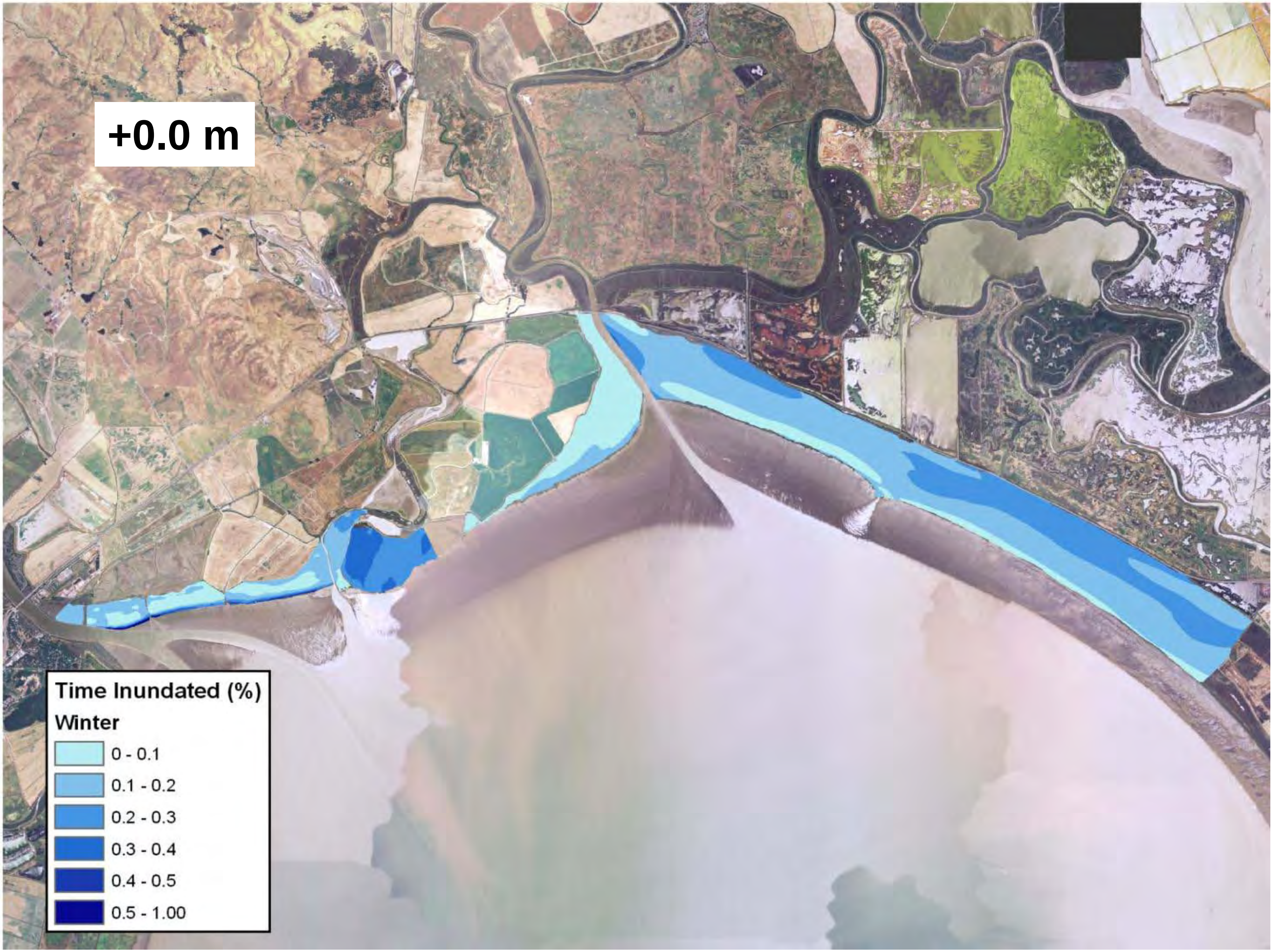
Data: Historic elevation data

- *San Pablo Bay National Wildlife Refuge historic (1998) elevation data.*

- *Used to determine if elevation has changed from 1998 - present.*

“potential for coastal marsh submergence should be expressed as an elevation deficit based on direct measures of surface elevation change rather than accretion deficits” (Cahoon *et al*. 1995)

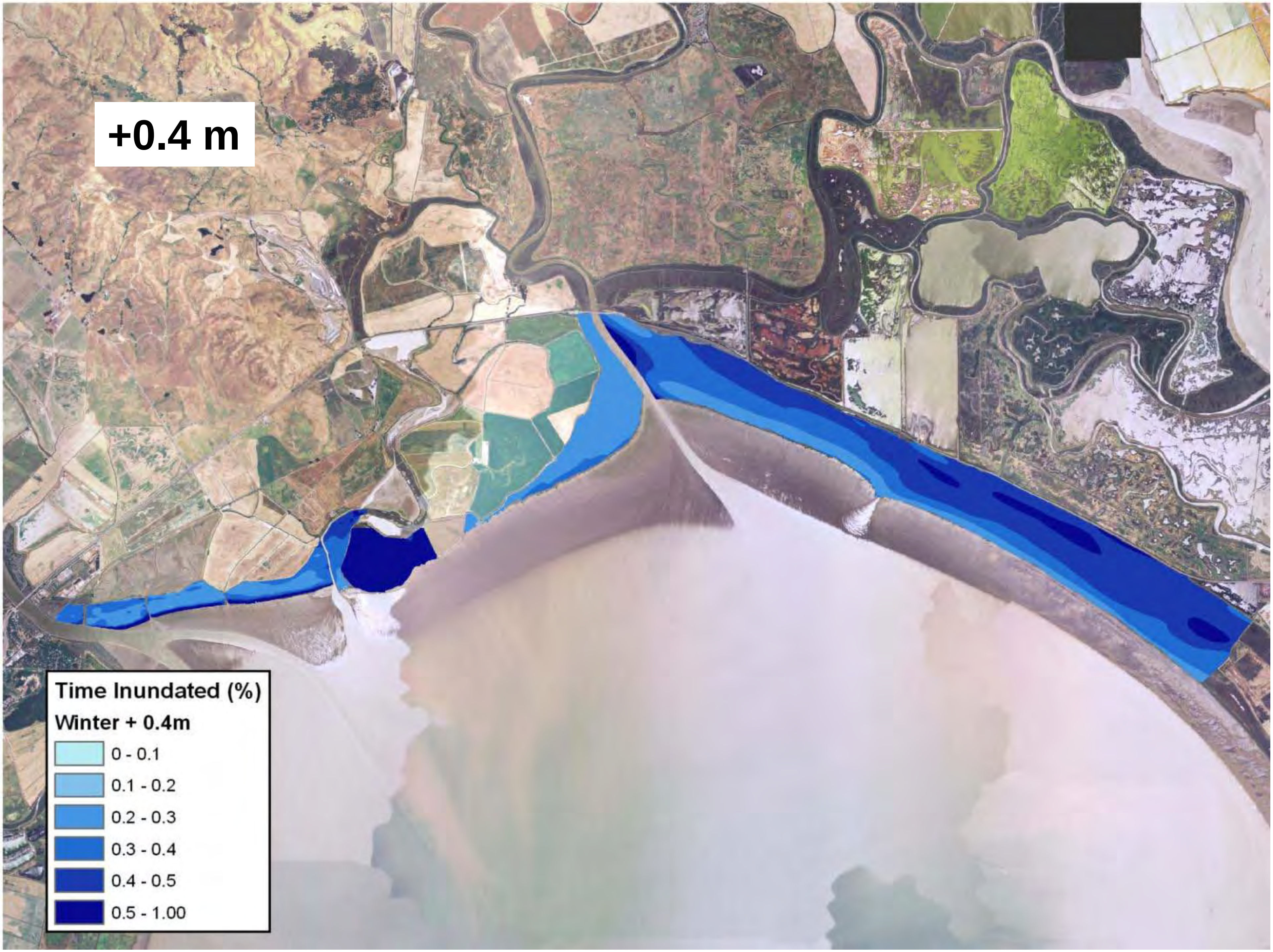

San Pablo Bay
Elevation Change
-1.16 - -0.30
-0.31 - -0.05
No Change
0.05 - 0.25
0.25 - 1
1998-2008
N
Kilometers
0 0.05 0.1 0.2 0.3 0.4

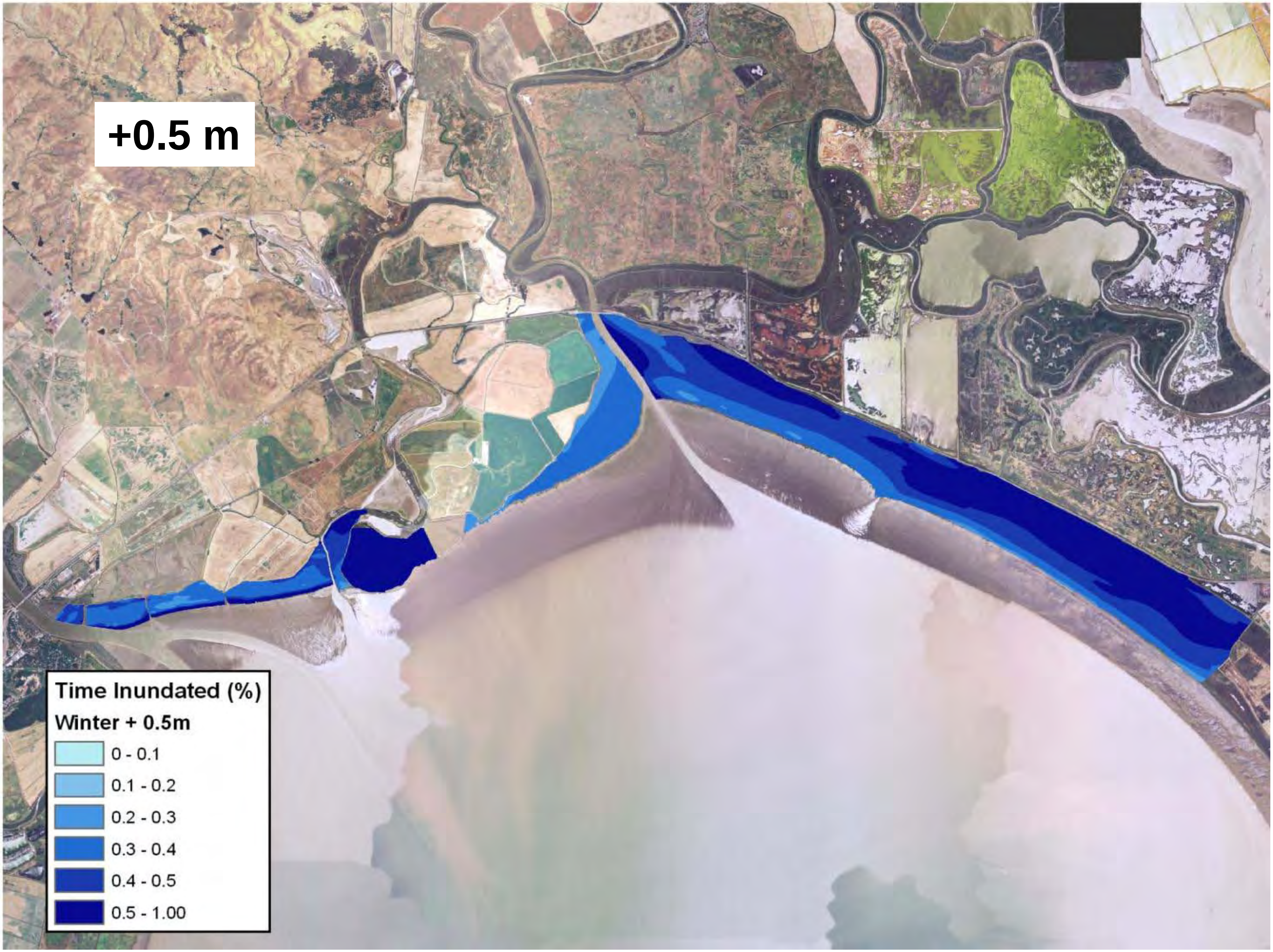

+0.0 m
Time Inundated (%)
Winter
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00


+0.1 m
Time Inundated (%)
Winter + 0.1m
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00

+0.2 m
Time Inundated (%)
Winter + 0.2m
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00


+0.3 m
Time Inundated (%)
Winter + 0.3m
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00


+0.4 m
Time Inundated (%)
Winter + 0.4m
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00


+0.5 m
Time Inundated (%)
Winter + 0.5m
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.00

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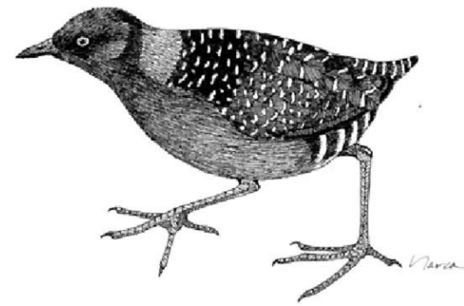
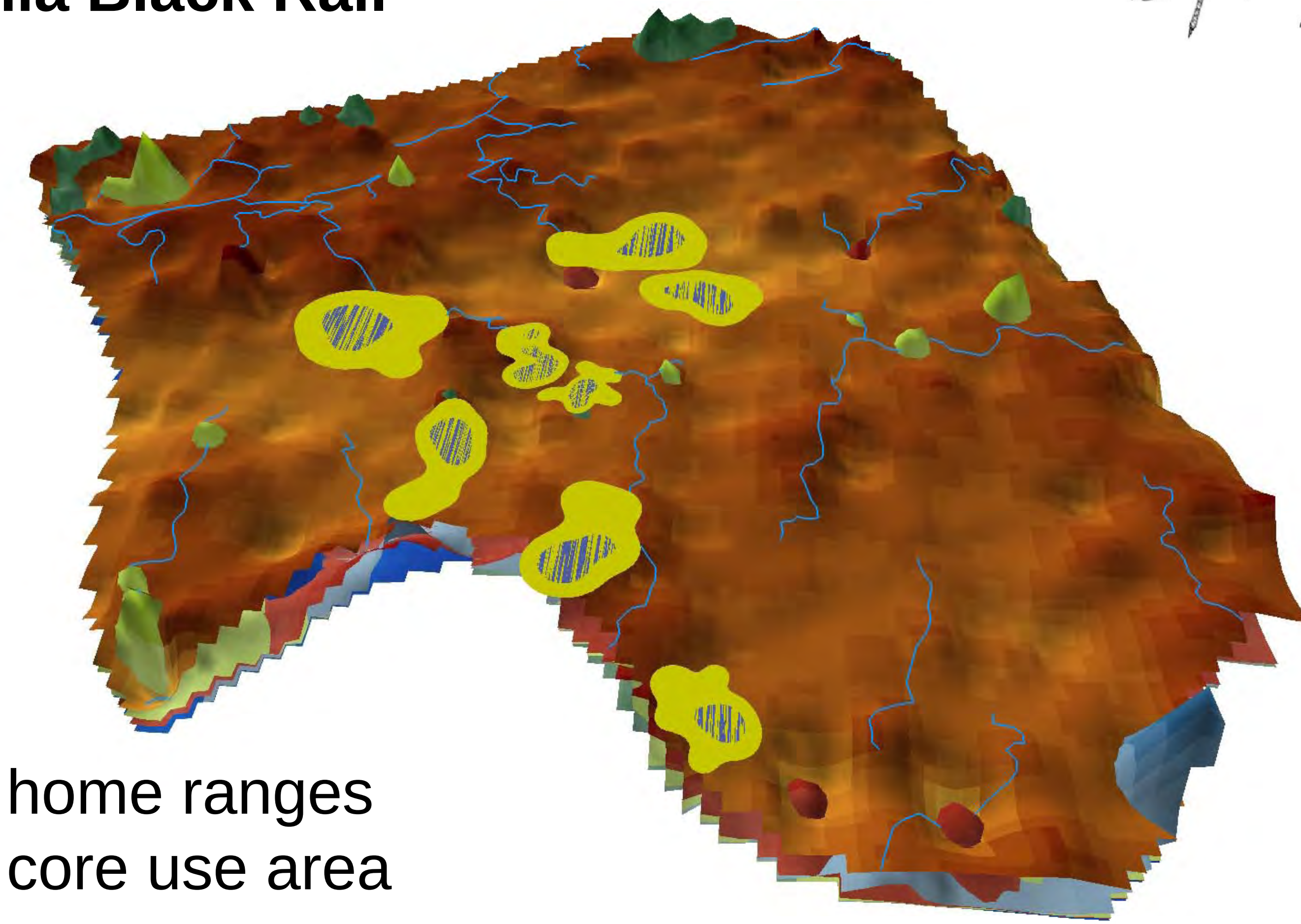
# Sea-level Rise Consequences for Endemic Vertebrates in Tidal Marsh

- **Distribution – When habitat is lost *endemic vertebrates emigrate or are lost***
- **Survival – *individual survival decreases when frequency of marsh flooding increases***
- **Reproduction – *productivity declines with flooding of nests and vulnerability of young***

# Distribution –

**Petaluma Tidal Marsh**
**California Black Rail**





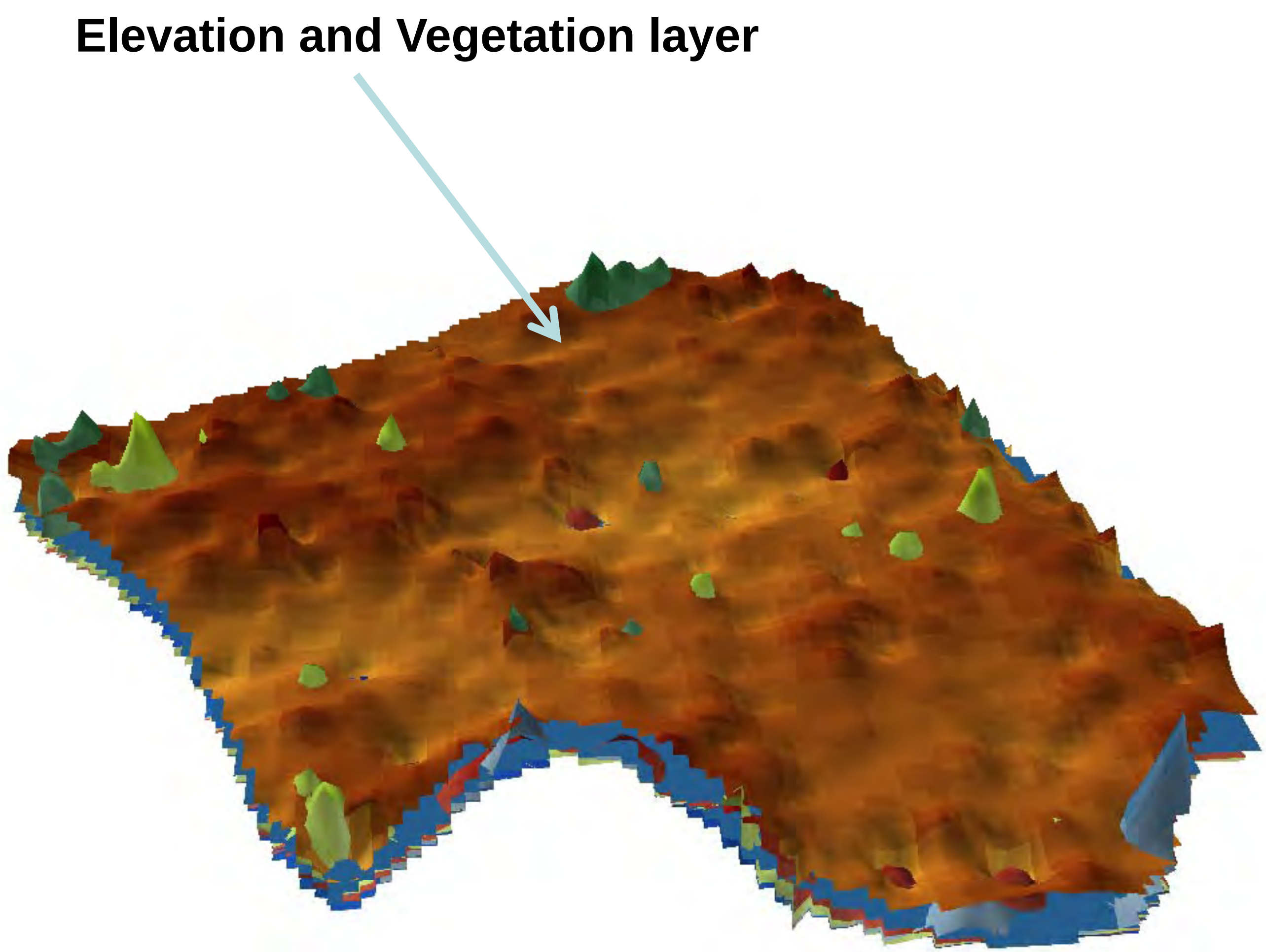
0.59 ha home ranges
0.14 ha core use area

*(Tsao et al. 2009, Condor 111:599-610)*

# Parcel level example: Petaluma Marsh

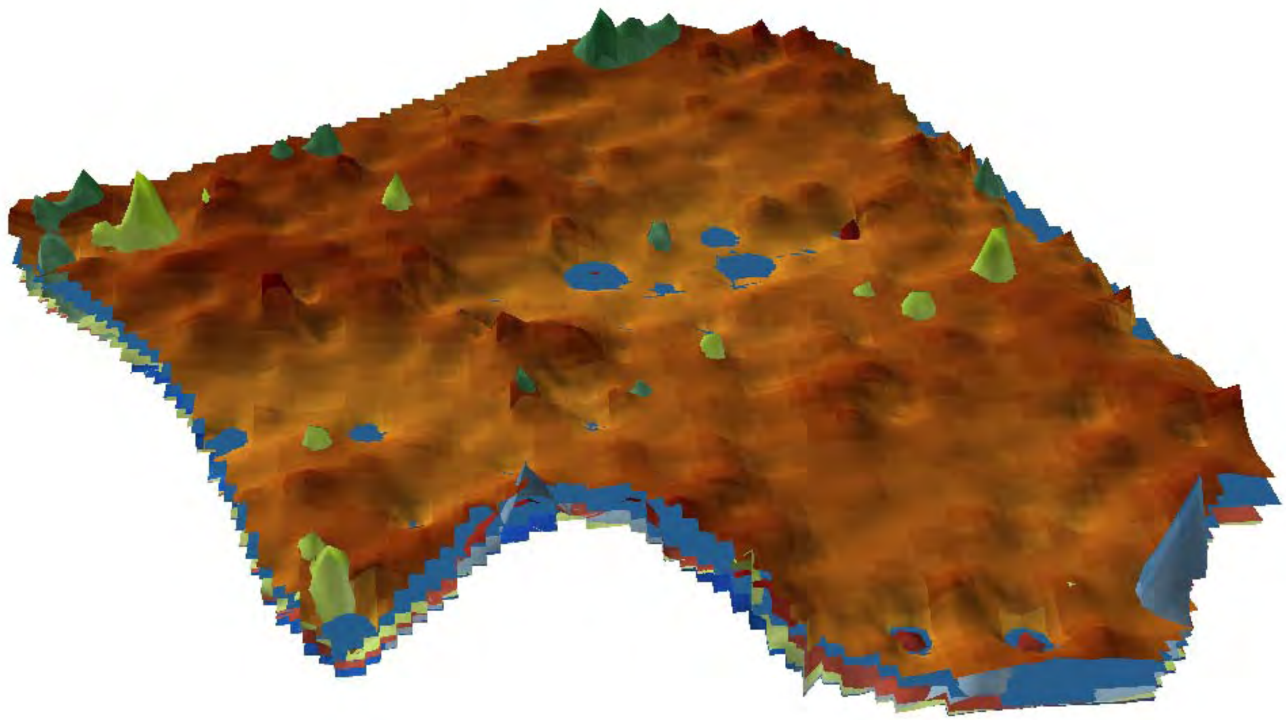
**Elevation model**

**Petaluma Marsh**
**At mean tide <1% is inundated**



# Petaluma Tidal Marsh
# 25 cm increase in sea-level

**Ground inundated,**
**little vegetation underwater**



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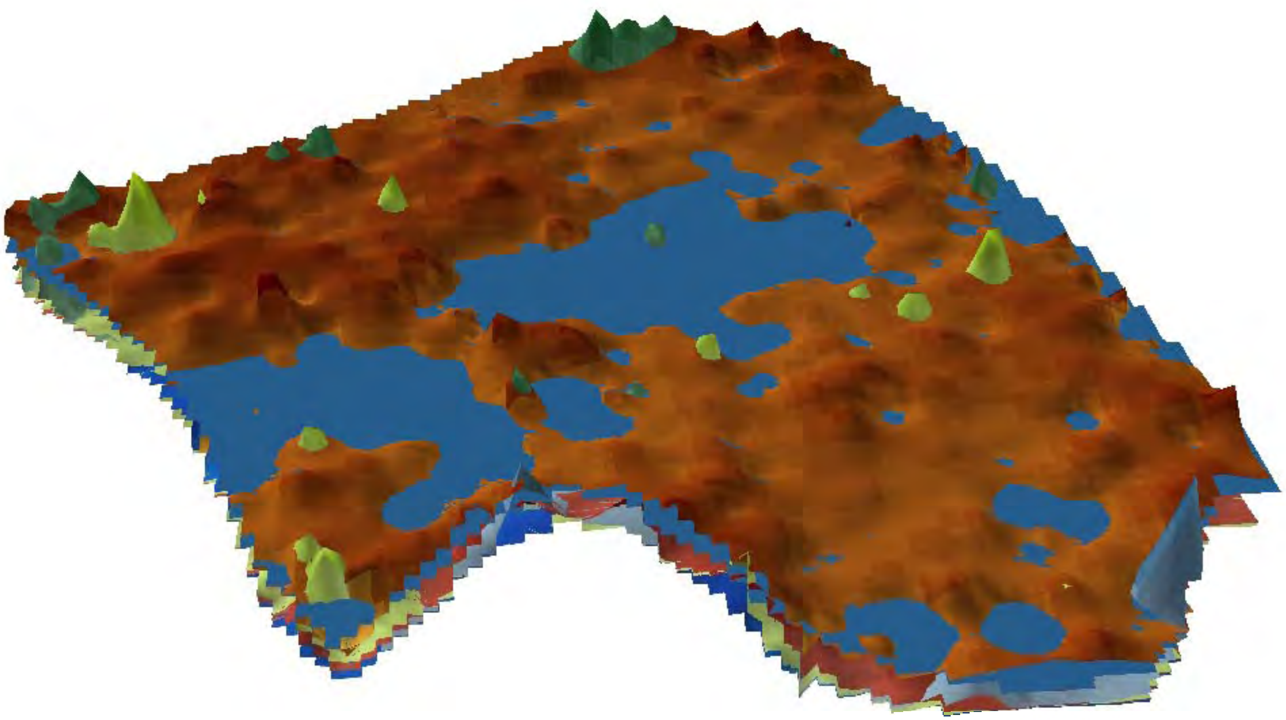
## Petaluma Tidal Marsh
## 40 cm increase in sea-level

**More vegetation underwater**



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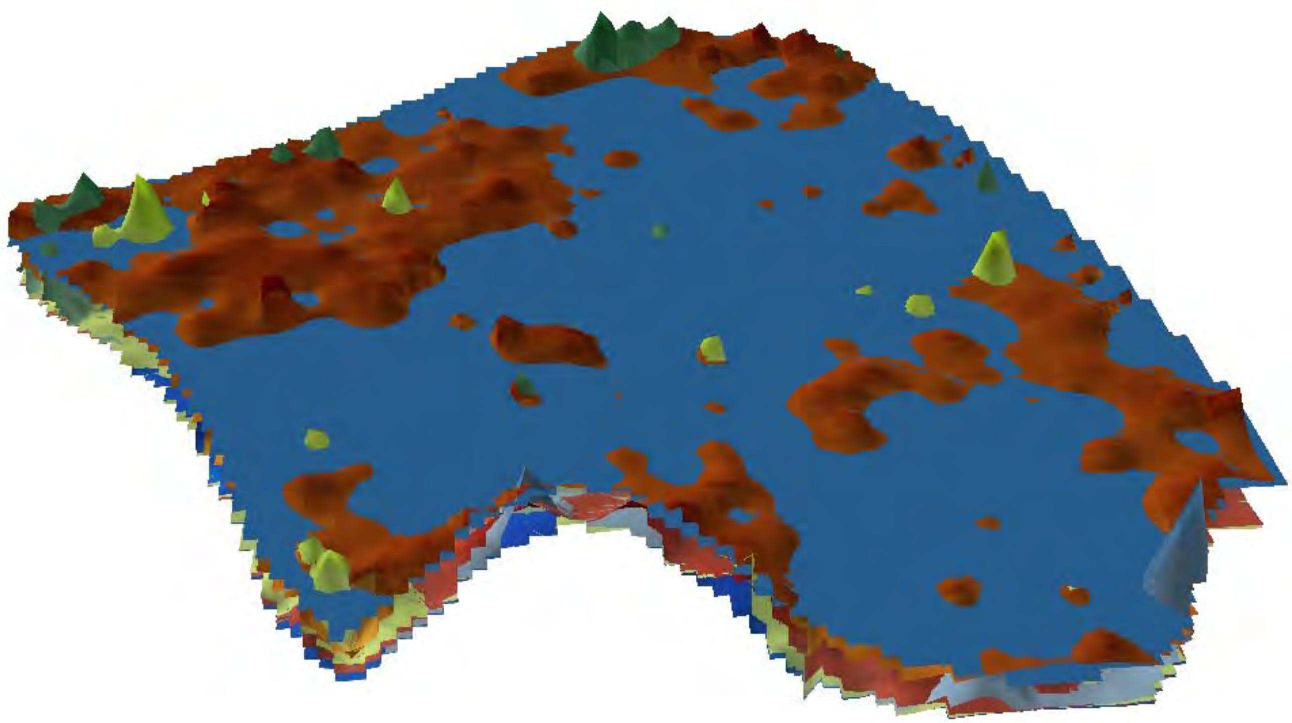
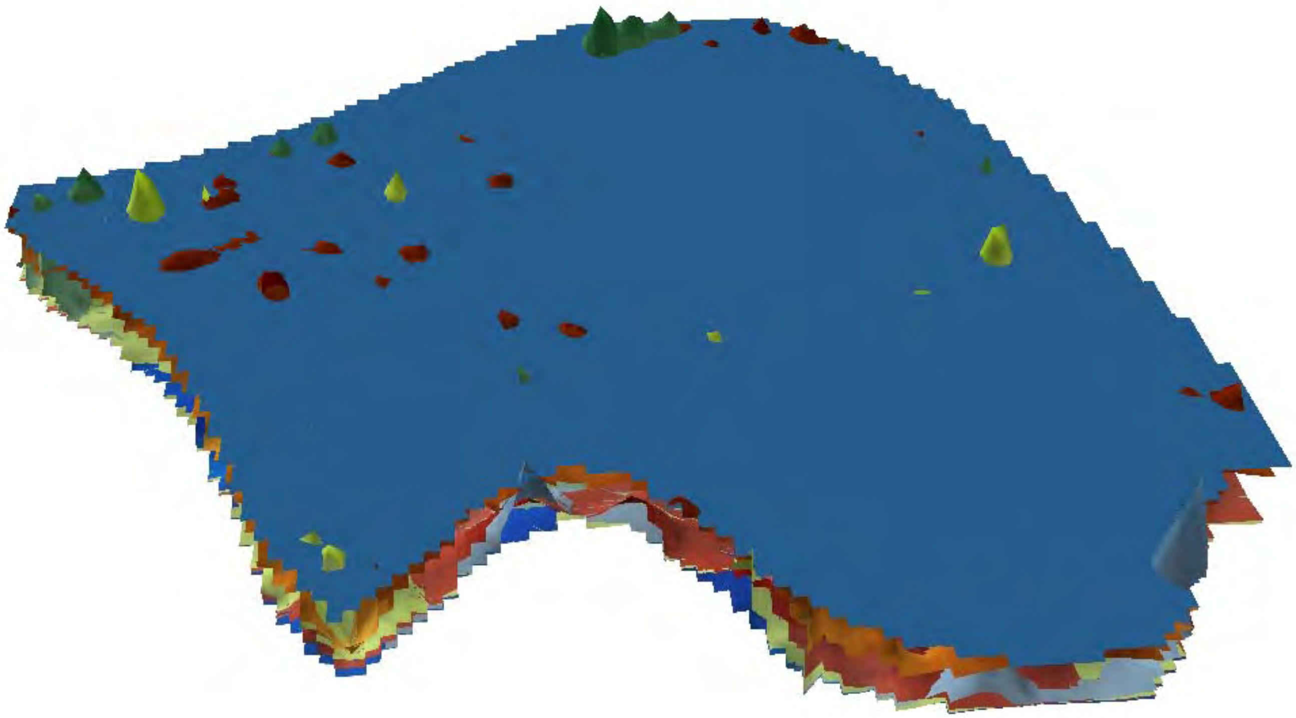
# Petaluma Tidal Marsh
# 50 cm increase in sea-level

**Most vegetation underwater,**
**Vegetation = wildlife habitat**



# Petaluma Tidal Marsh
# 65 cm increase in sea-level

All vegetation underwater



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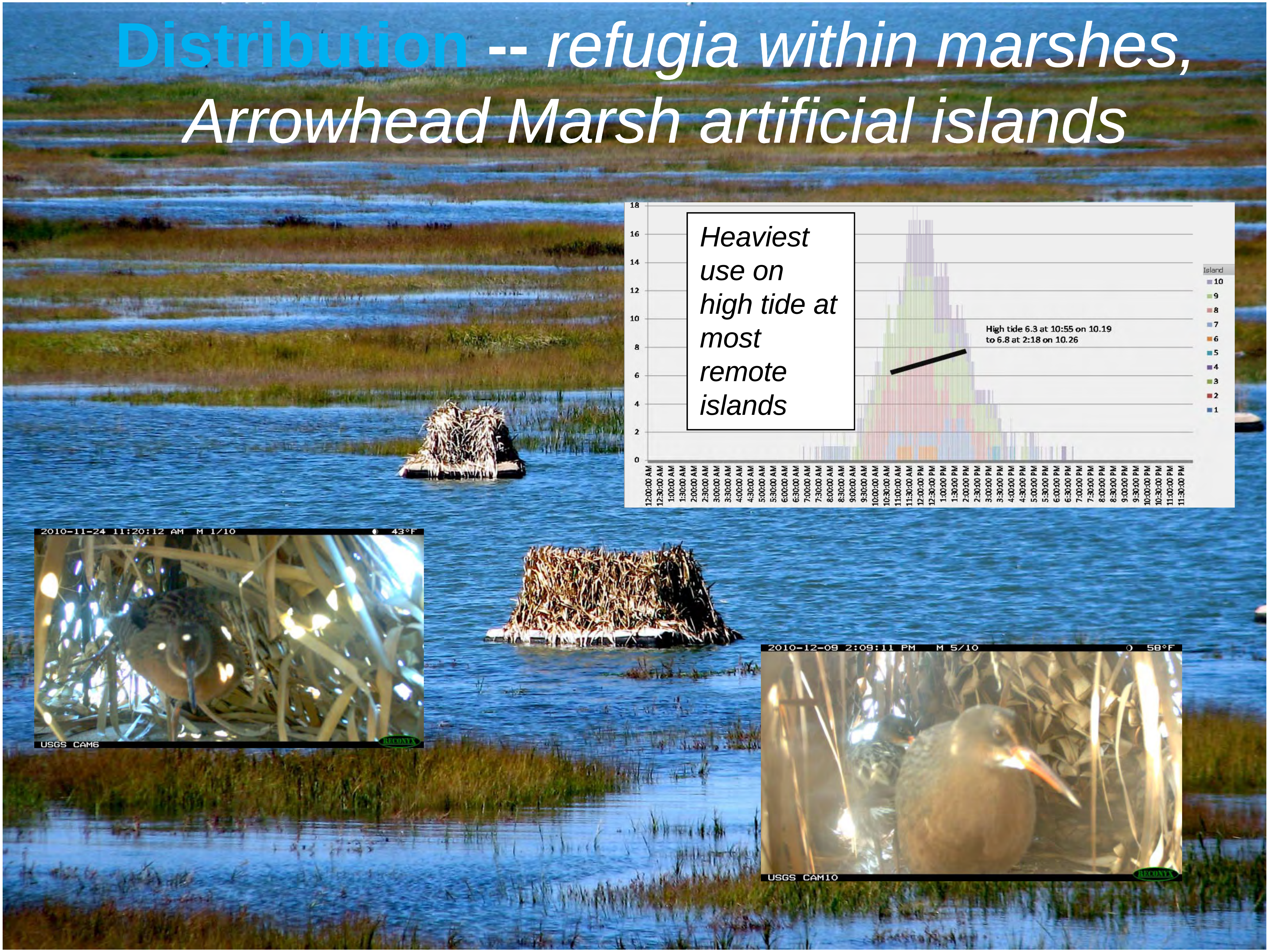
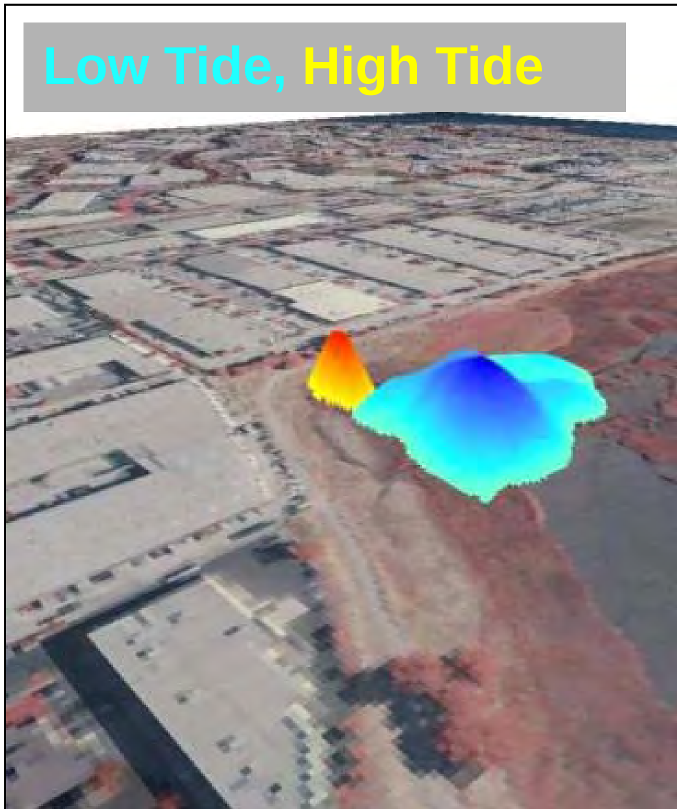
# **Distribution** -- *refugia within marshes, Arrowhead Marsh artificial islands*



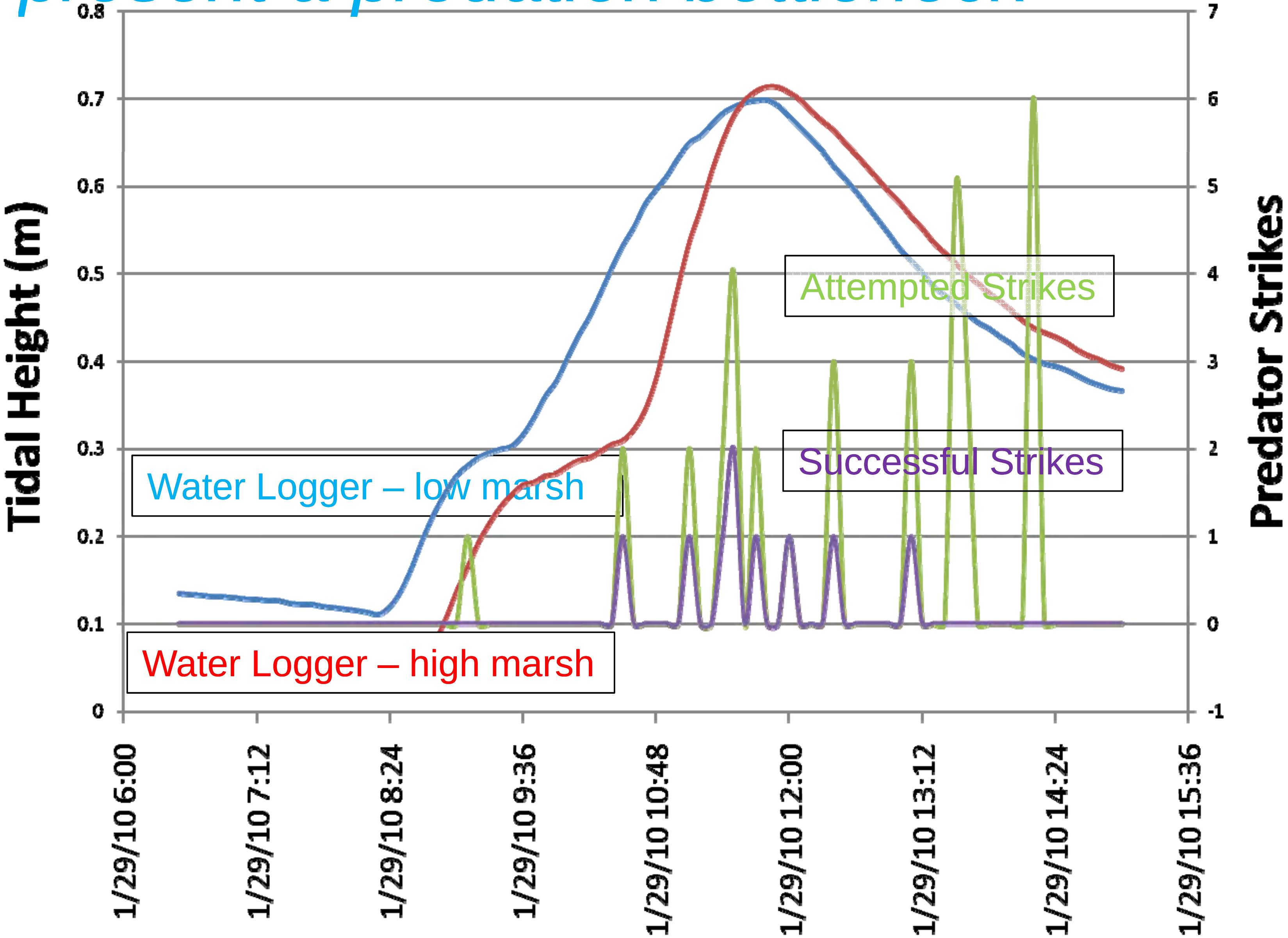
# **Survival** -- King Tide Predation Surveys





*Spragens et al.*

# **Survival** – *increasing tides may present a predation bottleneck*



# **Reproduction** – *nesting Clapper Rail*

**Success**
*Nest floats above tide*

**Failure**
*Nest is inundated*

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# On Decisions and Uncertainty

- Decisions are made difficult by uncertainty
- Uncertainty is pervasive and must be accommodated in informed decision processes

"The future's uncertain (and the end is always near)."

Roadhouse Blues (J. Morrison 1970)

*(Nichols etal. 2011, JWM; USGS Patuxent Wildlife Research Center)*

# Integrated Approach to Management/Conservation

- Scientist and manager work together in the decision-making process (may involve optimization methods)
- Information collection is focused on precisely the information most useful to management decisions
- Science focuses on hypotheses about how the managed system responds to potential management actions

*(Nichols etal. 2011, JWM; USGS Patuxent Wildlife Research Center)*

# USFWS/USGS Structured Decision Making Workshop

- **Sacramento**
- **October 17 – 21, 2011**
- **Topic: Prioritizing tidal marsh restoration or enhancement with sea-level rise.**
- **Goal: Take the first steps to develop a decision framework.**

**Participants:**

**Mendel Stewart – USFWS**

**Giselle Block – USFWS**

**Laura Valoppi – USGS**

**Nadine Peterson/ Matt Gerhart – CA Coastal Conservancy**

**Beth Huning / Christina Sloop– SFB Joint Venture**

**Valary Bloom – USFWS**

**Jamie O'Halloran – US Army Corps Engr.**

**Karen Taylor – CA Fish & Game**

**Steve Goldbeck – BCDC**

**Coordinators: John Takekawa, Karen Thorne**

**Coaches: Brady Mattson, Debby Crouse, Jonathan Cummings**

# The SDM Process (PrOACT)

- **Pr**oblem Statement
- **O**bjectives
- **A**lternatives
- **C**onsequences
- **T**radeoffs

# Problem Statement

- *To conserve SFB tidal marshes in light of future climate change, what actions (management, restoration, protection) if any should be conducted (where, when, and how)?*

# Primary Objective

- *Perpetuate tidal marsh ecosystem <u>functions</u>, <u>services</u>, and <u>human benefits</u> by maximizing resilience of the system.*

- Ecosystem functions – *interactions of biota with the environment (nesting habitat, food webs)*
- Ecosystem services – *indirect benefits to society from healthy ecosystems (water quality, carbon sequestration)*
- Human benefits – *direct benefits to interest groups (fishing, recreation)*
- Resilience – *capacity of ecosystem to respond to disturbance*

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# Alternatives Grouped into Strategies

A. **Marsh Migration** – upslope movement

B. **Climate Restoration** – engineer and manage marshes considering SLR and extreme events

C. **Wildlife Enhancement** – add habitat features, captive rearing, translocation

D. **Outreach** – education, involvement

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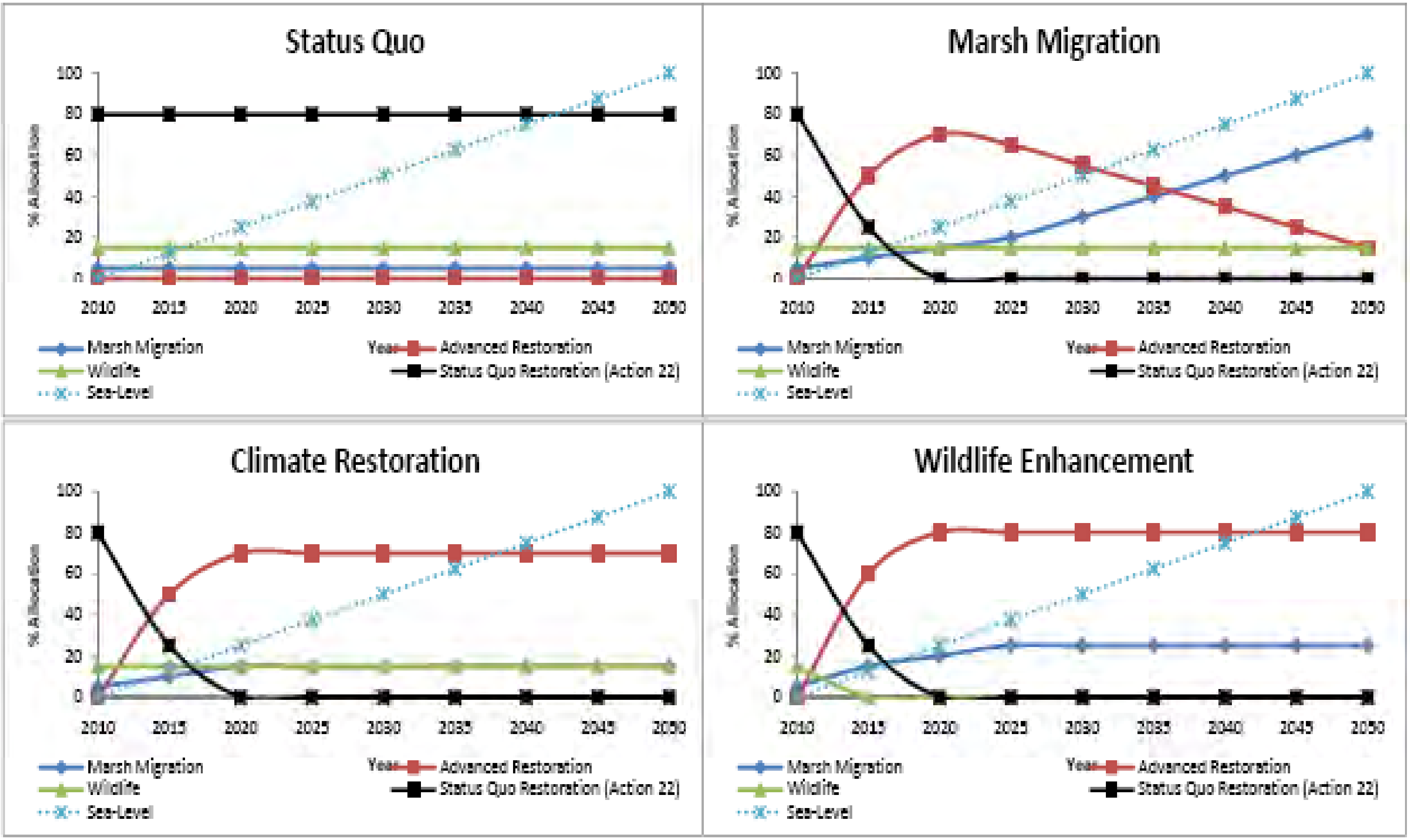
# Alternative Allocations with SLR
## (2010-2050)

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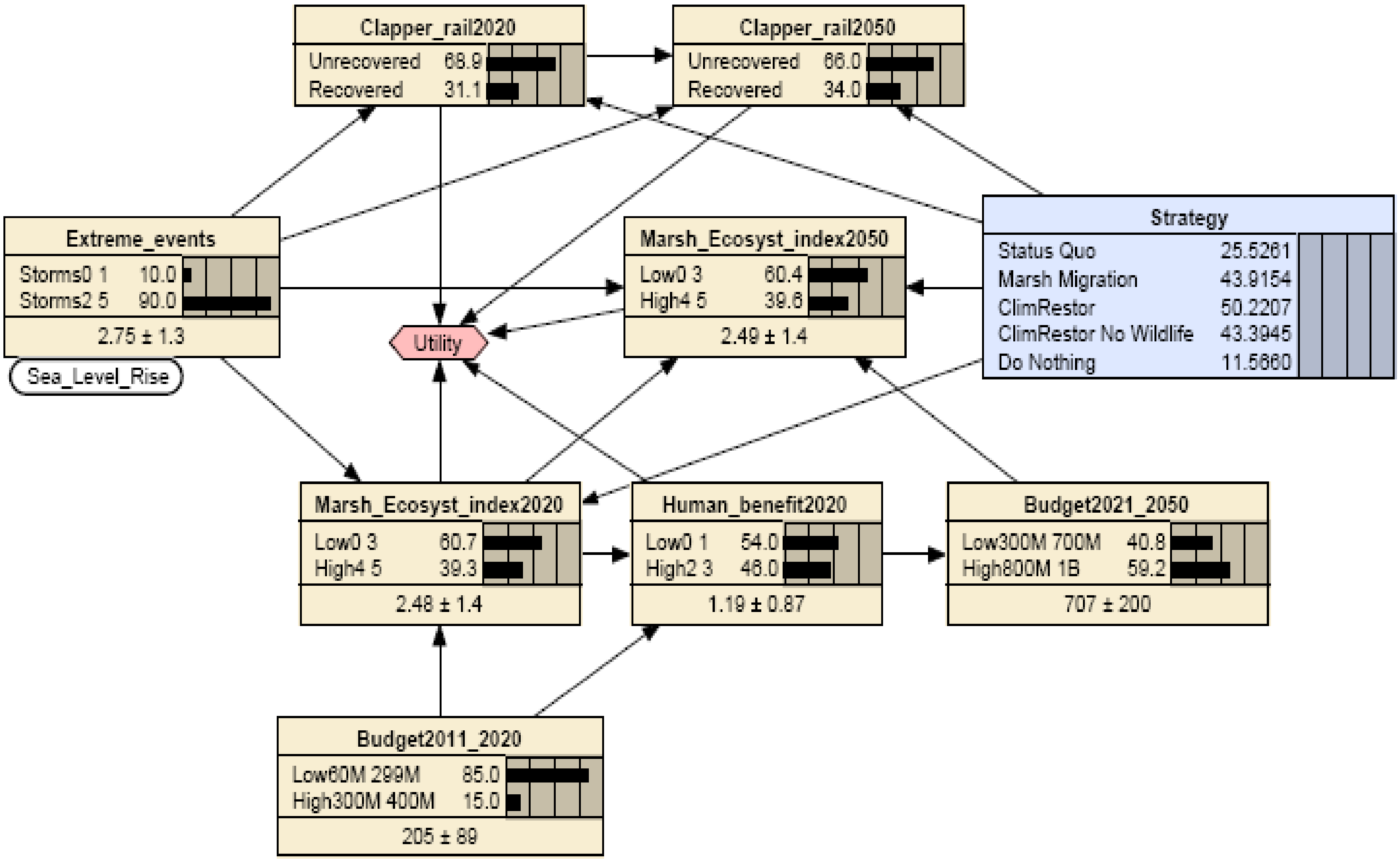
# Consequences and Tradeoffs: Netica model



# SDM Prototype Results

- Climate Restoration (50.2) was the best alternative adaptation to climate change followed by Marsh Migration (43.9) on 0-100 scale.

- The result was robust and consistent regardless of model input values.

- Status Quo (25.5) was half the value of Climate Restoration while Do Nothing (11.6) was much lower, suggesting that efforts to restore or enhance marshes were valued for climate change adaptation.

# Summary

1. Tidal marsh vertebrates are limited by tidal marsh habitat availability in SFB.

2. With sea level rise, upslope movement of tidal marshes is constrained by urbanization and levees.

3. Habitat reduction with fewer refugia and increased frequency of storm events may result in an ecological bottleneck.

4. Adaptation for tidal marsh recovery should identify specific marshes or features critical to save fragmented vertebrate populations through SDM approaches.

# Acknowledgments

**FWS California Landscape Conservation Cooperative**

**FWS North Pacific Landscape Conservation Cooperative**

**FWS – Recovery Branch, Refuges, Science Program**

**USGS National Climate Change and Wildlife Science Center**

**USGS Western Ecological Research Center**

**USGS California Water Science Center**

**East Bay Regional Parks**

**USGS Native American Internship Program**

**University of California, Davis**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