Value of Wetlands to Fish

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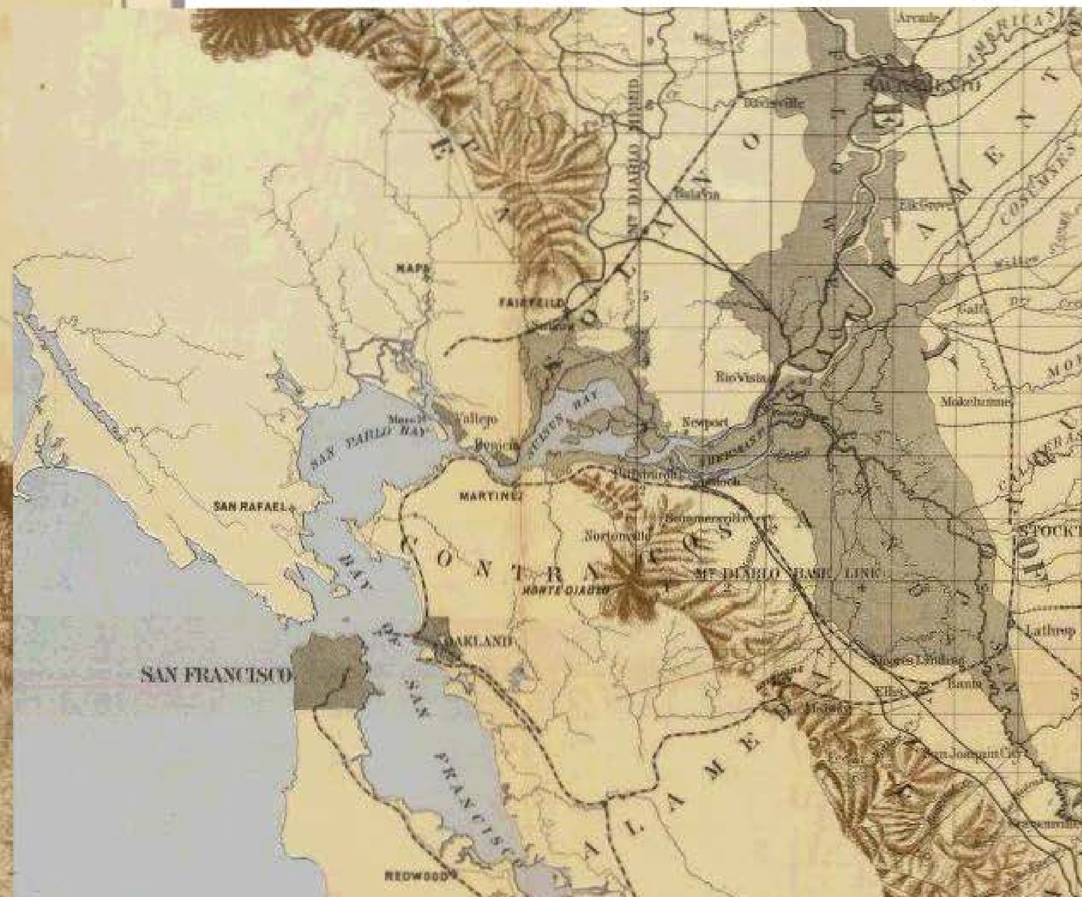
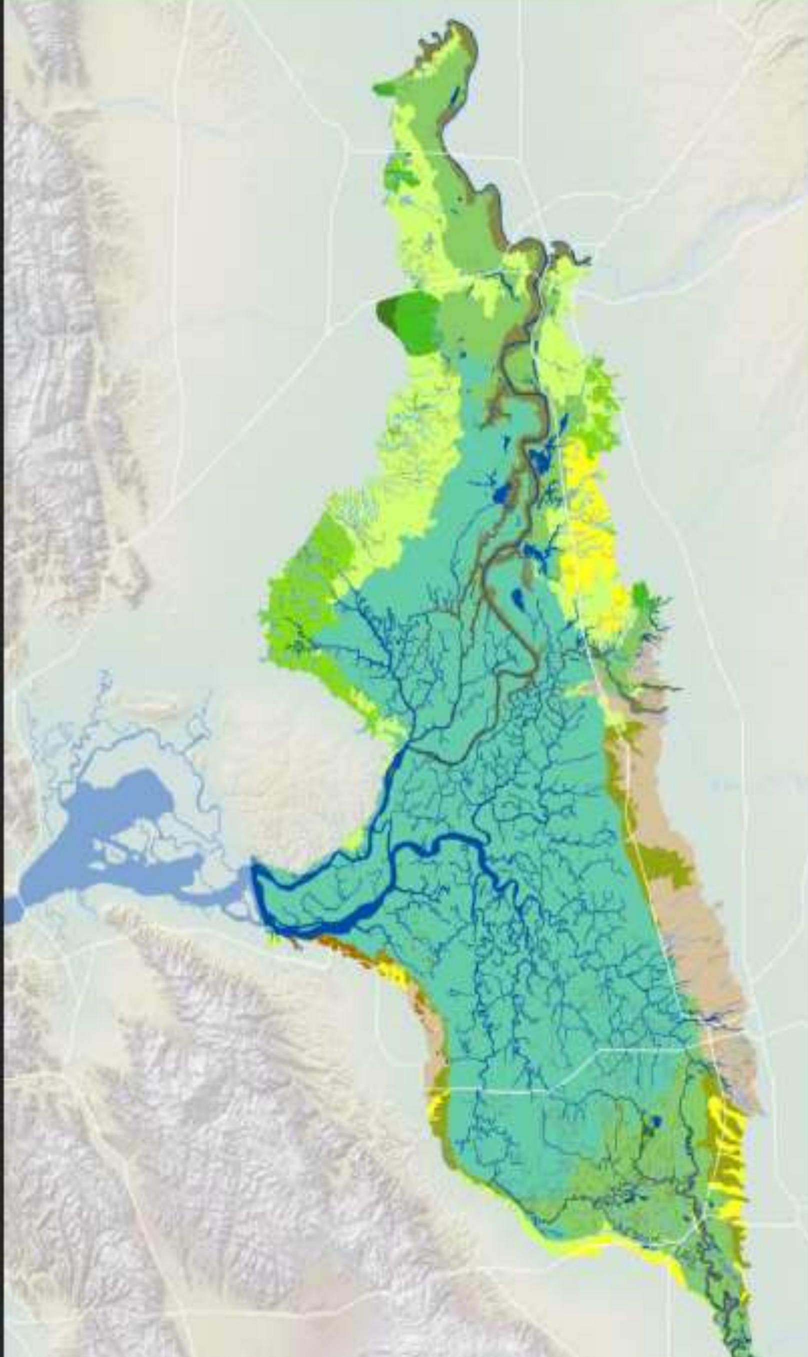
Estuarine Ecology Consultant,

Wim Kimmerer, Romberg Tiburon Center,
San Francisco State University


MAP
SAN JOAQUIN, SACRAMENTO
TULARE VALLEYS
STATE OF CALIFORNIA


SAN FRANCISCO
OAKLAND
SAN RAFAEL
NAPA
FAIRFEILD
MARTINEZ
Vallejo
Benicia
SAN PABLO BAY
SUISUN BAY
BAY OF SAN FRANCISCO
REDWOOD
Rio Vista
Newport
Mokelumne
Elk Grove
Batavia
C O N T R A C O S T A
A L A M E D A
MT. DIABLO BASE LINE
MONTE DIABLO
Lathrop
Arcade

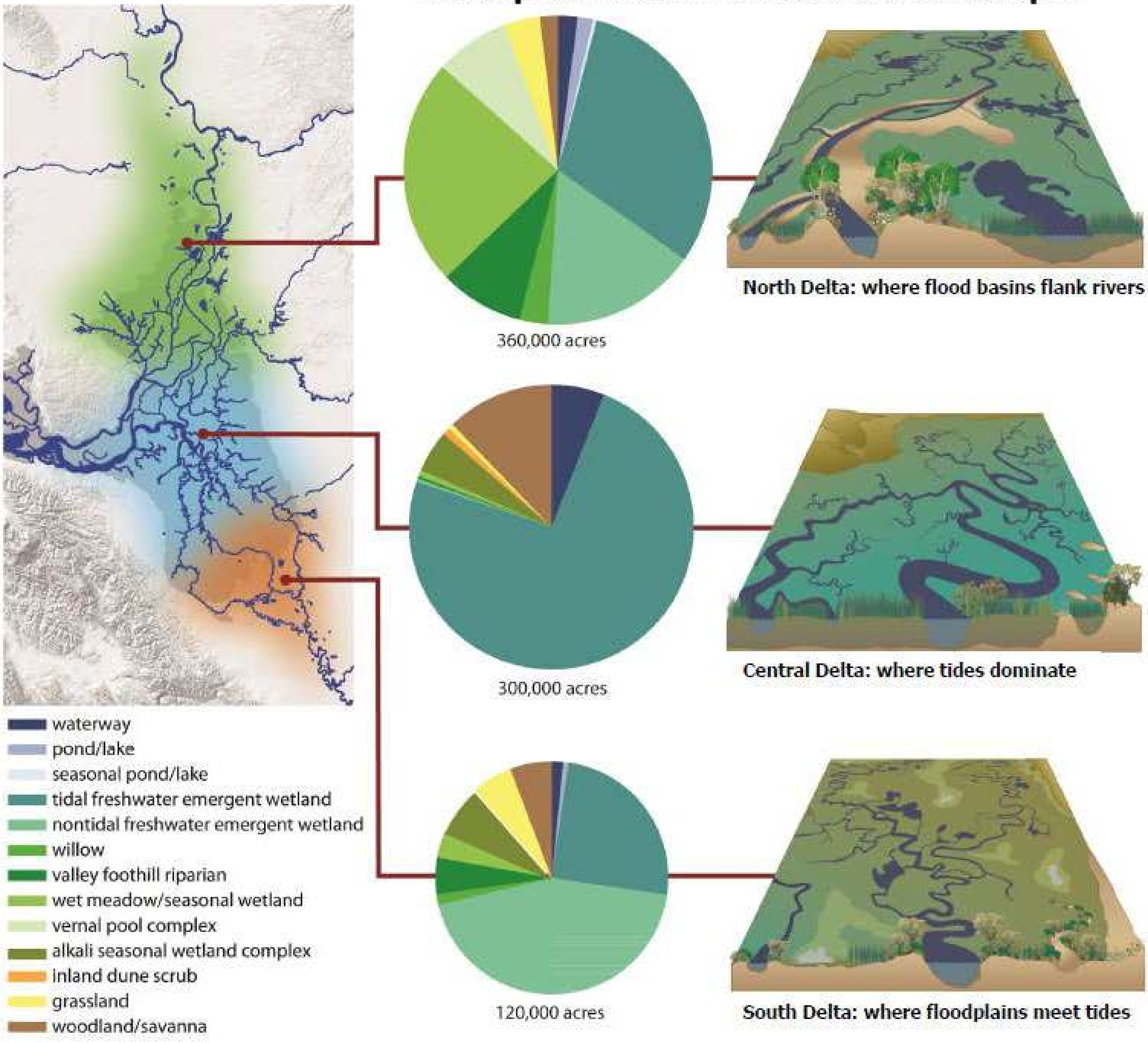


Salmon Slough: "The stream bed is **full of logs** and the boats grounded two or three times." (Abella 1811)

"The **small fish run into the sloughs and lakes** as soon as the water gets sufficiently high, and **return to the river when it begins to get low**." (Sacramento Daily Union, 6 June 1854)

Tule marsh water was "so thoroughly impregnated with decaying vegetable matter that **it looked more like sherry than water**..." (Wright ca. 1850)

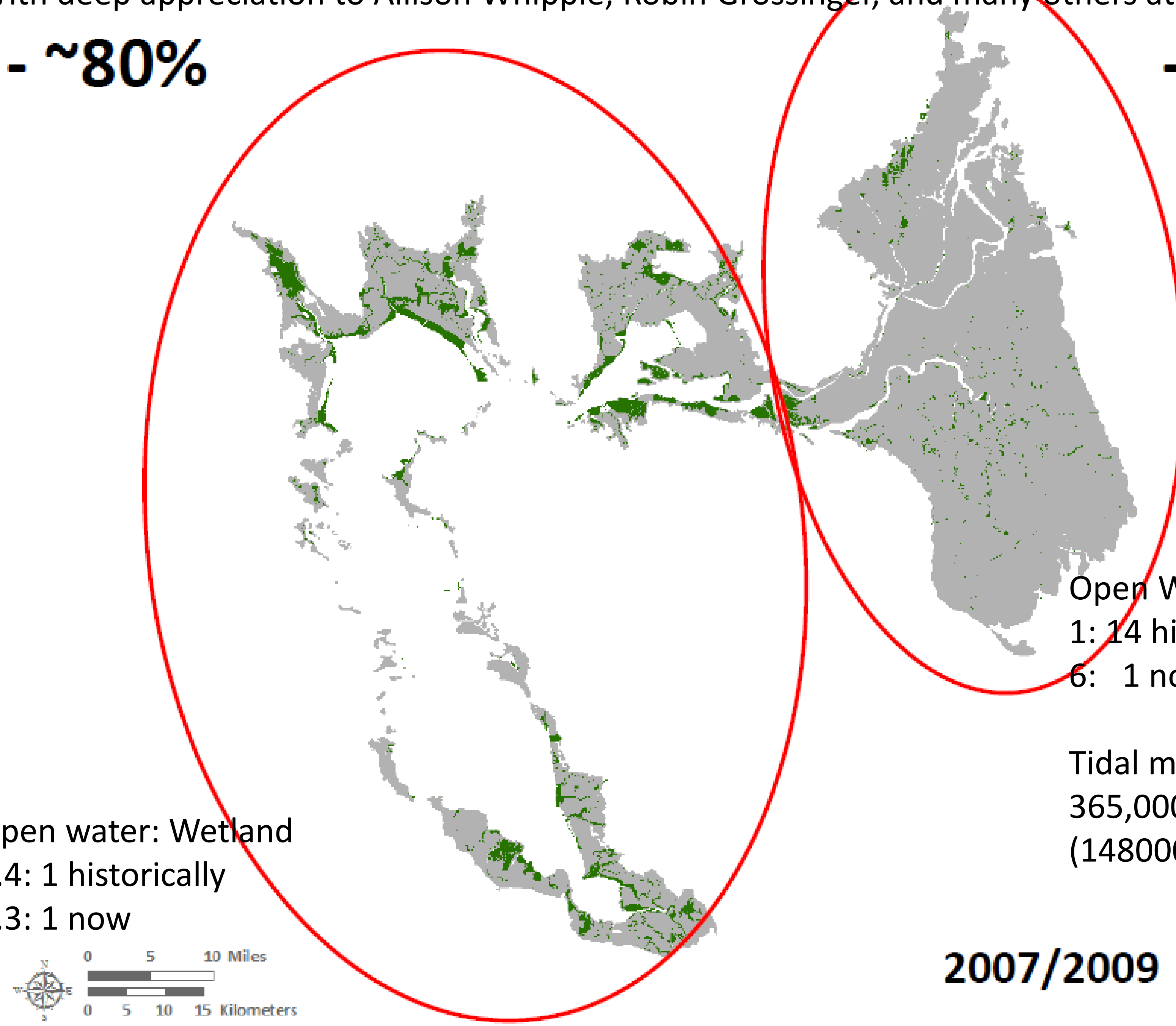
Conceptual models of historical landscapes



With deep appreciation to Allison Whipple, Robin Grossinger, and many others at SFEI

- ~80%

- ~97%*



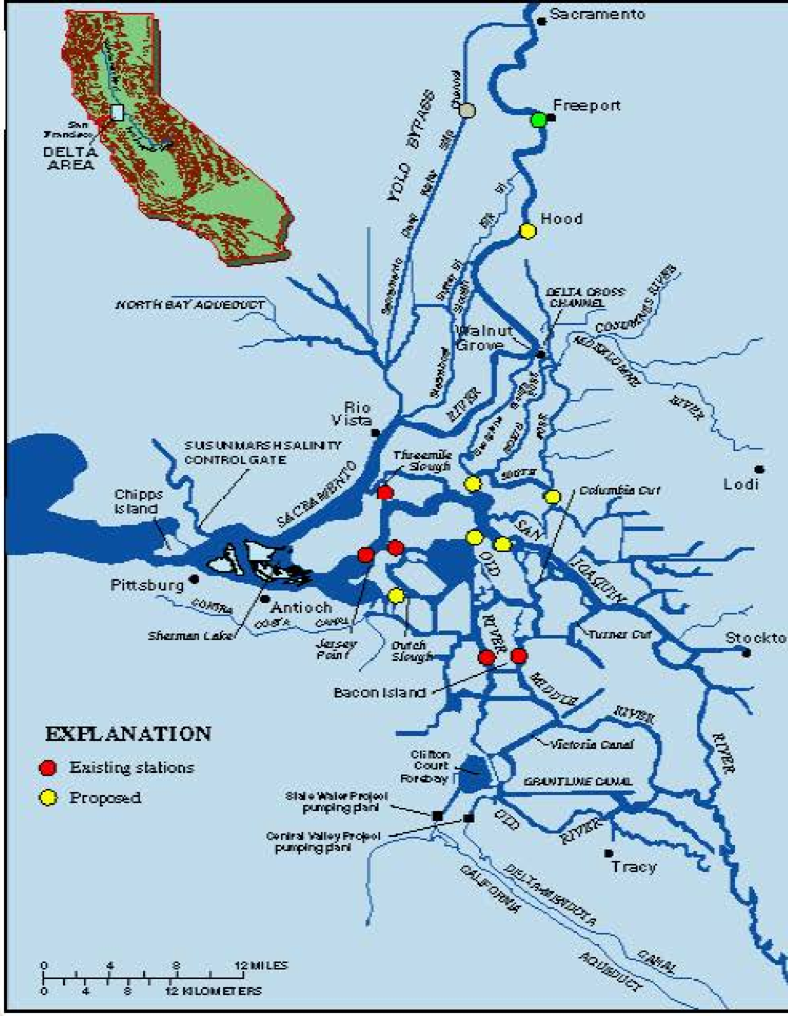
Open Water:Wetland
1: 14 historically
6: 1 now

Tidal marsh:
365,000 acres
(148000 ha)

Open water: Wetland
1.4: 1 historically
6.3: 1 now

2007/2009


Major Rivers
State Projects
Federal Projects
Local Projects
All Water Projects
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego


DELTA AREA
Sacramento
Freeport
Hood
YOLO BYPASS
NORTH BAY AQUEDUCT
DELTA CROSS CHANNEL
Walnut Grove
Rio Vista
SUISUN MARSH SALINITY CONTROL GATE
Chipps Island
SACRAMENTO
Threemile Slough
Columbia Cut
Lodi
SAN JOAQUIN
Pittsburg
Antioch
Sherman Lake
Jersey Point
Dutch Slough
Turner Cut
Bacon Island
Victoria Canal
Clifton Court Forebay
GRANTLINE CANAL
State Water Project pumping plant
Central Valley Project pumping plant
Tracy
EXPLANATION
Existing stations
Proposed
0 4 8 12 MILES
0 4 8 12 KILOMETERS

USGS

IEP Tidal Wetlands Monitoring Project Work Team DRAFT Conceptual Models

- Developed principally by: Adam Ballard, Jenny Bigman, Larry Brown, Louise Conrad, Dave Contreras, Steve Culberson, Chris Enright, Pascale Goetler, Rosemary Hartman, Bruce Herbold, Jim Hobbs, Joseph Kirsh, Alice Low, Anitra Pawley, Ted Sommer, Hildie Spautz, Stacy Sherman, Jan Thompson, and Dave Zezulak.
- With liberal borrowing from:
  - DRERIP models (https://www.dfg.ca.gov/erp/conceptual_models.asp)
  - the MAST draft report (Baxter et al 2013), and the
  - Suisun Marsh conceptual models draft (Siegel et al, 2010).

Tidal Wetland model

Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008

Tier 1: Landscape Attributes

Land use
Diversions
Outfalls

Seasonality

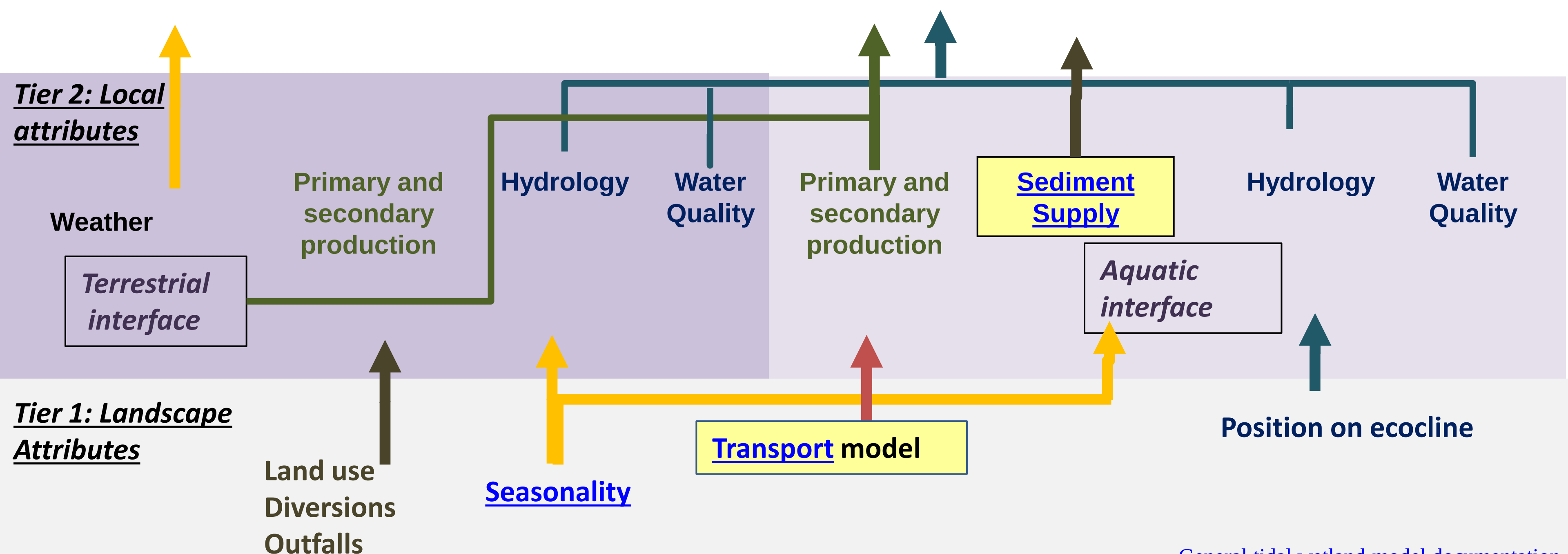
Transport model

Position on ecocline

- **Proximity to ocean**
- **Distance from midchannel**

Tidal Wetland model

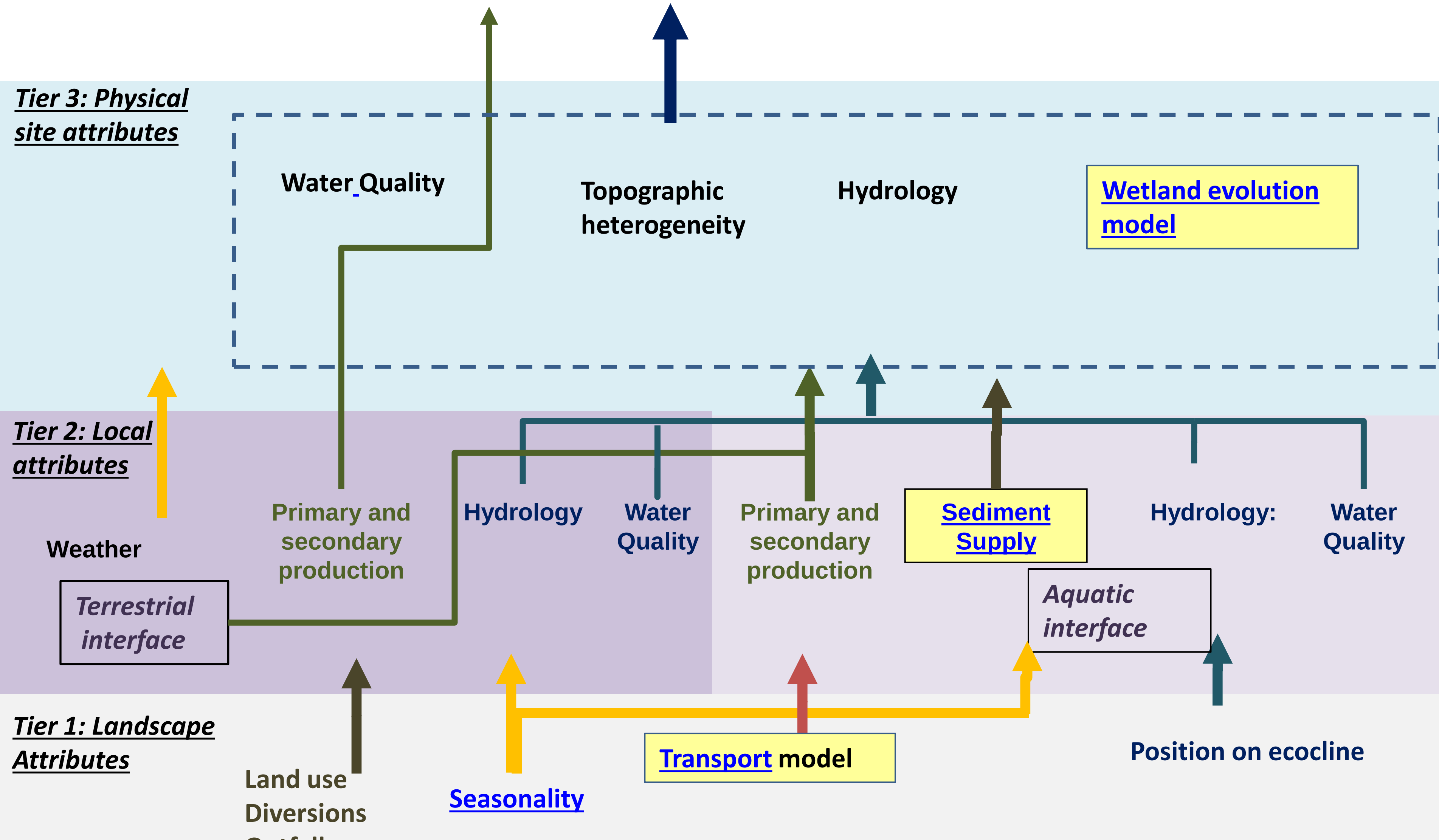
Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008



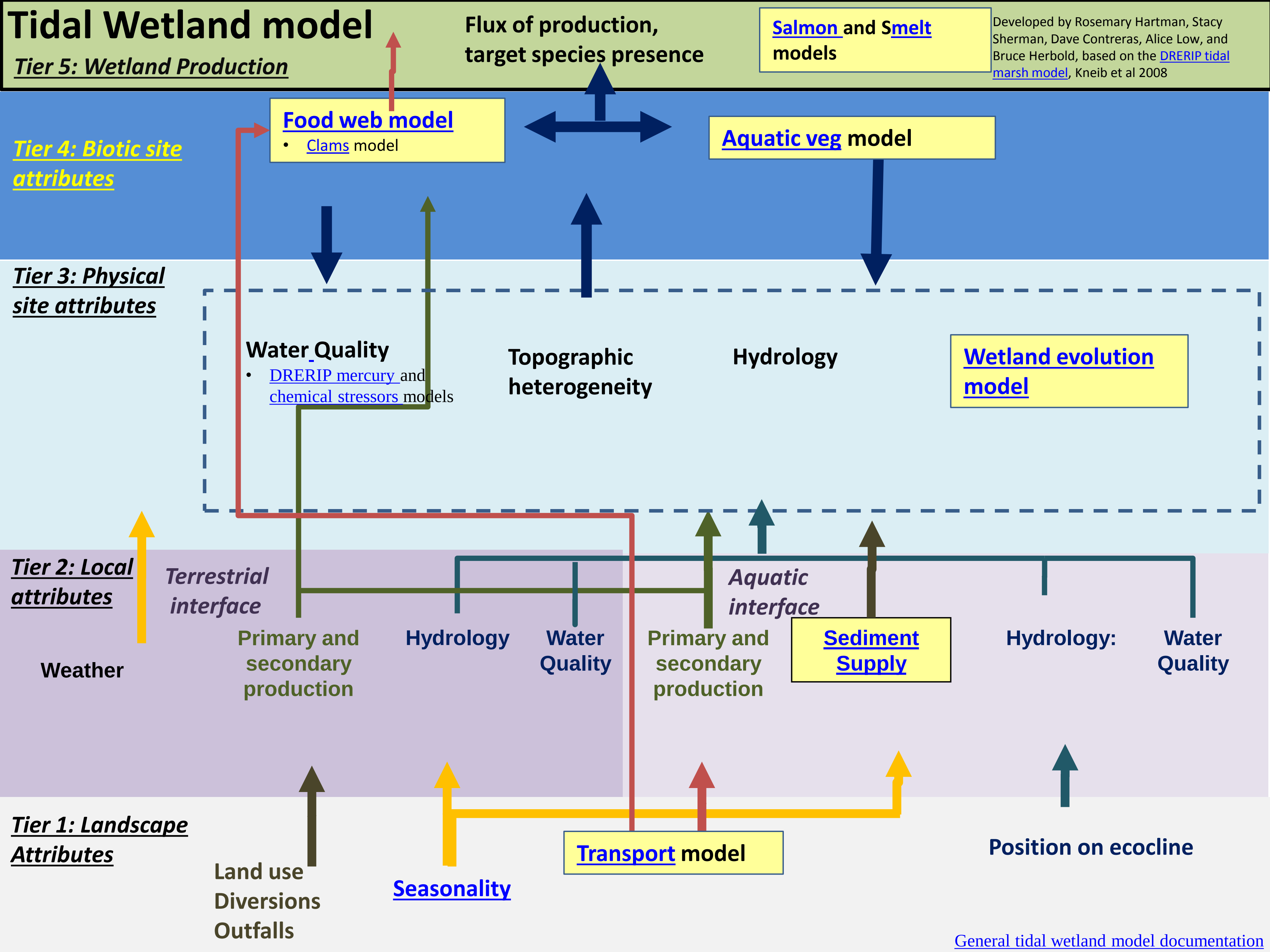
General tidal wetland model documentation

Tidal Wetland model

Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008

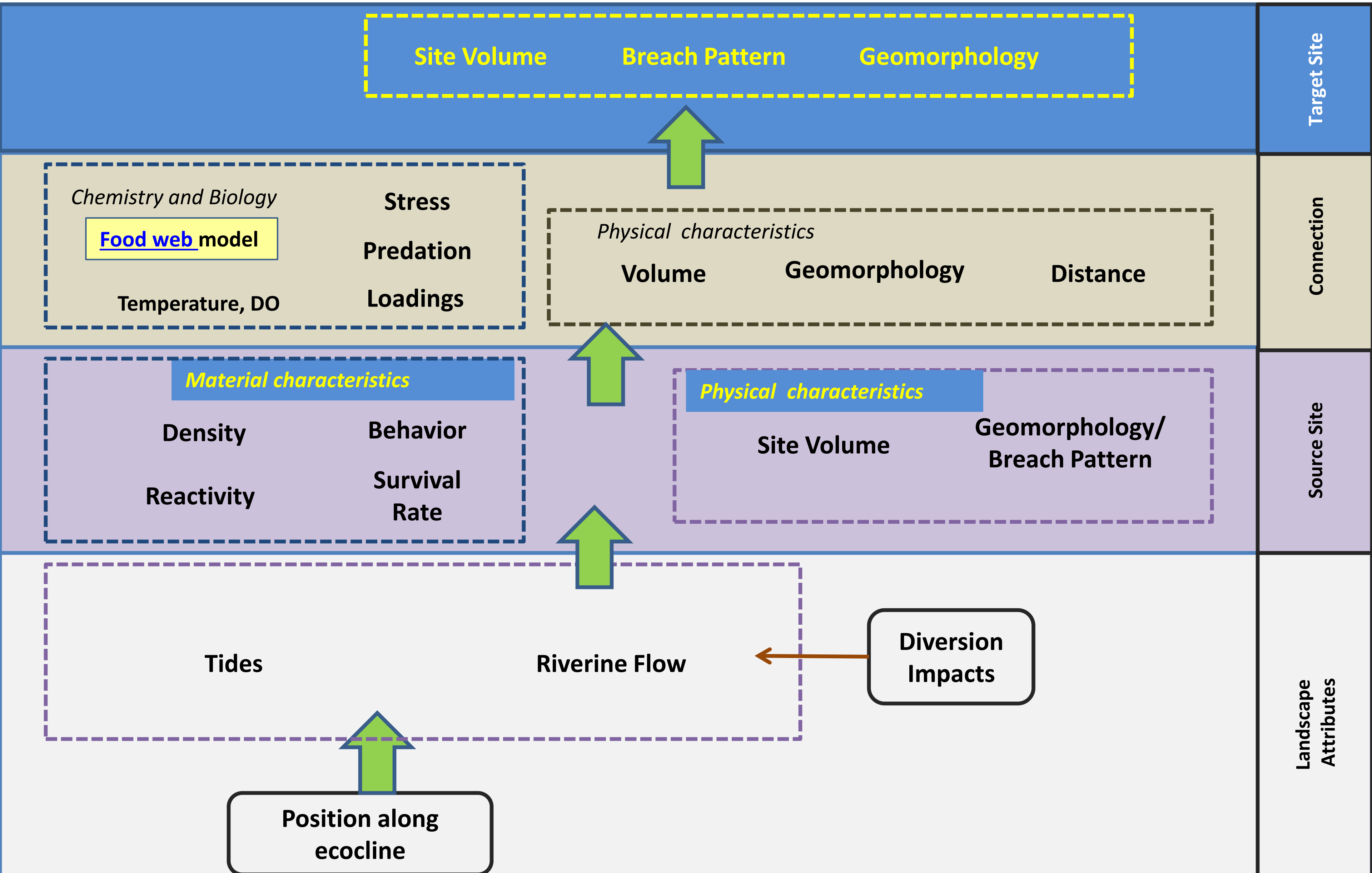


General tidal wetland model documentation

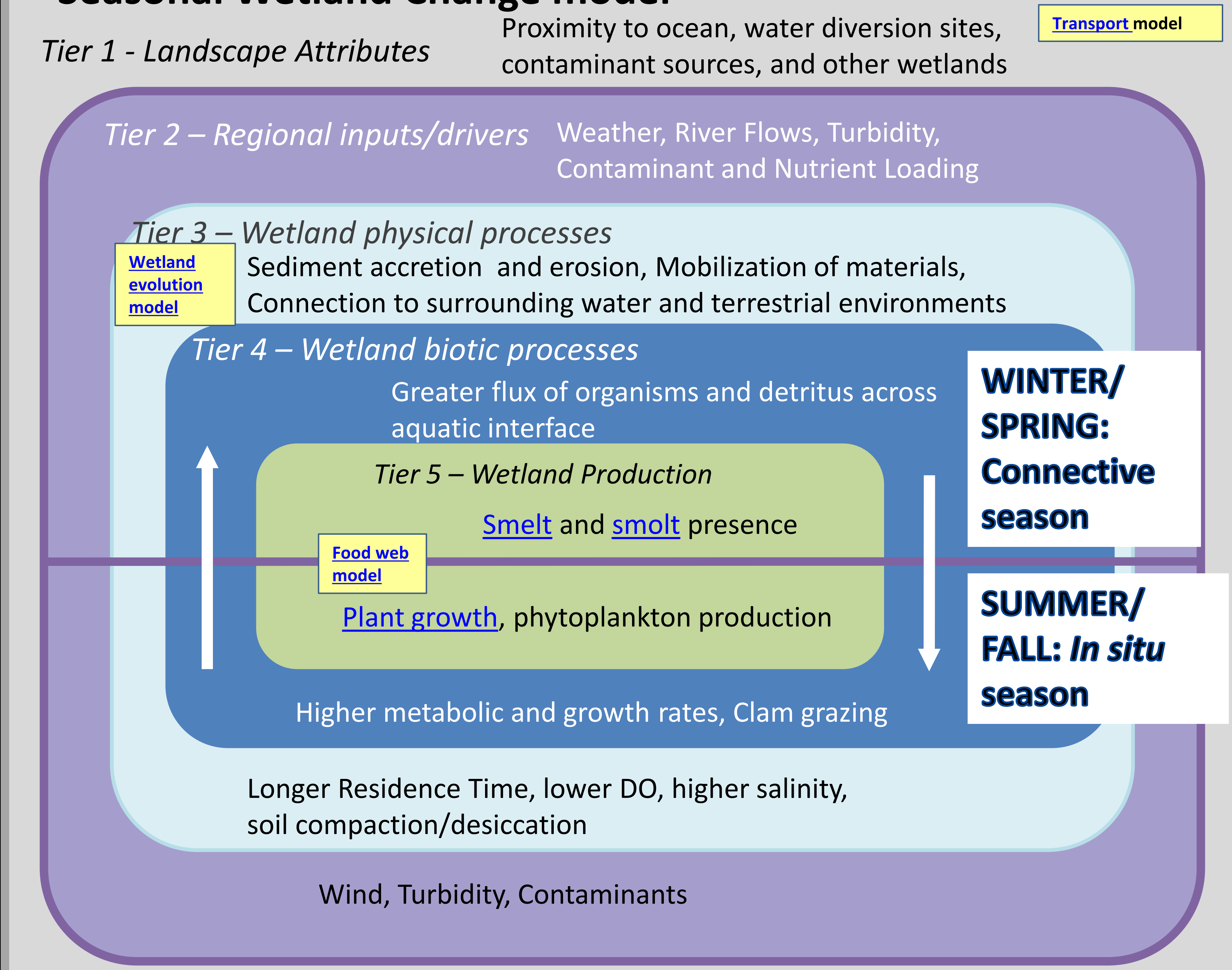

Tidal Wetland model
Tier 5: Wetland Production
Flux of production, target species presence
Salmon and Smelt models
Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008
Tier 4: Biotic site attributes
Food web model
Clams model
Aquatic veg model
Tier 3: Physical site attributes
Water Quality
DRERIP mercury and chemical stressors models
Topographic heterogeneity
Hydrology
Wetland evolution model
Tier 2: Local attributes
Terrestrial interface
Weather
Primary and secondary production
Hydrology
Water Quality
Aquatic interface
Primary and secondary production
Sediment Supply
Hydrology:
Water Quality
Tier 1: Landscape Attributes
Land use
Diversions
Outfalls
Seasonality
Transport model
Position on ecocline
General tidal wetland model documentation

Transport model

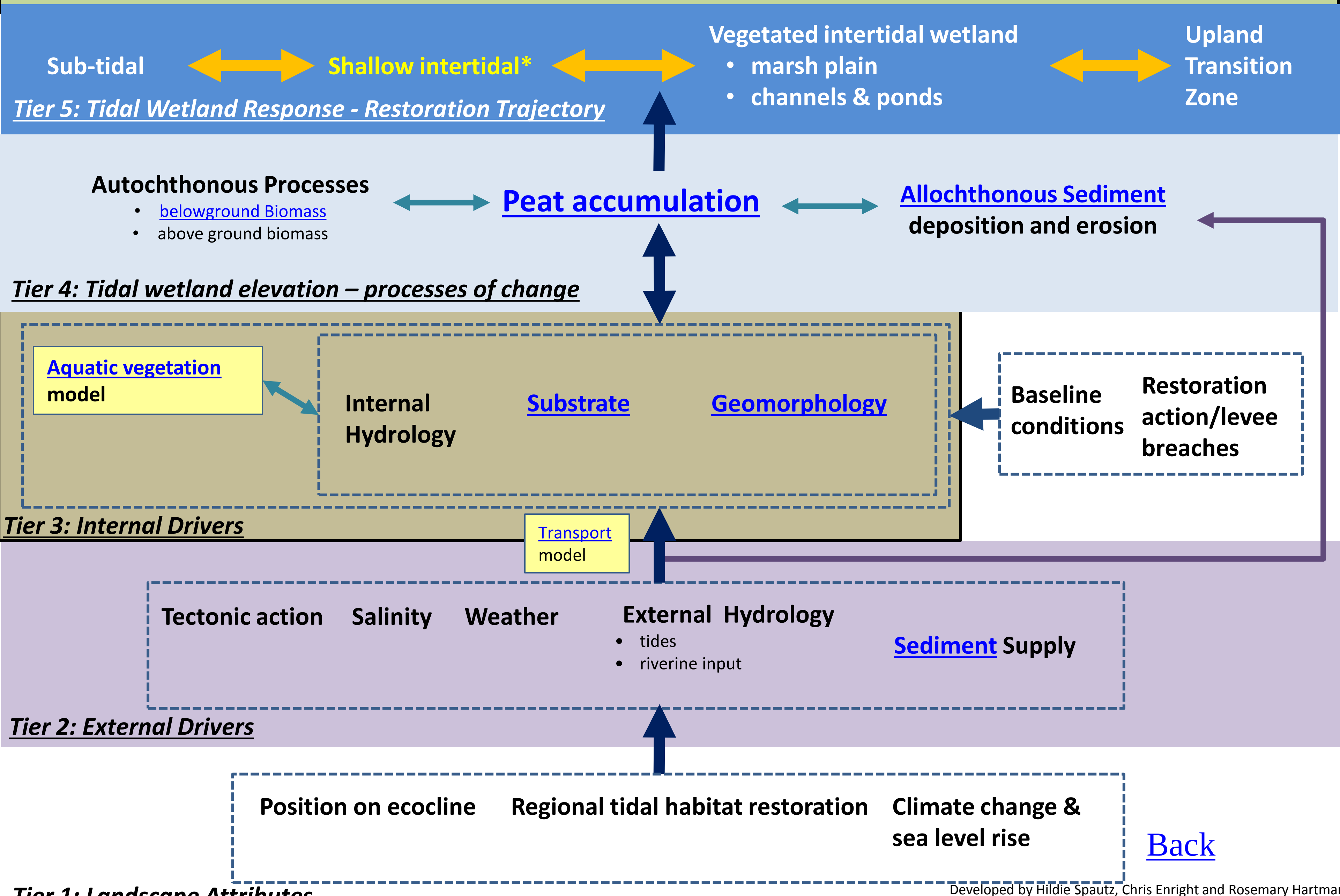
Exchange of Specified Material between Source and Target sites



Seasonal Wetland Change model



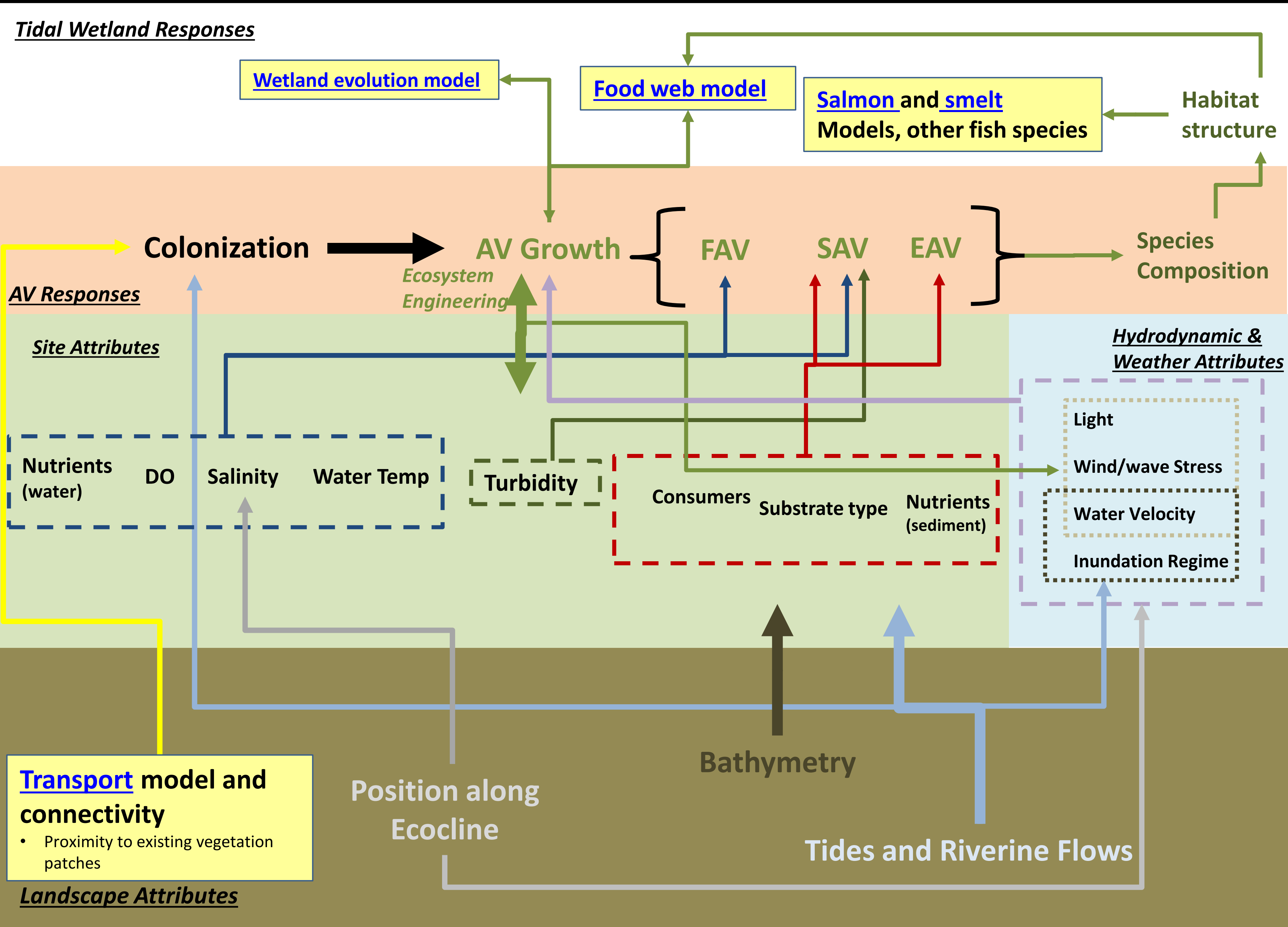
Tidal Wetland Restoration Evolution model

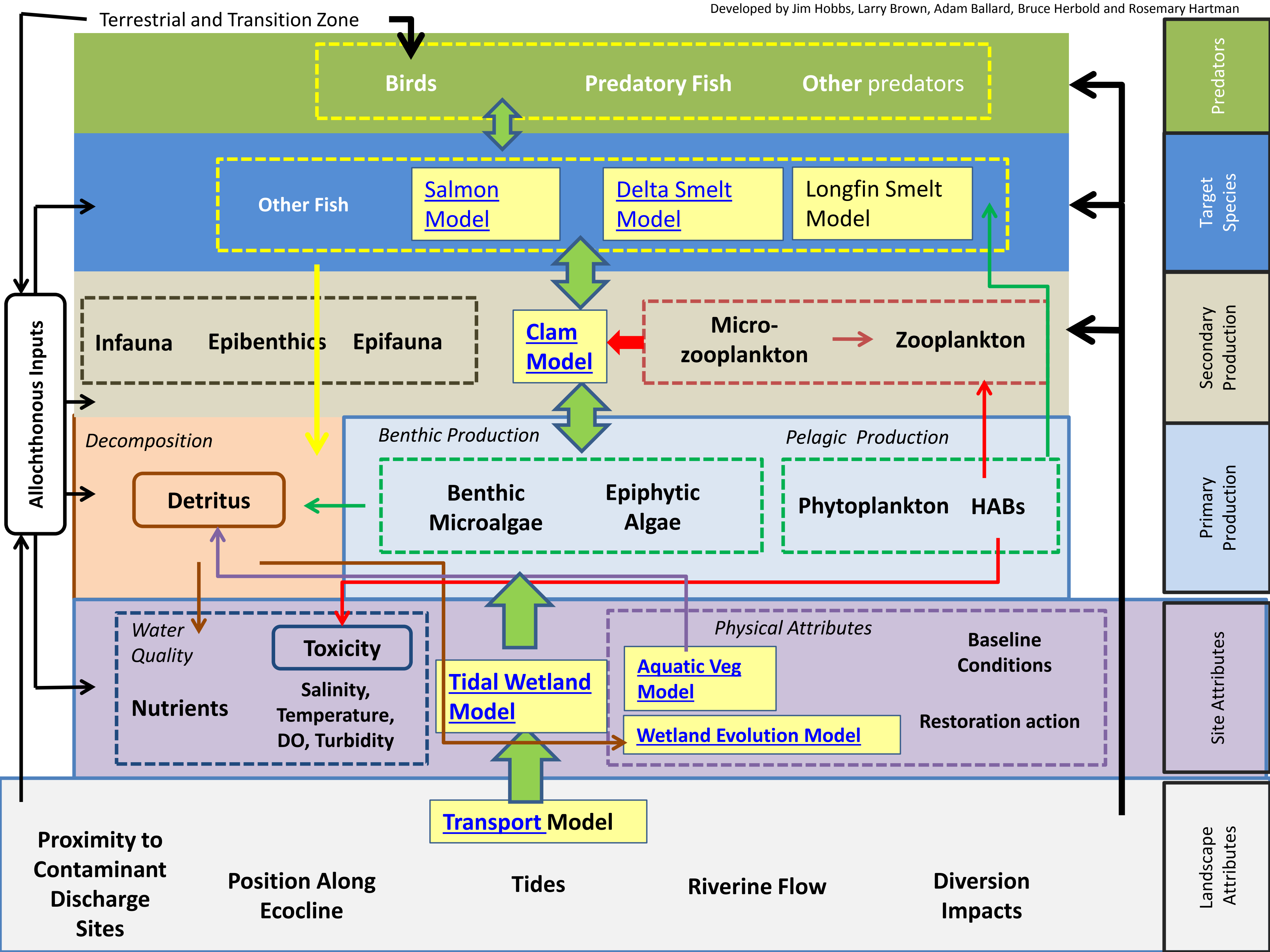


Developed by Hildie Spautz, Chris Enright and Rosemary Hartma
Modified from: Siegel et al 2010

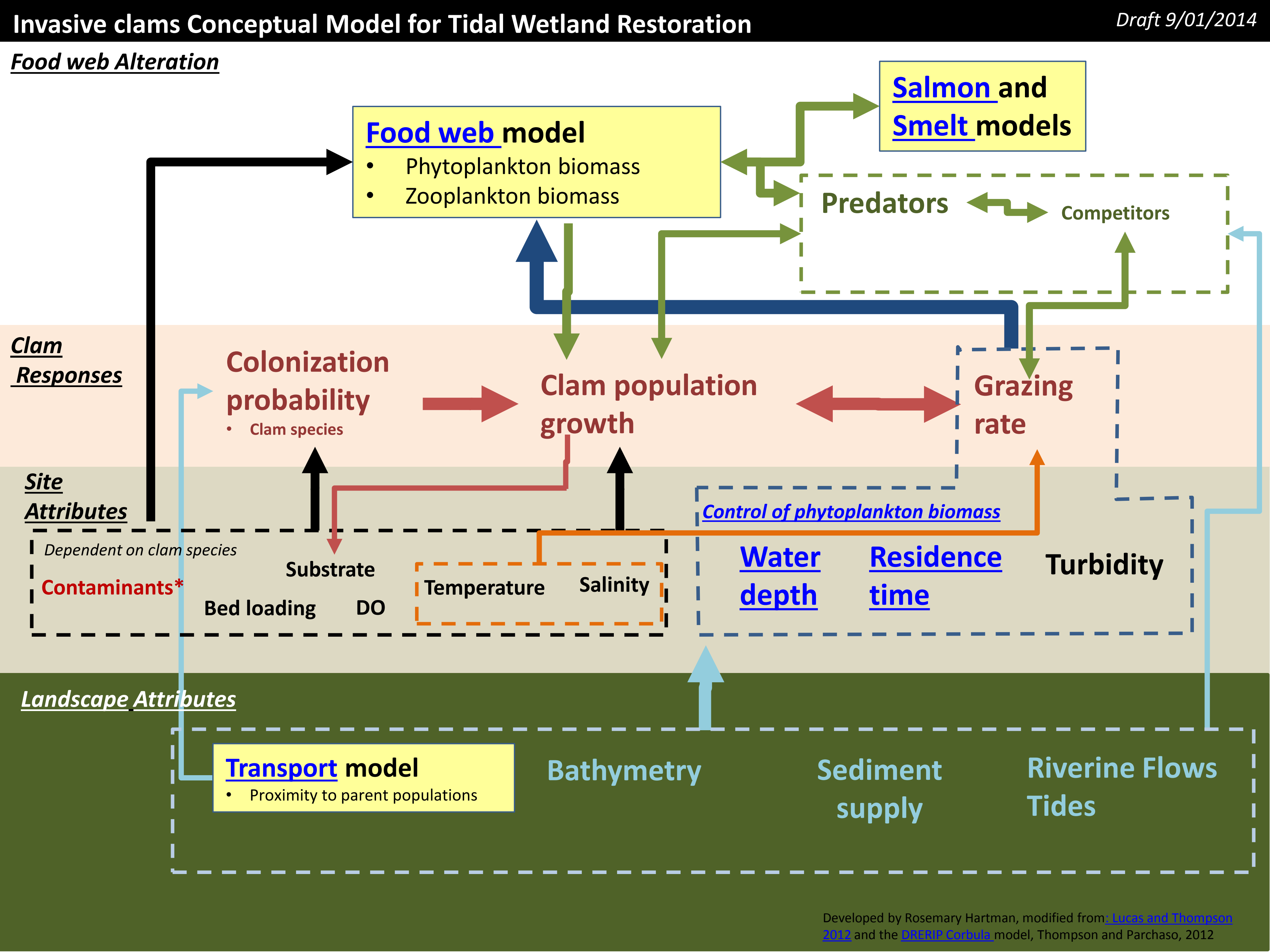
Aquatic Vegetation (AV) Conceptual Model for Tidal Wetland Restoration

Draft 8/14/2014



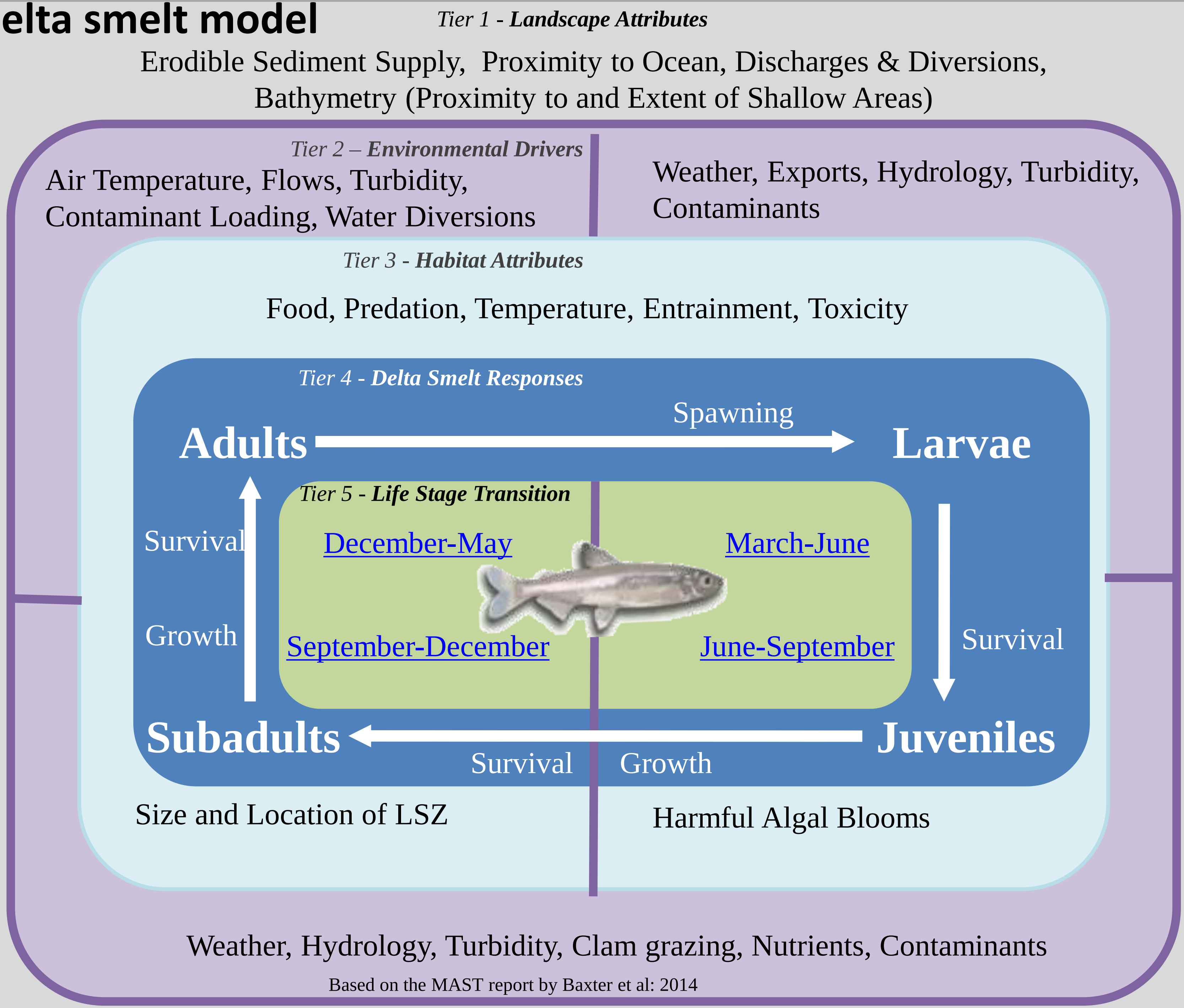


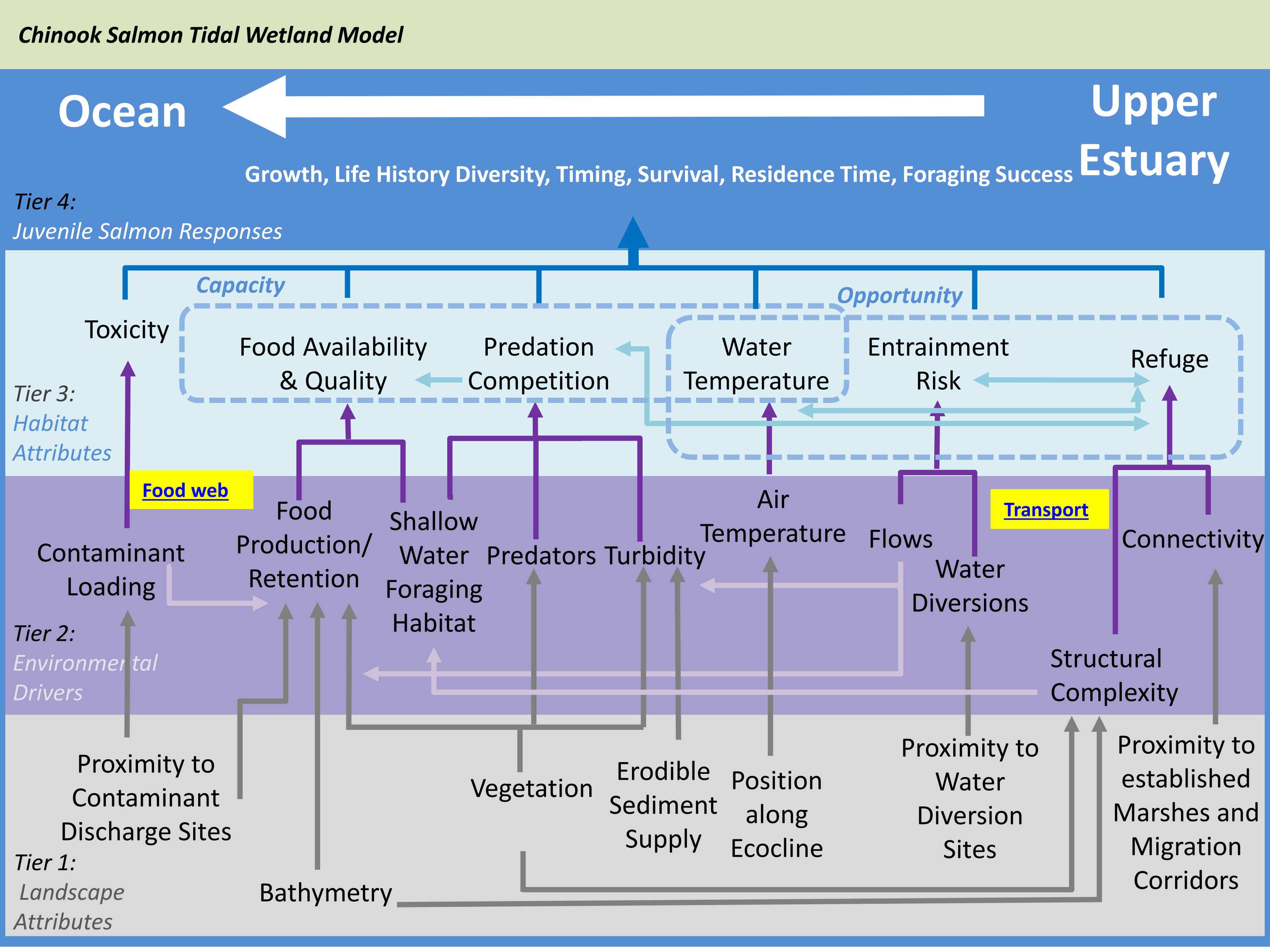
Developed by Jim Hobbs, Larry Brown, Adam Ballard, Bruce Herbold and Rosemary Hartman
Terrestrial and Transition Zone
Birds
Predatory Fish
Other predators
Other Fish
Salmon Model
Delta Smelt Model
Longfin Smelt Model
Infauna
Epibenthics
Epifauna
Clam Model
Micro-zooplankton
Zooplankton
Decomposition
Benthic Production
Pelagic Production
Detritus
Benthic Microalgae
Epiphytic Algae
Phytoplankton
HABs
Allochthonous Inputs
Water Quality
Toxicity
Nutrients
Salinity, Temperature, DO, Turbidity
Tidal Wetland Model
Physical Attributes
Aquatic Veg Model
Baseline Conditions
Restoration action
Wetland Evolution Model
Transport Model
Proximity to Contaminant Discharge Sites
Position Along Ecocline
Tides
Riverine Flow
Diversion Impacts
Predators
Target Species
Secondary Production
Primary Production
Site Attributes
Landscape Attributes

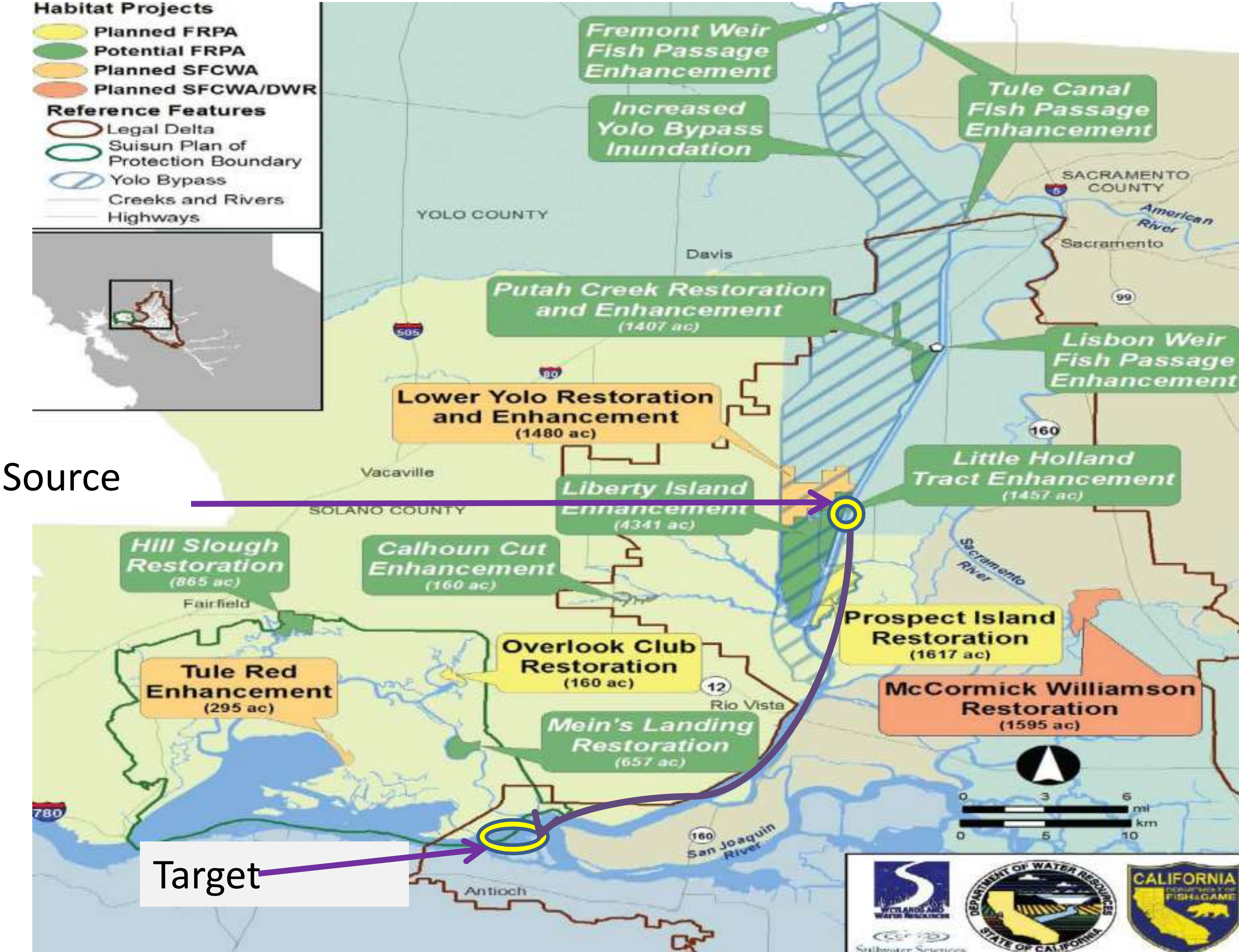


Invasive clams Conceptual Model for Tidal Wetland Restoration
Draft 9/01/2014
Food web Alteration
Food web model
Phytoplankton biomass
Zooplankton biomass
Salmon and Smelt models
Predators
Competitors
Clam Responses
Colonization probability
Clam species
Clam population growth
Grazing rate
Site Attributes
Dependent on clam species
Contaminants*
Substrate
Bed loading
DO
Temperature
Salinity
Control of phytoplankton biomass
Water depth
Residence time
Turbidity
Landscape Attributes
Transport model
Proximity to parent populations
Bathymetry
Sediment supply
Riverine Flows
Tides
Developed by Rosemary Hartman, modified from: Lucas and Thompson 2012 and the DRERIP Corbula model, Thompson and Parchaso, 2012

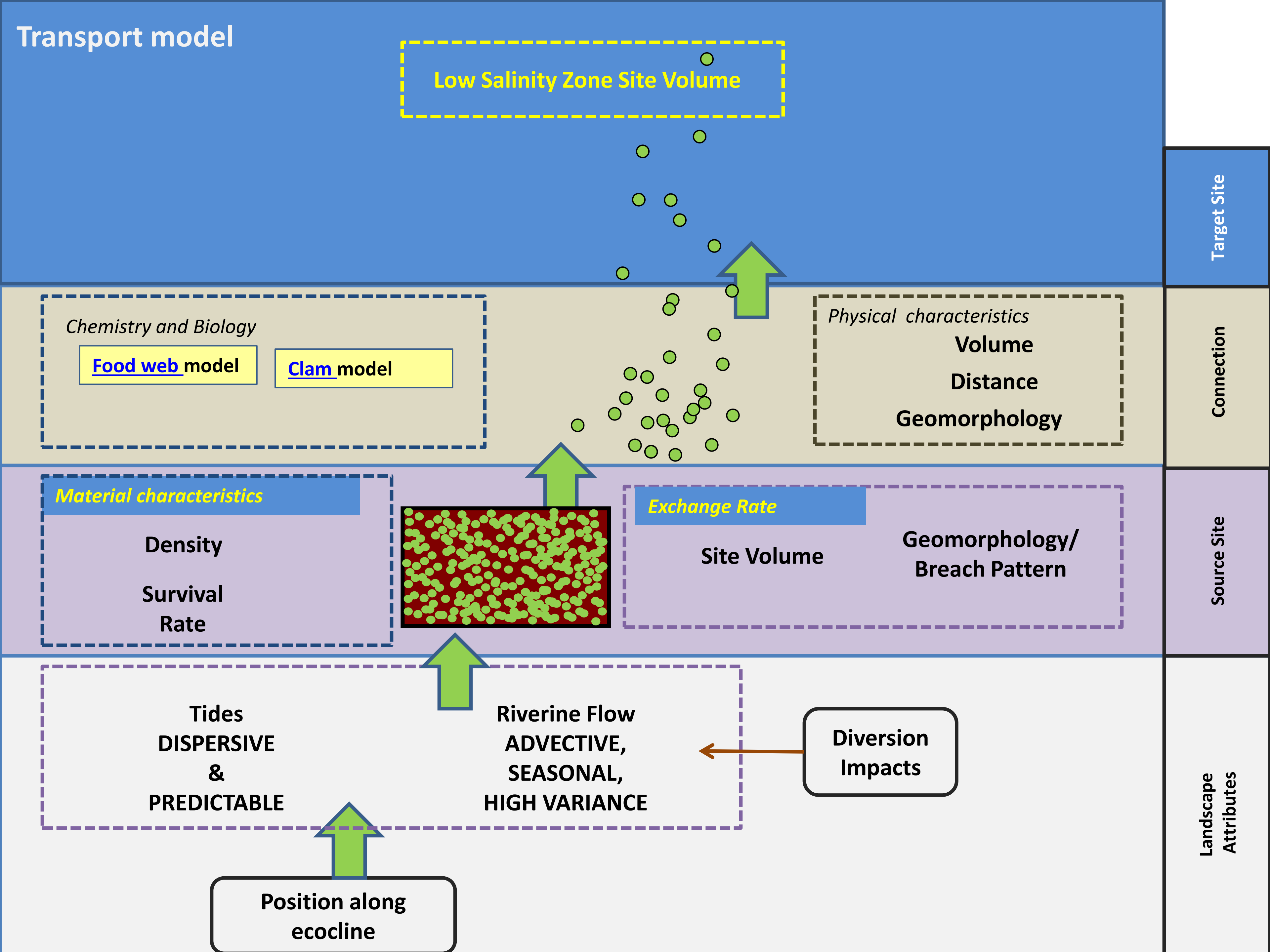
Delta smelt model




Chinook Salmon Tidal Wetland Model
Ocean
Upper Estuary
Growth, Life History Diversity, Timing, Survival, Residence Time, Foraging Success
Tier 4:
Juvenile Salmon Responses
Capacity
Opportunity
Toxicity
Food Availability & Quality
Predation Competition
Water Temperature
Entrainment Risk
Refuge
Tier 3:
Habitat Attributes
Food web
Transport
Contaminant Loading
Food Production/ Retention
Shallow Water Foraging Habitat
Predators
Turbidity
Air Temperature
Flows
Water Diversions
Connectivity
Structural Complexity
Tier 2:
Environmental Drivers
Proximity to Contaminant Discharge Sites
Vegetation
Erodible Sediment Supply
Position along Ecocline
Proximity to Water Diversion Sites
Proximity to established Marshes and Migration Corridors
Bathymetry
Tier 1:
Landscape Attributes

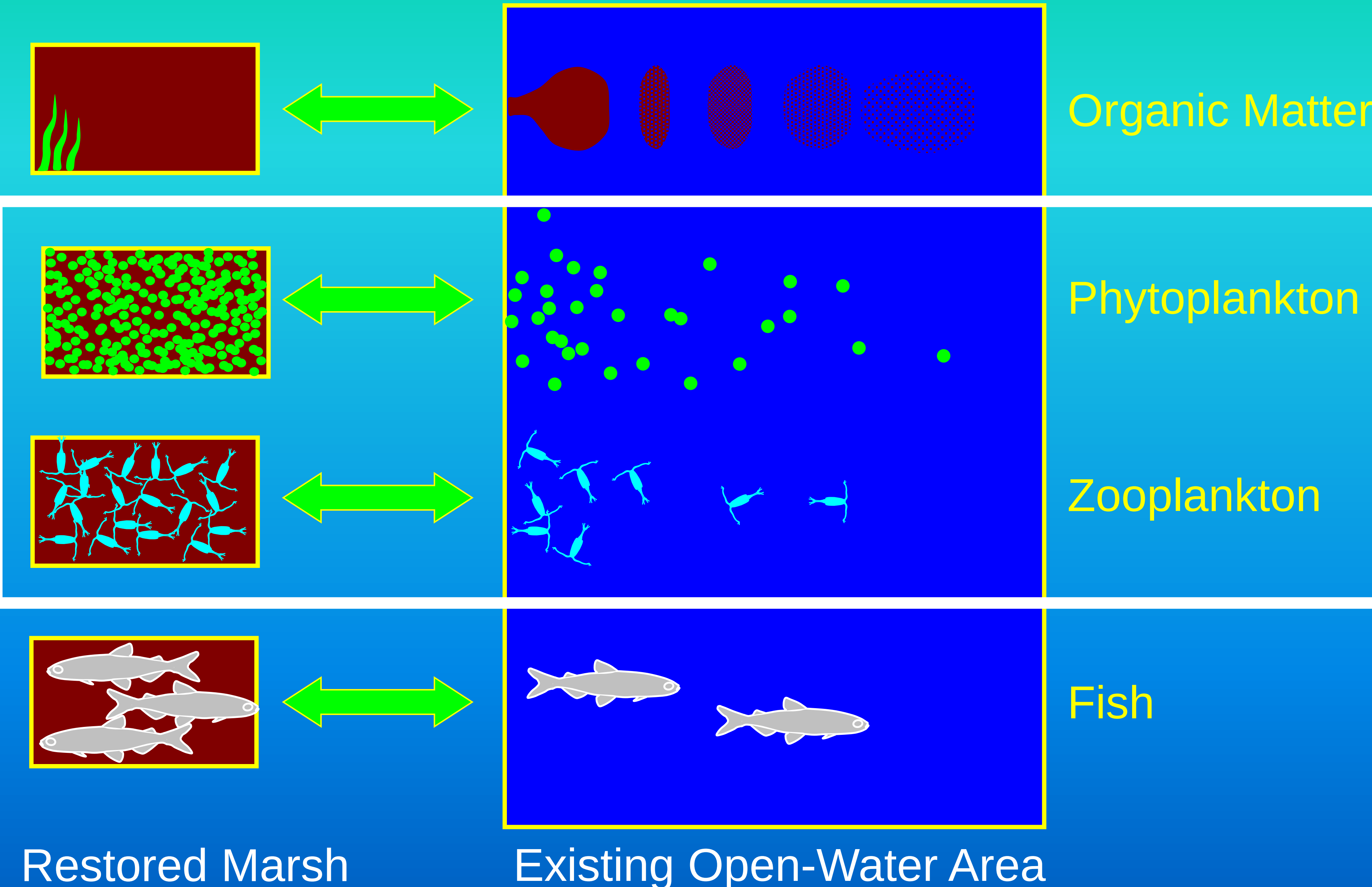


Habitat Projects
Planned FRPA
Potential FRPA
Planned SFCWA
Planned SFCWA/DWR
Reference Features
Legal Delta
Suisun Plan of Protection Boundary
Yolo Bypass
Creeks and Rivers
Highways
Fremont Weir Fish Passage Enhancement
Increased Yolo Bypass Inundation
Tule Canal Fish Passage Enhancement
SACRAMENTO COUNTY
American River
Sacramento
YOLO COUNTY
Davis
Putah Creek Restoration and Enhancement (1407 ac)
Lisbon Weir Fish Passage Enhancement
Lower Yolo Restoration and Enhancement (1480 ac)
Little Holland Tract Enhancement (1457 ac)
Vacaville
SOLANO COUNTY
Liberty Island Enhancement (4341 ac)
Source
Hill Slough Restoration (865 ac)
Calhoun Cut Enhancement (160 ac)
Sacramento River
Fairfield
Prospect Island Restoration (1617 ac)
Overlook Club Restoration (160 ac)
Tule Red Enhancement (295 ac)
Rio Vista
McCormick Williamson Restoration (1595 ac)
Mein's Landing Restoration (657 ac)
San Joaquin River
Antioch
Target
0 3 6 mi
0 5 10 km
CALIFORNIA DEPARTMENT OF FISH & GAME
DEPARTMENT OF WATER RESOURCES STATE OF CALIFORNIA
Stillwater Sciences

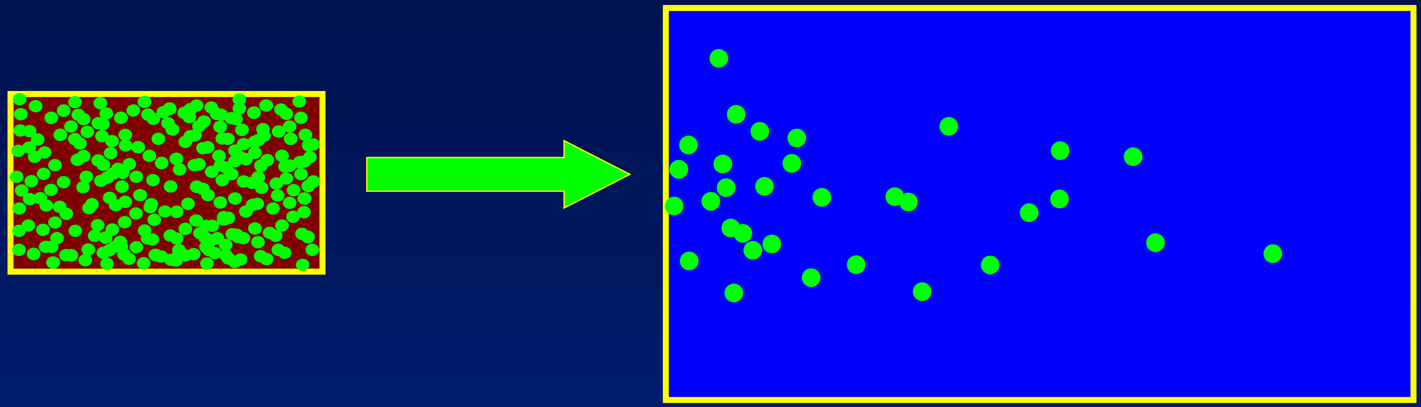


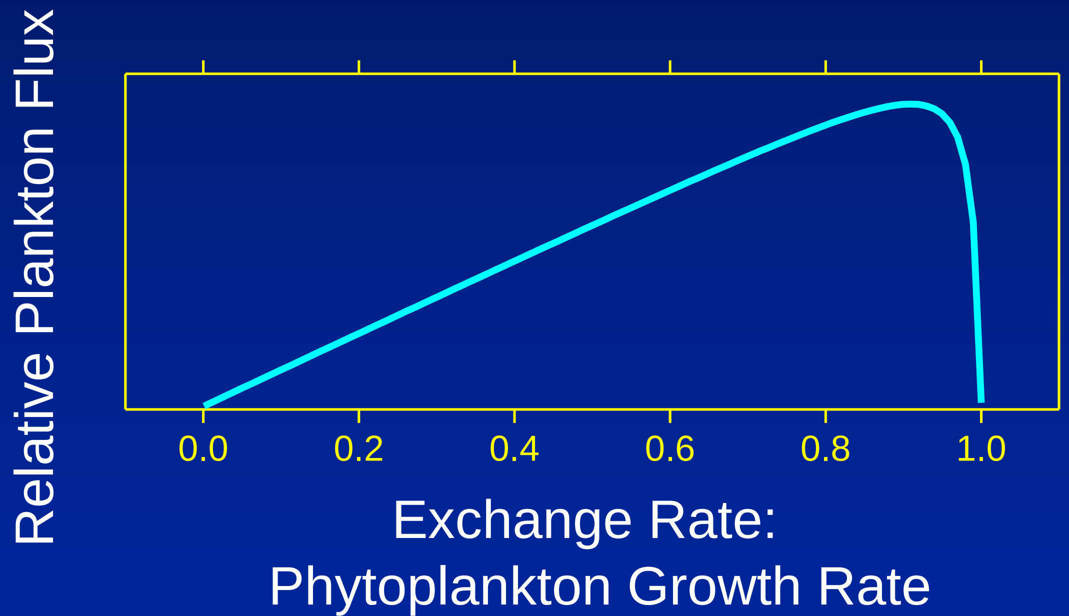
Transport model
Low Salinity Zone Site Volume
Chemistry and Biology
Food web model
Clam model
Physical characteristics
Volume
Distance
Geomorphology
Material characteristics
Density
Survival
Rate
Exchange Rate
Site Volume
Geomorphology/
Breach Pattern
Tides
DISPERSIVE
&
PREDICTABLE
Riverine Flow
ADVECTIVE,
SEASONAL,
HIGH VARIANCE
Diversion
Impacts
Position along
ecocline
Target Site
Connection
Source Site
Landscape
Attributes

Subsidies from wetland



Subsidies from marsh vary with exchange



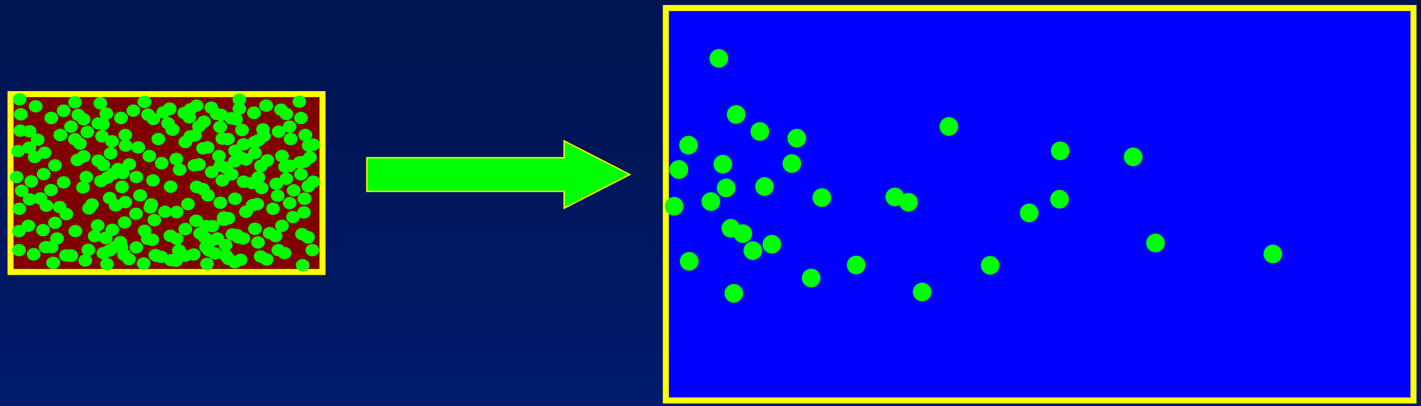


Model

- Steady state
- Single limiting nutrient
- Saturating uptake
- No grazing
- Negligible phytoplankton conc. in estuary

Exchange rate = Daily exchange volume / marsh volume
= 1 / Residence time of marsh

Subsidies from wetland: phyto model

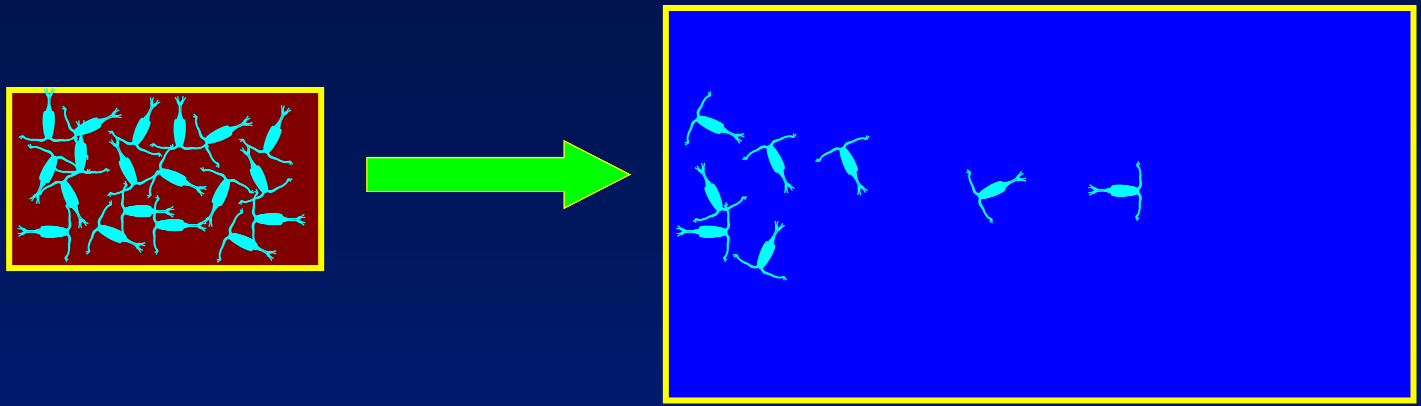


Area	1000 ha	Volume	0.5 km^3
Depth	2m	Phytoplankton	73 $mgC\ m^{-3}$
Phytoplankton	900 $mgC\ m^{-3}$		
Growth rate μ	0.86 d^{-1}		
Microzoo grazing	60% μ		
Residence time	10d		

Resulting subsidy:

5% of existing phytoplankton biomass d^{-1}

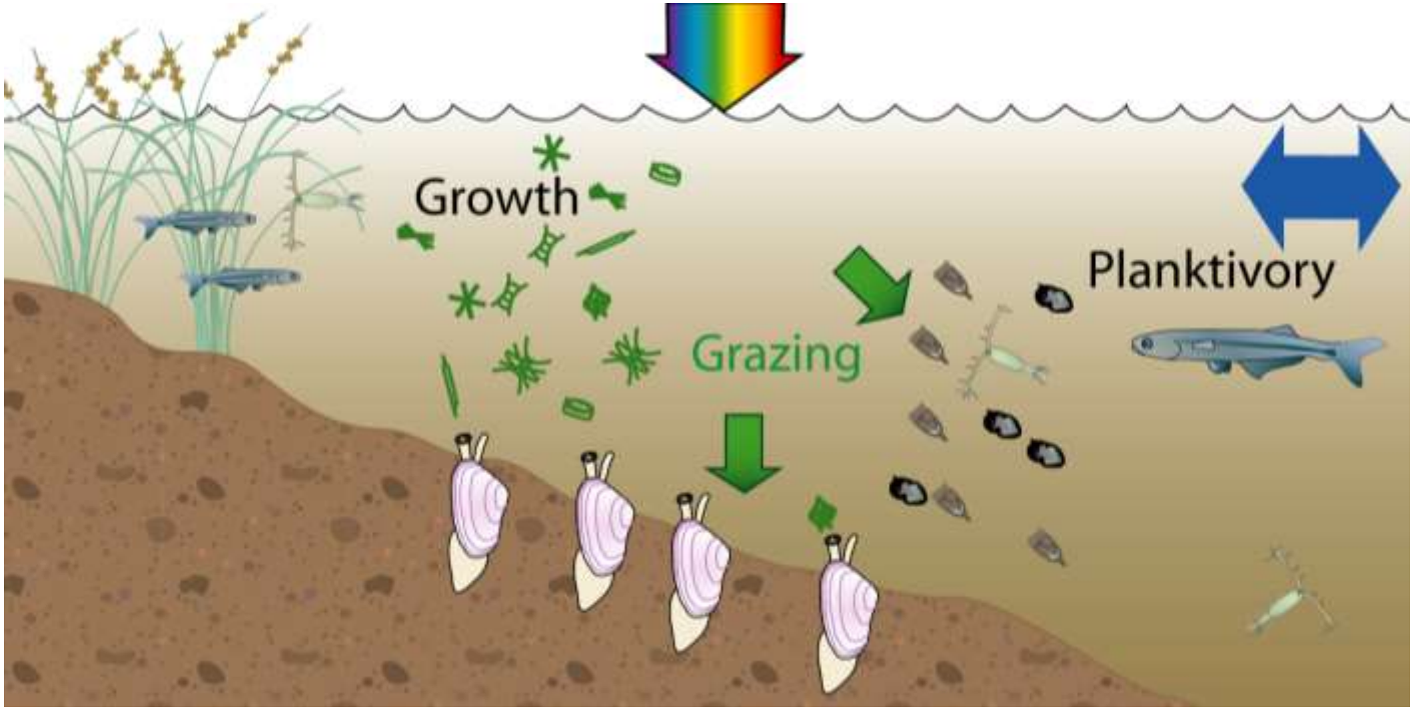
Subsidies from wetland: copepod model



Area	1000 ha	Volume	0.5 km^3
Depth	2m	Copepods	3 mgC m^{-3}
Copepods	23 mgC m^{-3}		
Growth rate μ	0.1 d^{-1}		
Residence time	10d		

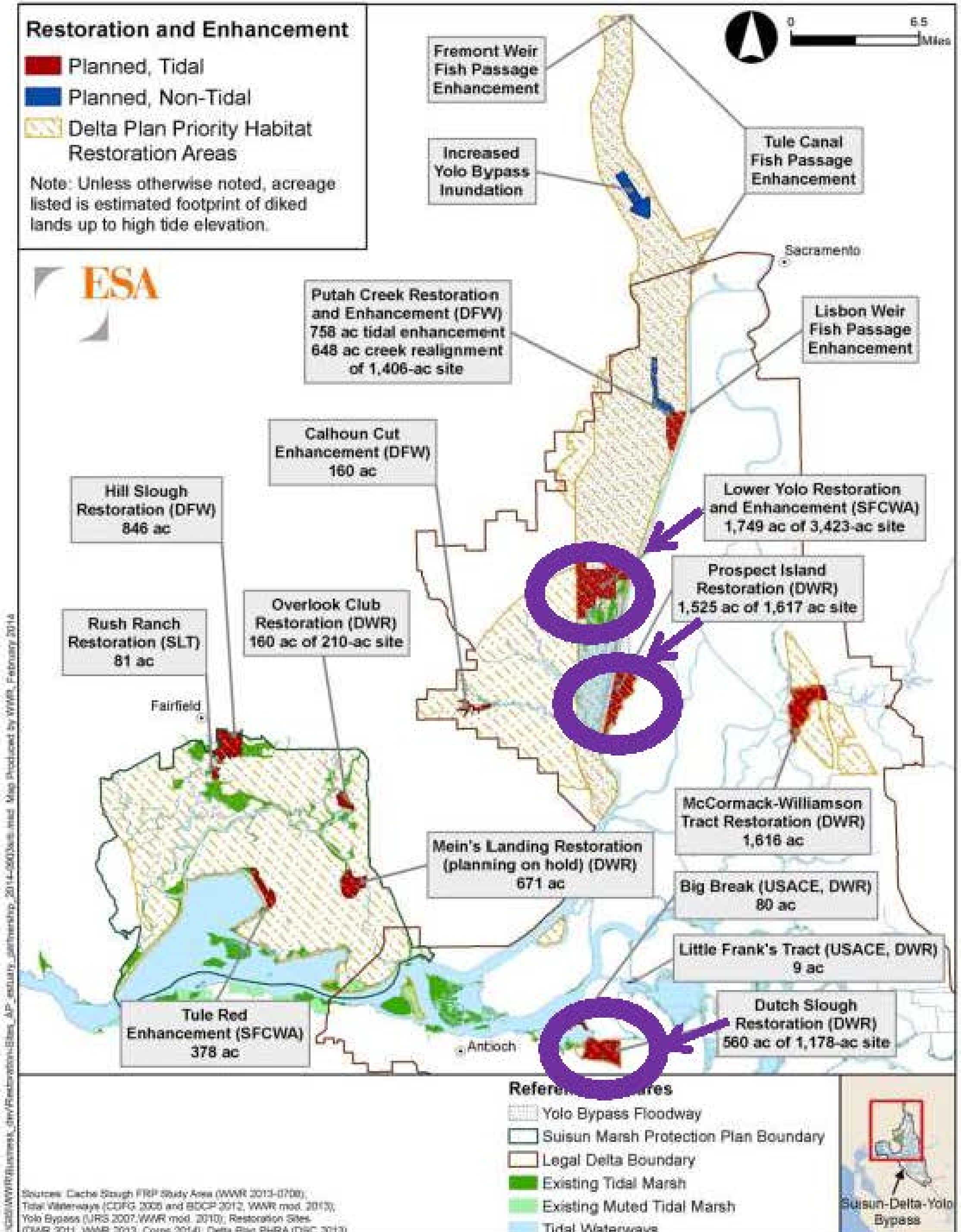
Resulting subsidy:

3% of existing copepod biomass d^{-1}



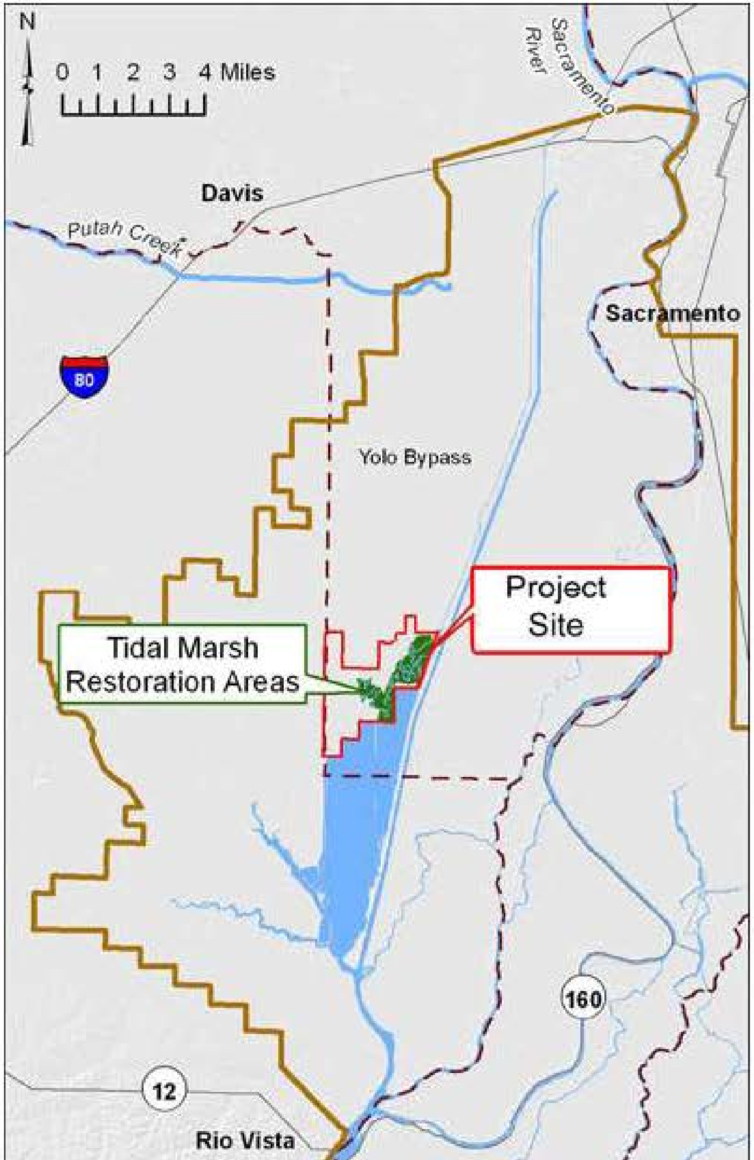
Depth and residence time control growth rates, grazing and biomass

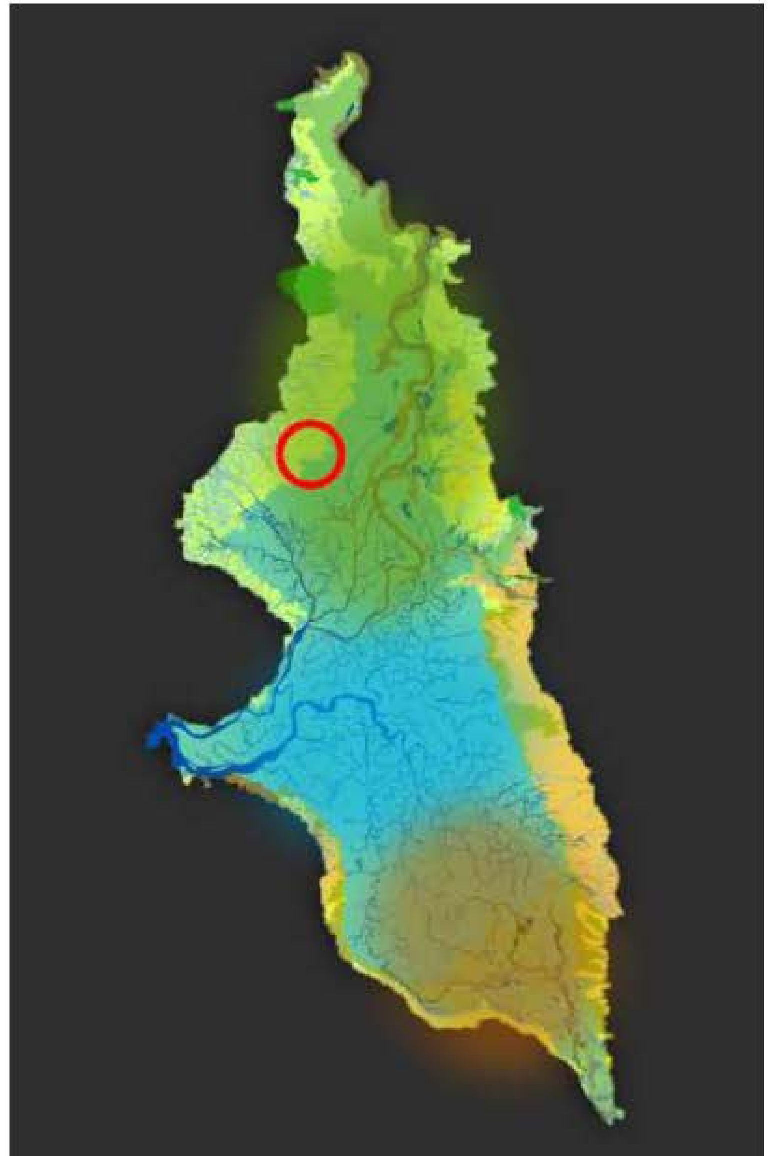
Thanks to Wim Kimmerer

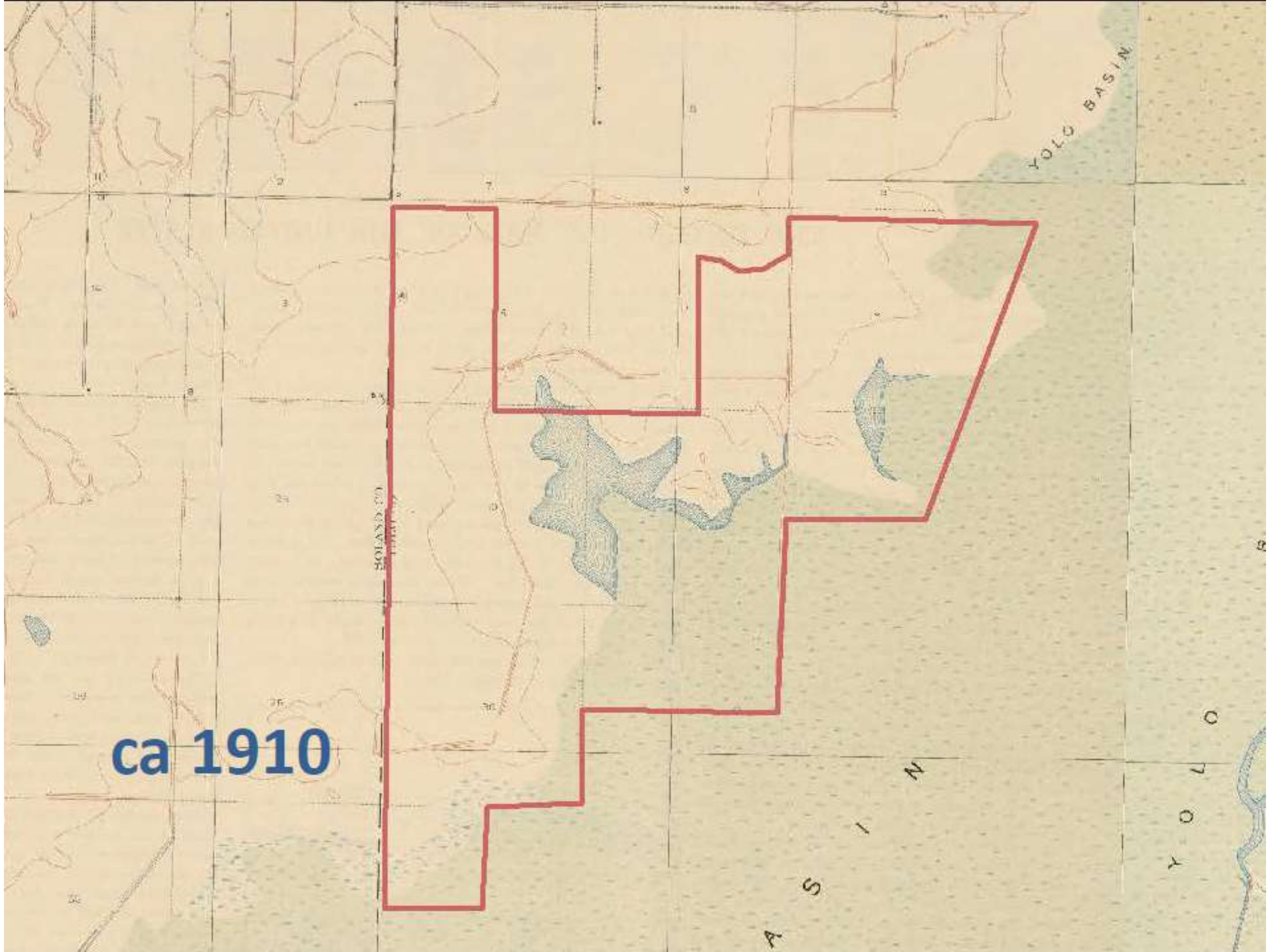


Restoration and Enhancement
Planned, Tidal
Planned, Non-Tidal
Delta Plan Priority Habitat Restoration Areas
Note: Unless otherwise noted, acreage listed is estimated footprint of diked lands up to high tide elevation.
ESA
0
6.5
Miles
Fremont Weir Fish Passage Enhancement
Increased Yolo Bypass Inundation
Tule Canal Fish Passage Enhancement
Sacramento
Putah Creek Restoration and Enhancement (DFW) 758 ac tidal enhancement 648 ac creek realignment of 1,406-ac site
Lisbon Weir Fish Passage Enhancement
Calhoun Cut Enhancement (DFW) 160 ac
Hill Slough Restoration (DFW) 846 ac
Lower Yolo Restoration and Enhancement (SFCWA) 1,749 ac of 3,423-ac site
Prospect Island Restoration (DWR) 1,525 ac of 1,617 ac site
Rush Ranch Restoration (SLT) 81 ac
Overlook Club Restoration (DWR) 160 ac of 210-ac site
Fairfield
McCormack-Williamson Tract Restoration (DWR) 1,616 ac
Mein's Landing Restoration (planning on hold) (DWR) 671 ac
Big Break (USACE, DWR) 80 ac
Little Frank's Tract (USACE, DWR) 9 ac
Dutch Slough Restoration (DWR) 560 ac of 1,178-ac site
Tule Red Enhancement (SFCWA) 378 ac
Antioch
Yolo Bypass Floodway
Suisun Marsh Protection Plan Boundary
Legal Delta Boundary
Existing Tidal Marsh
Existing Muted Tidal Marsh
Tidal Waterways
Suisun-Delta-Yolo Bypass
Sources: Cache Slough FRP Study Area (WWR 2013-0708); Tidal Waterways (CDFG 2005 and BDCP 2012, WWR mod. 2013); Yolo Bypass (URS 2007,WWR mod. 2010); Restoration Sites (DWR 2011, WWR 2013; Corps 2014); Delta Plan PHRA (DSC 2013)

Lower Yolo Ranch

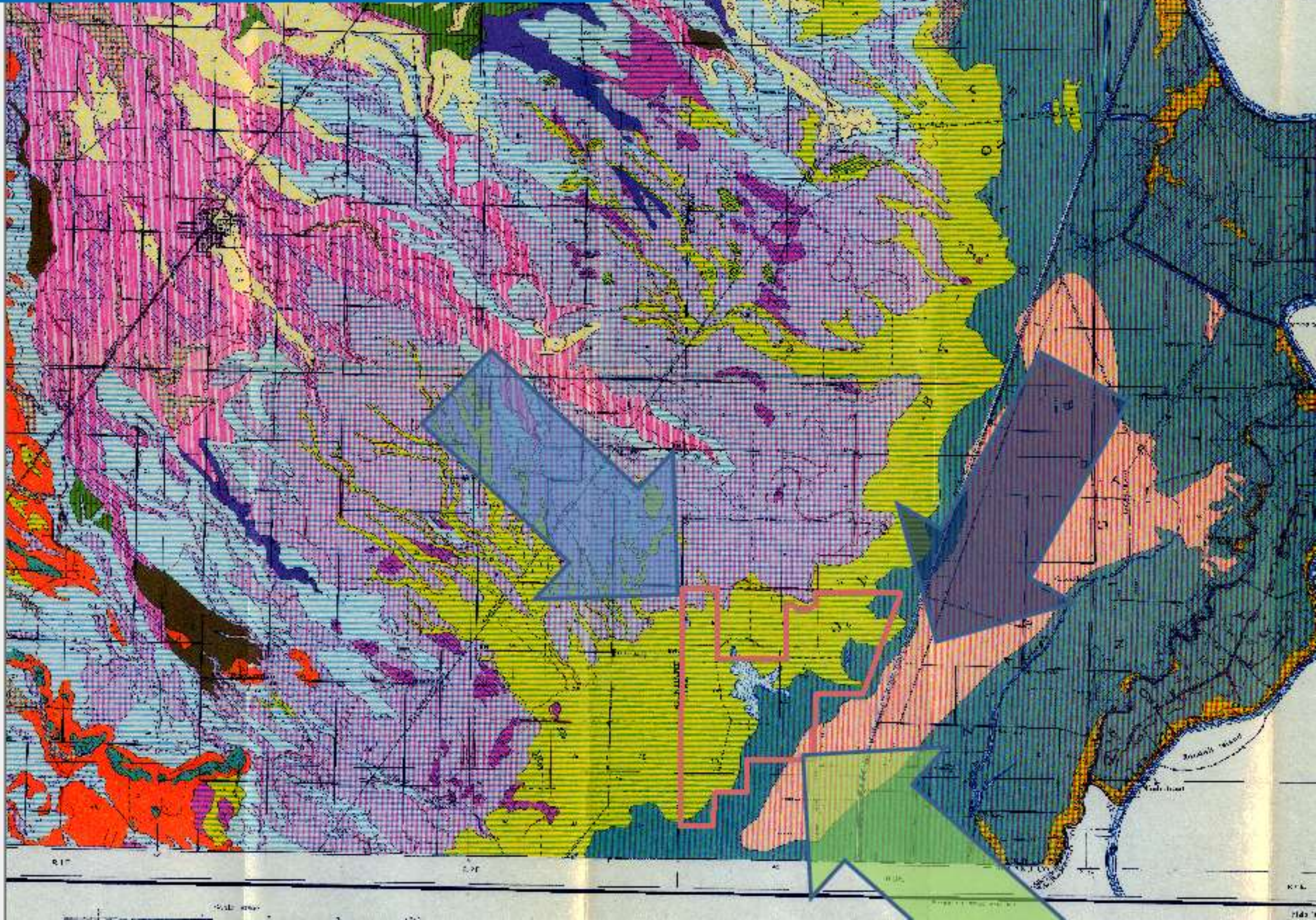




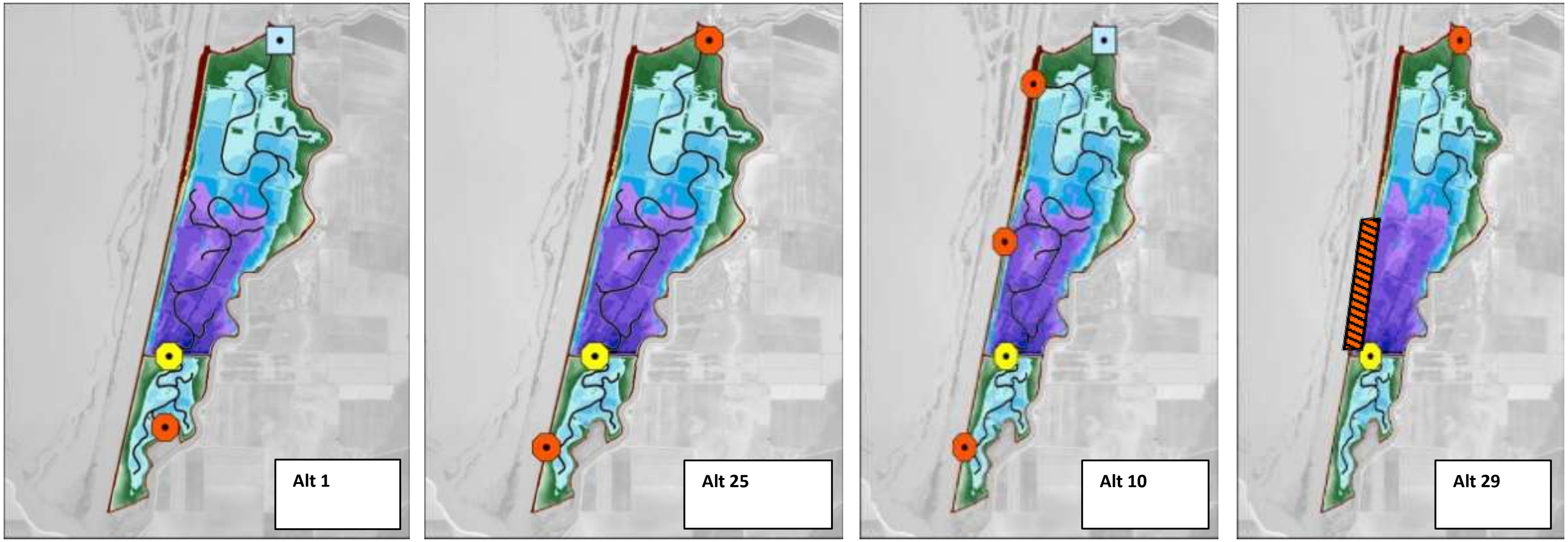


YOLO BASIN
SOLANO CO.
BASIN
YOLO
ca 1910

Alluvial topography

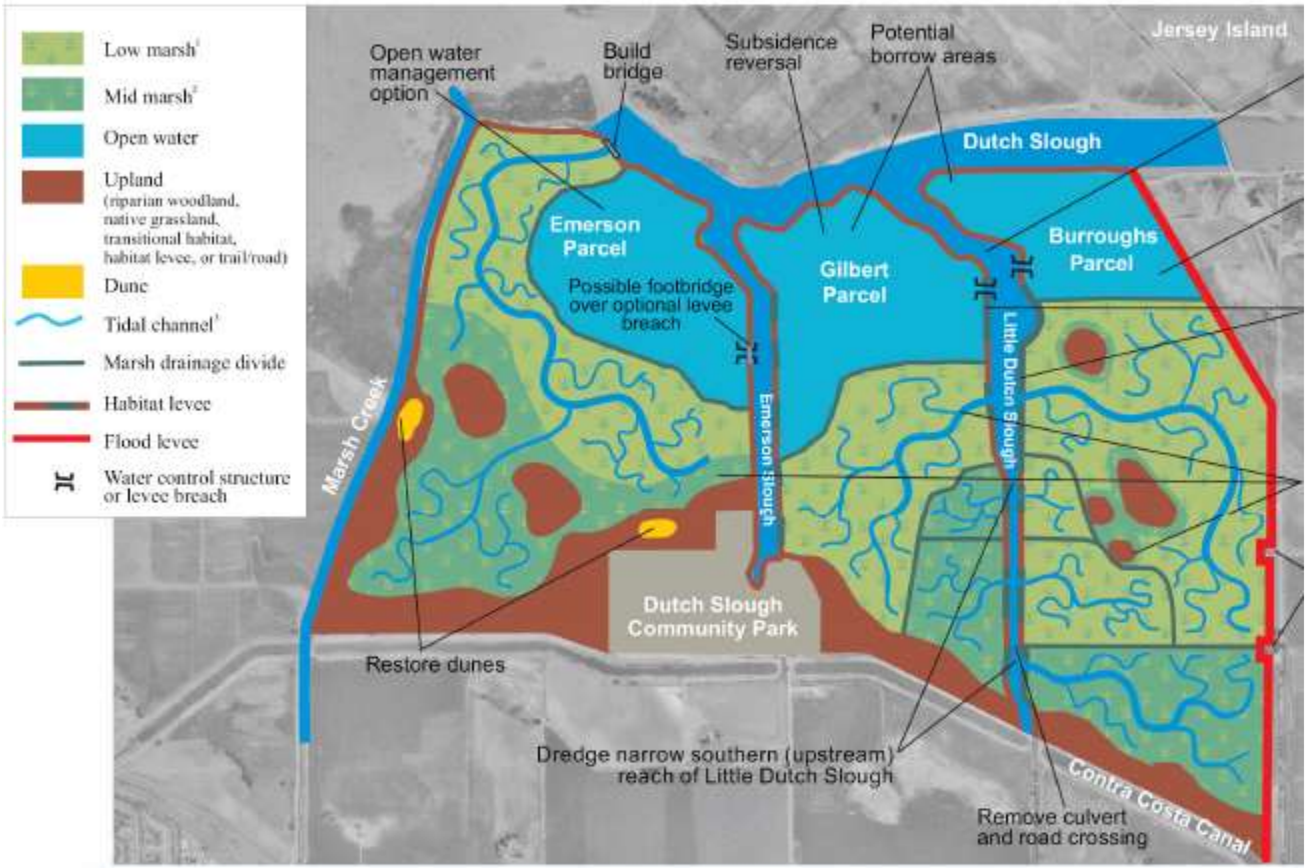


Prospect Island

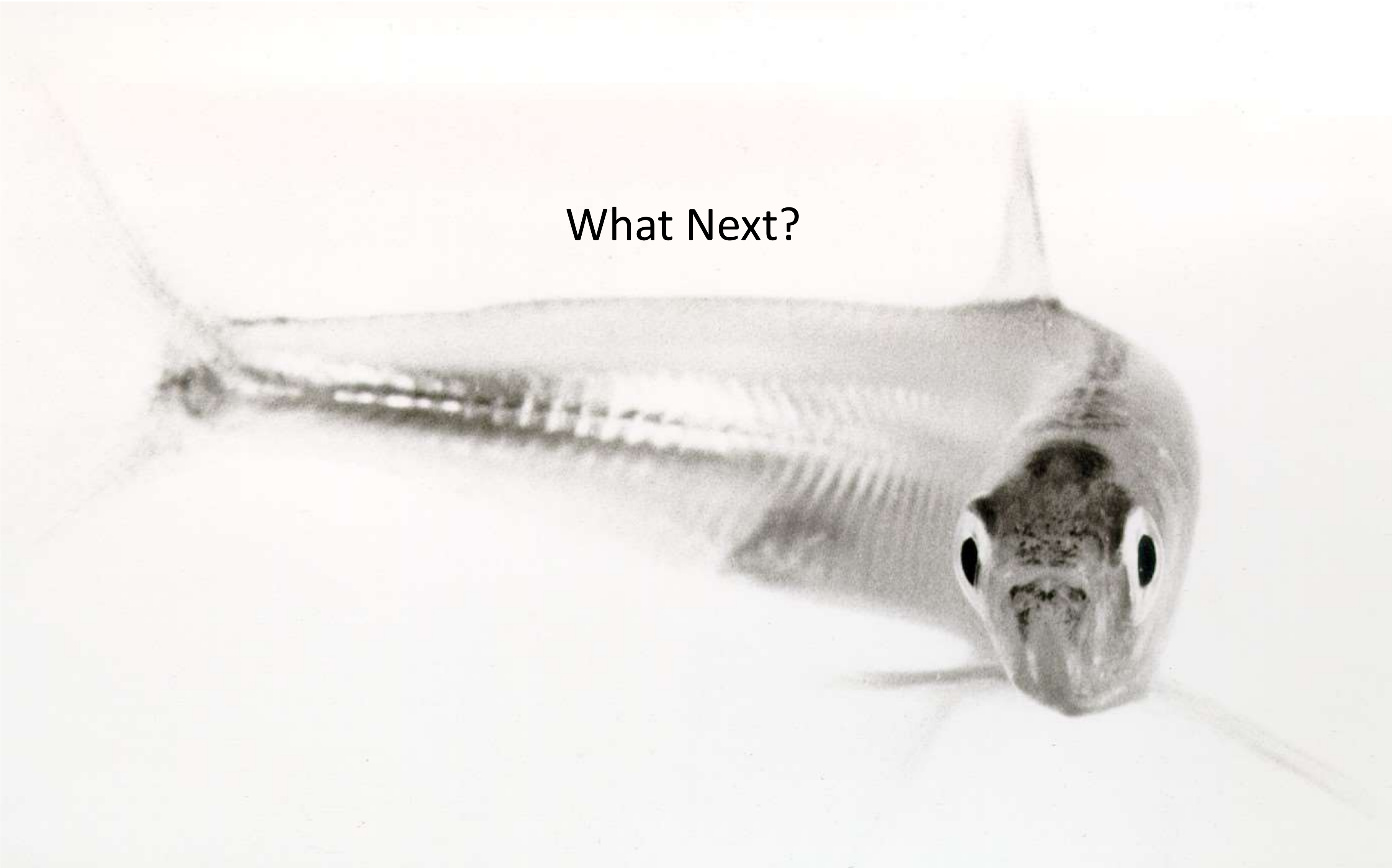


Thanks to Stuart Siegel, Carol Atkins and many other great folks on the Prospect Island project

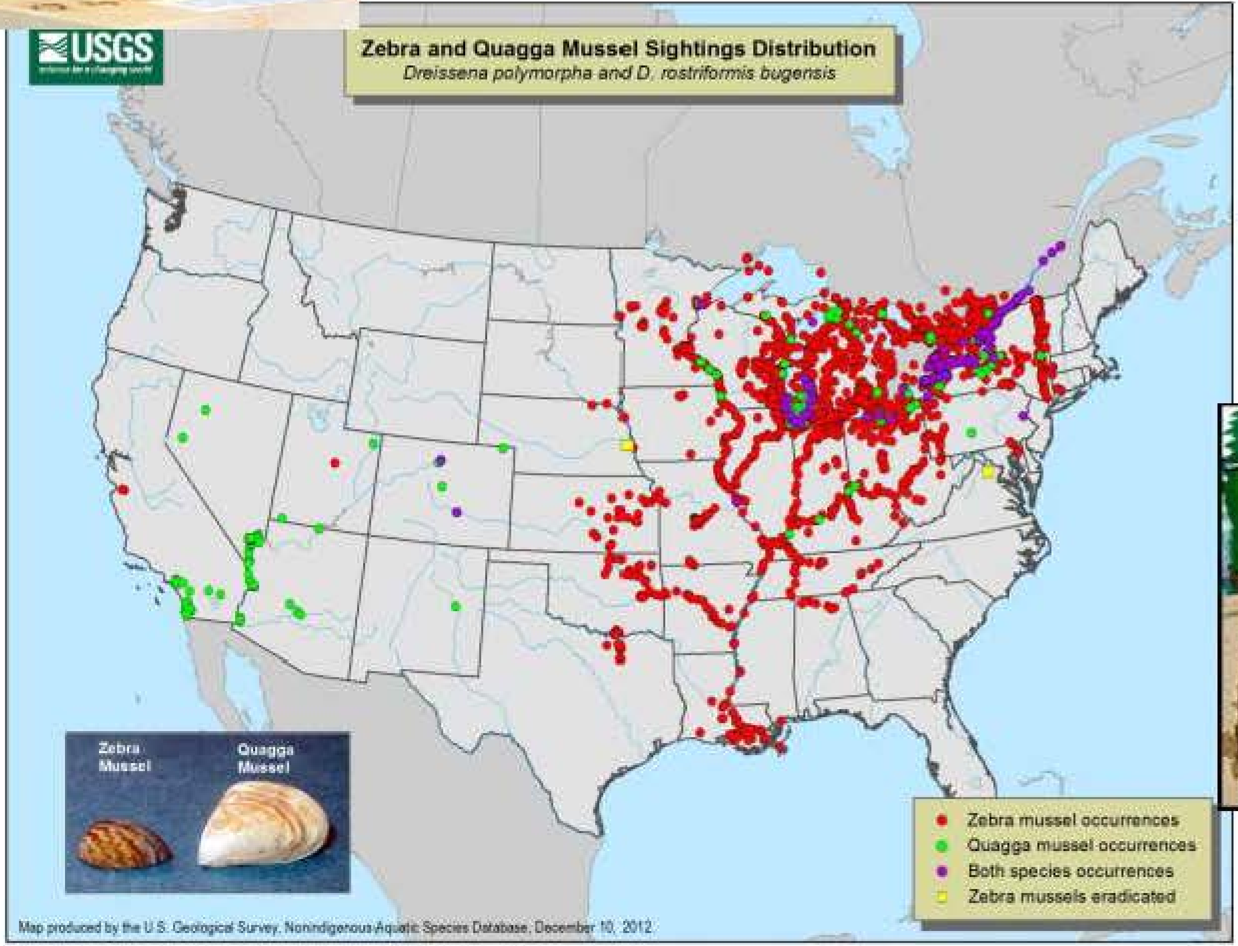
Dutch Slough



What Next?



Today?


USGS
Zebra and Quagga Mussel Sightings Distribution
Dreissena polymorpha and D. rostriformis bugensis
Zebra Mussel
Quagga Mussel
Zebra mussel occurrences
Quagga mussel occurrences
Both species occurrences
Zebra mussels eradicated
Map produced by the U.S. Geological Survey, Nonindigenous Aquatic Species Database, December 10, 2012

Earthquake or flood
64% chance in 50 years

1 M sea level rise in 100 years?