Linking Temporal and Spatial Data Sets for Hierarchical Bayesian Network Analysis and Prediction of Delta Smelt Populations

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The first of two presentations

Our Purpose

- A different predictive model, Bayesian Network Analysis, for delta smelt (and similar problems)
- Recommendations to improve sampling & routine monitoring
- Preliminary results ranking factors important to larval-juvenile delta smelt

The Delta Smelt Problem

- Abundance declined by 2 orders of magnitude this century
- On St/Fed Endangered Species lists
- Persistent record low levels
- Many regression-based analyses
- No prediction models to inform management

The Fish & Wildlife Manager and the Bank President

Fish & Wildlife Manager

- Numbers of Delta Smelt
- Multiple factors
- Factors act hierarchically
- Identify important factors

Bank President

- Probability of loan default
- Multiple factors
- Factors act hierarchically
- Identify important factors

The Fish & Wildlife Manager and the Bank President

Fish & Wildlife Manager

- Numbers of Delta Smelt
- Multiple factors
- Factors act hierarchically
- Identify important factors
- **No solution—fix everything that can be fixed**

Bank President

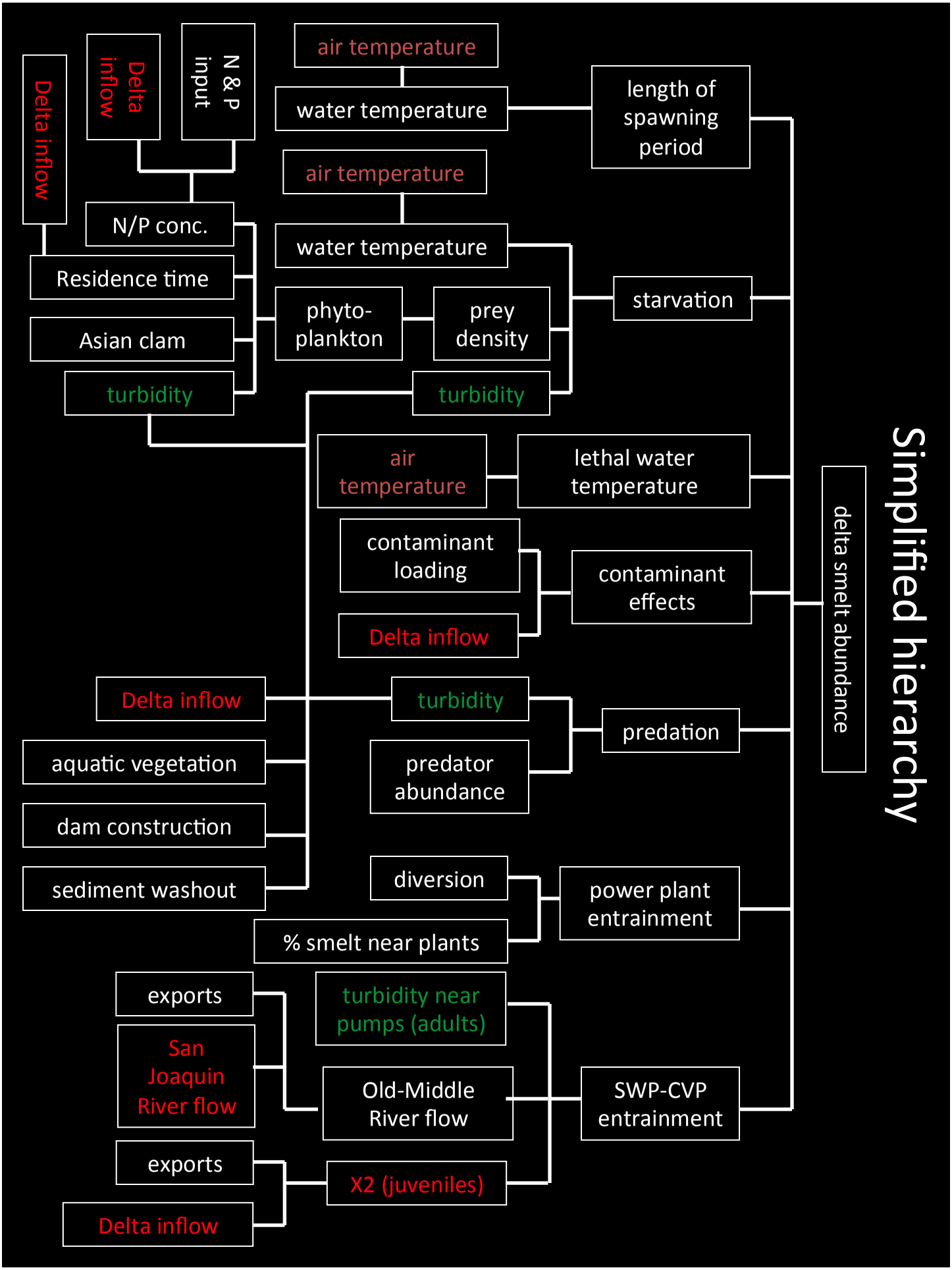
- Probability of loan default
- Multiple factors
- Factors act hierarchically
- Identify important factors
- **Solved using Bayesian methods—credit rating**

Method

- Initial focus on 20 mm survey (1995-2014)
  - Samples for important early life stages
  - Concurrent samples for zooplankton prey
  - Samples biweekly
- Identified possibly important factors
- Considered hierarchical influences
- Divided habitat into zones
- Allowed for time variance in relationships

How Does the Method Work?

- Experts collaboratively draw the influence diagram: BUGSAT
- Organize data
- Analyze influence diagram with data
- Modify the influence diagram based on expert opinion or analysis results
- Repeat until satisfied


Simplified hierarchy
delta smelt abundance
Delta inflow
Delta inflow
N & P input
N/P conc.
Residence time
Asian clam
turbidity
air temperature
water temperature
length of spawning period
air temperature
water temperature
phyto-plankton
prey density
starvation
turbidity
air temperature
lethal water temperature
contaminant loading
Delta inflow
contaminant effects
Delta inflow
turbidity
predator abundance
predation
aquatic vegetation
dam construction
sediment washout
diversion
% smelt near plants
power plant entrainment
exports
San Joaquin River flow
turbidity near pumps (adults)
Old-Middle River flow
SWP-CVP entrainment
exports
Delta inflow
X2 (juveniles)

Conceptual Model
Delta Smelt

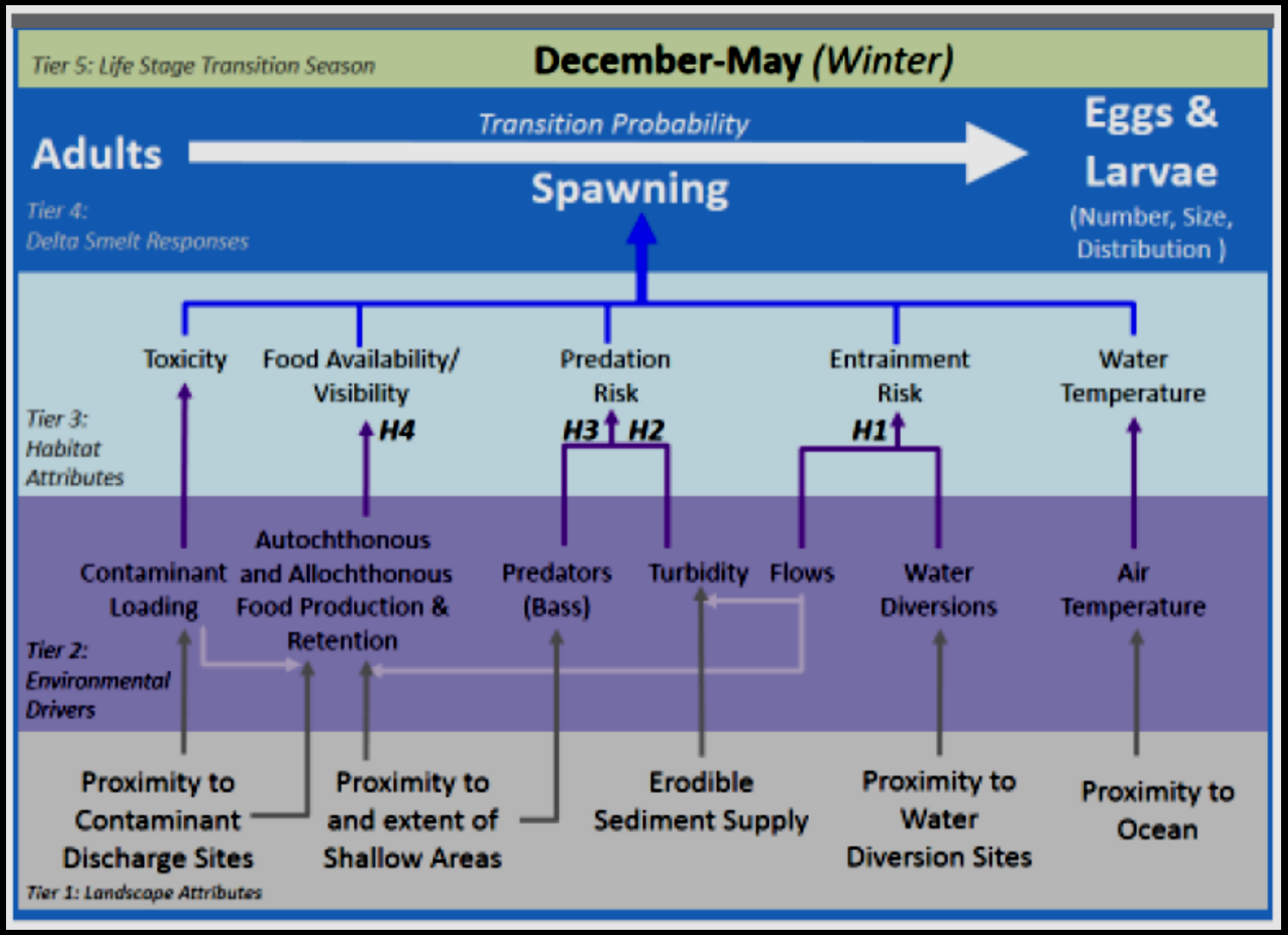
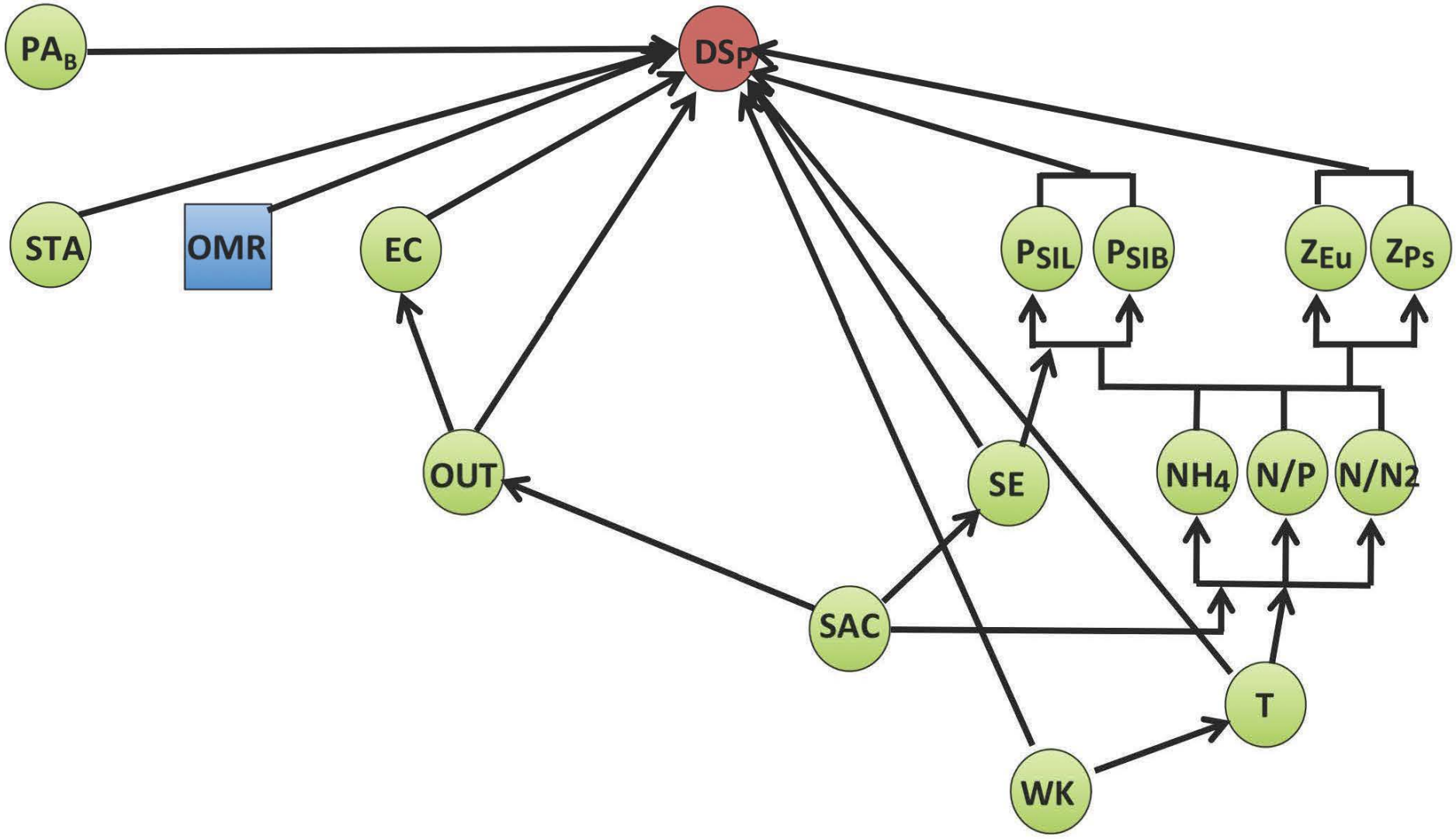


Chart from "Delta Smelt Resiliency Strategy"

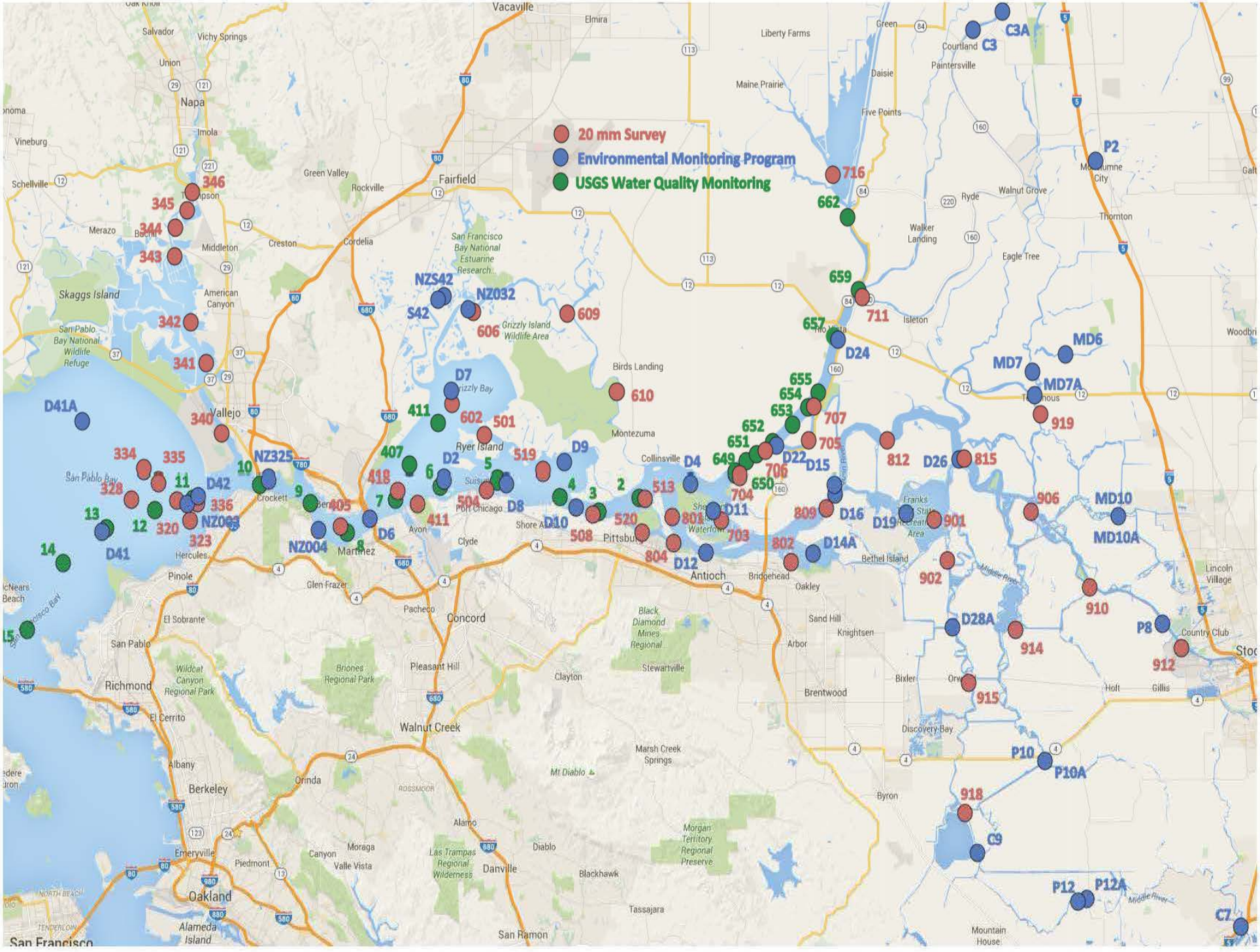
Influence Diagram



The Data Problem

Data Issues

- Missing data
- Sample dates and locations vary from survey to survey
- Sampling does not cover all important locations
- Important factors not sampled well


20 mm Survey
Environmental Monitoring Program
USGS Water Quality Monitoring
Vacaville
Elmira
Liberty Farms
Courtland
C3
C3A
Paintersville
Daisie
Maine Prairie
Five Points
Green
Napa
Salvador
Vichy Springs
Union
Imola
Vineburg
Schellville
Green Valley
Rockville
Fairfield
Merazo
Bocni
Middleton
Creston
Cordelia
Skaggs Island
American Canyon
San Pablo Bay National Wildlife Refuge
San Francisco Bay National Estuarine Research
Grizzly Island Wildlife Area
Birds Landing
Montezuma
Ryer Island
Suisun Bay
Collinsville
Port Chicago
Shore Area
Avon
Clyde
Martinez
Vallejo
Crockett
Hercules
Pinole
Glen Frazer
Pacheco
Concord
El Sobrante
San Pablo
Richmond
Wildcat Canyon Regional Park
El Cerrito
Briones Regional Park
Pleasant Hill
Walnut Creek
Albany
Berkeley
Orinda
Emeryville
Piedmont
Oakland
Alameda Island
San Francisco
Moraga
Canyon
Valle Vista
Las Trampas Regional Wilderness
Alamo
Danville
Diablo
Blackhawk
Tassajara
San Ramon
Mt Diablo
Marsh Creek Springs
Morgan Territory Regional Preserve
Byron
Discovery Bay
Brentwood
Oakley
Bridgehead
Antioch
Bethel Island
Pittsburg
Black Diamond Mines Regional
Stewartville
Clayton
Sand Hill
Knightsen
Arbor
Bixler
Holt
Gillis
Lincoln Village
Country Club
Stockton
Middle River
Mountain House
Isleton
Walnut Grove
Ryde
Eagle Tree
Thornton
Woodbridge
Lodi
Galt
Franks Tract State Recreation Area
Mokelumne City
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D15
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D14A
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NZ004
NZ325
NZ068
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MD10
MD10A
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D28A
P8
MD6
MD7
MD7A
919
P10
P10A
918
C9
P12
P12A
C7

Conclusions

- Analyze with method that is appropriate for
  - Hierarchical influences
  - Varying relationships over years
  - Varying relationships by zones
- Lamination is necessary, but not ideal
- Obvious requirements for routine monitoring
  - Extend historical records
  - Sample where Delta Smelt are
  - Sample simultaneously for all potentially important factors

Conclusion

Bayesian Network Analysis

- Is collaborative
- Has been extensively used to solve important problems
- Requires sophisticated, well-developed analytical methods
- Offers the possibility of converting the hopelessly complex problem to Delta Smelt into a simpler problem