

Water Quality Trends in along the Central Coast of California

Marc Los Huertos
Carol Shennan,
Center for Agroecology &
Sustainable Food Systems
UC Santa Cruz

Monterey Bay Surface Waters: Headwaters, lowland streams, coastal wetlands

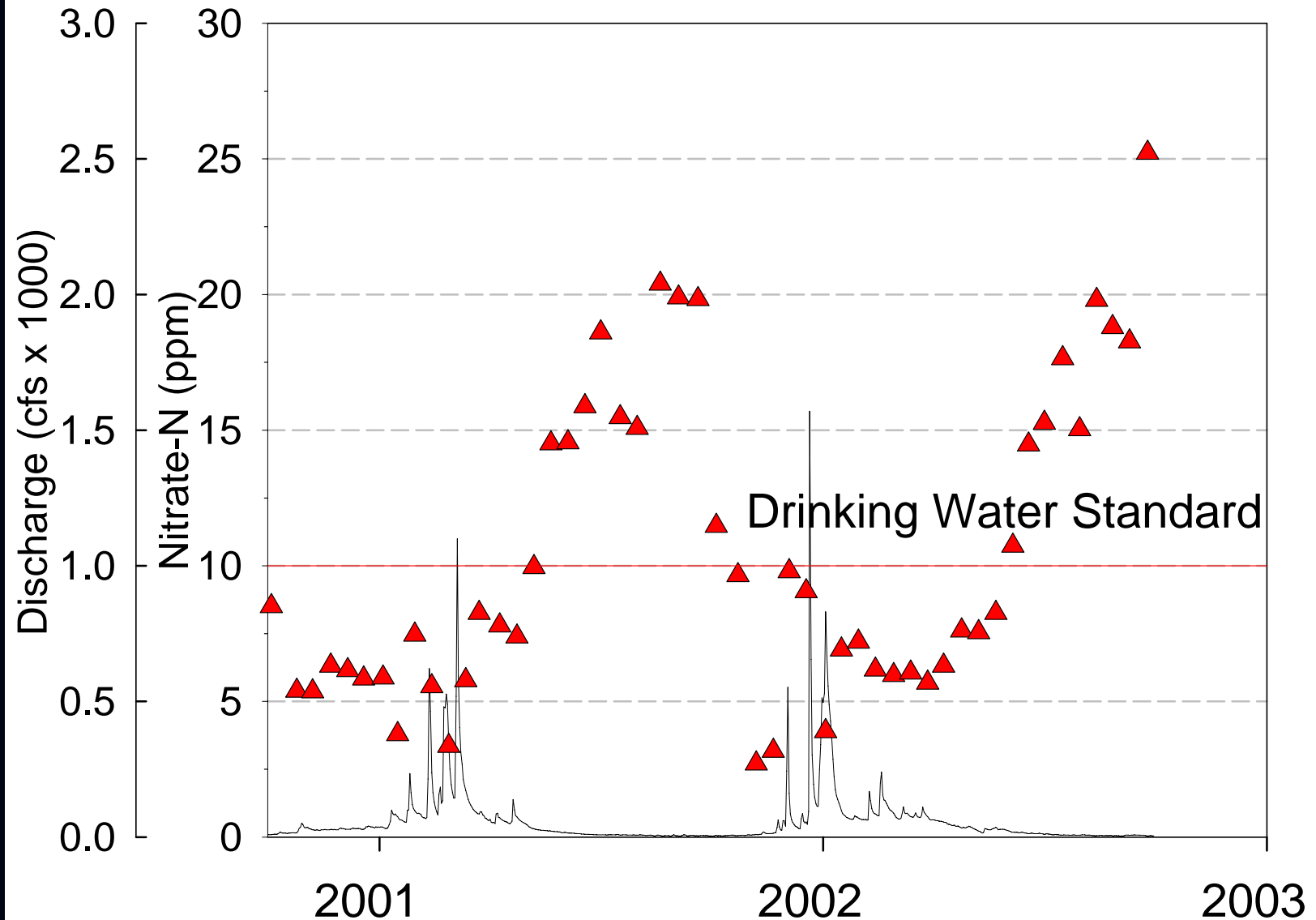
- Pajaro River is impaired by nitrate contamination
- Numeric standard is based on the drinking water standard
- Stakeholder conflict concerning the source of these elevated nitrate concentrations



Conclusions concerning the Pajaro River and Elkhorn Slough

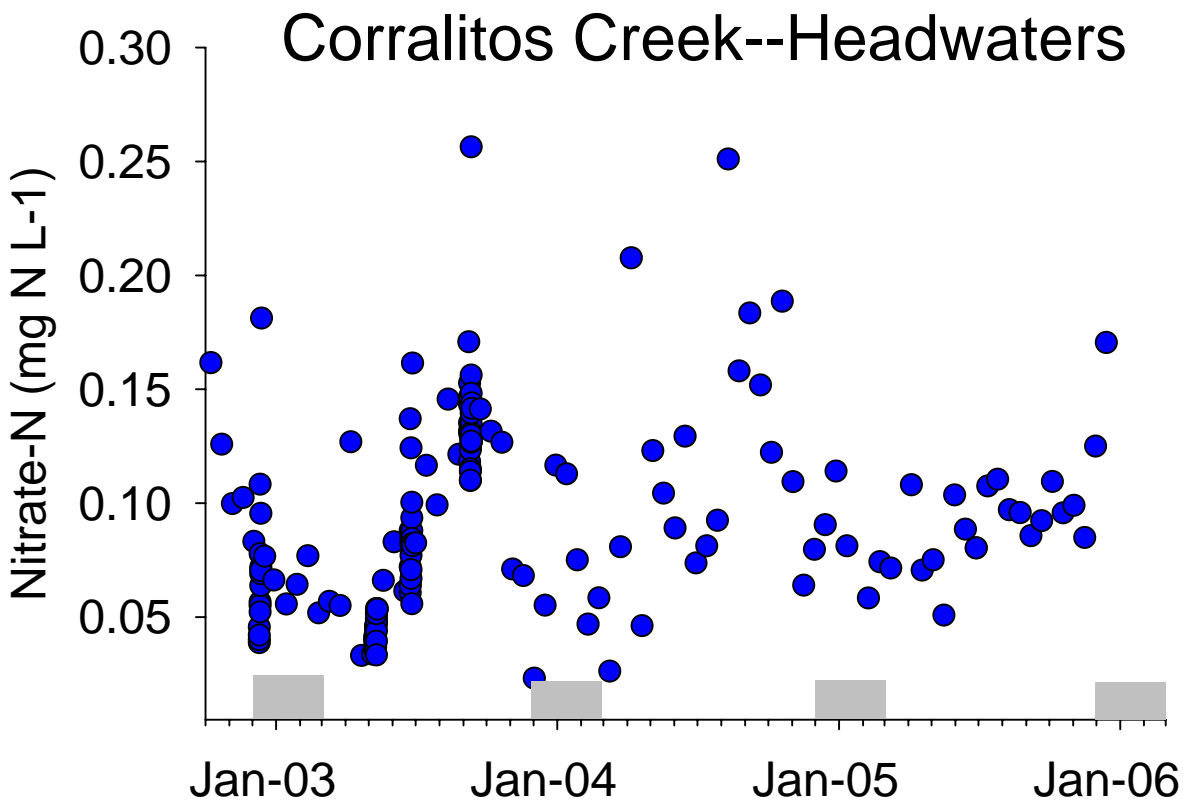
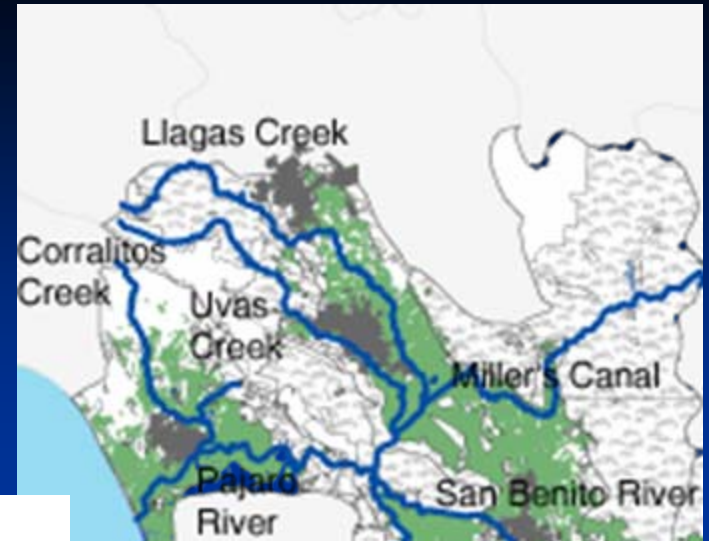
- Nitrate concentrations are elevated
- Sources of Nitrate are derived from row crops but there is a great deal of variation
- Nitrate concentrations in the region are increasing and some monitoring plans can detect these changes
- Real-time nitrate sampling may provide important information regarding elevated nutrient concentrations.

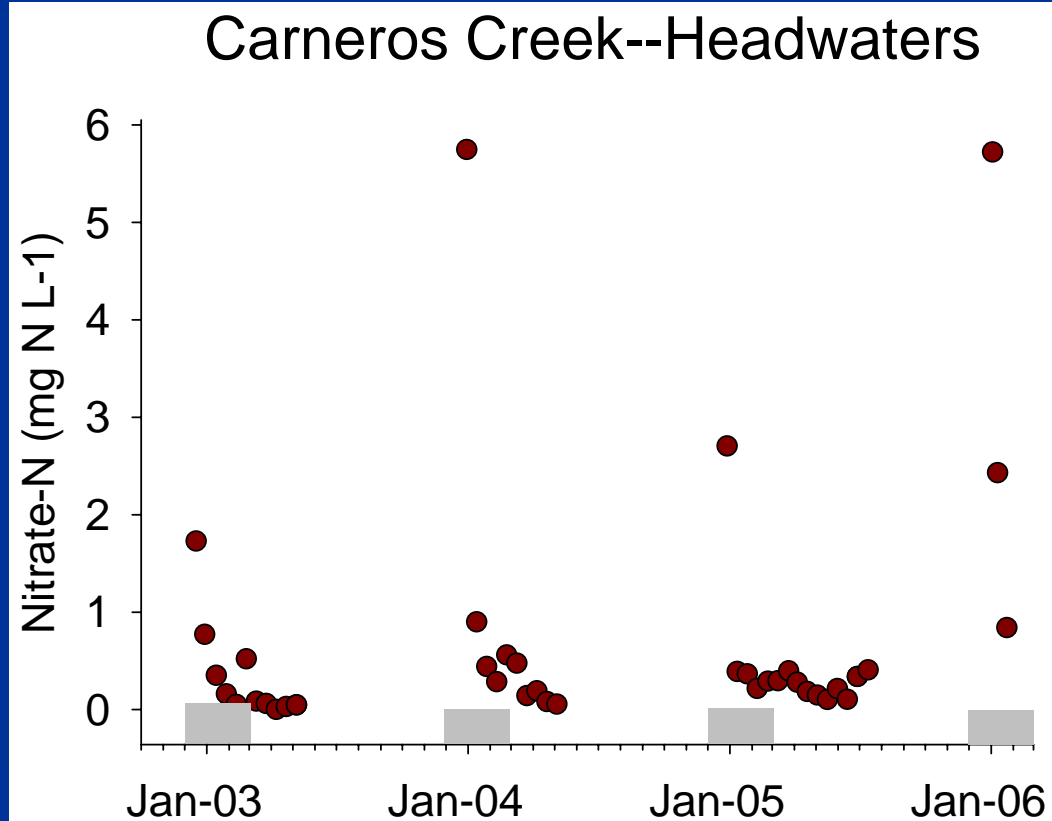
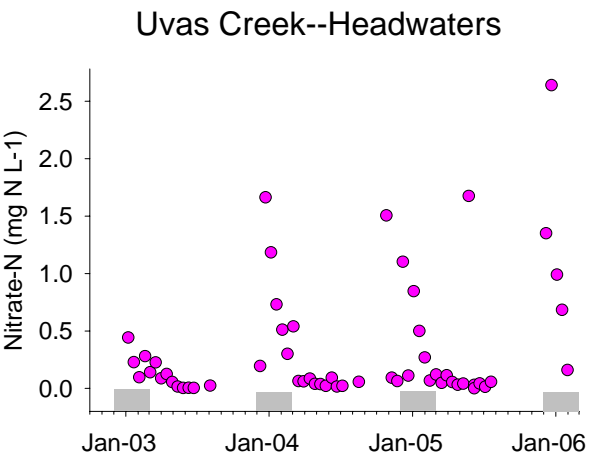
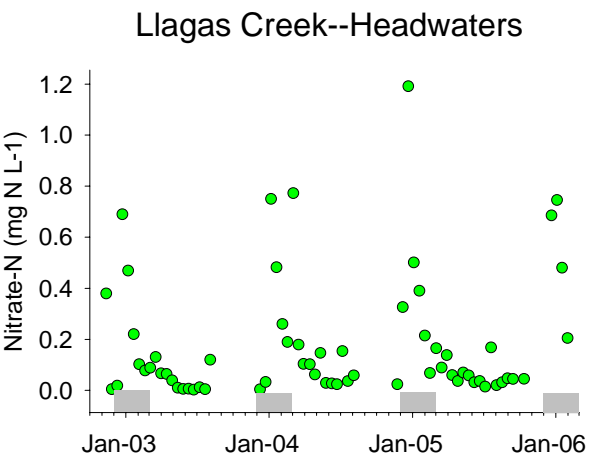
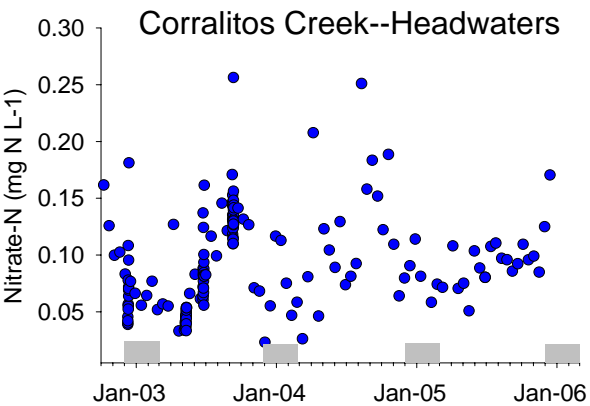
Nitrate and Discharge in the Pajaro River



Headwaters

- Are headwater sources of nitrate in the watershed?
 - Grazing, silvaculture, protected open space
 - Atmospheric deposition
 - Natural sources
- Are there seasonal patterns that explain the elevated nitrate concentrations in the Pajaro?





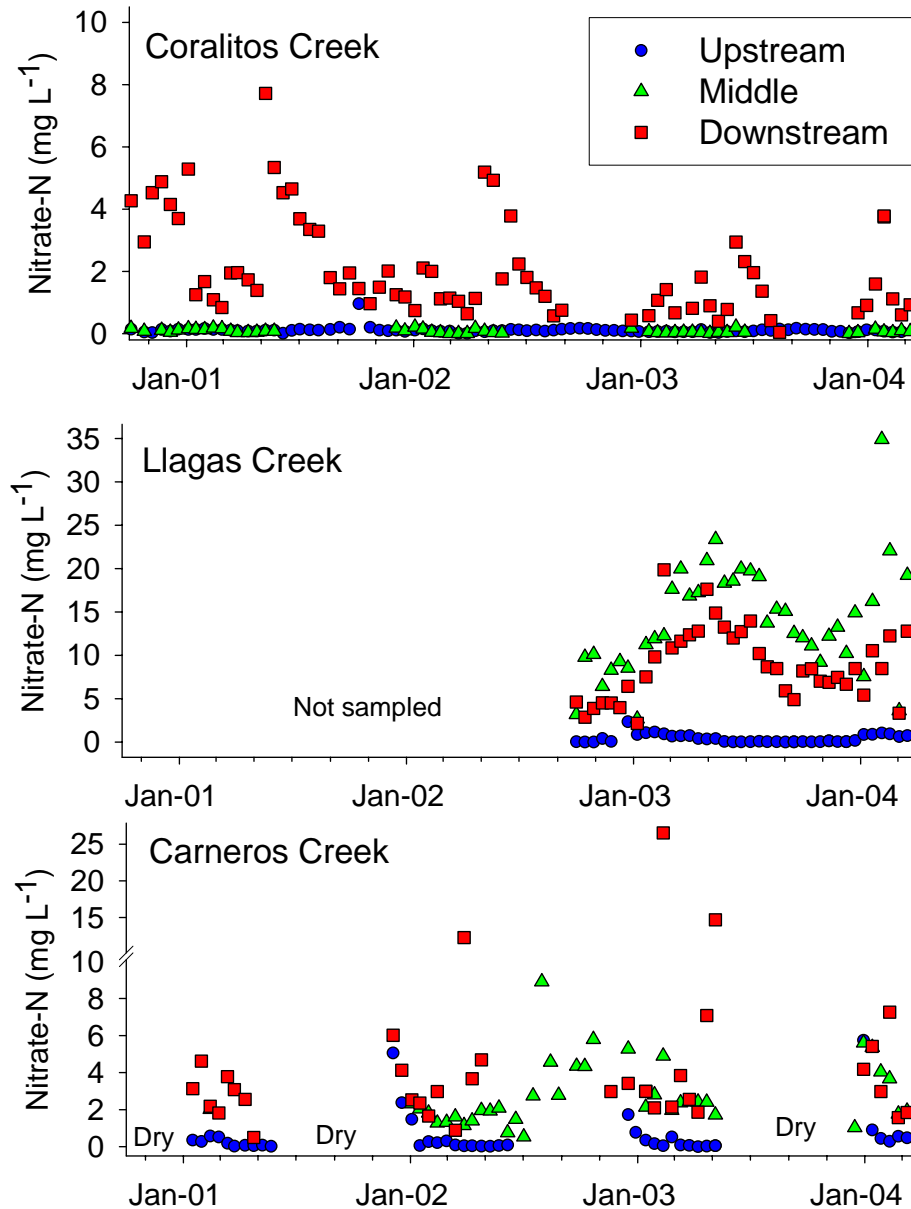
Headwater Nitrate

- Some variability by sub-watershed
- Concentrations tend to be low during the rainy season
- Inland areas have highest concentrations after the rainy season has begun

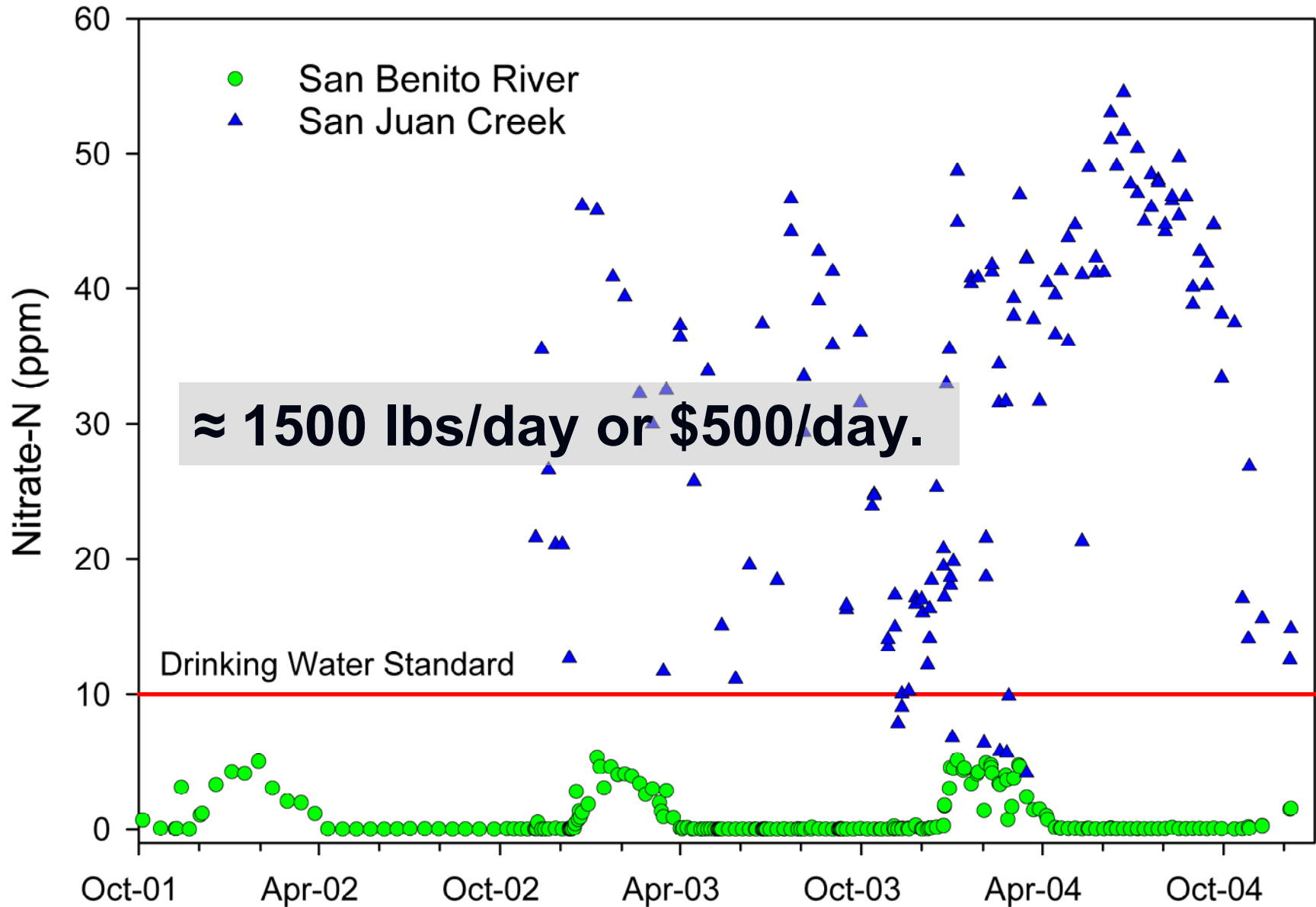
Lowland Nitrate Concentration

- Multiple land uses
 - Suburban
 - Rural/ranchettes (septic)
 - Orchard crops
 - Row crops
- Upstream and Downstream Sampling of Discrete land use types

Upstream and Downstream of Agriculture



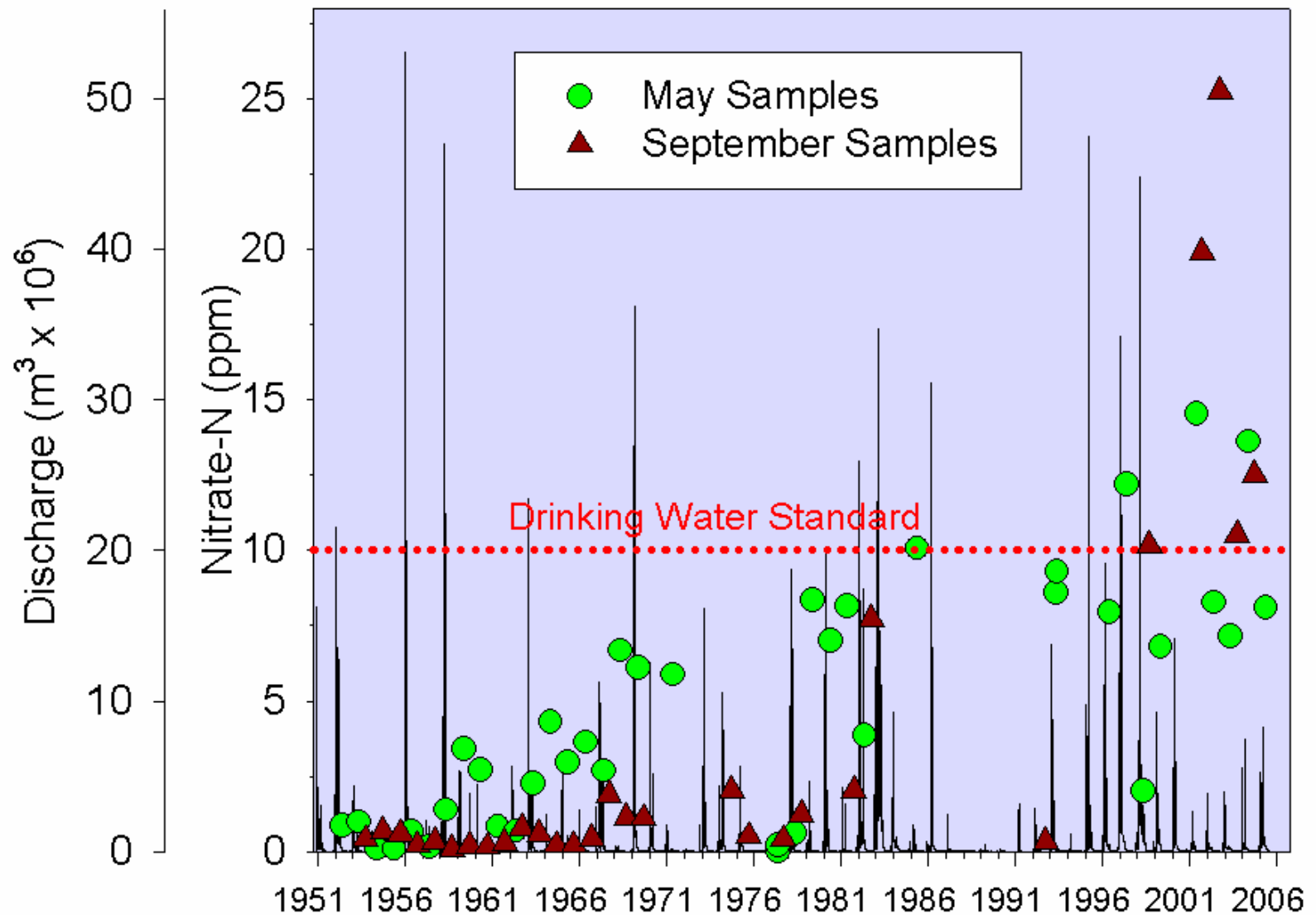
Nitrate Concentrations in Surface Waters Draining San Juan Valley



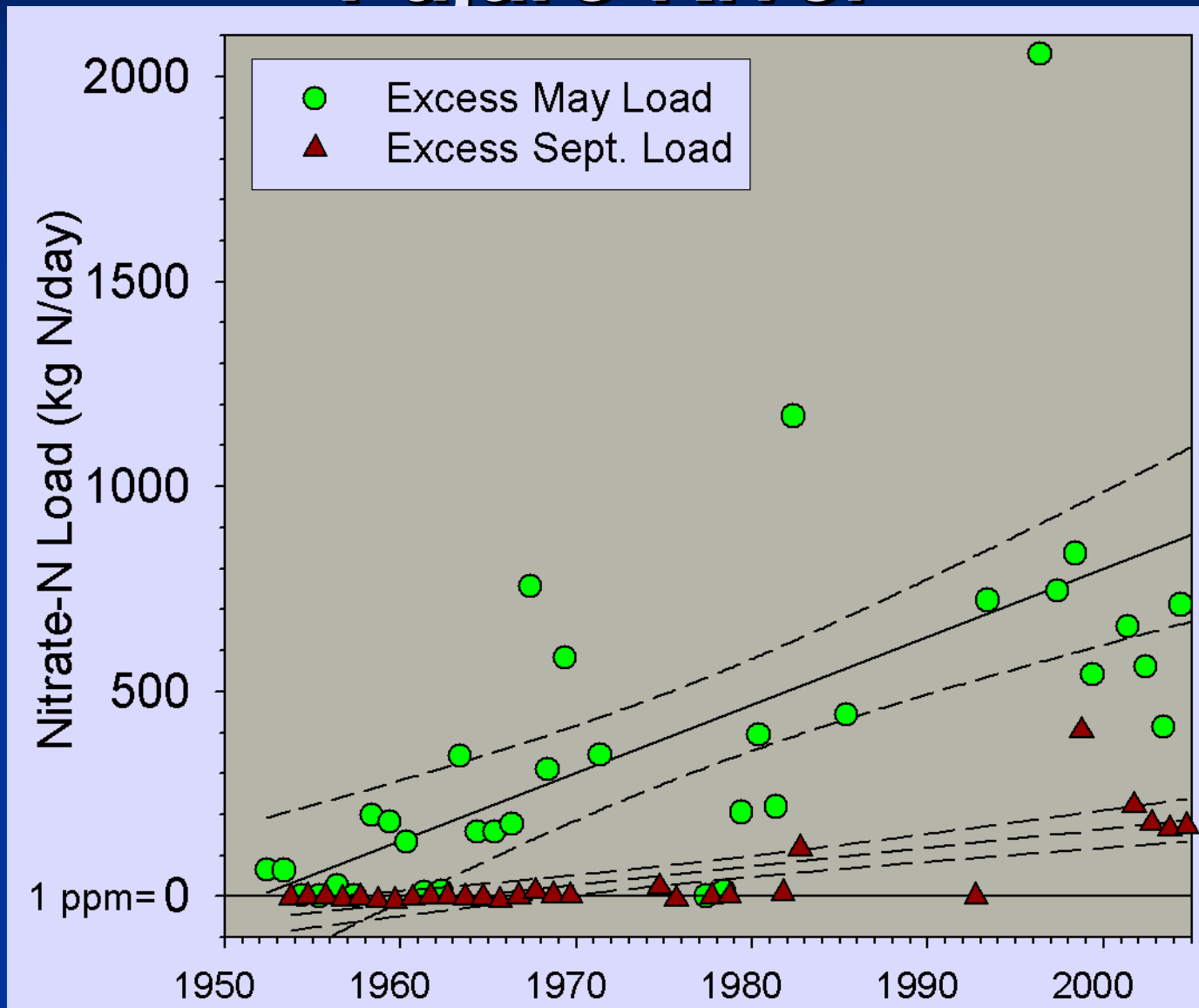
Can We Detect Changes?

- Time series data are limited
- Temporal and Spatial autocorrelation

Patterns of Nitrate in the Pajaro River



Changes in Nitrate Load in the Pajaro River



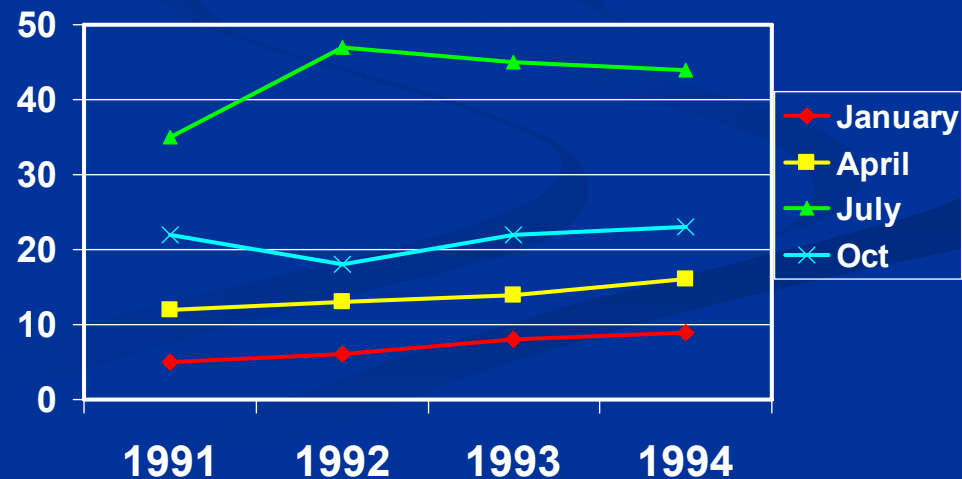
Elkhorn Slough Water Quality Monitoring (1989-present)

- 24 sites sampled on a monthly basis and analyzed for conventional constituents.
 - temperature
 - conductivity
 - dissolve oxygen
 - pH
 - ammonium
 - nitrate
 - ortho-phosphorous
- Non-normal, time series data



Seasonal Kendall Test

- Time series data
 - Non-parametric test of slope
 - Seasonality is taken into account (each season has a separate slope)
 - Slopes are combined and the median slope is tested for its significance.



Nitrate Changes in Elkhorn Slough

Result: 12 sites out of 24 show an increasing trend

However...

- changing laboratories
- changes in detection limit
- method interference with matrix
- poorly documented QA/QC

- No Trend
- Increasing Concentration



Logistic Regression

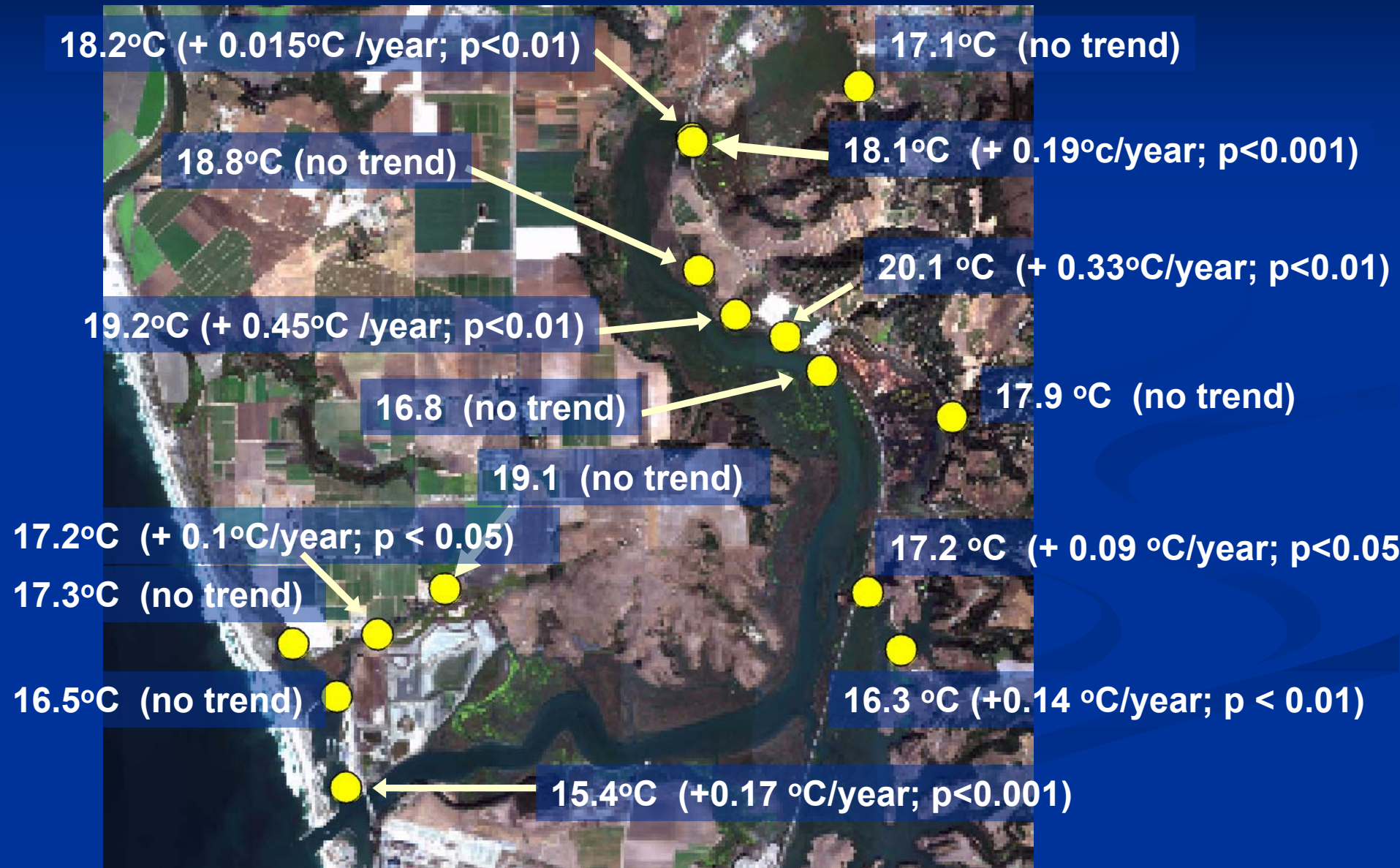
- Changes in the incidence of changed of a threshold (1 mg N L^{-1})
- Odd ratio and associated probability, suggest relative strength of change
 - e.g. at Potrero Road, there is a 4:1 chance that nitrate concentrations are increasing above 1 mg N L^{-1} /16-year period.

Nitrate Changes (con't)

- 9 sites had an increase in nitrate concentrations above 1 mg N L⁻¹ over the sampling period.

Is there a more satisfying approach?

Elkhorn Slough Estuary and Long-term temperature changes

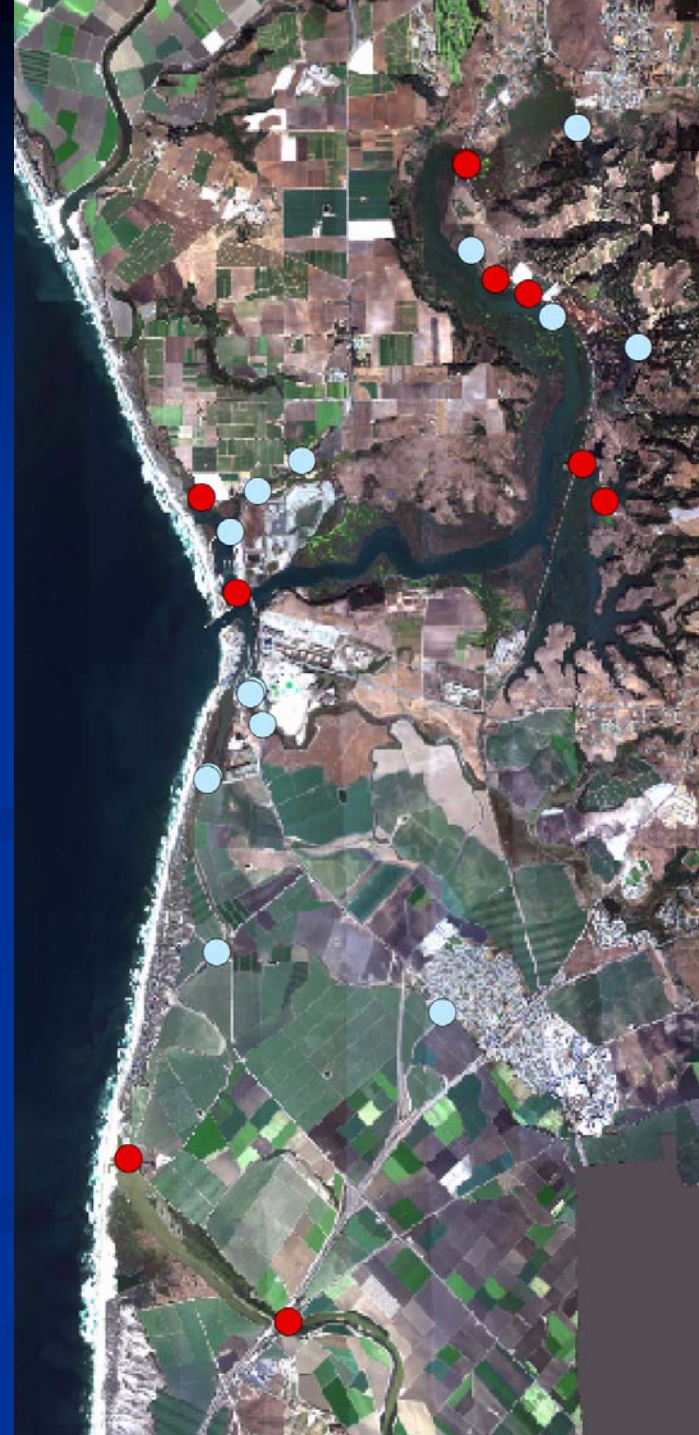


Elkhorn Slough Temperature Changes (1989-2005)

- 12 sites no trend
- 12 sites with significant increase in temperature with a Seasonal Kendall test.

Is there an alternative model that could include spatial information 16 years of data?

- No Trend
- Increasing Temperatures



Time Series Analysis

- Dynamic models
 - Incorporate seasonality
 - Non-stationary
 - Robust results with autocorrelation
 - Constrained with missing data
- Elkhorn Slough May affect

An alternative approach

- Coastal and inland pattern
- Allow pattern to change with time
- Station Temp=
inland monthly pattern and coastal monthly pattern
Inland long-term change and coastal long-term change

$$\mathbf{x}_{m,y}(\mathbf{s}) = \alpha(\mathbf{s})\boldsymbol{\eta}_m^{(i)} + (1 - \alpha(\mathbf{s}))\boldsymbol{\eta}_m^{(c)} + \beta(\mathbf{s})\mathbf{y}_m^{(i)} + (1 - \beta(\mathbf{s}))\mathbf{y}_m^{(c)} + \lambda_t + \varepsilon_{m,y}(\mathbf{s})$$

An alternative approach

- Coastal and inland pattern
- Allow pattern to change with time
- Station Temp=
 - inland monthly pattern and coastal monthly pattern
 - Inland long-term change and coastal long-term change
 - Station weighting factor for inland/coastal patterns

$$x_{m,y}(s) = \alpha(s)\eta_m^{(i)} + (1 - \alpha(s))\eta_m^{(c)} + \beta(s)\gamma_m^{(i)} + (1 - \beta(s))\gamma_m^{(c)} + \lambda_t + \varepsilon_{m,y}(s)$$

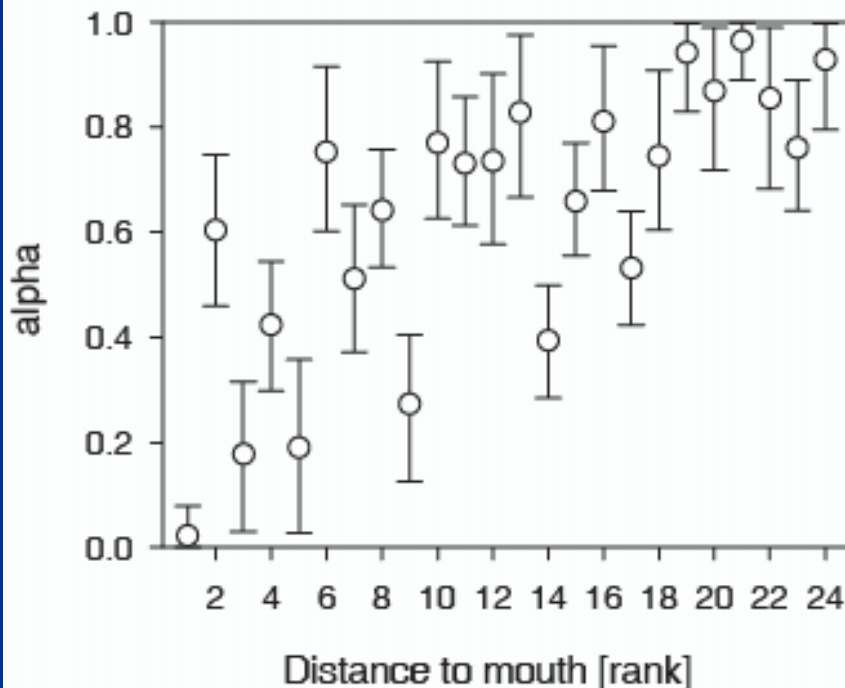
An alternative approach

- Coastal and inland pattern
- Allow pattern to change with time
- Station Temp=
 - inland monthly pattern and coastal monthly pattern
 - Inland long-term change and coastal long-term change
 - Station weighting factor for inland/coastal patterns
 - Short-term temperature variation
 - Random noise

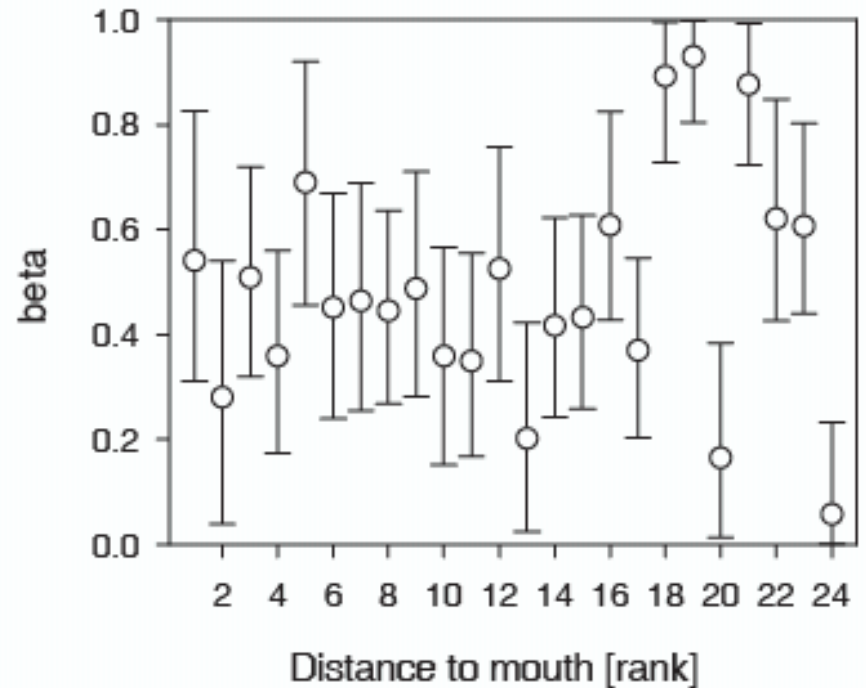
$$x_{m,y}(s) = \alpha(s)\eta_m^{(i)} + (1 - \alpha(s))\eta_m^{(c)} + \beta(s)\gamma_m^{(i)} + (1 - \beta(s))\gamma_m^{(c)} + \lambda_t + \varepsilon_{m,y}(s)$$

Coastal and Inland Weights

Monthly Pattern Weight

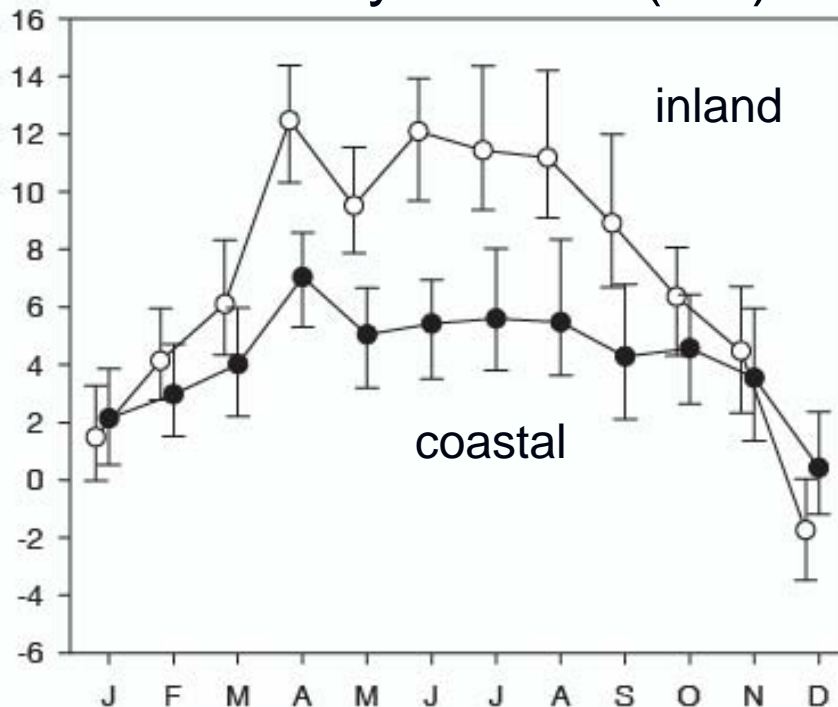


Long-term Monthly Weight

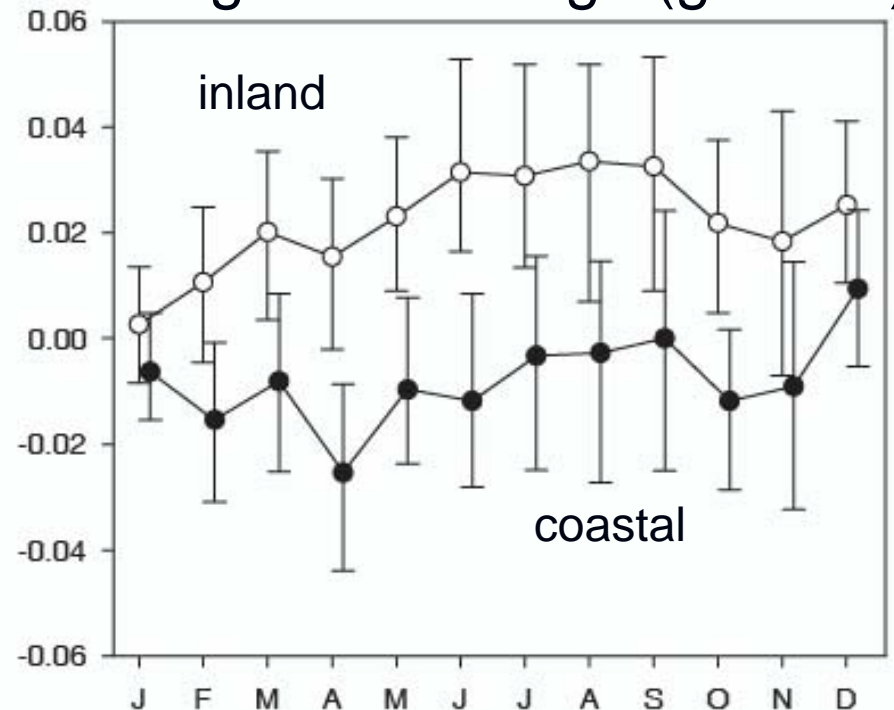


Monthly Pattern and Long-term Temperature Change

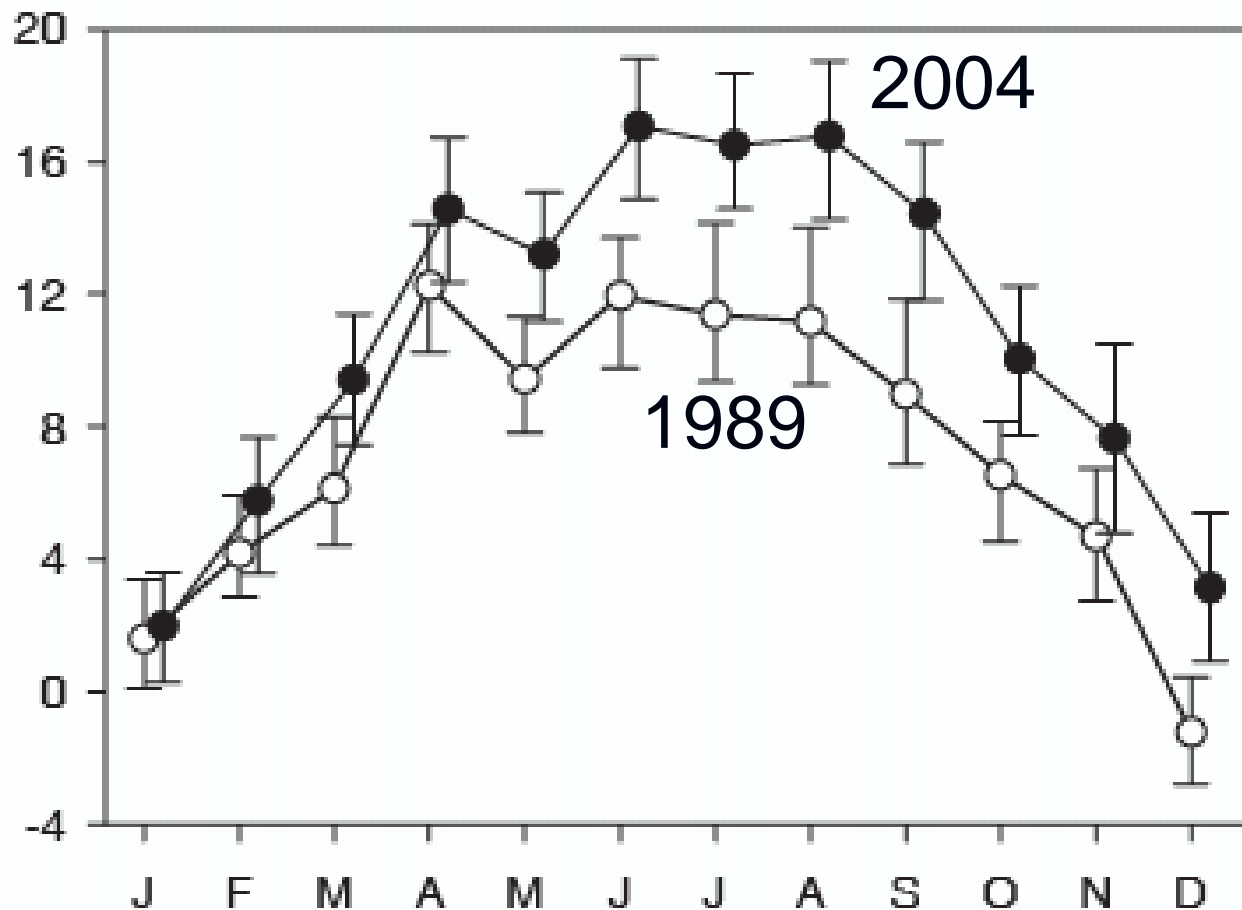
Monthly Pattern (eta)



Long-term Change (gamma)

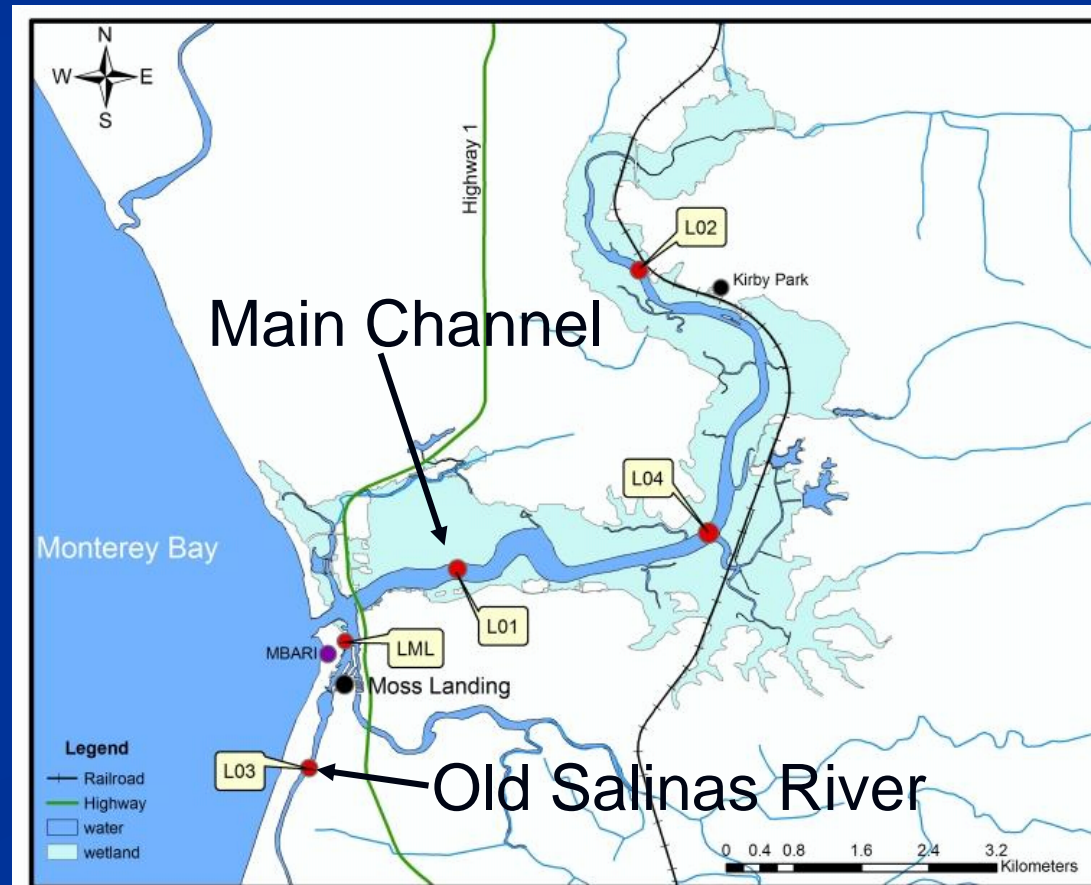


Elkhorn Slough Temperatures have an increasing marine influence

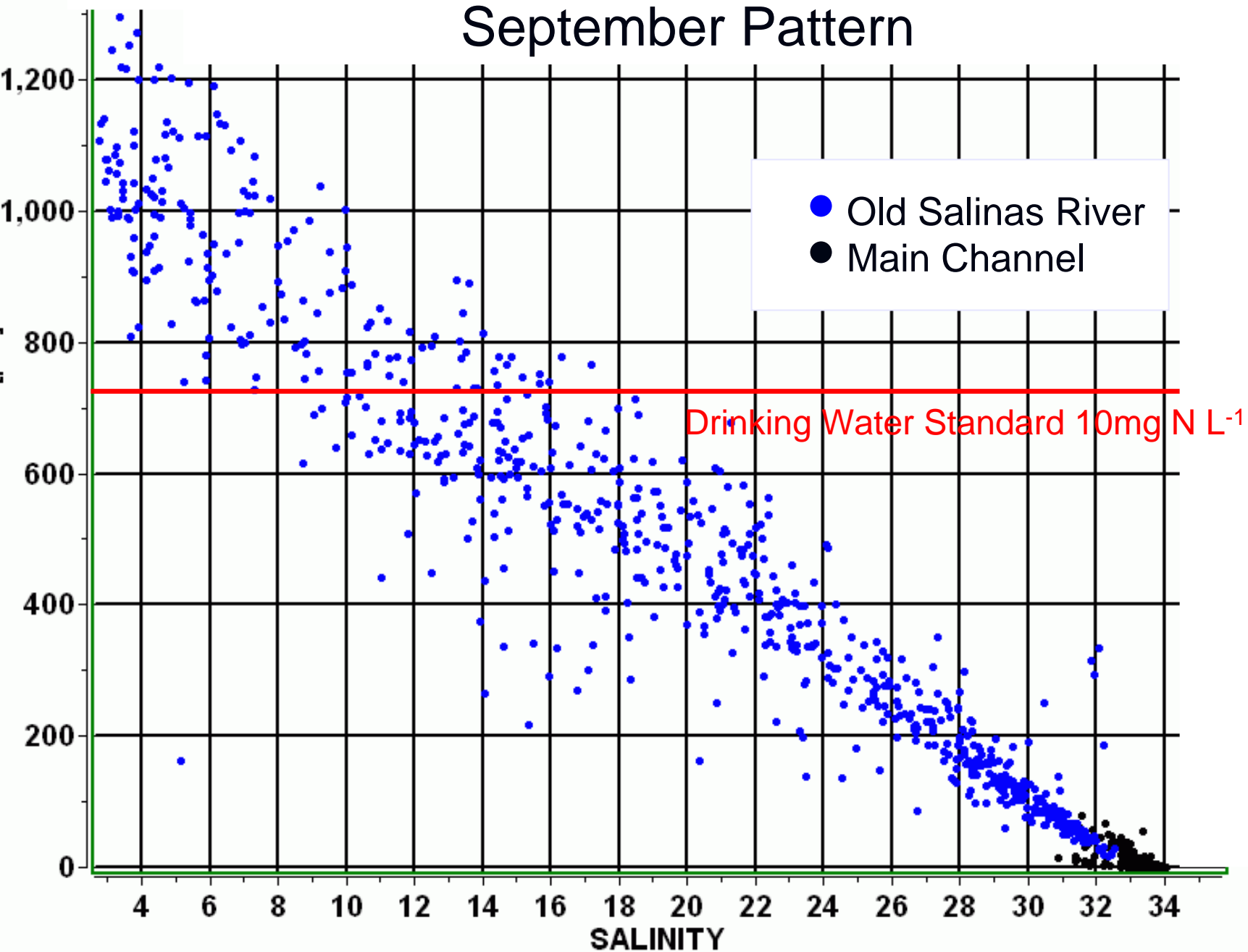


Real Time Water Quality Data

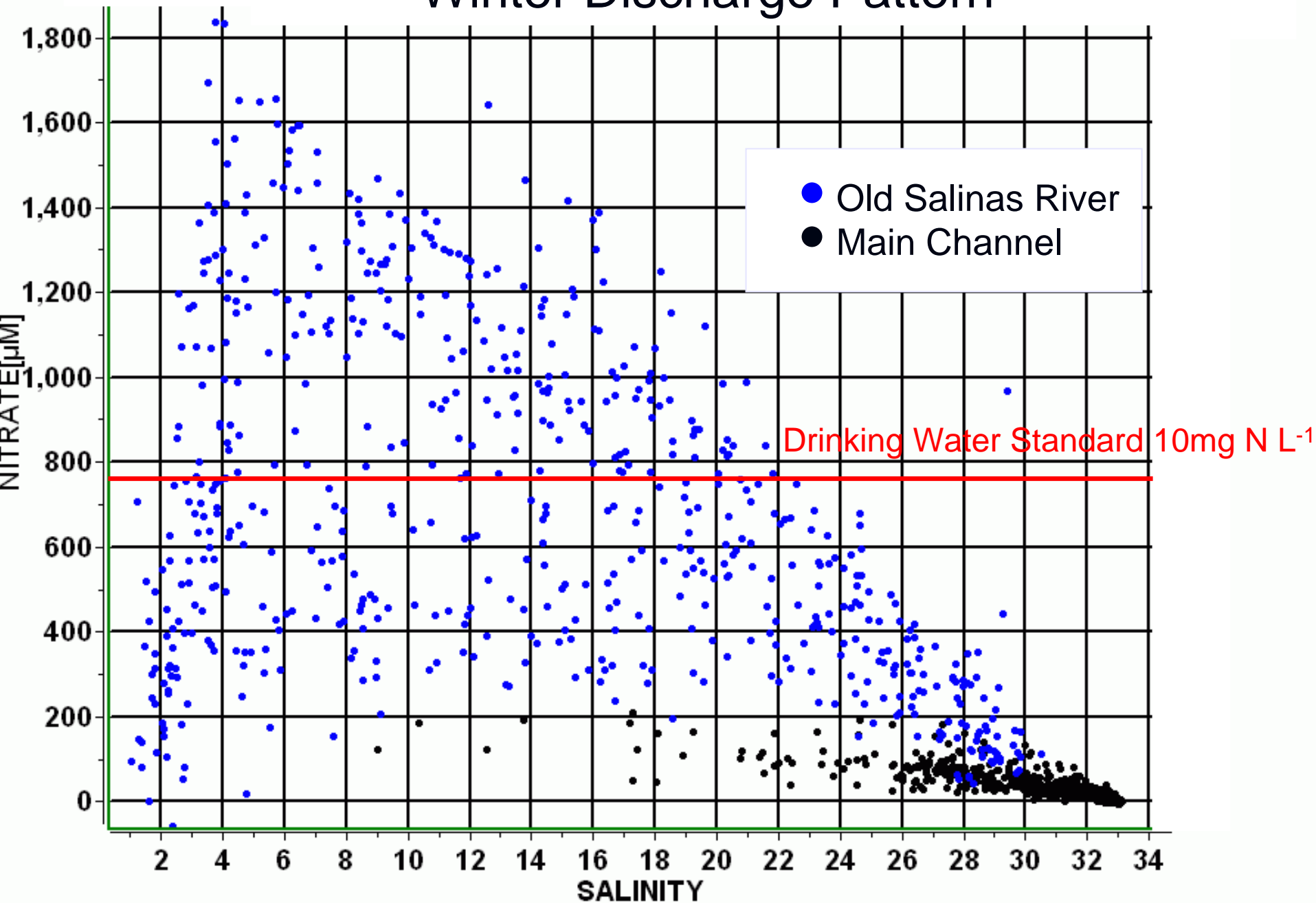
- Four buoys located in Elkhorn Slough
- Radio transmitter
- In Site nitrate analyzer



September Pattern



Winter Discharge Pattern



Summary

- Nutrient concentrations are elevated and increasing along the central coast
- Long-term changes are difficult to gauge in complex systems like estuaries, but combining spatial and temporal data significant patterns can be found
- Real-time water quality methods can be use to capture spatial and temporal patterns of nutrient loads

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