Lower Columbia Estuary Partnership

# Multivariate Analysis of Ecosystem Monitoring Data 2011-2013

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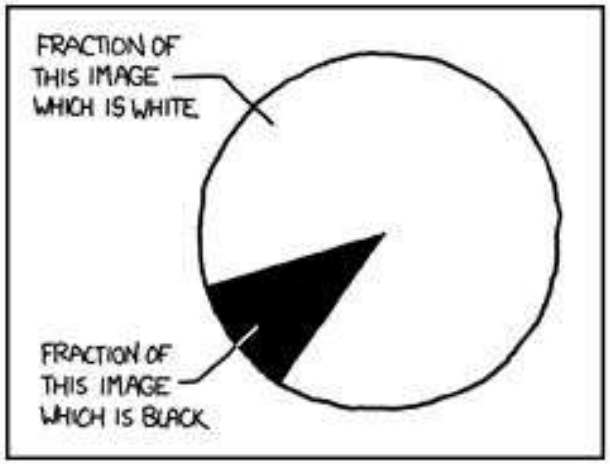
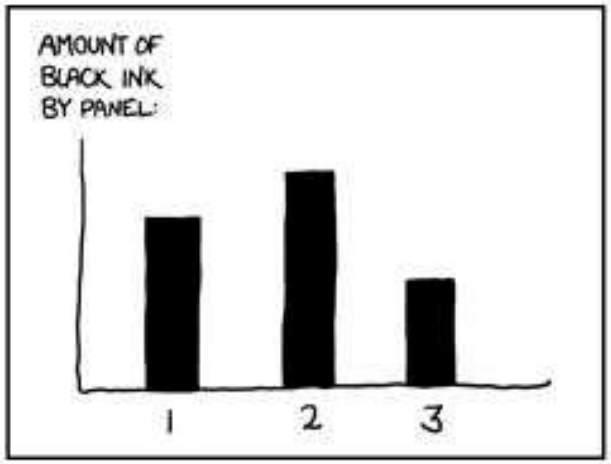
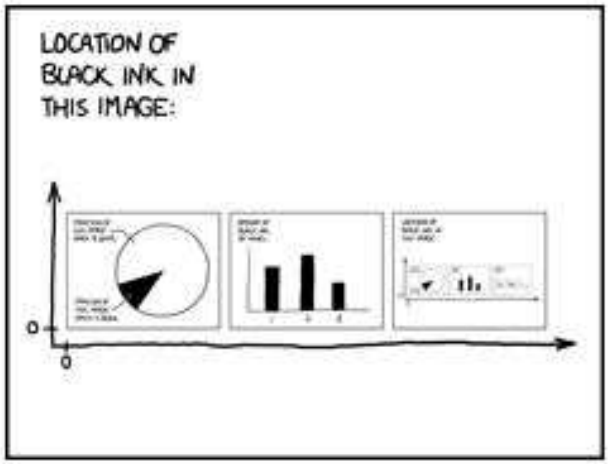
1-27-2014



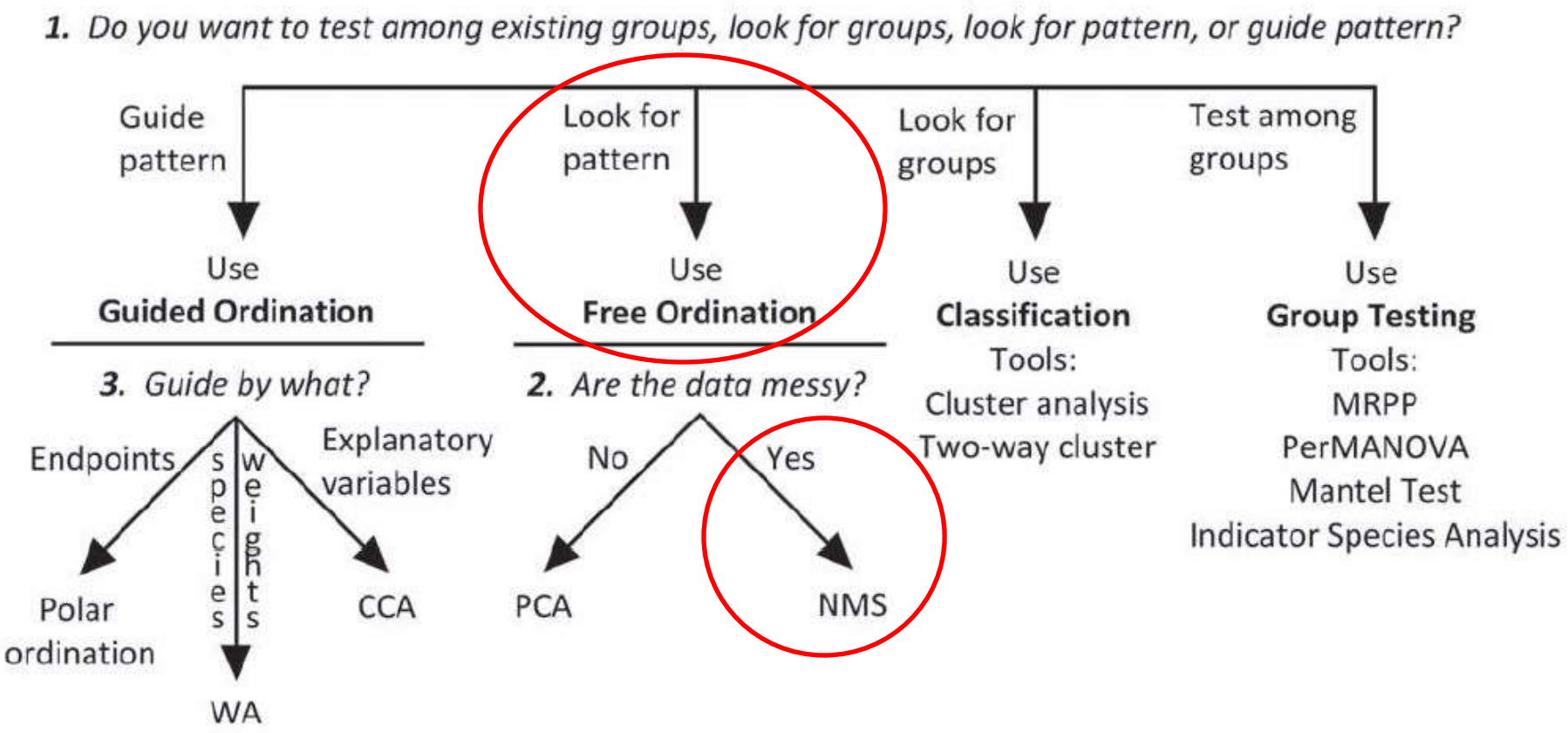

XKCD 1/2014
http://xkcd.com/688/

# Overview

- Multivariate analysis
  - What is Ordination/non-Metric Multidimensional Scaling (NMS)
  - Methods
- Results
  - Primary production and water quality
  - Vegetation and water quality
  - Macroinvertebrate abundance and water quality
  - Macroinvertebrate abundance and vegetation
  - Fish abundance and macroinvertebrate abundance

# Multivariate Analysis

(Peck 2010)



# Ordination

(McCune and Grace 2002)

- Ordination - is simply arranging items along a scale (axis) or multiple axes
- Ordination is most often used in ecology to seek and describe pattern
  - In community ecology, we expect redundancy in species datasets to reflect the effects of the same underlying environmental gradients on different species, resulting in covarying of species' presence and absence

# Ordination

(McCune and Grace 2002)

- Ordination helps to:
  - Select the most important factors from multiple factors
  - Separate strong important patterns from weak ones
  - Reveal unforeseen patterns and suggest unforeseen processes

# Why NMS?

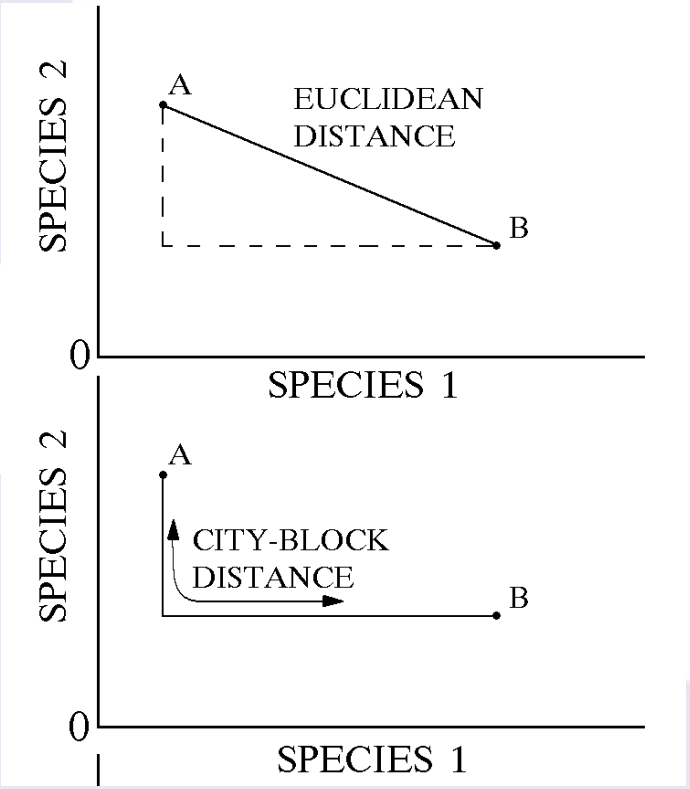
- Well suited to data that are nonnormal or on arbitrary, discontinuous, or otherwise questionable scales
- Main advantages:
  - Avoids the assumption of linear relationships
  - Allows the use of any distance measure or relativization

# NMS Methods

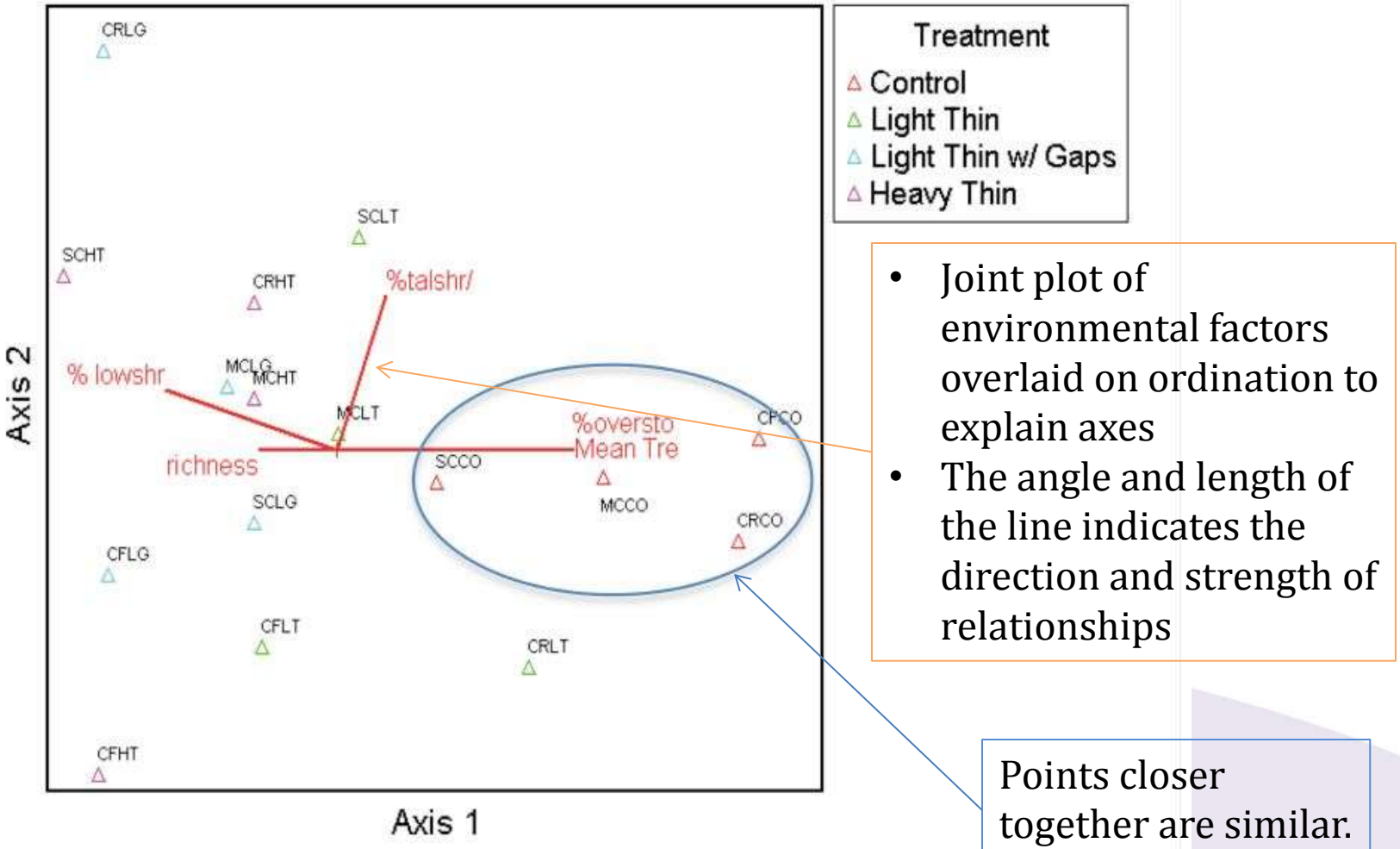
- PC-Ord version 6.14 (McCune and Medford 2011)
- Two Matrices
  - Species matrix and "Environmental" matrix
  - Both matrices must have the same sample units
- Evaluated for outliers
  - Species with no occurrence or occur in <5% of sample (McCune and Medford 2011)
  - Monotonic transform (general log transform)
  - Relativization

# NMS Methods

- Distance Measure –City-block distance (Sørensen Distance)
- Random starting configuration
  - 250 runs performed with real data
  - Monte Carlo randomization (250 runs) was used to asses the number of significant axes with a low stress solution



# NMS Example




- Joint plot of environmental factors overlaid on ordination to explain axes
- The angle and length of the line indicates the direction and strength of relationships

Points closer together are similar.

# Results

- Caveats
  - Exploratory Analysis
  - Correlation ≠ Causation
  - Applicable to sites and years included in analysis

# Primary Production and Water Quality

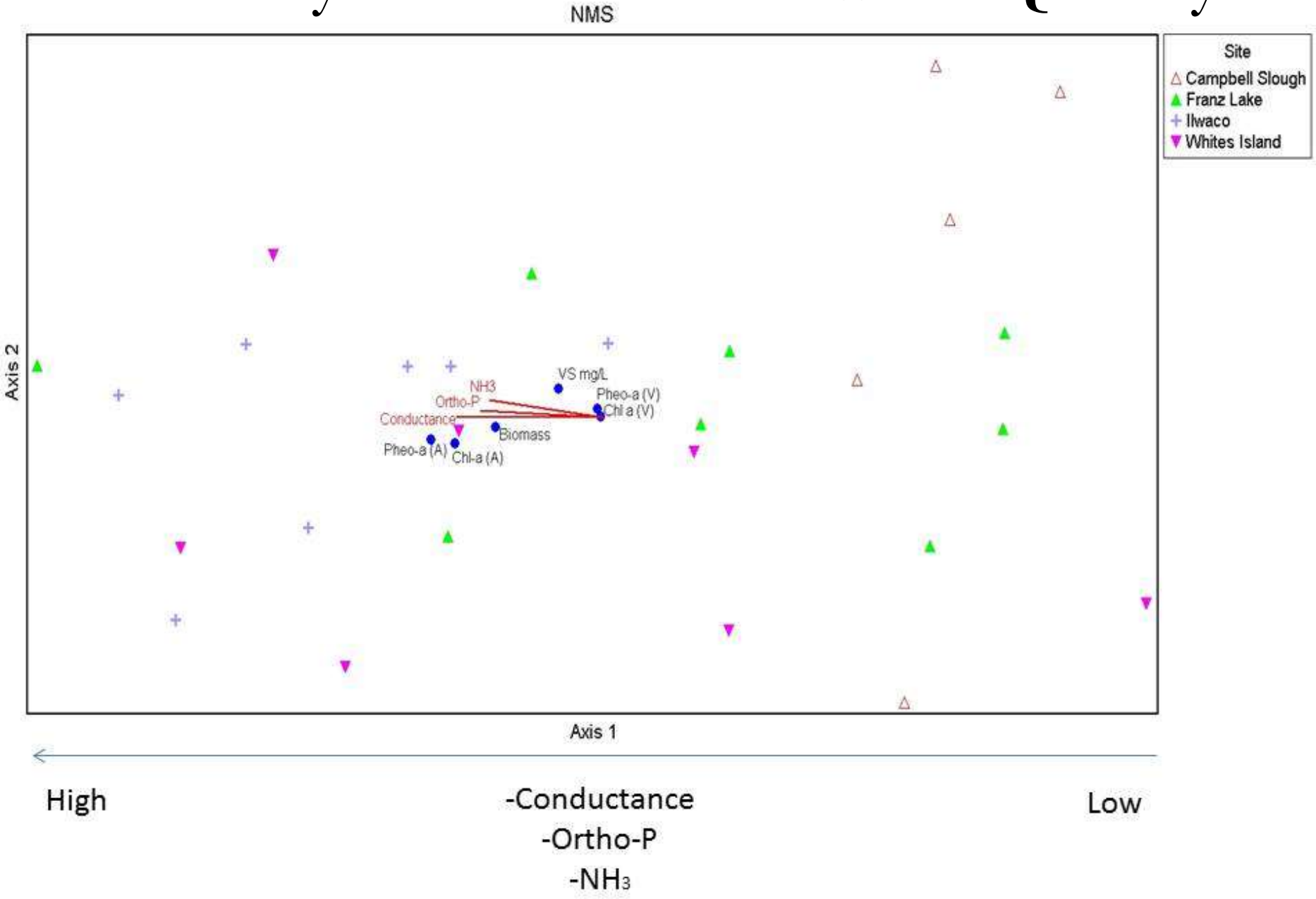
- Sites Included in analysis (n=27)
  - Campbell Slough
  - Franz Lake
  - Ilwaco
  - Whites Island
- Primary Production Measures
  - Periphyton (A) data was represented by Chl-a (A) $mg/m^2$, Pheo-a (A) $mg/m^2$, and Biomass $g/m^2$.
  - Phytoplankton was reported by Chl-a (V) $mg/m^3$, Pheo-a (V) $mg/m^3$, VS mg/L.

# Primary Production and Water Quality

- Water Quality Measures

| | |
|---|---|
| Month | Total Kjeldahl Nitrogen+ Nitrate+Nitrite (TKN+NO3+NO2) |
| Year | Orthophosphate (Ortho-P) |
| Nitrate/Nitrite (NO3/NO2) | Total Phosphate (T-Phos) |
| Nitrate (NO3) | Total Nitrate+Total Phosphate (TN+TP) |
| Nitrite (NO2) | Temperature |
| Ammonia (NH3) | Conductance |
| Total Kjeldahl Nitrogen (TKN) | pH |

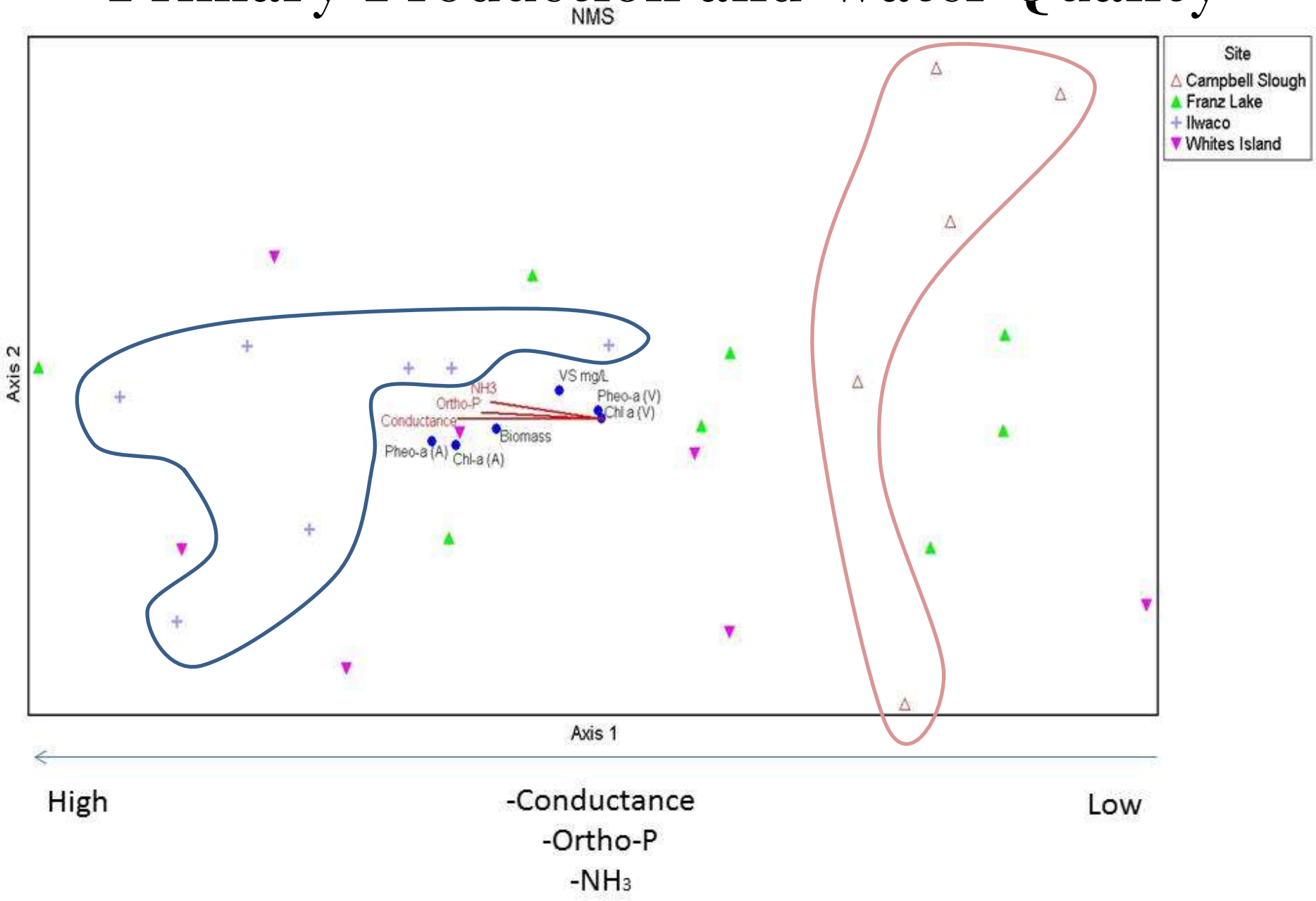
# Primary Production and Water Quality



# Primary Production and Water Quality

- Axis one gradients conductance, orthophosphate, and ammonia ($NH_3$)
- Measures of Periphyton (A), Chl-a (A) $mg/m^2$ (r=.953), Pheo-a (A) $mg/m^2$ (r=.957), and Biomass $g/m^2$ (r=.861) had a strong positive correlation with axis one.
- Ilwaco correlated with higher levels of conductance, orthophosphate, and ammonia ($NH_3$)
- Campbell Slough correlated with lower levels of conductance, orthophosphate, and ammonia ($NH_3$)

# Primary Production and Water Quality



# Vegetation and Water Quality

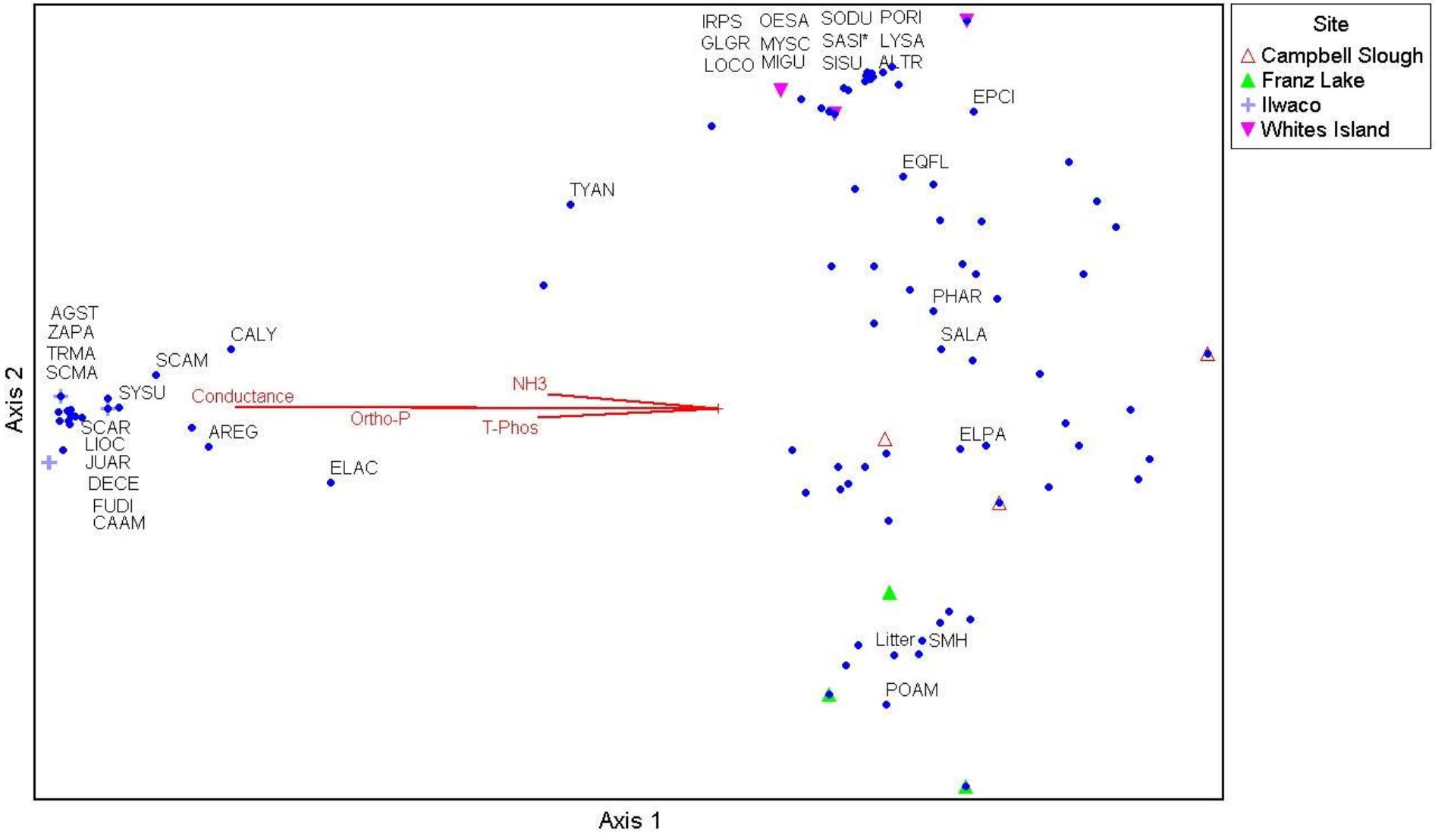
- Sites Included in analysis (n=36)
  - Campbell Slough
  - Franz Lake
  - Ilwaco
  - Whites Island
- Vegetation Measure
  - Percent Cover

# Vegetation and Water Quality

- Water Quality Measures

| | |
|---|---|
| Month | Total Kjeldahl Nitrogen+ Nitrate+Nitrite (TKN+NO3+NO2) |
| Year | Orthophosphate (Ortho-P) |
| Nitrate/Nitrite (NO3/NO2) | Total Phosphate (T-Phos) |
| Nitrate (NO3) | Total Nitrate+Total Phosphate (TN+TP) |
| Nitrite (NO2) | Temperature |
| Ammonia (NH3) | Conductance |
| Total Kjeldahl Nitrogen (TKN) | pH |

# Vegetation and Water Quality




High — Conductance, Ortho-P, $NH_3$ — Low

# Vegetation and Water Quality

- A correlation related to conductance (r=-.913), Orthophosphate, ammonia, and total phosphate (r=-.544) (r=-.557) along axis one.

- Ilwaco is associated with native wetland obligate and facultative wet plants and is associated with higher conductance, Orthophospate, total phosphate, and ammonia. AGST, AREG, CAAM (FACW+), CALY (OBL), DECE, (FACW), ELAC (OBL), FUDI (OBL), JUAR , LIOC (OBL), SCAM (OBL), SCAR, SCMA (OBL), SYSU (FACW), TRMA (OBL), ZAPA (OBL)

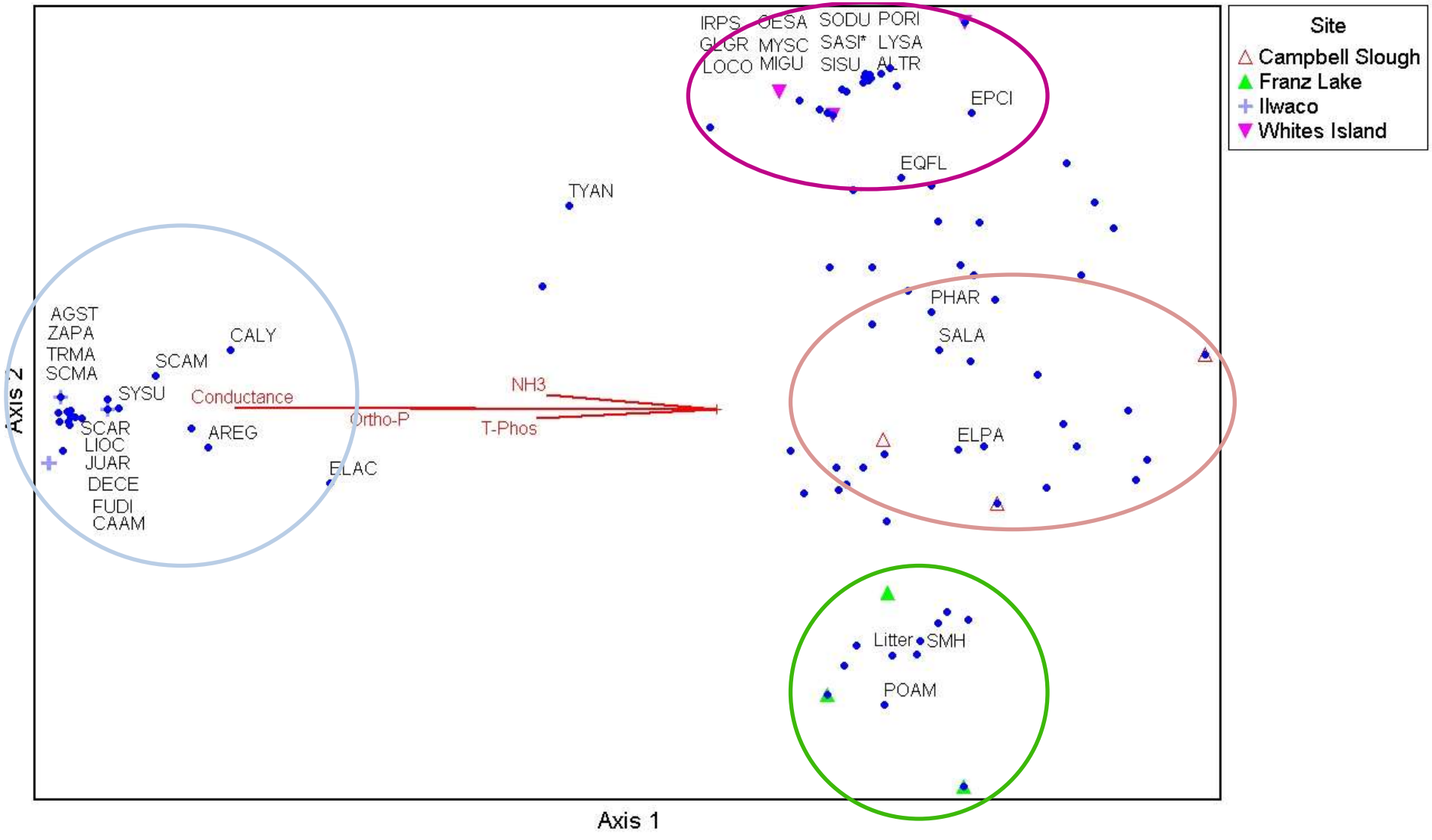
# Vegetation and Water Quality

- Native and invasive wetland obligate and facultative wet plants were associated with Campbell Slough and were associated with lower conductance, Orthophosphate, total phosphate, and ammonia. ELPA (OBL), PHAR (FACW, Invasive), SALA (OBL)

- Native and invasive wetland obligate and facultative wet plants were associated with Whites Island. More invasive species were associated with Whites Island than other sites. ALTR (OBL), EPCI (FACW-), EQFL(OBL), GLGR (OBL), IRPS (OBL, invasive), LOCO (FAC, invasive), LYSA (FAC+, invasive), MIGU (OBL), MYSC (FACW, invasive), OESA (OBL), PORI (OBL), SASI* (FACW) , SISU (OBL), SODU (FAC+ invasive), TYAN (OBL, invasive)

- Litter, POAM (OBL), small mixed herbs were associated with Franz Lake.

# Vegetation and Water Quality




High Conductance, Ortho-P, $NH_3$ Low

# Macroinvertebrates and Water Quality

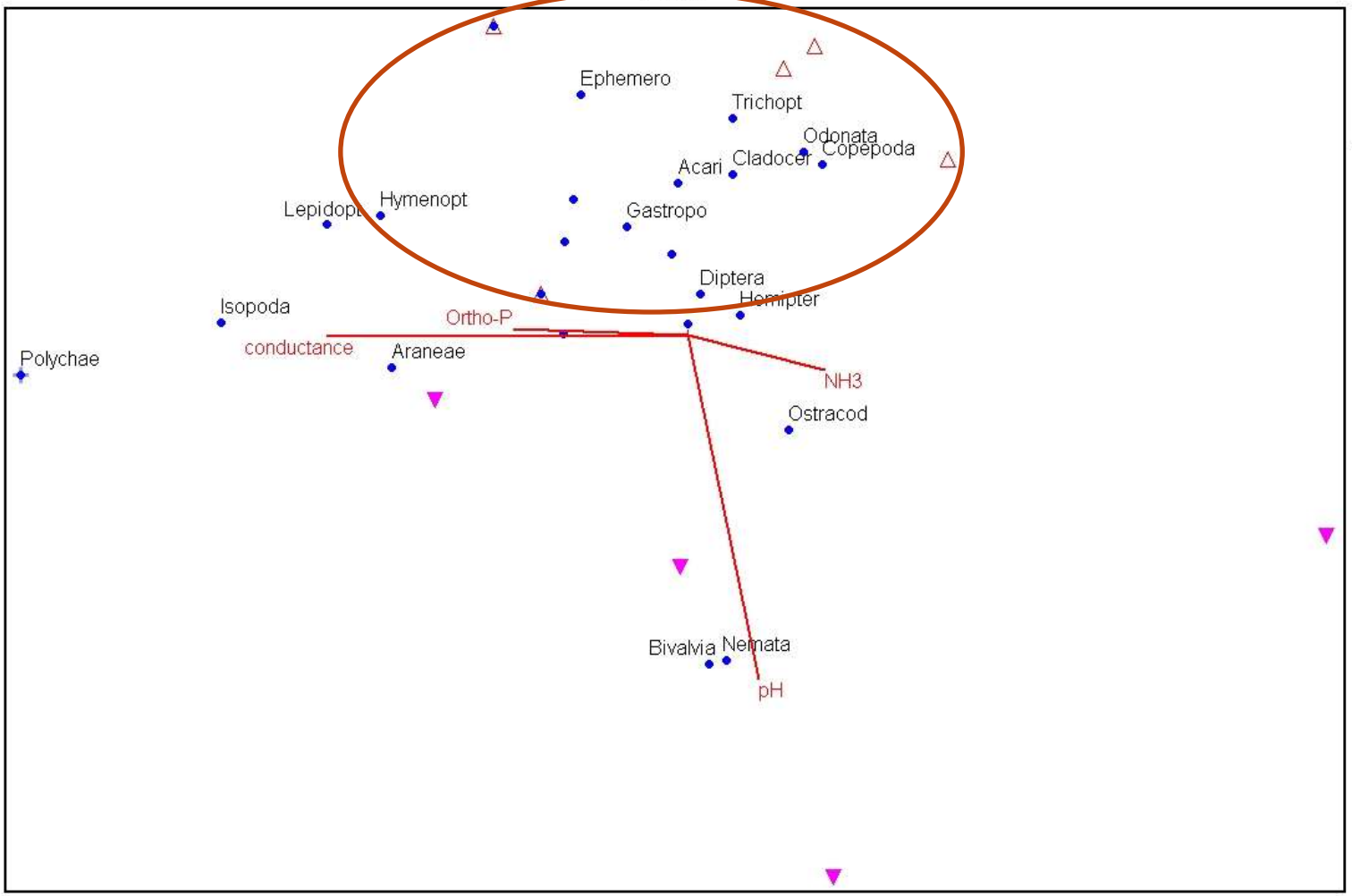
- Sites Included in analysis (n=10)
  - Campbell Slough
  - Ilwaco
  - Whites Island
- Macroinvertebrate Measure
  - Macroinvertebrates collected in emergent vegetation
  - Macroinvertebrates per meter towed

# Macroinvertebrate and Water Quality

- Water Quality Measures

| | |
|---|---|
| Month | Total Kjeldahl Nitrogen+ Nitrate+Nitrite (TKN+NO3+NO2) |
| Year | Orthophosphate (Ortho-P) |
| Nitrate/Nitrite (NO3/NO2) | Total Phosphate (T-Phos) |
| Nitrate (NO3) | Total Nitrate+Total Phosphate (TN+TP) |
| Nitrite (NO2) | Temperature |
| Ammonia (NH3) | Conductance |
| Total Kjeldahl Nitrogen (TKN) | pH |

# Macroinvertebrate and Water Quality




Low

pH

High

High

Conductance, Orthophosphate

Low

Low

$NH_3$

High

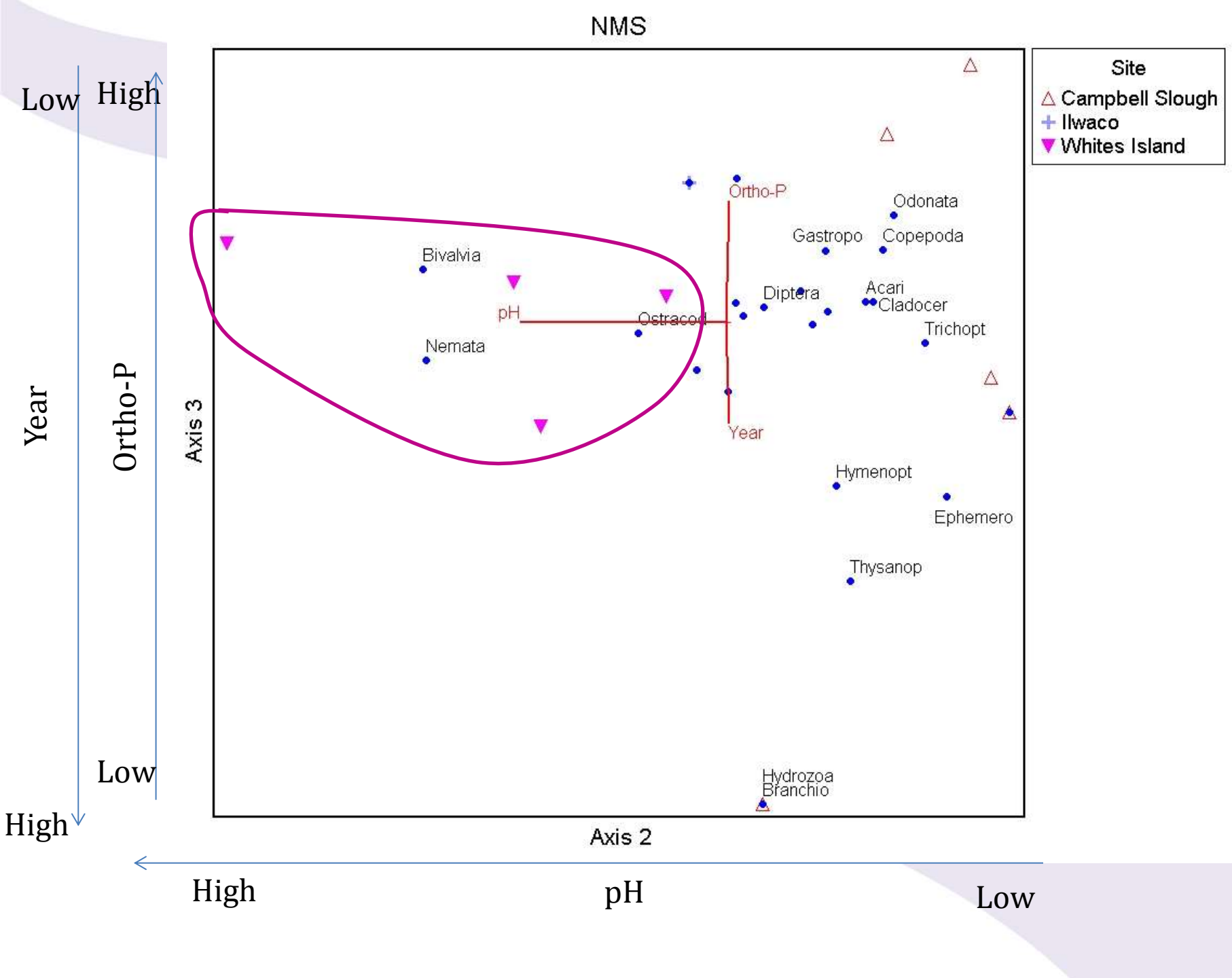
# Macroinvertebrate and Water Quality

- A correlation related to conductance (r = .752), orthophosphate, (r = -.516) and ammonia(r = .444) was found with axis one.
- A correlation related to pH (r=-.747) was found with axis two and a correlation related to year (r=-.501) and Ortho-P (r=.555) was associated with axis three.
- Polychae (r=-.683), Isopoda (r=-.709), Lepidotera (r=-.668), Hymenoptera (r=-.582), Araneae (r=-.840) were associated with higher levels of conductance and Ortho-P and lower levels of $NH_3$, while Hemipetera (r=.588) followed an opposite trend (Figure XX).

# Macroinvertebrate and Water Quality

- Acari (r=.806), Cladocera (r=.719), Copepoda (r=.632), Diptera (r=.552), Ephemeroptera (r=.557), Gastropoda (r=.627), Odonata (r=.557), and Trichoptera (r=.688) were associated with lower pH levels, while Bivalvia (r=-.714), Nemata (r=-.747), and Ostrcods (r=-.594) associated with higher pH levels

- Branchiobdellida (r=-.819), Ephemeroptera, (r=-.515), Hydrozoa (r=-.819), Hymenoptera (r=-.536), and Thysanoptera (r=-.873) were associated with later year and less Ortho-P, while Gastopoda (r=.544) followed the opposite trend.


NMS
Site
Campbell Slough
Ilwaco
Whites Island
Ortho-P
Odonata
Gastropo
Copepoda
Bivalvia
pH
Diptera
Acari
Cladocer
Ostracod
Trichopt
Nemata
Year
Hymenopt
Ephemero
Thysanop
Hydrozoa
Branchio
Axis 3
Axis 2
Low
High
Year
Ortho-P
Low
High
High
pH
Low

# Macroinvertebrate and Water Quality

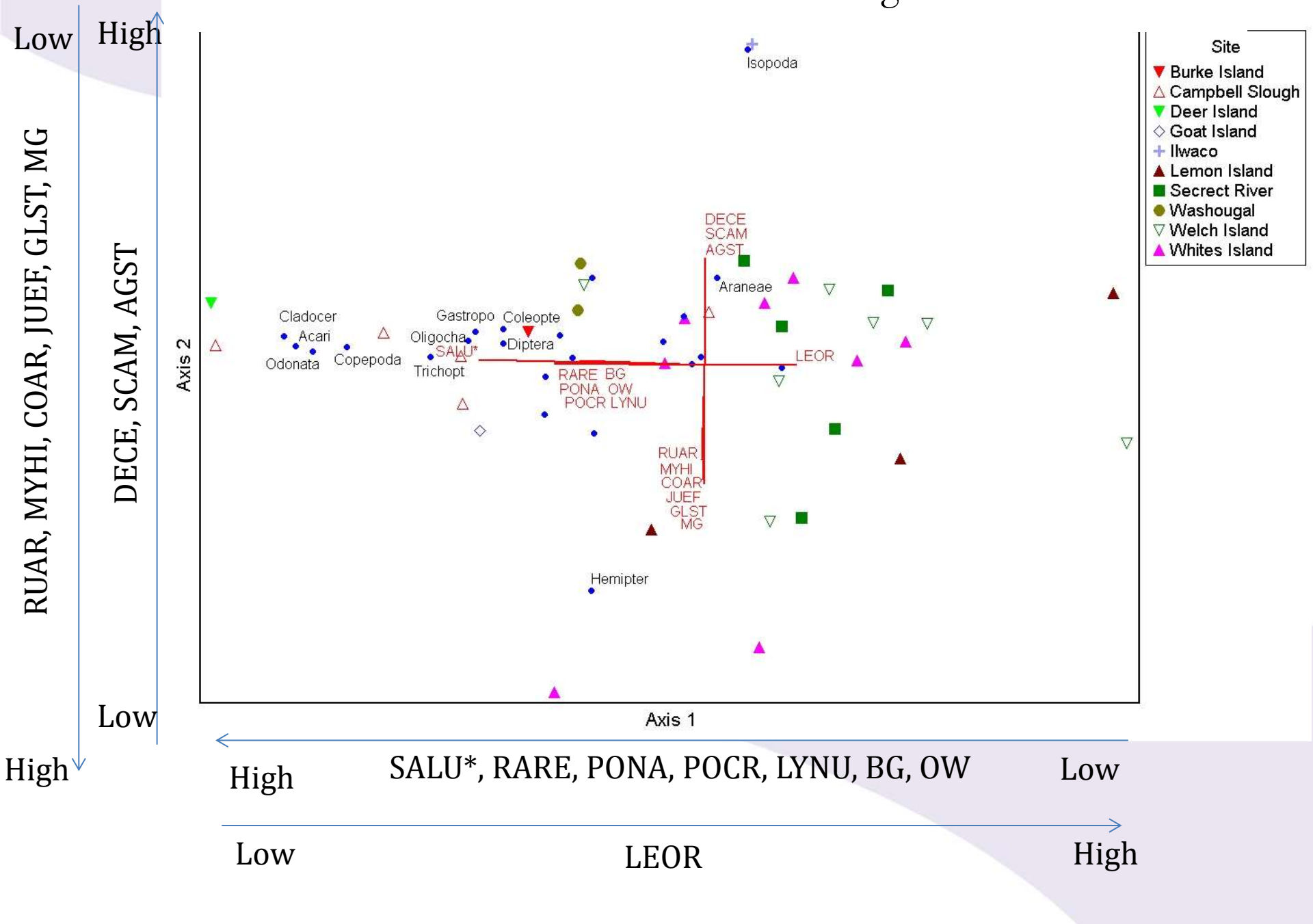
- Acari, Cladocera, Copepoda, Diptera, Ephemeroptera, Gastropoda, Odonata, and Trichoptera, were associated with Campbell Slough.

- Bivalvia, Nemata, and Ostrcods were associated with Whites Island.

# Macroinvertebrates and Vegetation

- Sites Included in analysis (n=34)
  - Burke Island
  - Campbell Slough
  - Ilwaco
  - Whites Island
  - Deer Island
  - Goat Island
  - Lemon Island
  - Welch Island
- Macroinvertebrate Measure
  - Macroinvertebrates collected in emergent vegetation
  - Macroinvertebrates per meter towed
- Vegetation Measure
  - Percent Cover
  - Single data collection event applied to multiple months

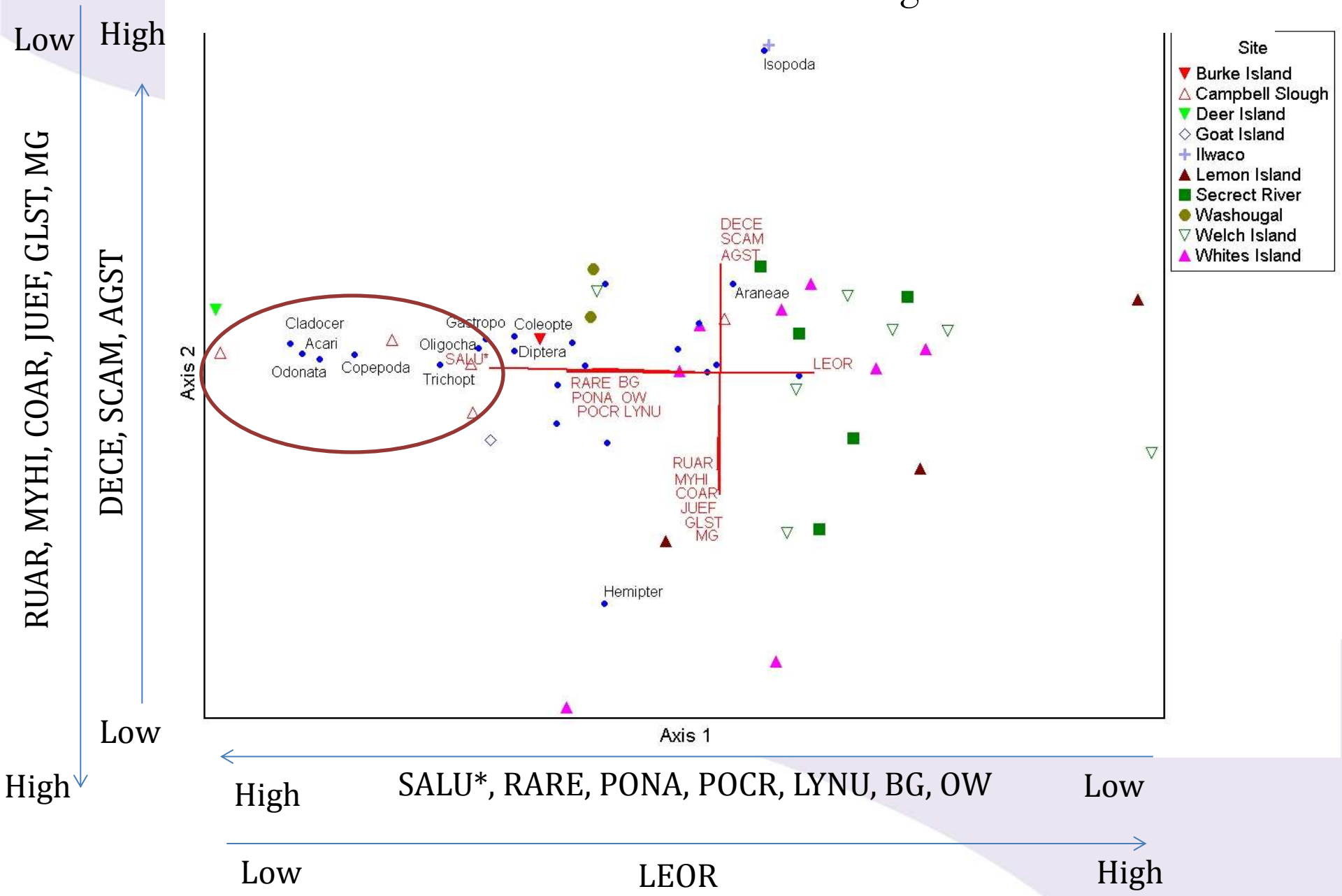
# Macroinvertebrates and Vegetation



# Macroinvertebrates and Vegetation

- Copepoda (r=-.741), Cladocera (r=-.682), Diptera (r=-.682), Oligocha (r=-.685), Gastropoda (r=-.514), Odonata (r=-.534), Trichoptera (r=-.598), Acari (r=-.482), and Coleoptera (r=-.464) were associated with higher percent cover of SALU*, RARE (invasive), PONA, BG, POCR (invasive), OW, LYNU (invasive), and lower percent cover of LEOR.
- Hemiptera (r=-.606) was associated with higher percent cover of RUAR, MYHI, COAR, JUEF, GLST, and MG.
- Araneae (r=.461) and Isopoda (r=.481) were associated with higher percent cover of DECE, SCAM, and AGST (invasive).

# Macroinvertebrates and Vegetation



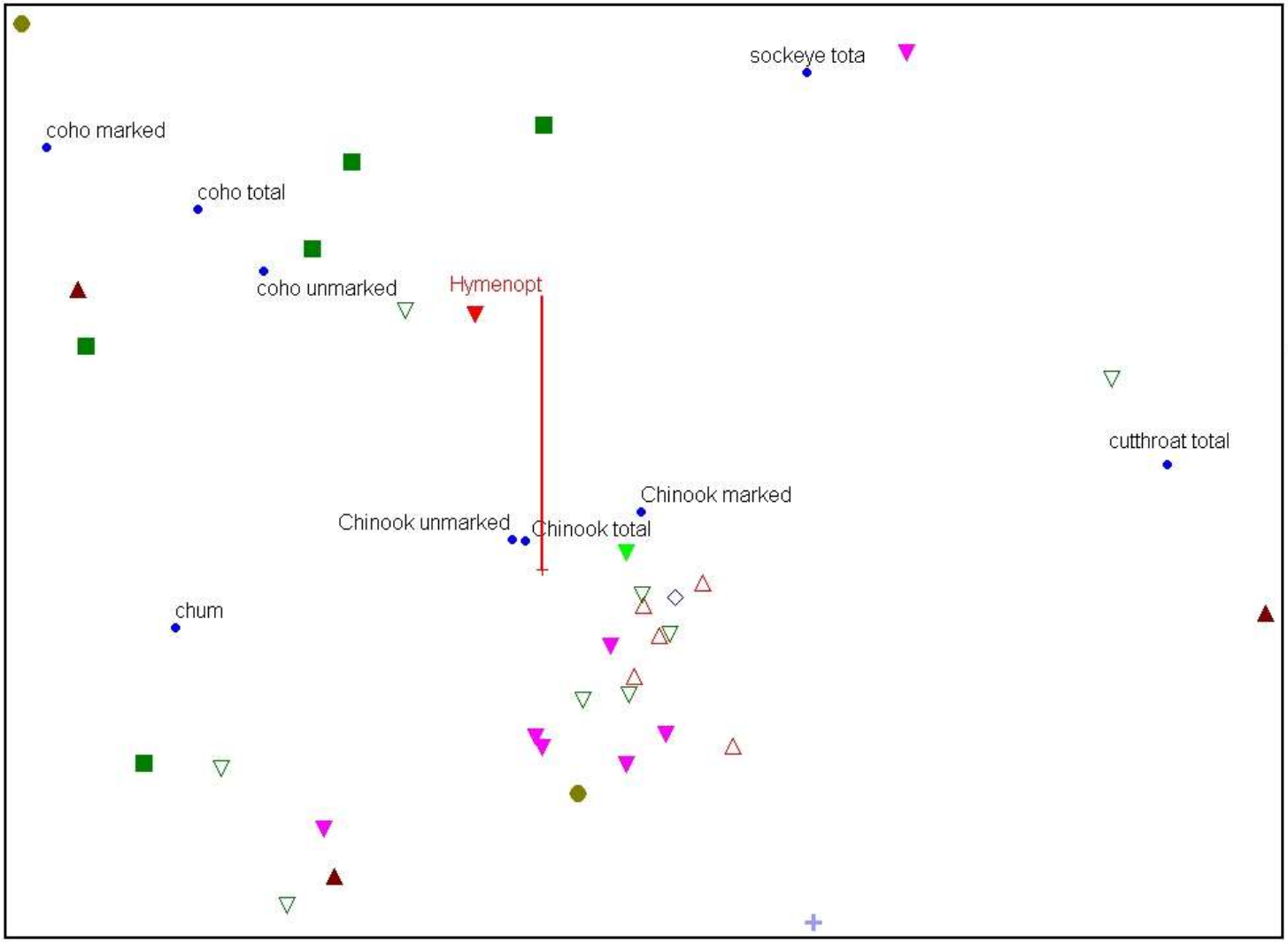
# Salmonids and Macroinvertebrates

- Sites Included in analysis (n=34)
  - Burke Island
  - Campbell Slough
  - Deer Island
  - Goat Island
  - Whites Island
  - Ilwaco
  - Lemon Island
  - Secret River
  - Washougal
  - Welch Island
- Salmonid Measure
  - Number of fish per 1000$m^2$
- Macroinvertebrate Measure
  - Macroinvertebrates per meter towed

  (Macroinvertebrates collected in emergent vegetation)

# Salmonids and Macroinvertebrates

High



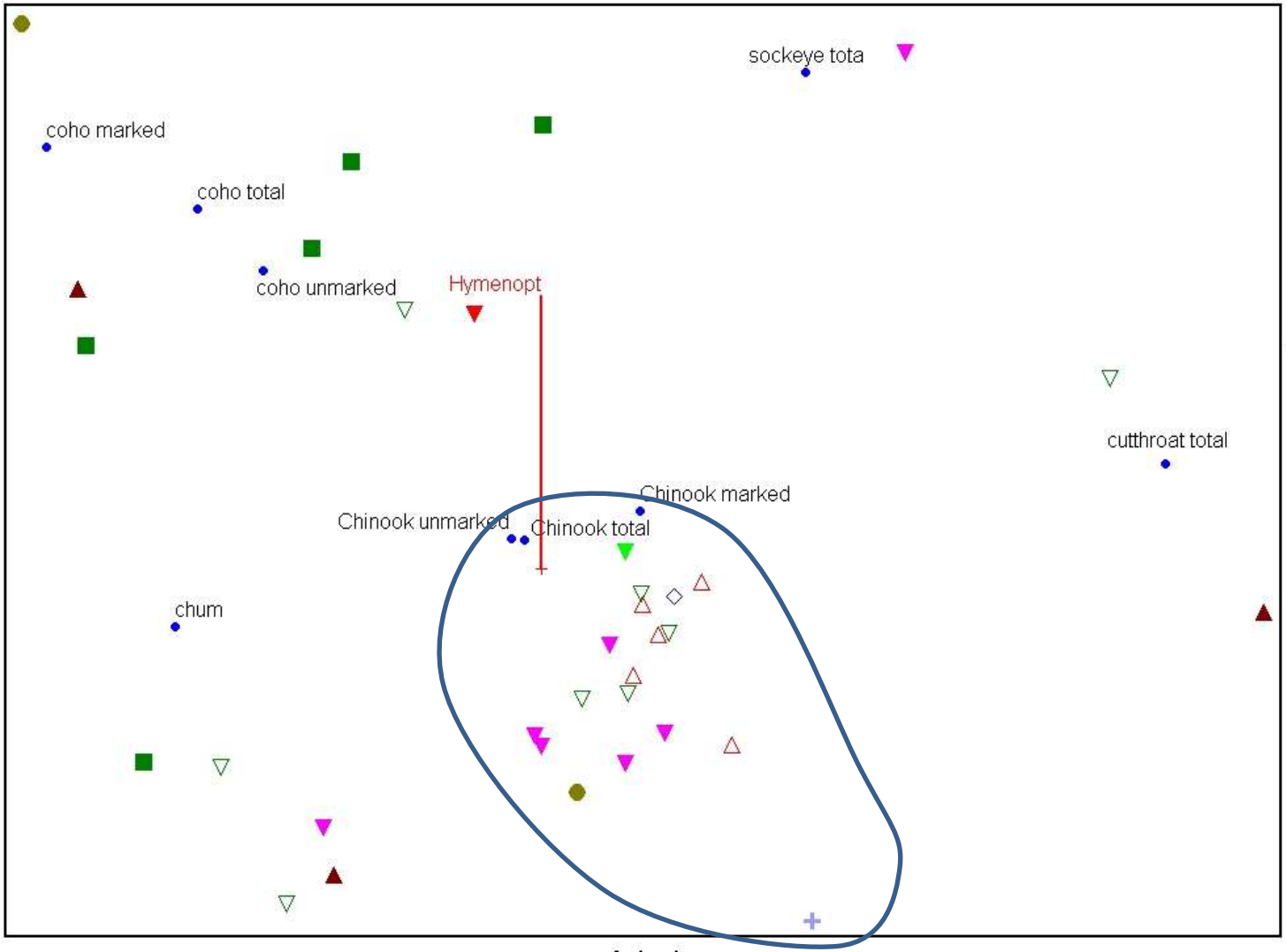

Low

# Salmonids and Macroinvertebrates

- A moderate correlation related to Hymenoptera abundance (r = .593) was found with marked Chinook (r = .473), unmarked sockeye (r = .543), and unmarked chum (r = -.425)

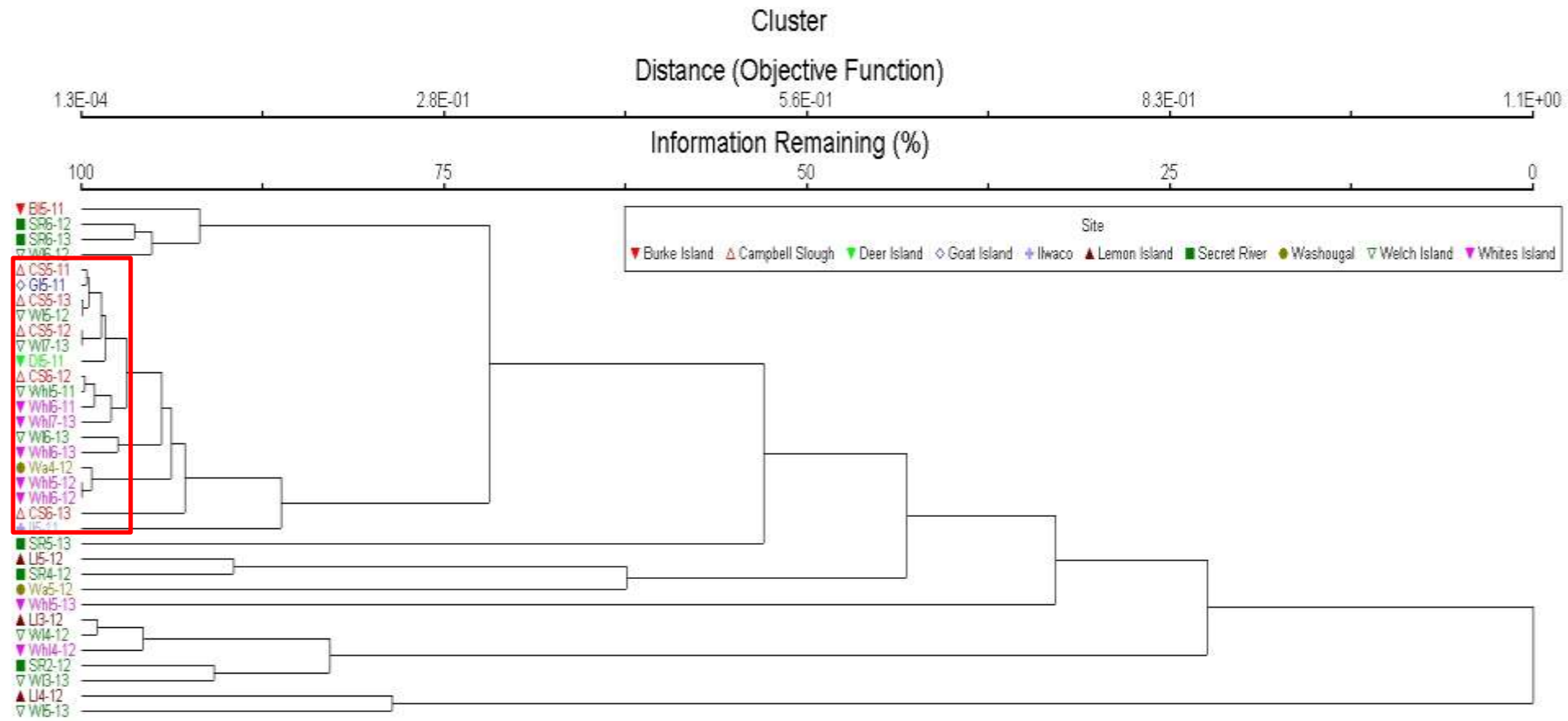
# Salmonids and Macroinvertebrates

High




Low

# Cluster Analysis




- Chinook only salmonid captured at sites in box

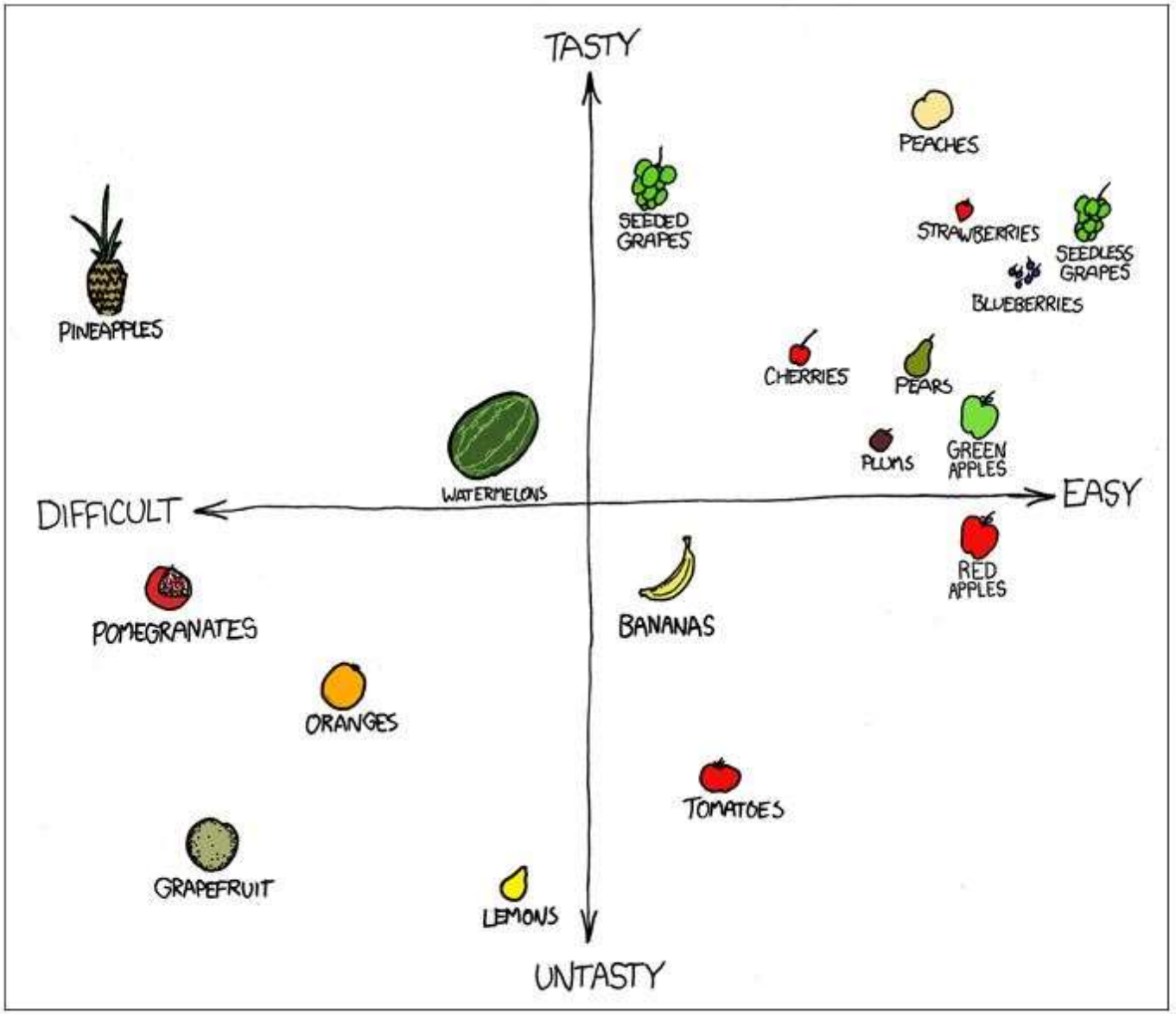
# Preliminary Conclusions

- Conductance and Orthophosphate appear to be the strongest water quality gradients.
- More invasive plants are associated mid-river sites (Whites Island and Campbell Slough) than with the extreme lower (Ilwaco) and upper sites (Franz Lake).
- Macro invertebrate abundance does not correlate well with fish abundance
- Higher abundance of unmarked Chinook Salmon at sites with higher salmonid species diversity.

# More Analysis to be done!

- Zooplankton and Phytoplankton/Periphyton
- Vegetation and other environmental variables (SEV, Rkm, sediment accretion)

# Questions/Comments




XKCD 1/2014
http://xkcd.com/388/