Climate Driven Dynamics of Eelgrass Along the U.S. Pacific Coast: Resilience and Vulnerability of a Critical Nearshore Fisheries Habitat

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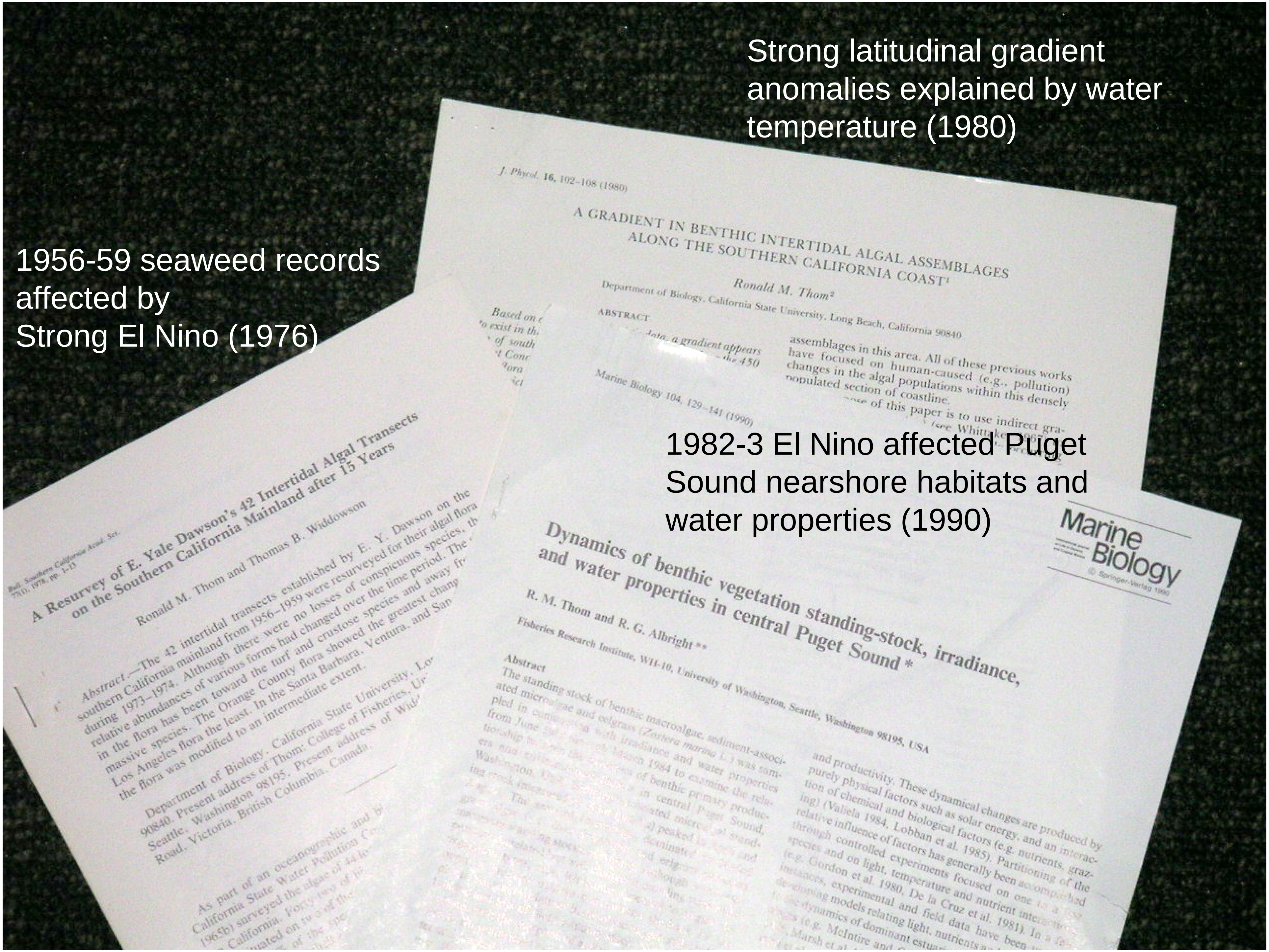
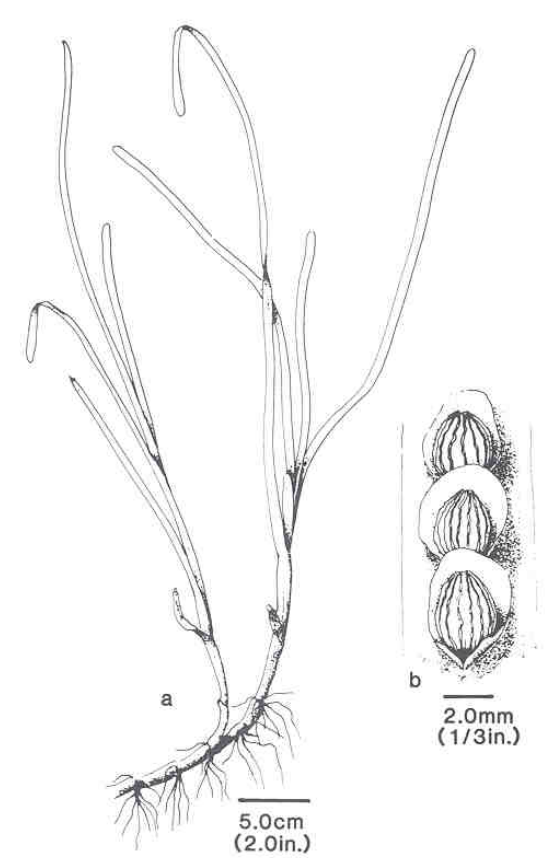
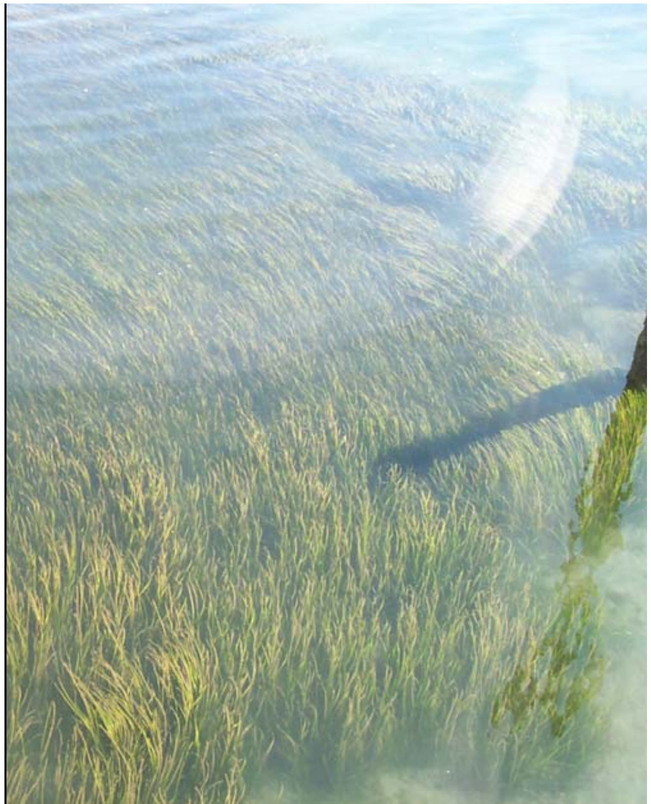
Purpose

Illustrate links between interannual variations in eelgrass and some climate-related indicators, speculate on mechanisms of effect, discuss importance to carbon budgets

- Points-
  - Interannual variations can be large
  - Factors controlling eelgrass growth are climate-linked
  - Warming could alter these factors
  - Changes in eelgrass will affect fisheries resources and ecological processes
  - It is important to include nearshore systems discussions of climate effects on the biosphere


Strong latitudinal gradient anomalies explained by water temperature (1980)
1956-59 seaweed records affected by Strong El Nino (1976)
1982-3 El Nino affected Puget Sound nearshore habitats and water properties (1990)
J. Phycol. 16, 102–108 (1980)
A GRADIENT IN BENTHIC INTERTIDAL ALGAL ASSEMBLAGES ALONG THE SOUTHERN CALIFORNIA COAST
Ronald M. Thom
Department of Biology, California State University, Long Beach, California 90840
A Resurvey of E. Yale Dawson's 42 Intertidal Algal Transects on the Southern California Mainland after 15 Years
Ronald M. Thom and Thomas B. Widdowson
Marine Biology 104, 129–141 (1990)
Marine Biology
Dynamics of benthic vegetation standing-stock, irradiance, and water properties in central Puget Sound
R. M. Thom and R. G. Albright
Fisheries Research Institute, WH-10, University of Washington, Seattle, Washington 98195, USA

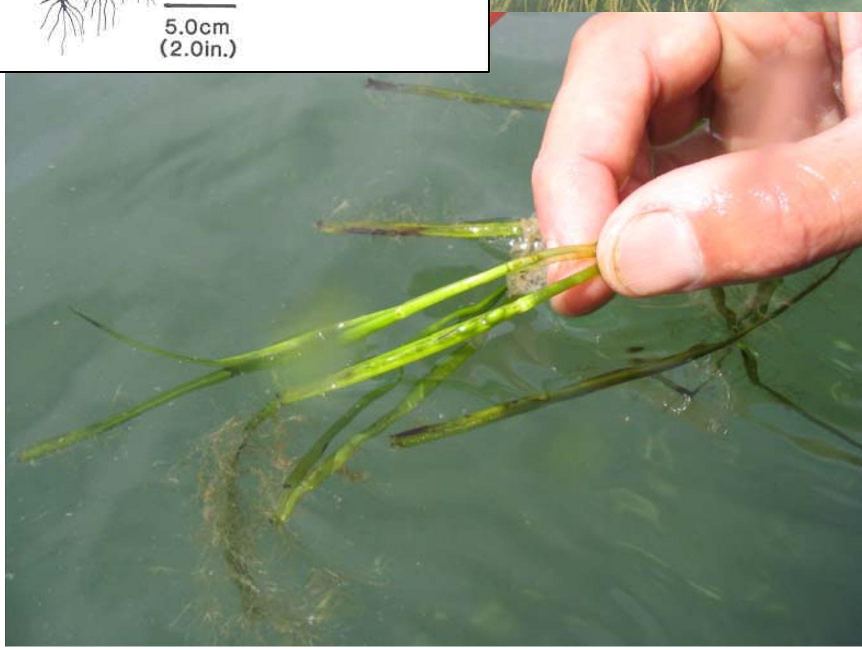




Eelgrass

(Zostera marina)

- Most widespread of ~65 seagrass species
- One of 5 species in the PNW
- Flowering/rooted plant that forms meadows
- Spreads by rhizomes and seeds



Indices and Hypotheses

- **SOI** = Southern oscillation index
- **ONI** = Oceanic Niño Index
- **MEI** = Multivariate ENSO Index
- **PDO** = Pacific decadal oscillation
- **Mean Sea Level Anomaly** = Difference between long-term mean sea level and actual mean sea level

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- $\mathbf{H_0}$ = no correlation between climate indexes and eelgrass variation
- $\mathbf{H_1}$ = there is a correlation (so what is mechanism?)

Indexes and Mechanisms

- "Large scale climate indices (e.g., PDO, SOI) do a poor job of capturing the details of environmental changes at the scale of many (perhaps most) meaningful ecosystem interactions"
- There is a need to better understand the biophysical mechanisms underlying ecosystem changes
- Need to work at the correct scale
- Climate may act on ecosystems at a variety of dimensions
- Studies of physiological mechanism are needed to predict climate effects on ecosystems at species and community levels.

Mantua. 2005. Upscaling for a better understanding of climate links to ecosystems. *Pices Press* 13:12-14

Portner and Parrell. 2008. Physiology and climate. *Science* 322:690-692)

Climate Change and Seagrasses

(Short, F.T. and H.A. Neckles. 1999. The effects of global climate change on seagrasses. Aquatic Botany 63:169-196)

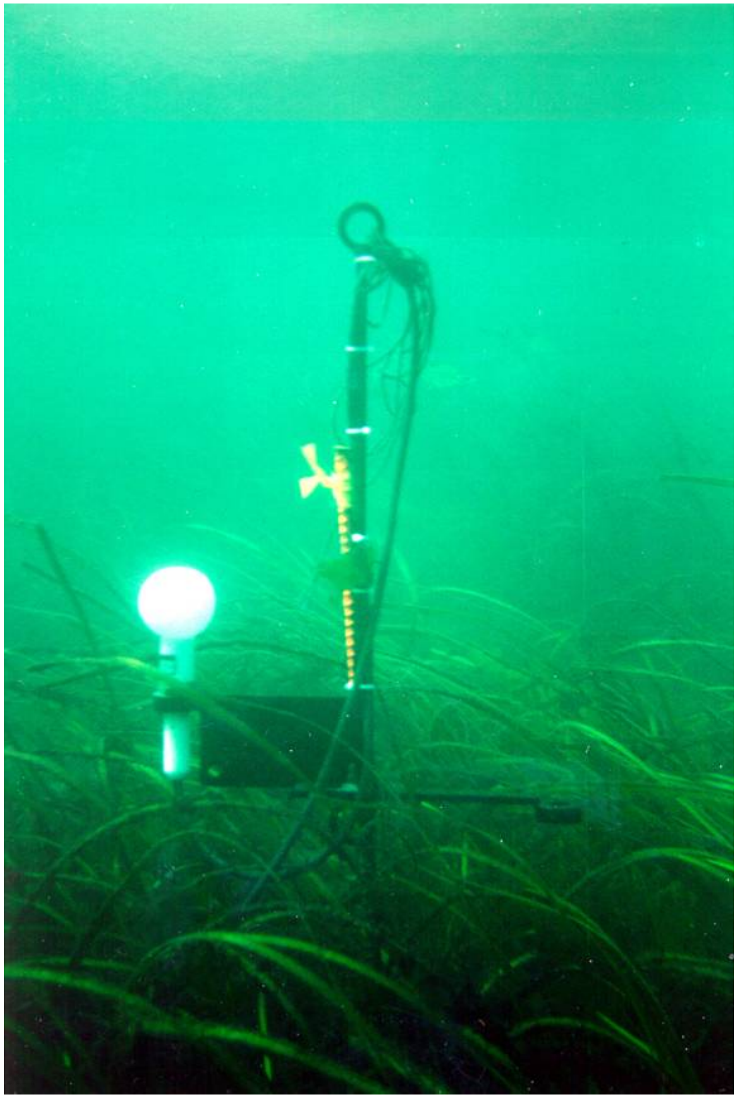
- Temperature
- Sea level rise
- Water movement
- Salinity intrusion
- Increasing carbon dioxide
- UV-B radiation

Data Sets

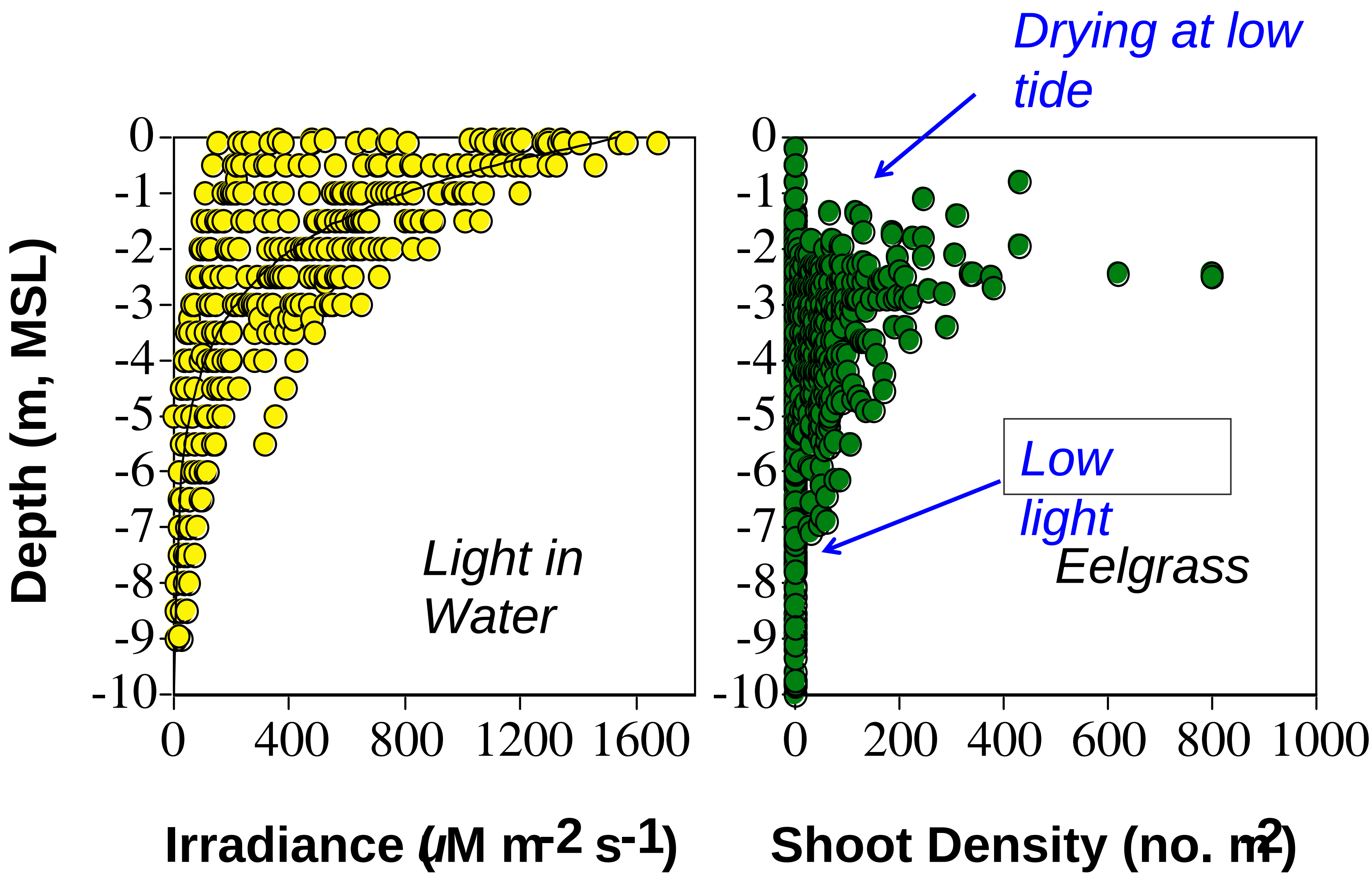
- Willapa Bay (1998-2001) - annual sampling at 6 sites
- Clinton Ferry terminal (1996-2008) - annual sampling at 3 sites
- Sequim Bay mouth (1991-2008) - summer sampling in 14 of the 18 years; experimental studies
- Morro Bay – Mapping (1960-2007) & depth v. density (2006)

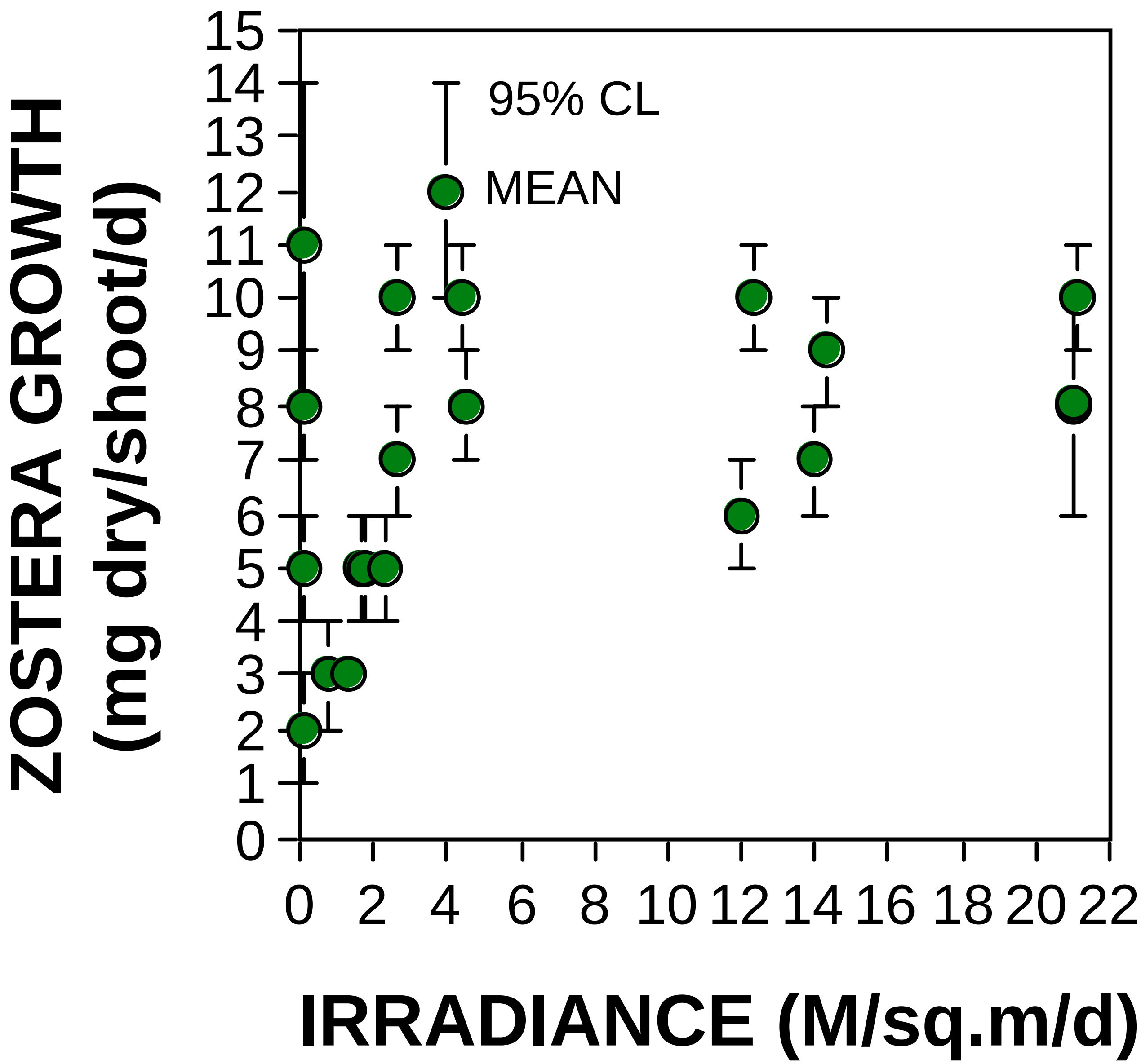
Factors Affecting Eelgrass

- ***Light***
- ***Temperature***
- ***Desiccation***
- Salinity
- Substrata
- Nutrients
- Wave energy
- Eutrophication
- Grazing and Bioturbation

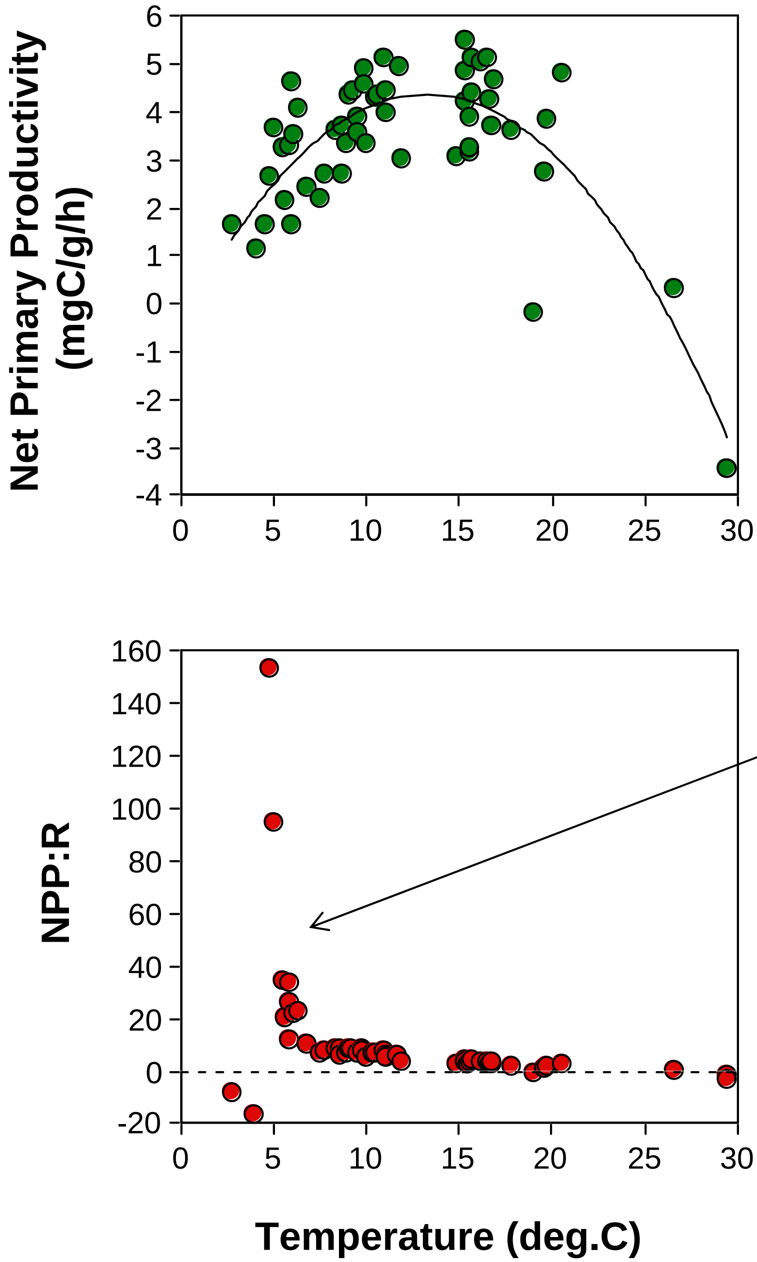


Light and Desiccation

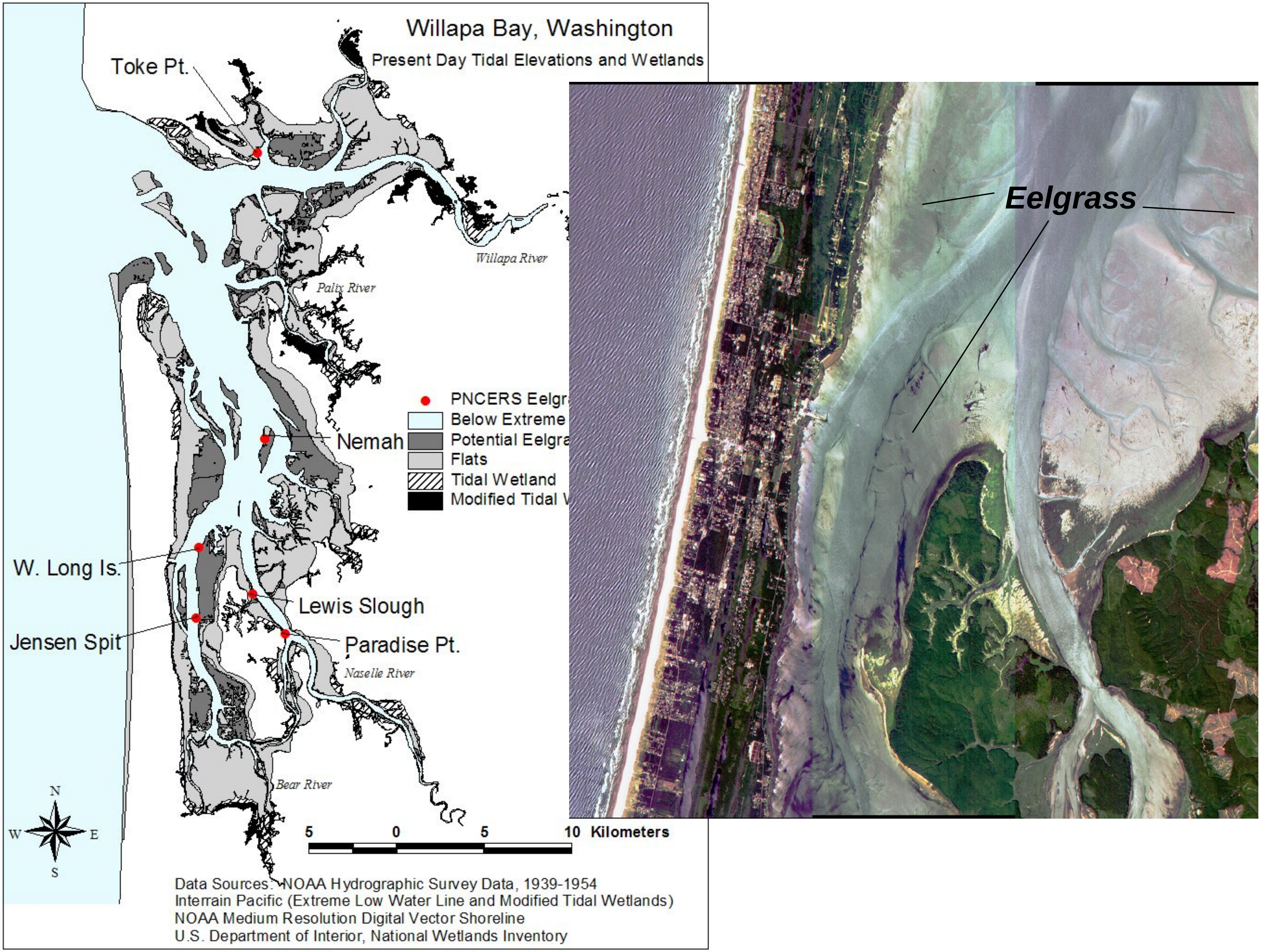


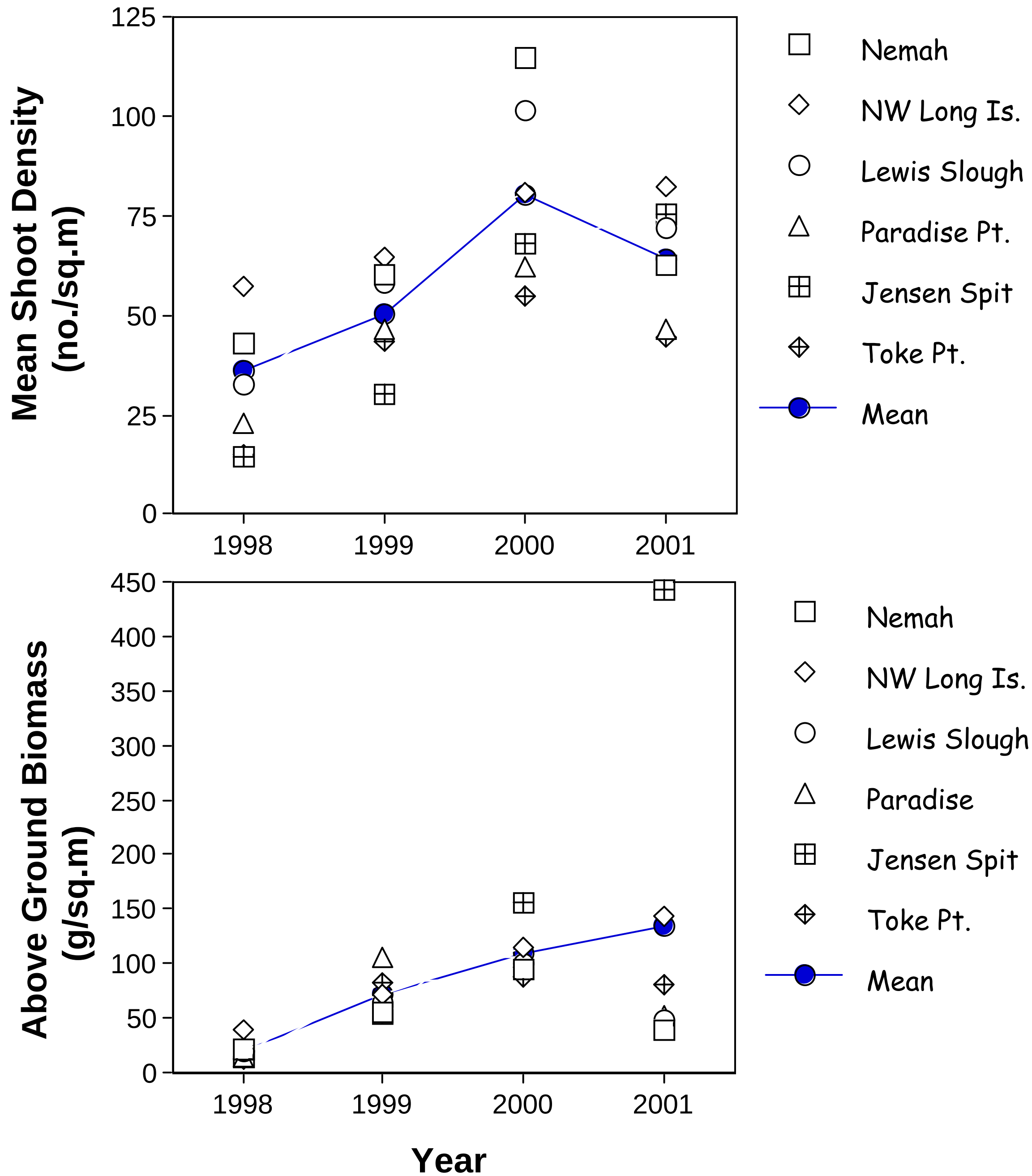

ZOSTERA GROWTH
(mg dry/shoot/d)
95% CL
MEAN
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0 2 4 6 8 10 12 14 16 18 20 22
IRRADIANCE (M/sq.m/d)

Temperature



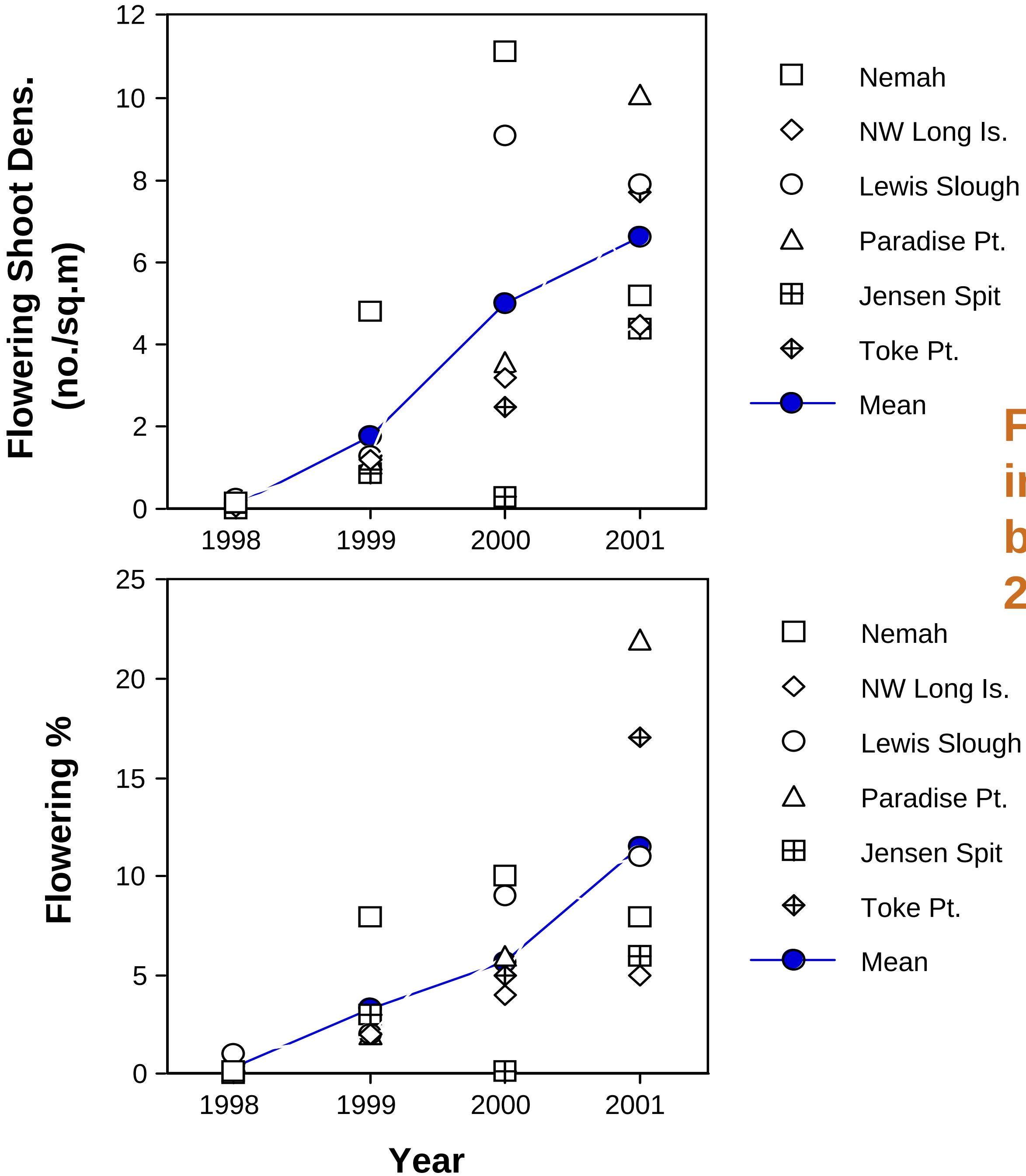
Plants are healthiest within a narrow temperature range


Willapa Bay, Washington
Present Day Tidal Elevations and Wetlands
Toke Pt.
Willapa River
Palix River
Nemah
W. Long Is.
Lewis Slough
Jensen Spit
Paradise Pt.
Naselle River
Bear River
PNCERS Eelgr
Below Extreme
Potential Eelgra
Flats
Tidal Wetland
Modified Tidal W
N
W
E
S
5
0
5
10 Kilometers
Data Sources: NOAA Hydrographic Survey Data, 1939-1954
Interrain Pacific (Extreme Low Water Line and Modified Tidal Wetlands)
NOAA Medium Resolution Digital Vector Shoreline
U.S. Department of Interior, National Wetlands Inventory
Eelgrass

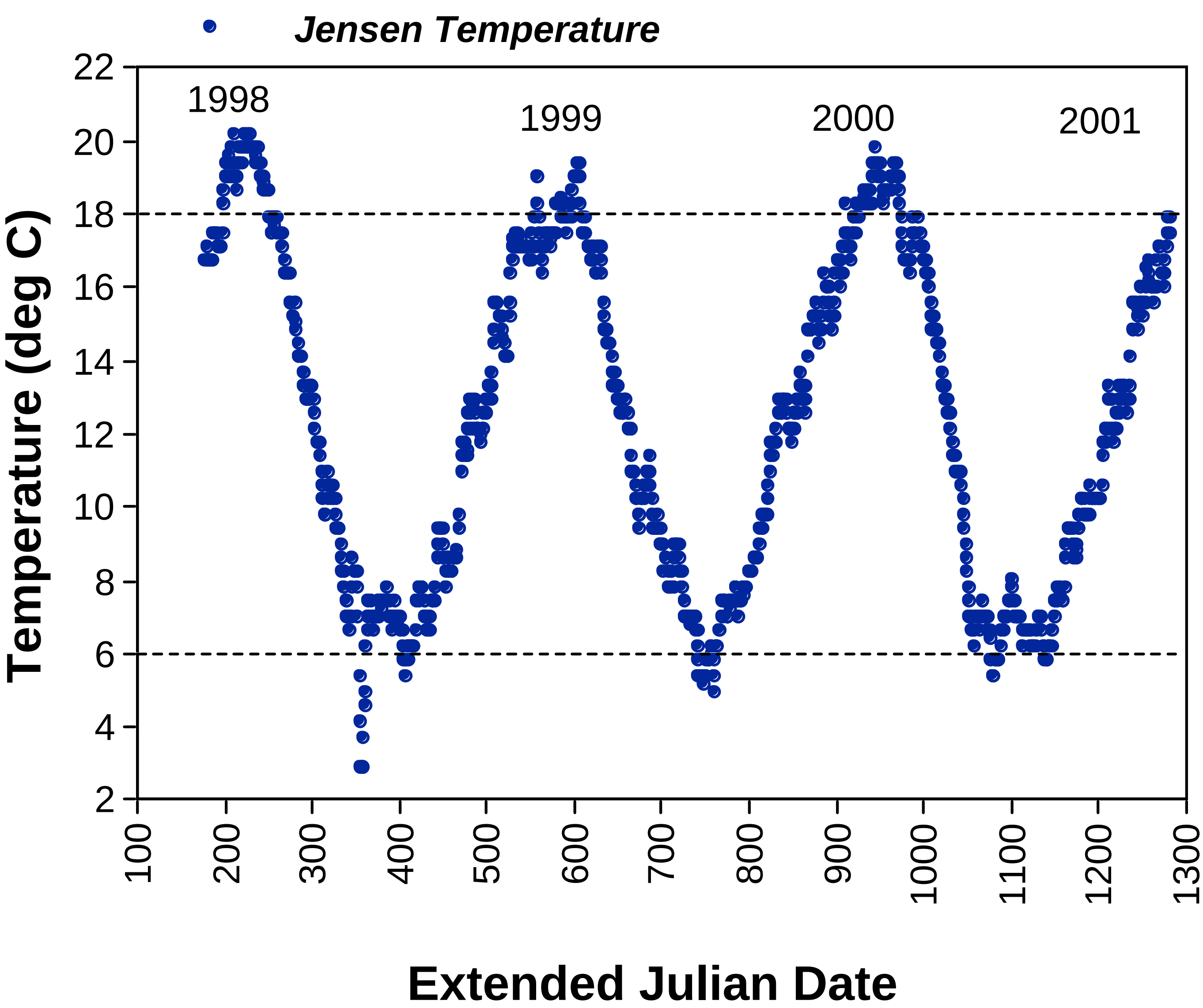


Density increased ~2.5X between 1998 and 2000

Biomass increased ~5X between 1998 and 2000

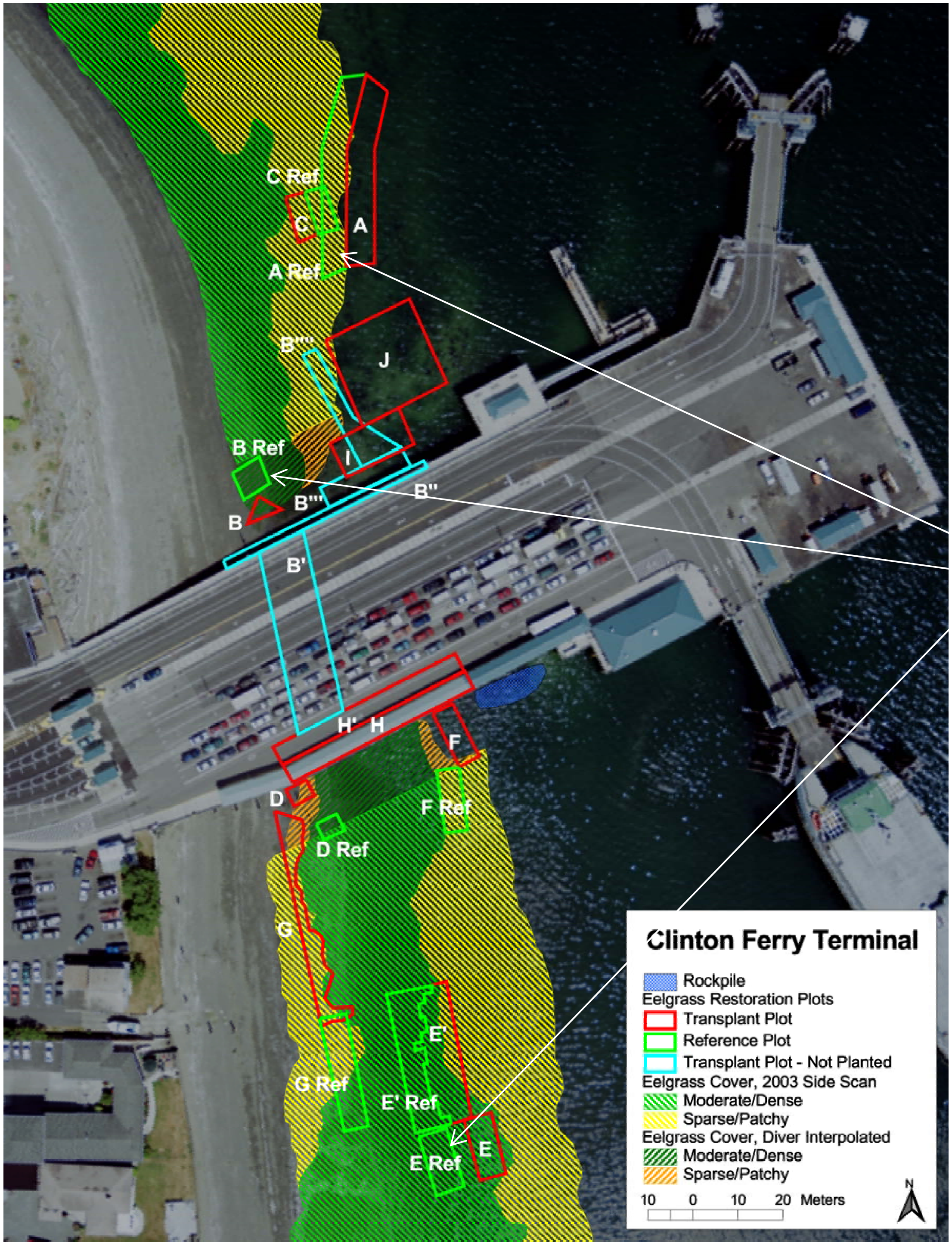


Flower production increased ~35X between 1998 and 2000

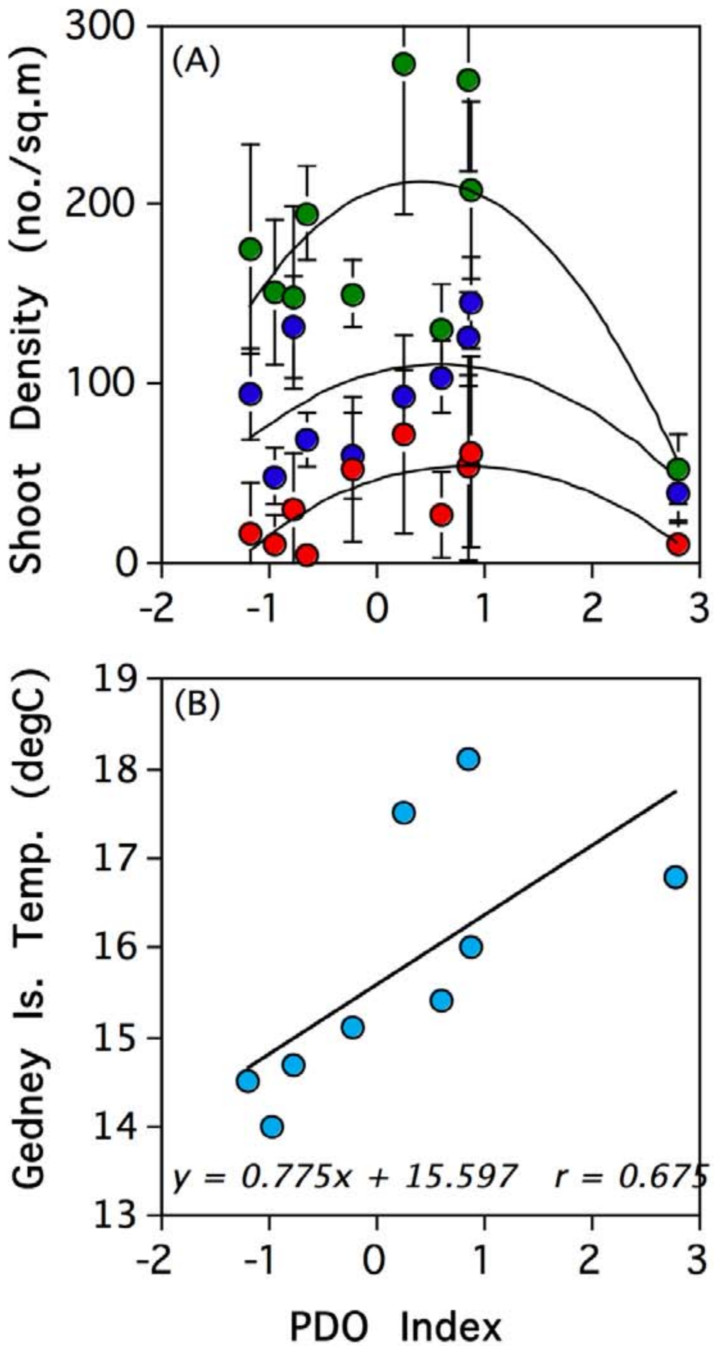


Warmer summer and colder winter in 1998 - 1999

Clinton Ferry Terminal Eelgrass Plots



Reference plots



Plot A: $y = -11.411x^2 + 19.152x + 45.289$
$r = 0.779$

Plot B: $y = -27.440x^2 + 22.517x + 208.062$
$r = 0.714$

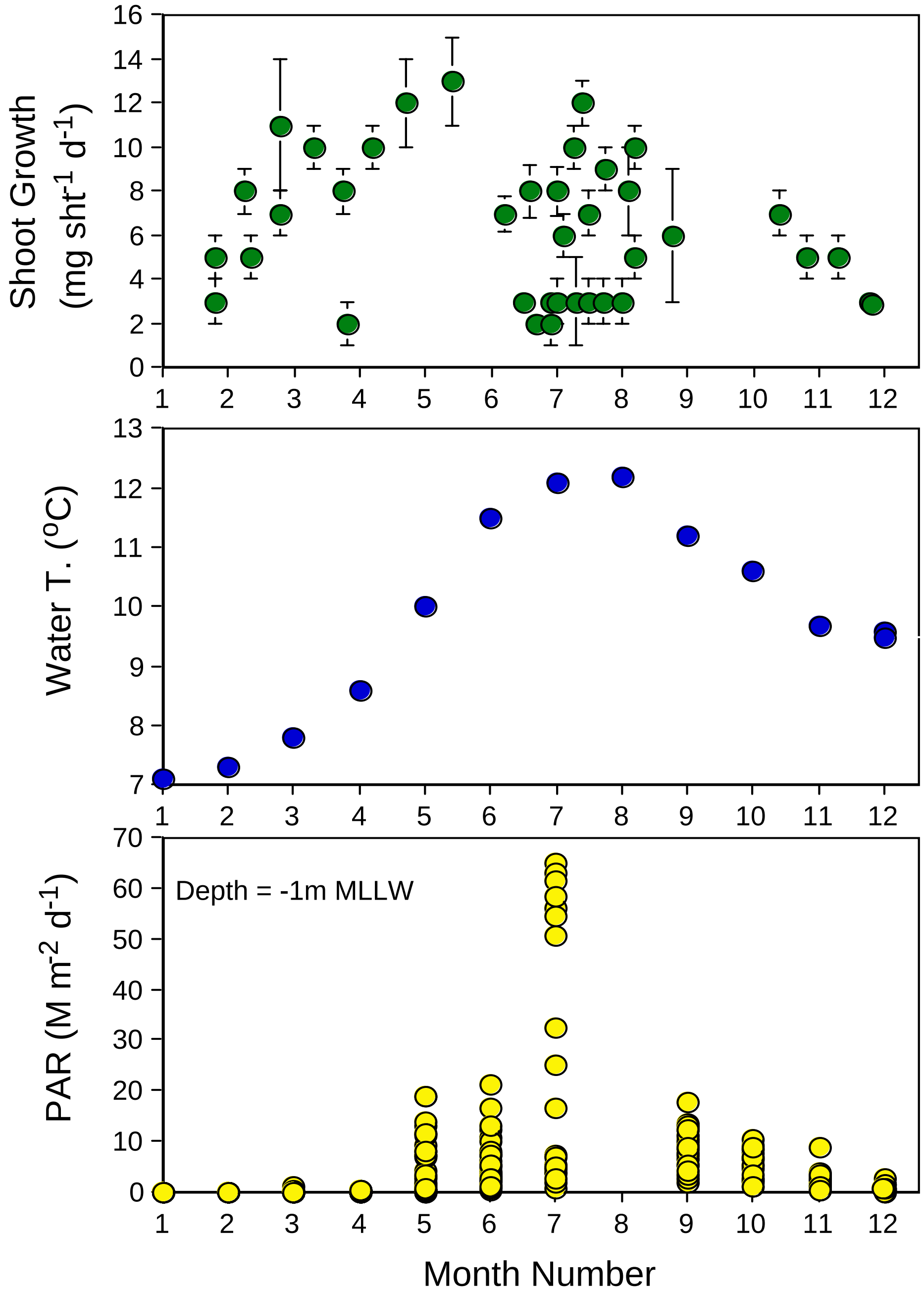
Plot E: $y = -13.192x^2 + 15.699x + 105.338$
$r = 0.588$

Clinton Reference Eelgrass Plots (1998-2007)

Shoot density greatest at ~neutral PDO

Growth at Sequim Bay (1991-2008)

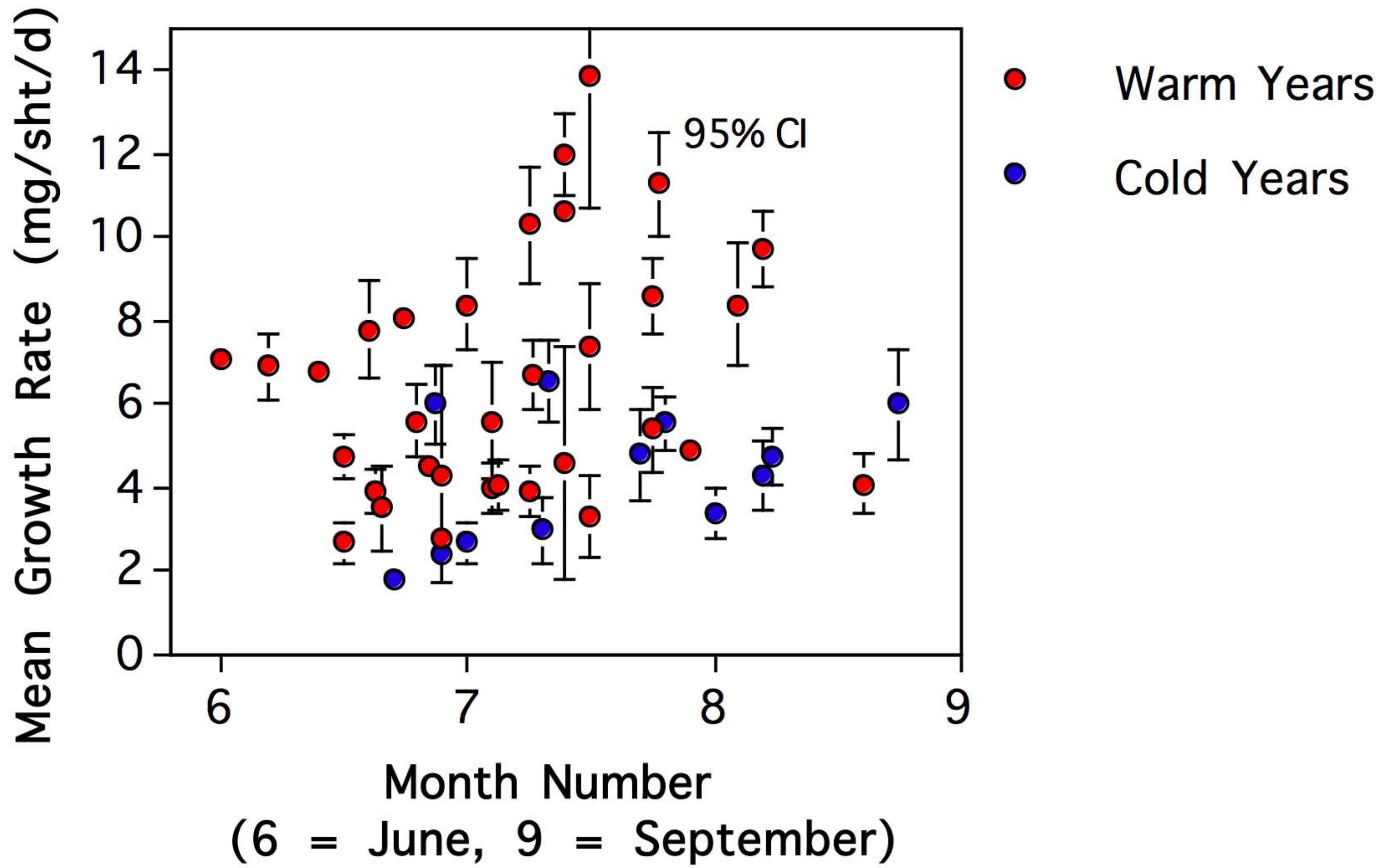

Sampling sites



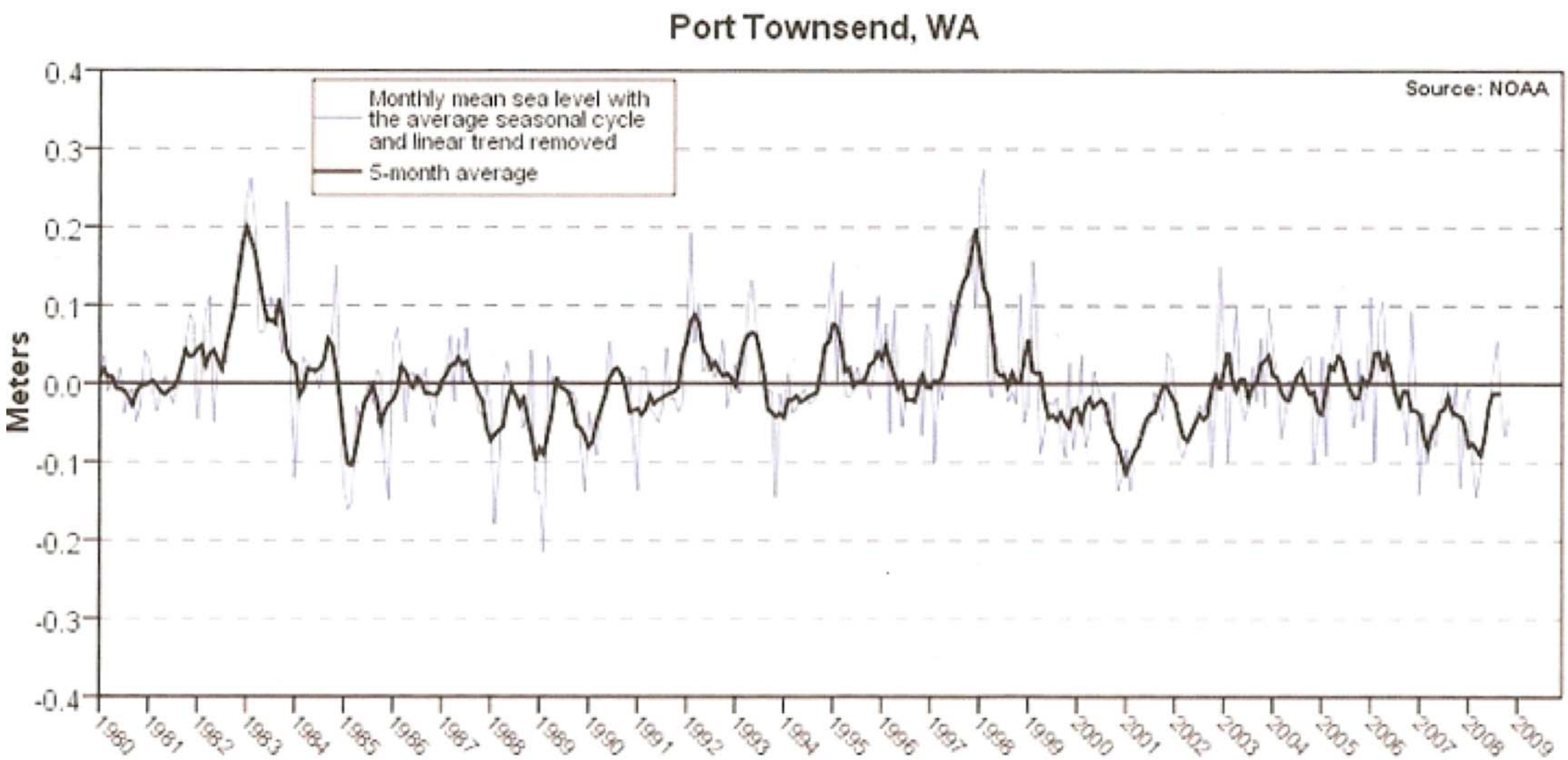
Sequim Bay Seasonal Dynamics (NPP = 599 gC m^{-2} y^{-2})

- **Growth is seasonal**
- **Winter growth occurs under extreme low light**
- **Late winter temperature may drive growth**

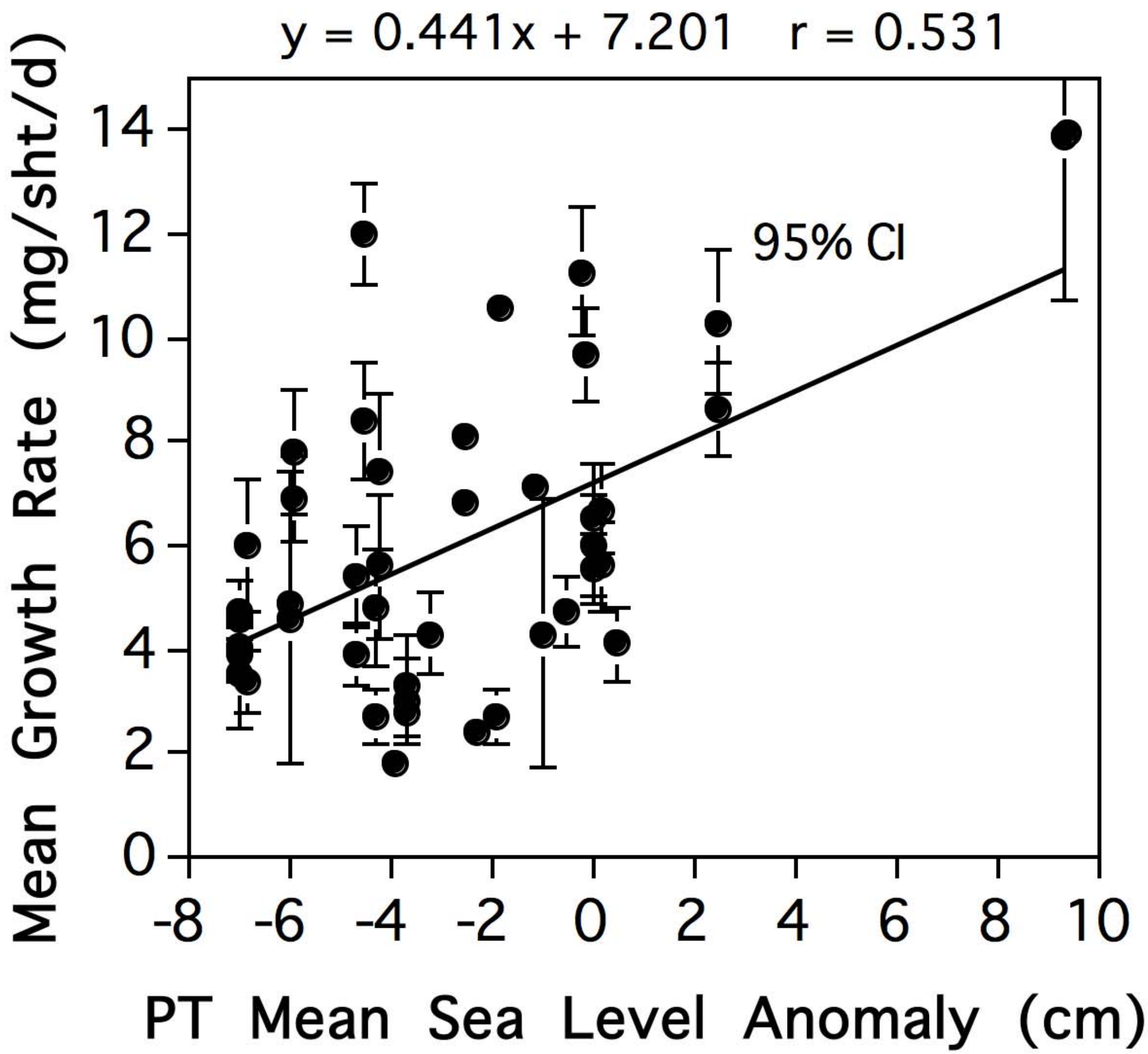
Summer Growth Rates



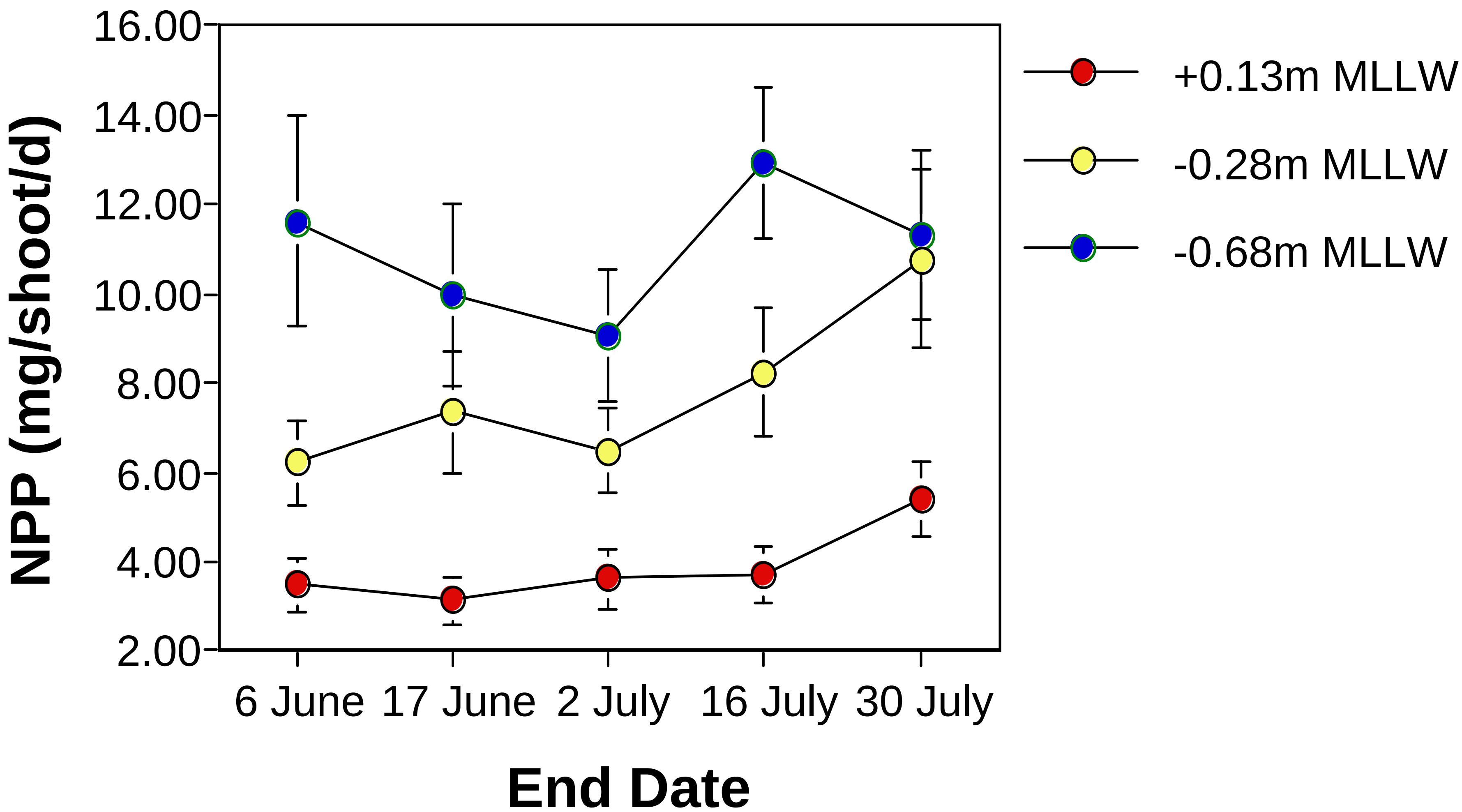
Variation of Mean Sea Level from 1980 to the Present at Port Townsend, Washington



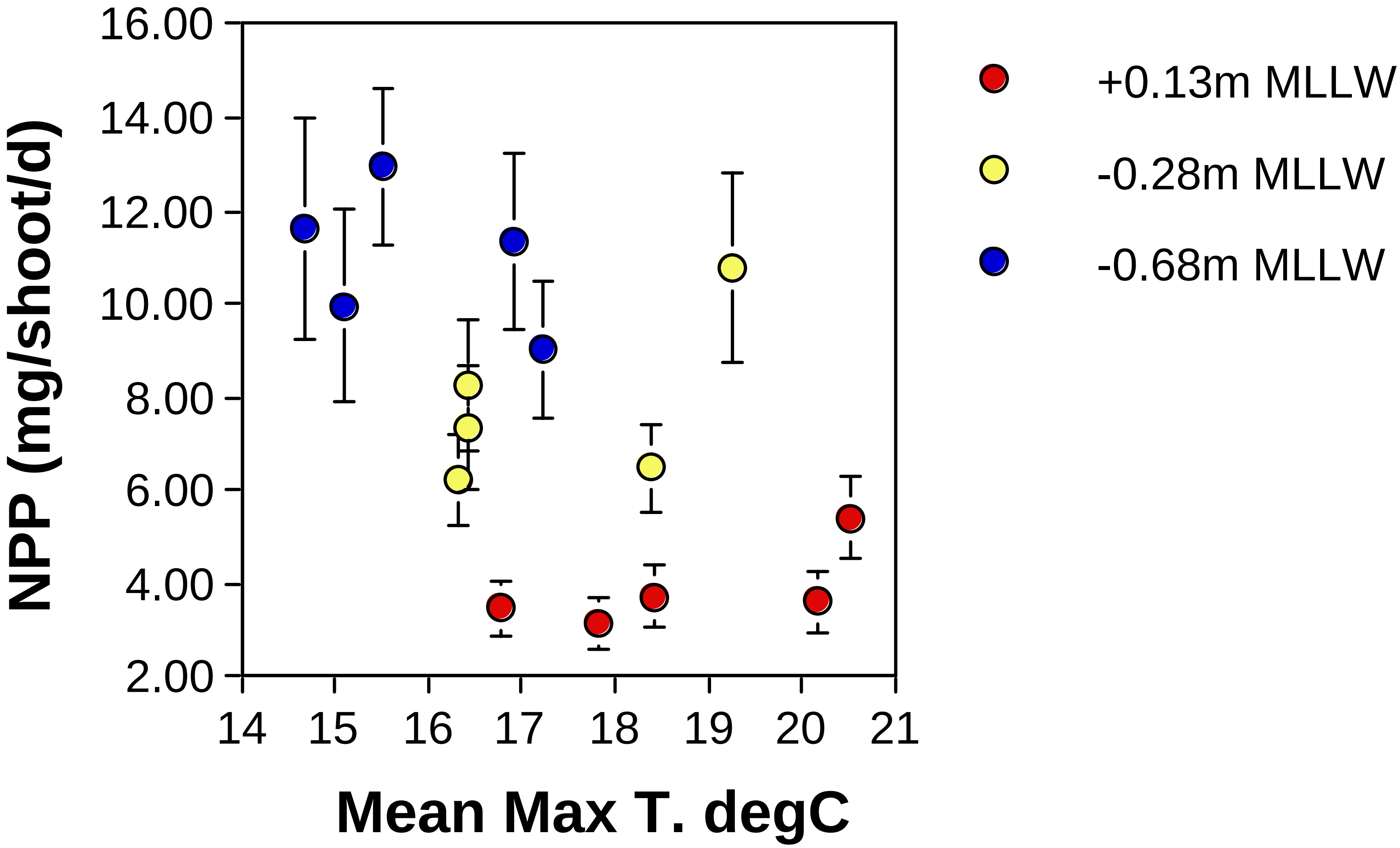
Summer Growth Rates vs Mean Sea Level Anomaly



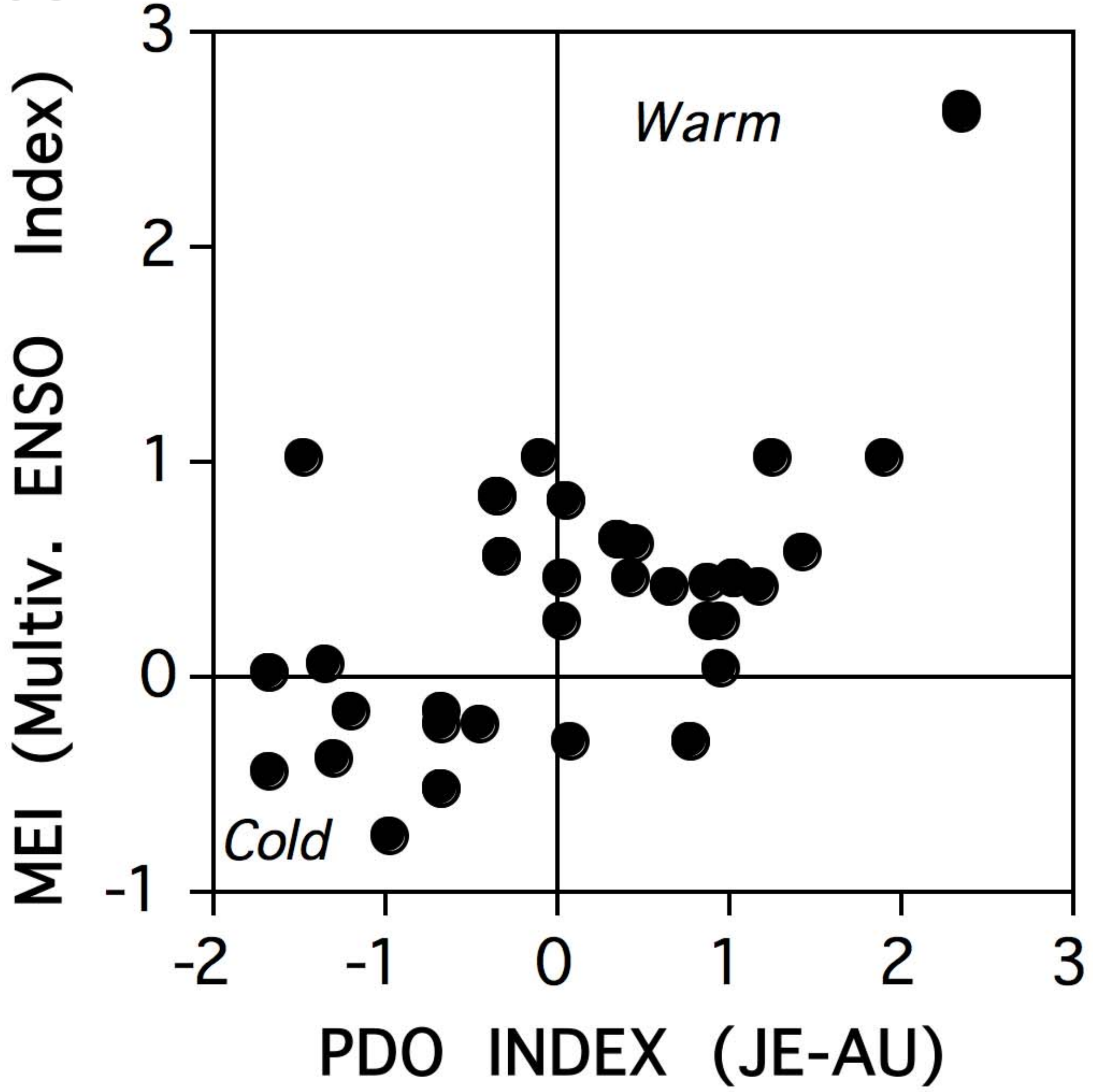
Growth Rates at Three Elevations in Sequim Bay (2004) □□□



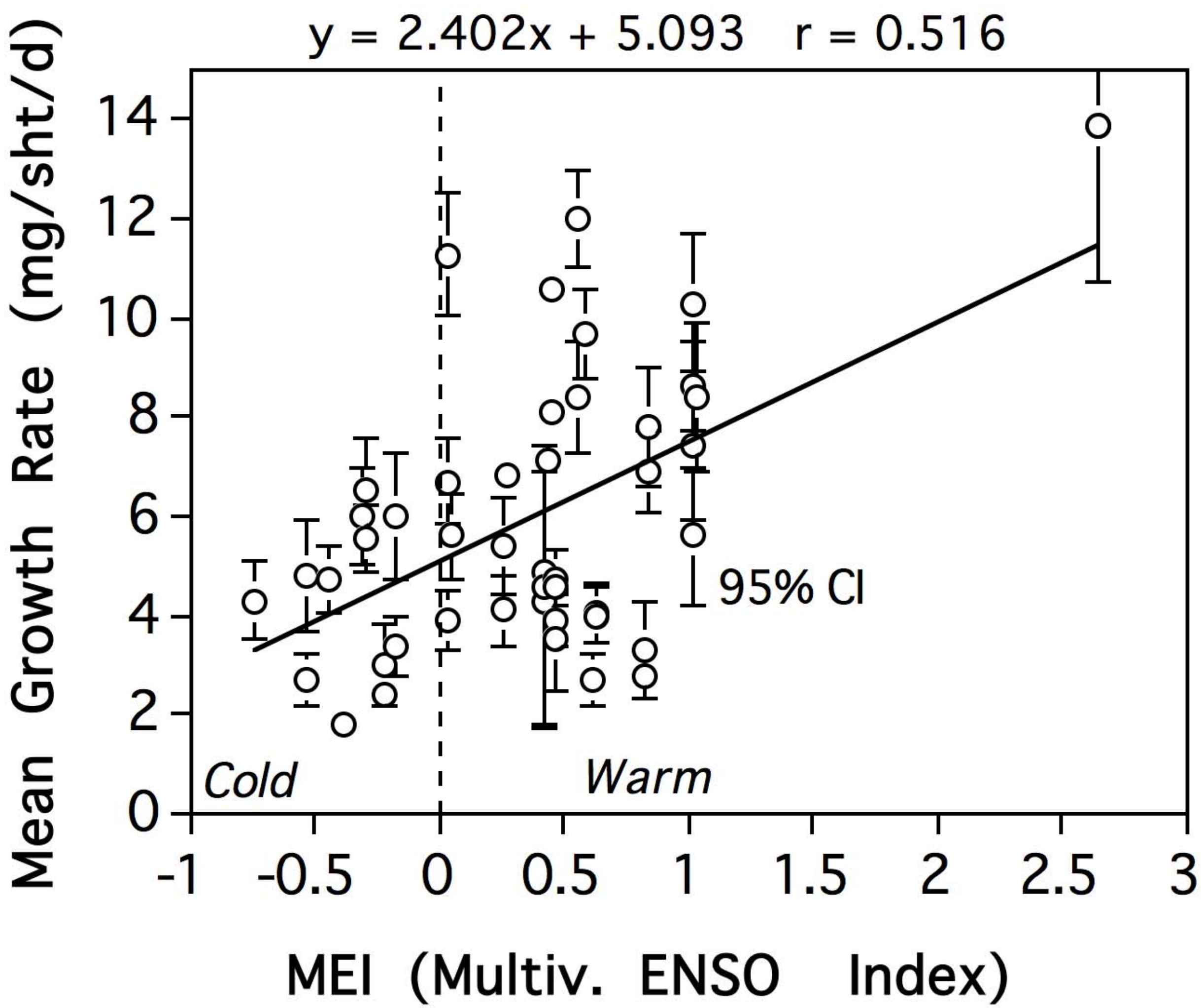
Growth Rates vs Temperature at Three Elevations in Sequim Bay (2004)



Pacific Decadal Oscillation Index vs Multivariate ENSO Index for Summers 1991-2008

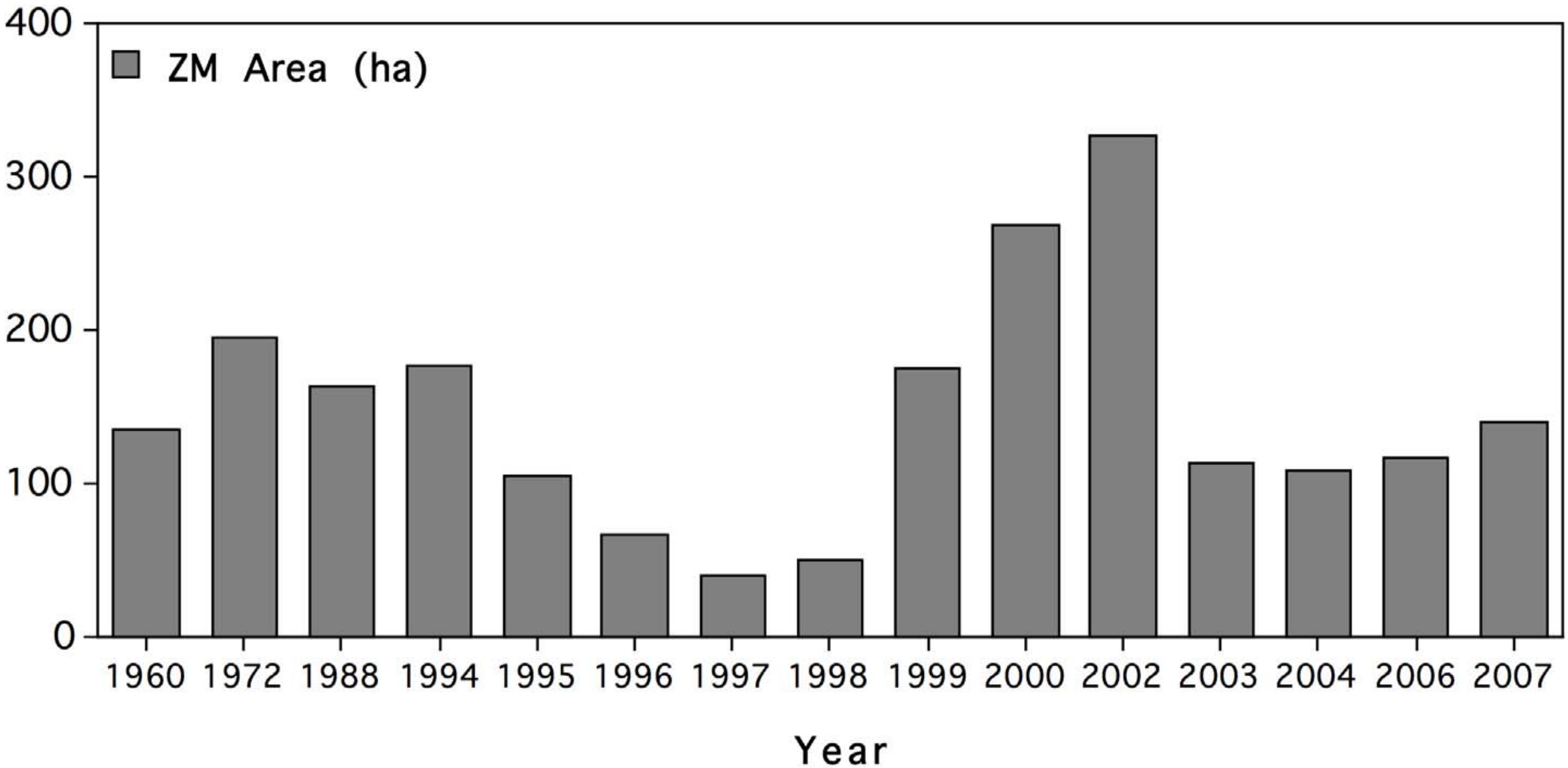


Summer Growth Rate vs Multivariate ENSO Index

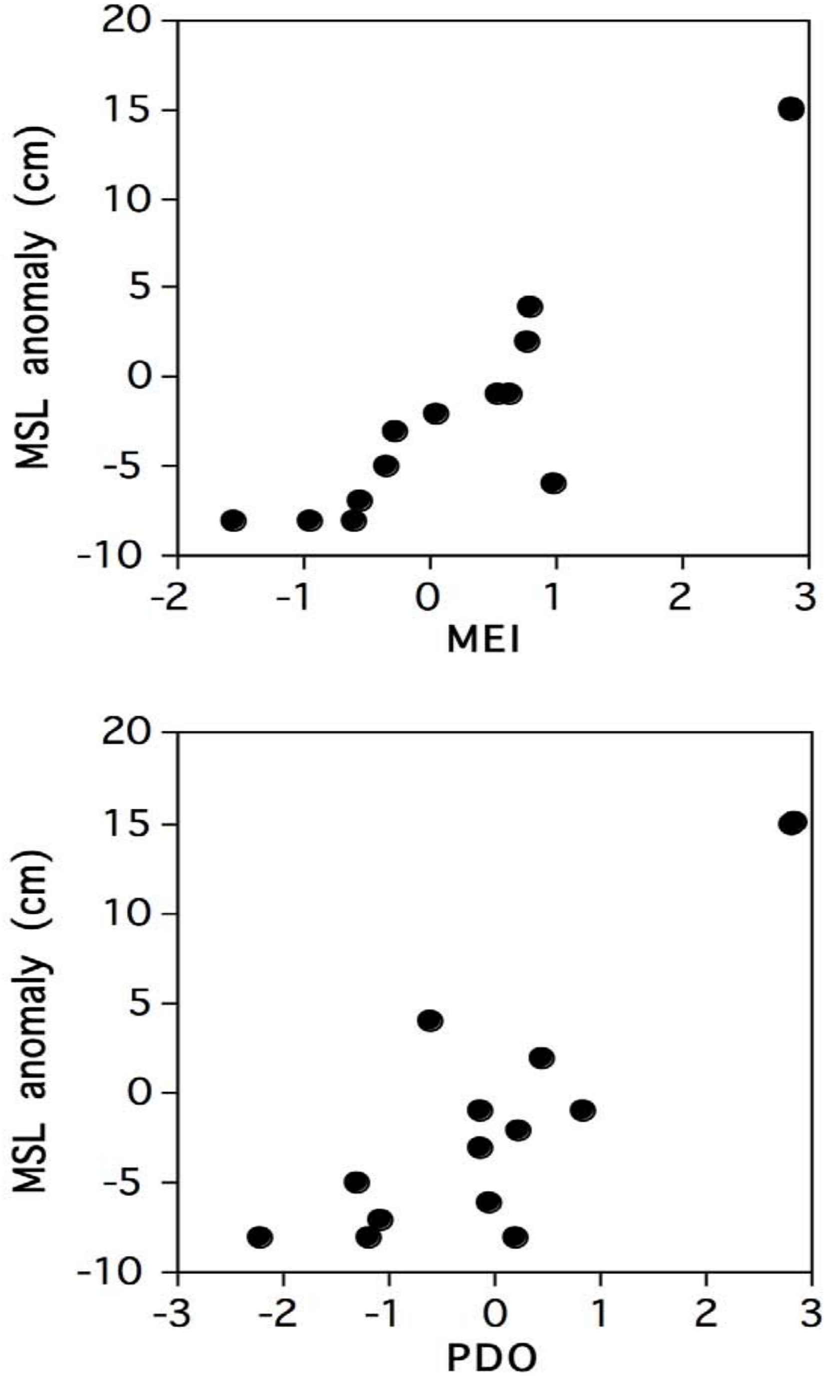


Morro Bay eelgrass
(Data courtesy of Morro Bay National Estuary Program)

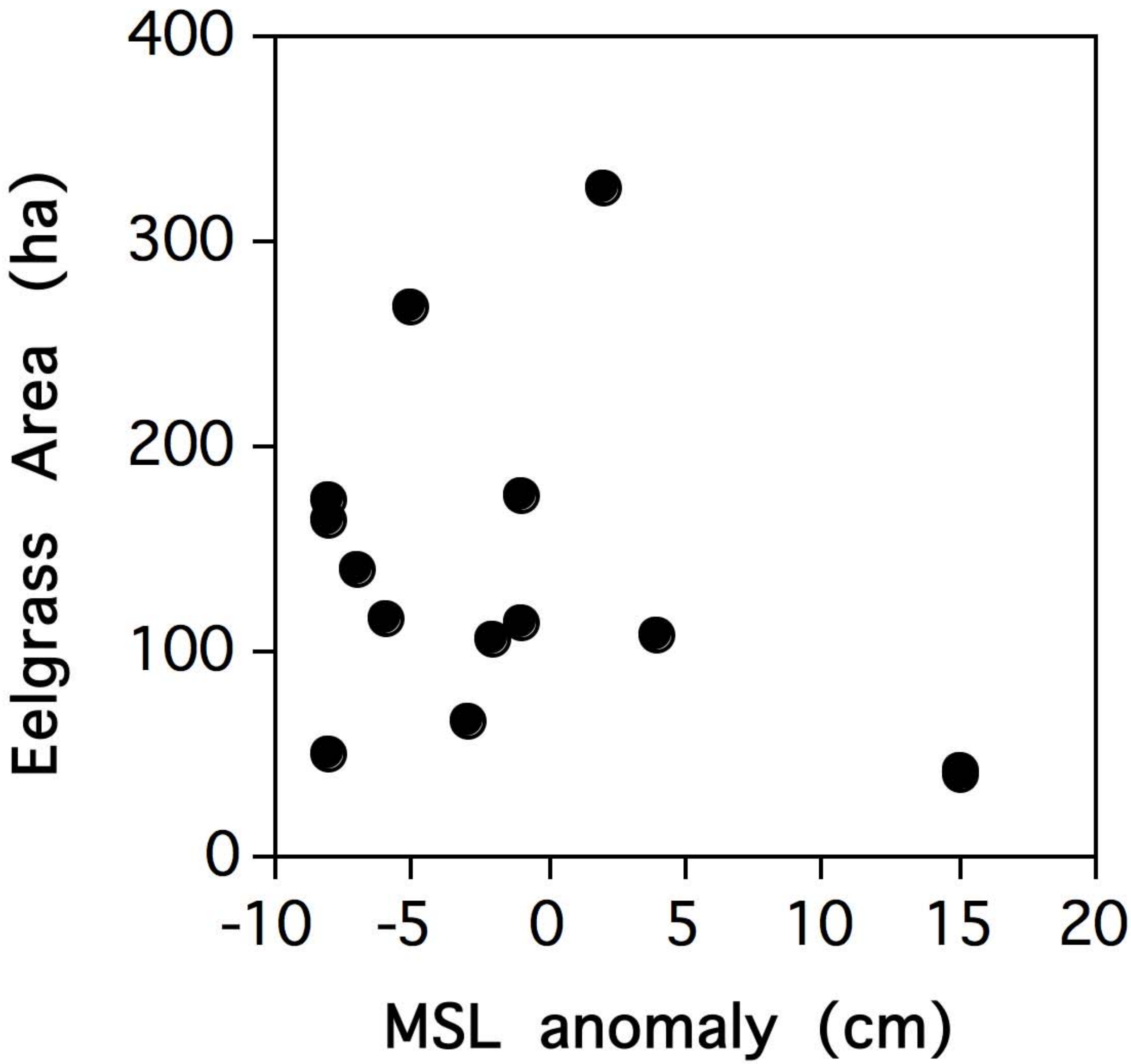
Interannual Variation in Eelgrass Area at Morro Bay



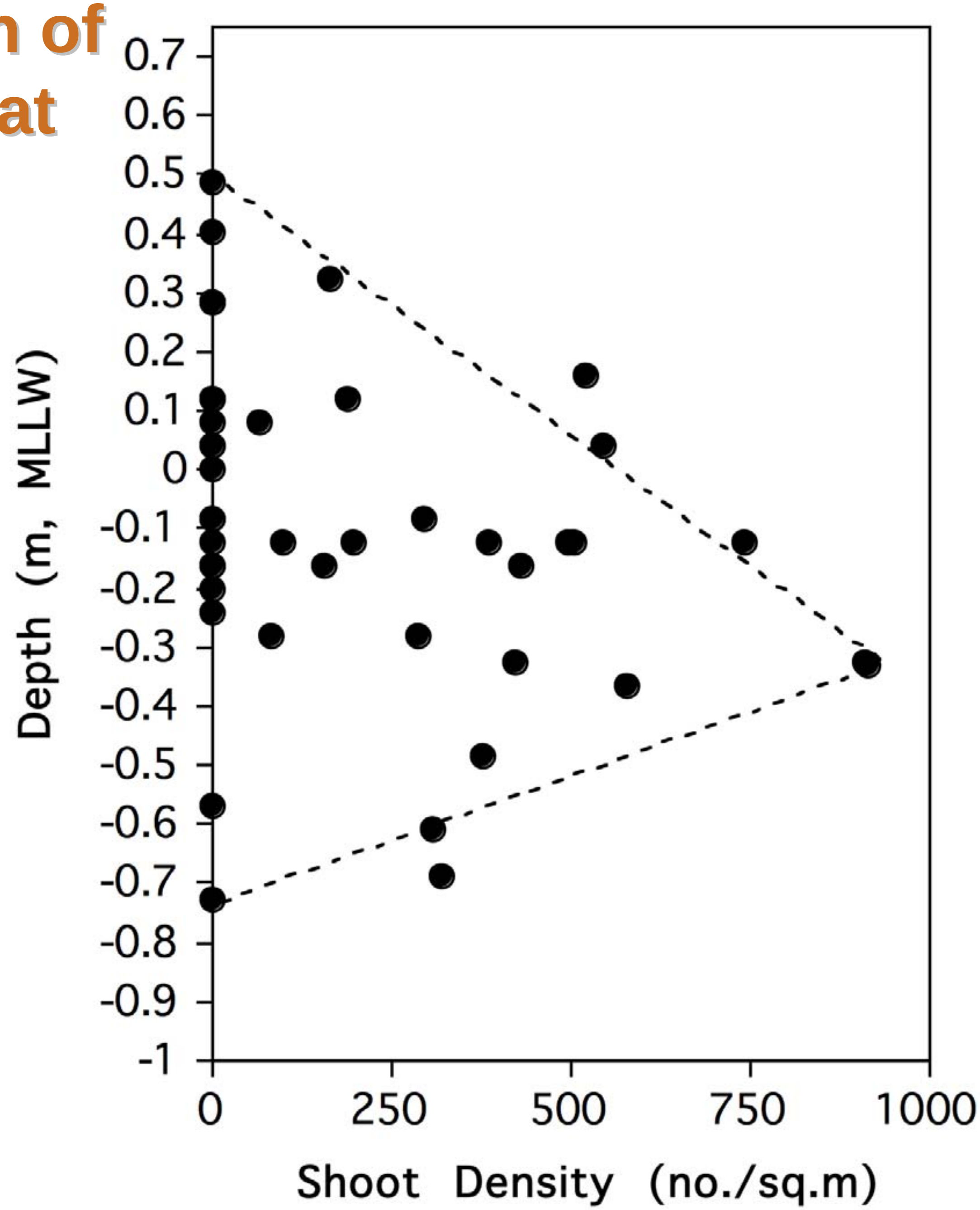
MEI and PDO vs Mean Sea Level 1988-2007 near Morro Bay

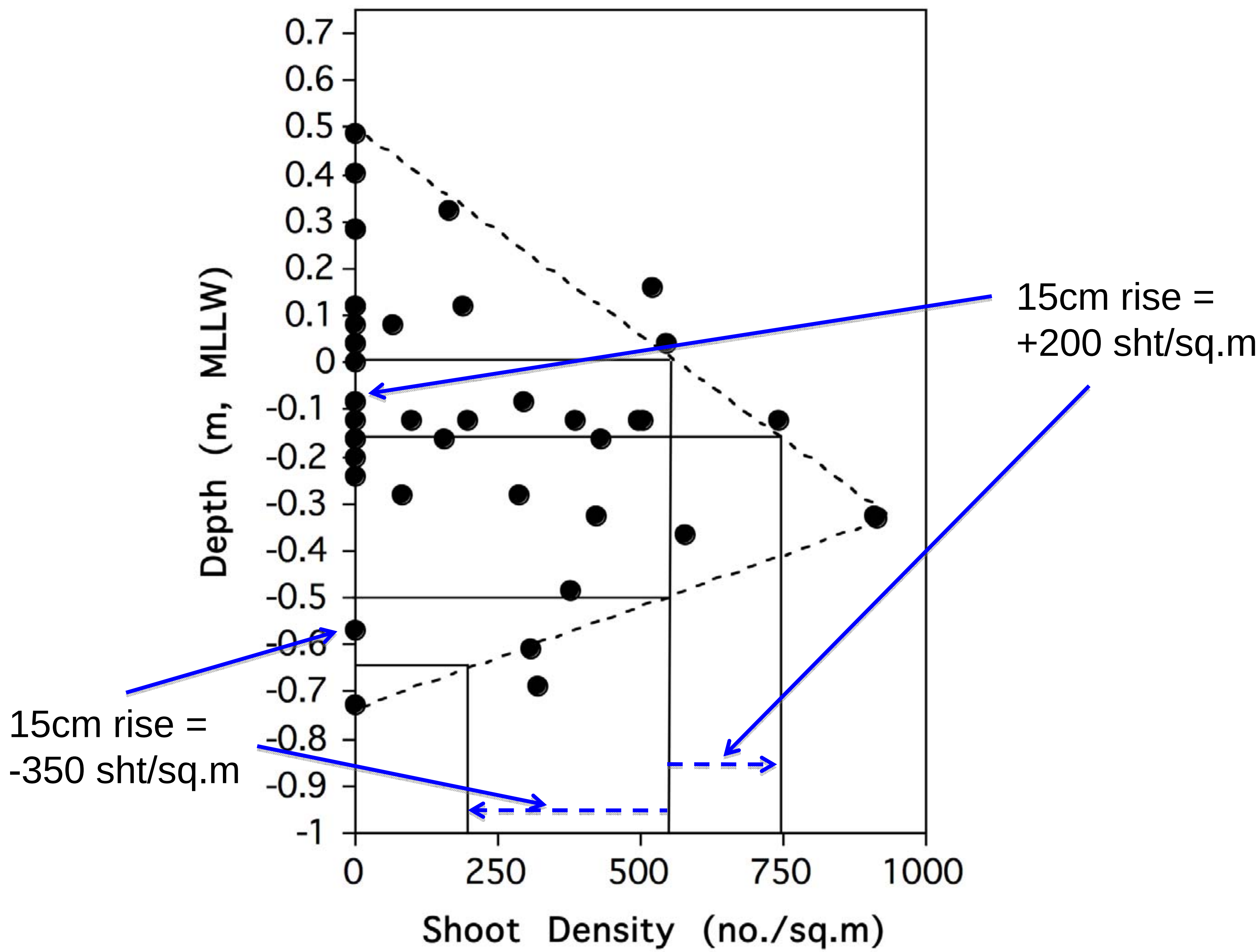


Morro Bay Eelgrass Area vs Mean Sea Level Anomaly



Depth Distribution of Eelgrass Density at Morro Bay (2006)





0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
Depth (m, MLLW)
0
250
500
750
1000
Shoot Density (no./sq.m)
15cm rise =
+200 sht/sq.m
15cm rise =
-350 sht/sq.m


Slope & substrata break
Beach
Eelgrass

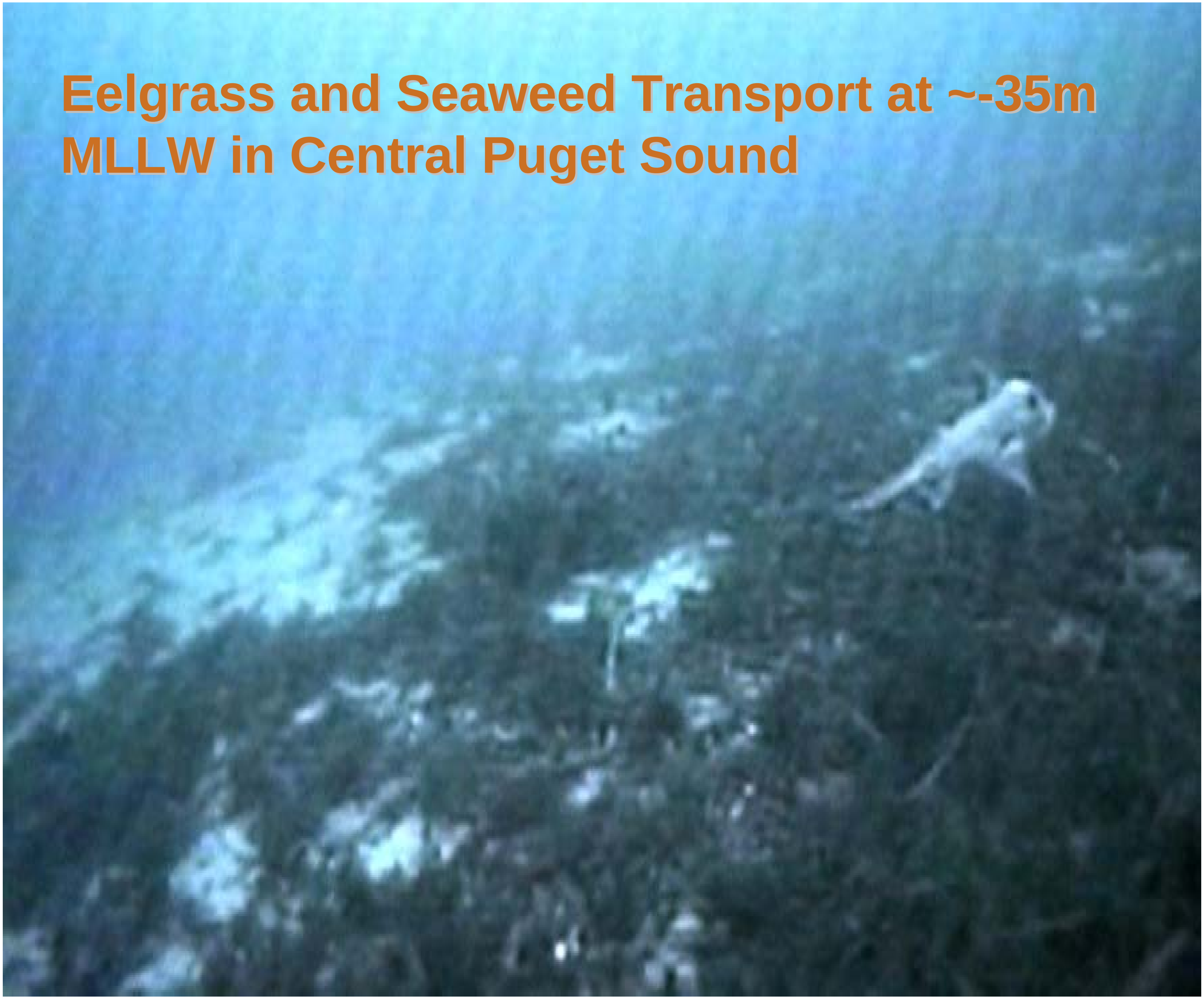
Total Annual NPP Estimates

System	*Eelgrass area*	*NPP*
Puget Sound	10,522ha	63,132 mT C
Willapa Bay	5,810	34,860
Coos Bay	510	3,060

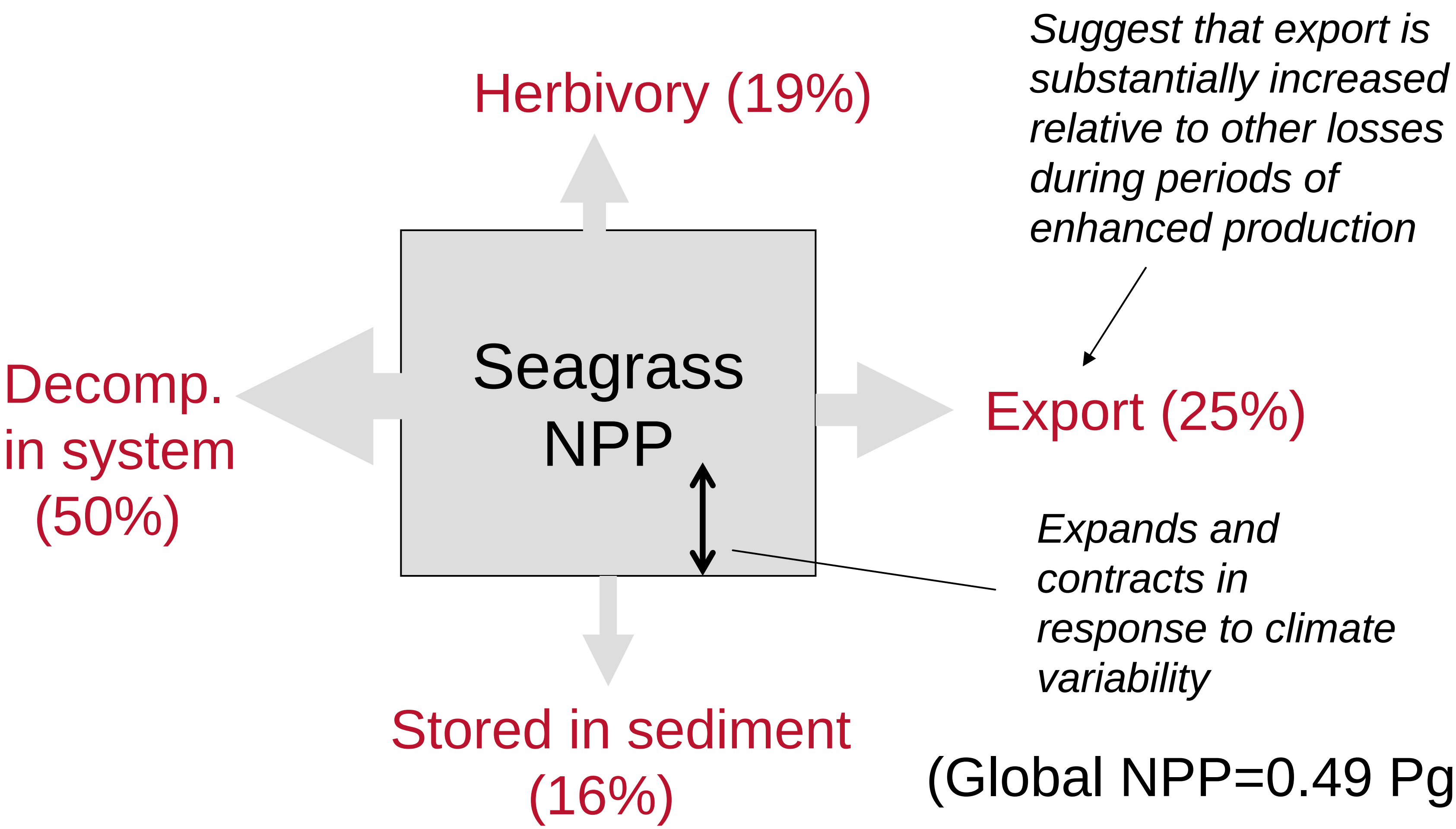
Marine angiosperms contribute 4% of total ocean NPP (Duarte and Cebrian 1996)

Padilla Bay - eelgrass detritus

Eelgrass and Seaweed Transport at ~-35m MLLW in Central Puget Sound



Fate of Seagrass NPP
(after Duarte and Cebrian 1996)



(Global NPP=0.49 Pg/y)

Conclusions (1 of 2)

- Weather affects plants, seagrasses are no exception
- Light, temperature and desiccation are reasonable factors to focus on relative to eelgrass response to climate change
- Climate driven mechanisms include mean sea level variation, factors that affect light, and temperature extremes
- Small changes in light or temperature can have a big effect on growth and abundance
- Eelgrass density and cover can vary dramatically between years
- Coupling monitoring programs (e.g., WADNR), models (EPA Newport), and experimental studies is critical to predicting future eelgrass changes

Conclusions (2 of 2)

- Elimination of eelgrass in some PNW bays goes largely unexplained (Westcott Bay, Hood Canal, Homes Harbor)
  - Suggest regional regime shifts
  - Marginal conditions (temperature, light, hypoxia) in these bays vulnerable to shifts
  - May be driven by altered circulation forced by such things as sea level variations, ocean forcing
  - Disease - another possible issue
  - WADNR, UW, USGS are investigating large losses
- Plan for resilience through (1) nurturing sources of renewal[a] (e.g., rhizomes, seeds), (2) pathways for dispersal (i.e., genetic stock), and (3) space for recruitment
- Argue for more emphasis on the coastal ecosystem in the global carbon budget

[a]Gunderson (2000)

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Thanks for Listening!

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