

Impacts of Global Climate Change on Eelgrass: Lessons from the U.S. West Coast

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**Status, Trends and Conservation of Eelgrass in Atlantic Canada
and the Northeastern United States (24-25 February 2009)**

Portland, Maine

Purpose

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

► Points-

- Inter-annual 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 in 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)

J. Phycol. 16, 102-108 (1980)

A GRADIENT IN BENTHIC INTERTIDAL ALGAL ASSEMBLAGES ALONG THE SOUTHERN CALIFORNIA COAST¹

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ABSTRACT

Based on
to exist in th
of south
t Con
flora
461

Marine Biology 104, 129-141 (1990)

assemblages in this area. All of these previous works have focused on human-caused (e.g., pollution) changes in the algal populations within this densely populated section of coastline.

One of the purposes of this paper is to use indirect gra-

1982-3 El Nino affected Puget
Sound nearshore habitats and
water properties (1990)

Dynamics of benthic vegetation standing-stock, irradiance, and water properties in central Puget Sound *

R. M. Thom and R. G. Albright **

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Abstract

The standing stock of benthic macroalgae, sediment-associated microalgae and molluscs (*Zostera marina* L.) was sampled in conjunction with irradiance and water properties from June 1984 to March 1985 to examine the relationship between the standing stock of benthic primary producers and water properties in central Puget Sound, Washington. The standing stock of benthic primary producers peaked in late summer and early fall, while irradiance and water properties peaked in late summer and early fall.

The standing stock of benthic primary producers was positively correlated with irradiance and water properties. The standing stock of benthic primary producers was also positively correlated with sediment-associated microalgae and molluscs. The standing stock of benthic primary producers was negatively correlated with sediment-associated microalgae and molluscs.

and productivity. These dynamical changes are produced by purely physical factors such as solar energy, and an interaction of chemical and biological factors (e.g. nutrients, grazing) (Valiela 1984, Lobban et al. 1985). Partitioning of the relative influence of factors has generally been accomplished through controlled experiments focused on one factor (e.g. Gordon et al. 1980, De la Cruz et al. 1981). In a few instances, experimental and field data have been used to develop models relating light, nutrients and other factors to the dynamics of dominant estuarine species (e.g. McIntire and Marsh 1985).

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

Abstract—The 42 intertidal transects established by E. Y. Dawson on the southern California mainland from 1956–1959 were resurveyed for their algal flora during 1973–1974. Although there were no losses of conspicuous species, the relative abundances of various forms had changed over the time period. The flora in the transects has been toward the turf and crustose species and away from the massive species. The Orange County flora showed the greatest change. The Los Angeles flora the least. In the Santa Barbara, Ventura, and San Diego floras the flora was modified to an intermediate extent.

Department of Biology, California State University, Los Angeles, 90032, Present address of Thom: College of Fisheries, University of Washington, Seattle, Washington 98195, Present address of Widdowson: Fisheries Research Institute, WH-10, University of Washington, Seattle, Washington 98195, USA.

As part of an oceanographic and biological survey of the California State Water Pollution Control Board, the 42 intertidal algal transects established by E. Y. Dawson in 1956–1959 were resurveyed in 1973–1974. The purpose of the survey was to determine if the algal flora had changed since the original survey. The results of the survey are presented in this paper.

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

-
- **H₀** = no correlation between climate indexes and eelgrass variation
 - **H₁** = there is a correlation (so what is mechanism?)

Indexes and Mechanisms

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)

- “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.

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

Bjork, M, F. Short, E. Mcleod and S. Beer. 2008. *Managing seagrasses for resilience to climate change*. IUCN, Gland, Switzerland.

- ▶ Temperature
- ▶ Sea level rise
- ▶ Water movement
- ▶ Salinity intrusion
- ▶ Increasing carbon dioxide
- ▶ UV-B radiation
- ▶ Storms
- ▶ Freshwater runoff

Climate Change and Seagrasses

► *Temperature*

- uncertain of level of change at the scale of eelgrass
- affects net productivity, reproduction and distribution

► *Sea level rise*

- 0.3m-1.0m this century
- affects light and desiccation

► *Carbon dioxide*

- affects growth

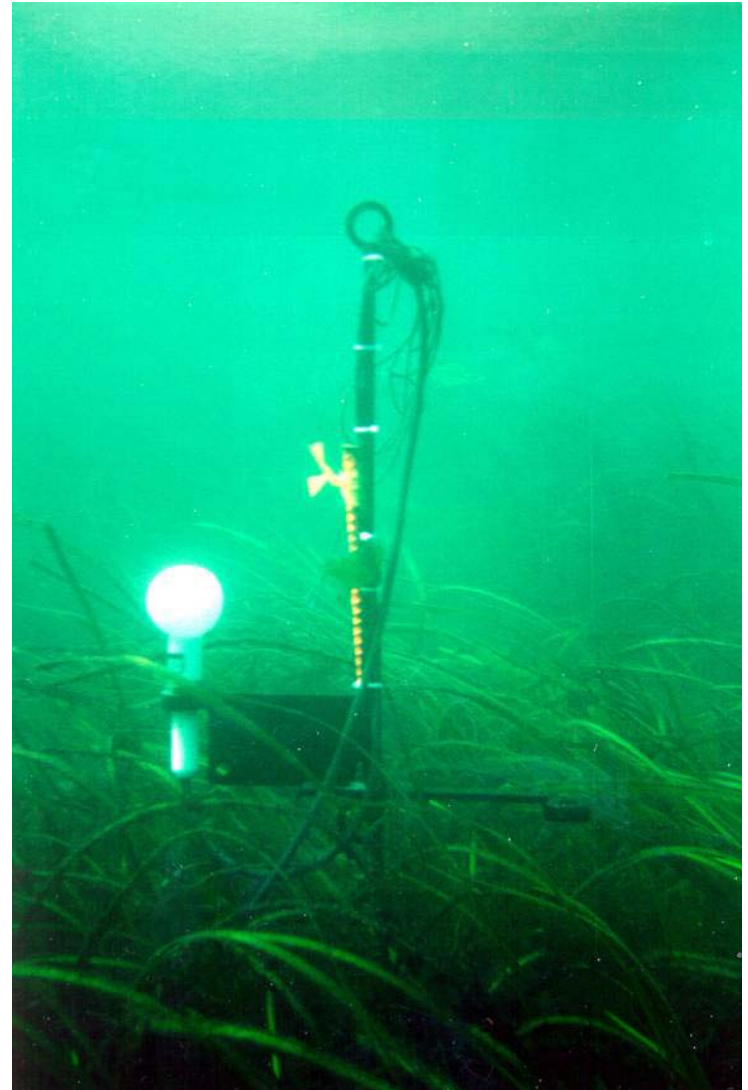
Data Sets

- ▶ 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)

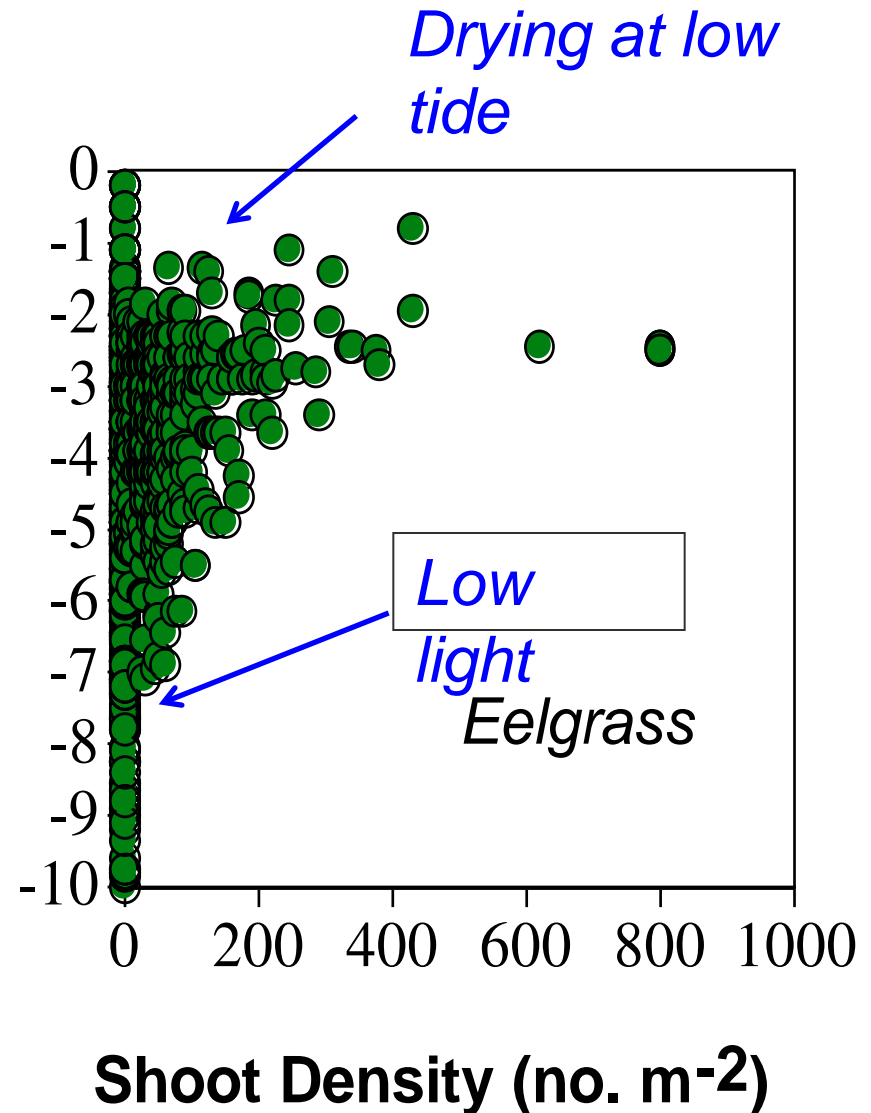
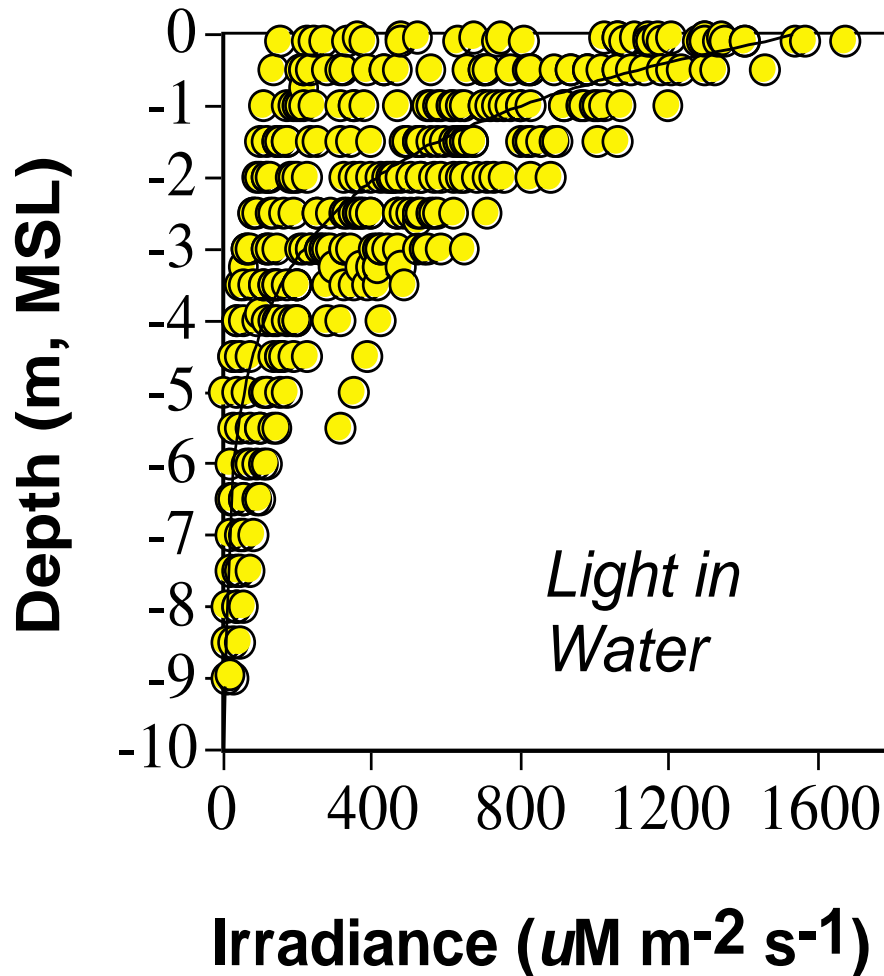


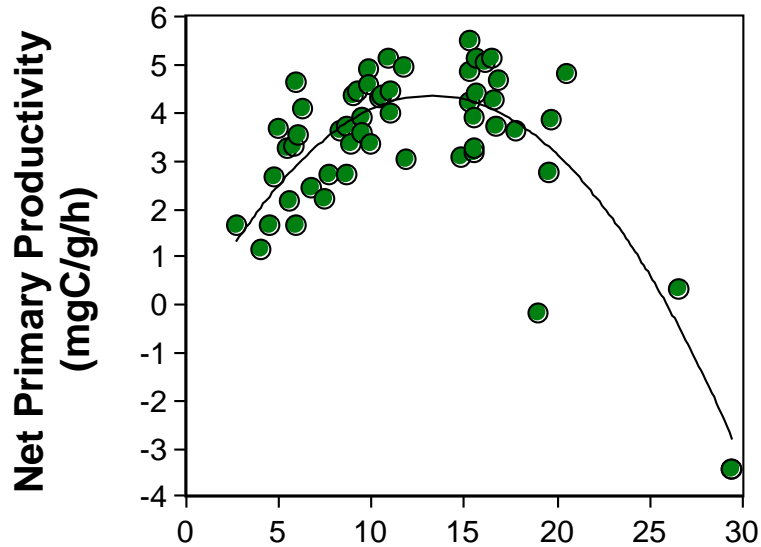
Factors Affecting Eelgrass

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

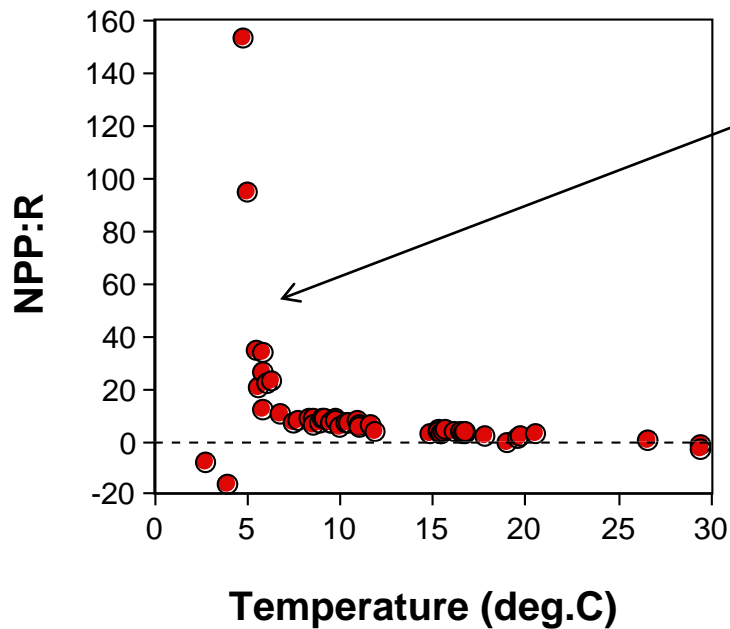


Light and Desiccation





Temperature



Plants are healthiest within a narrow temperature range

Willapa Bay, Washington

Present Day Tidal Elevations and Wetlands

Toke Pt.

Willapa River

Paitz River

Nemah

Lewis Slough

Paradise Pt.

Naselle River

Bear River

W. Long Is.

Jensen Spit

- PNCERS Eelgrass
- Below Extreme Low Water Line
- Potential Eelgrass
- Flats
- Tidal Wetland
- Modified Tidal Wetland

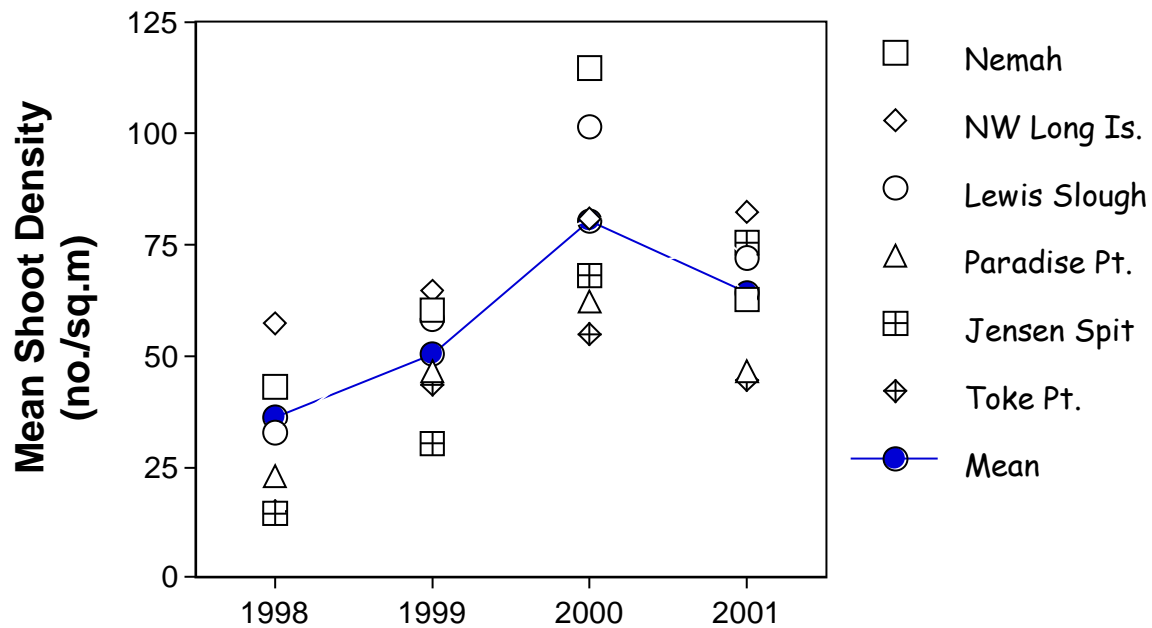


5 0 5 10 Kilometers

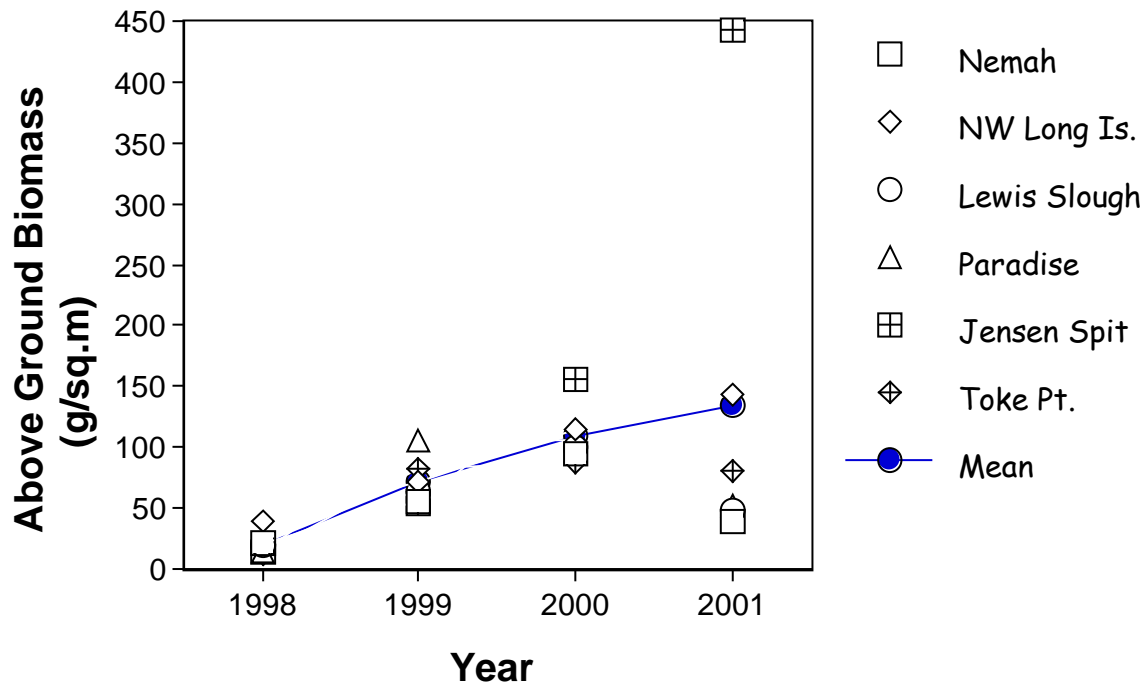
Data Sources: NOAA Hydrographic Survey Data, 1939-1954
 Intertain Pacific (Extreme Low Water Line and Modified Tidal Wetlands)
 NOAA Medium Resolution Digital Vector Shoreline
 U.S. Department of Interior, National Wetlands Inventory

Eelgrass

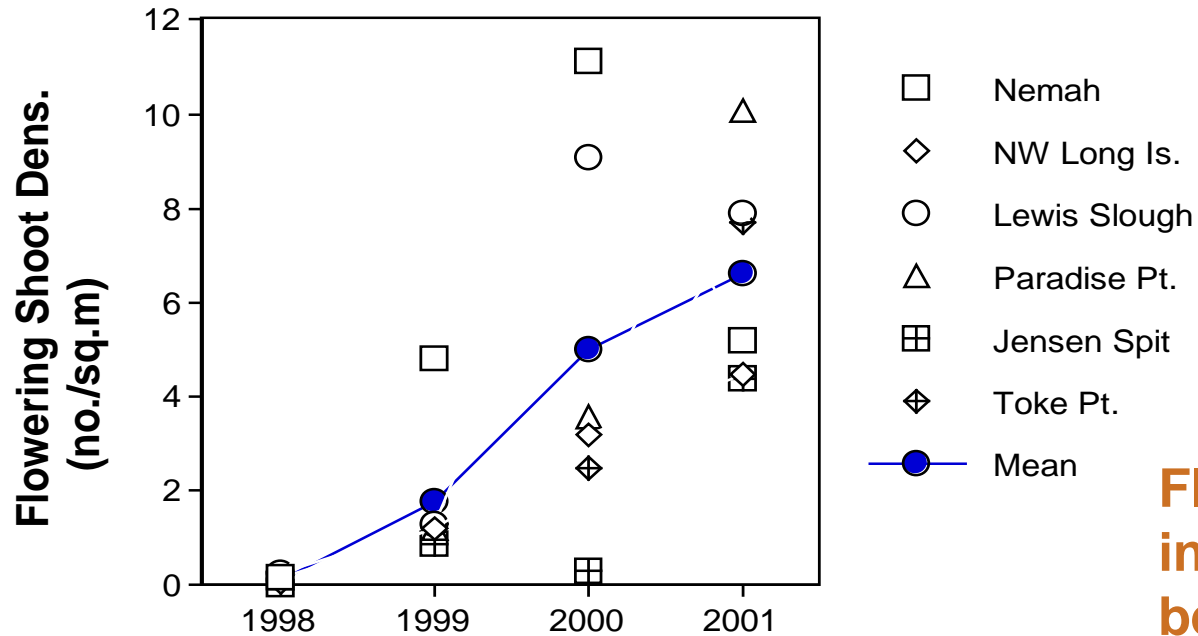




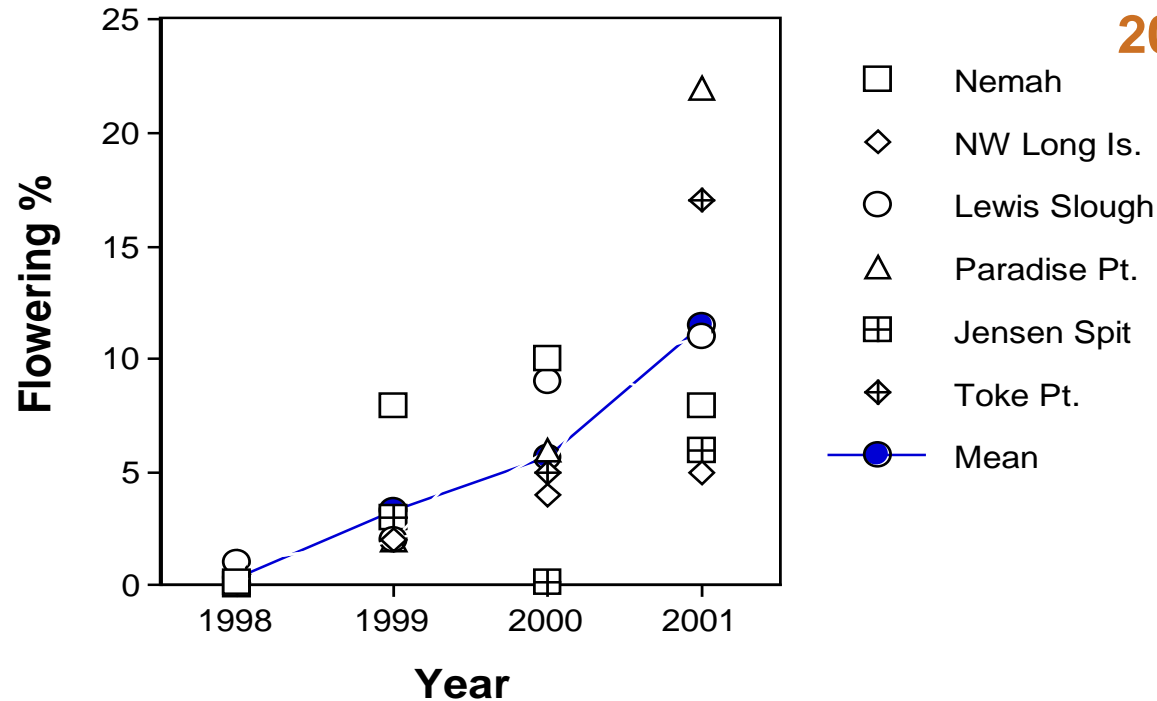
**Density increased
~2.5X
between 1998
and 2000**

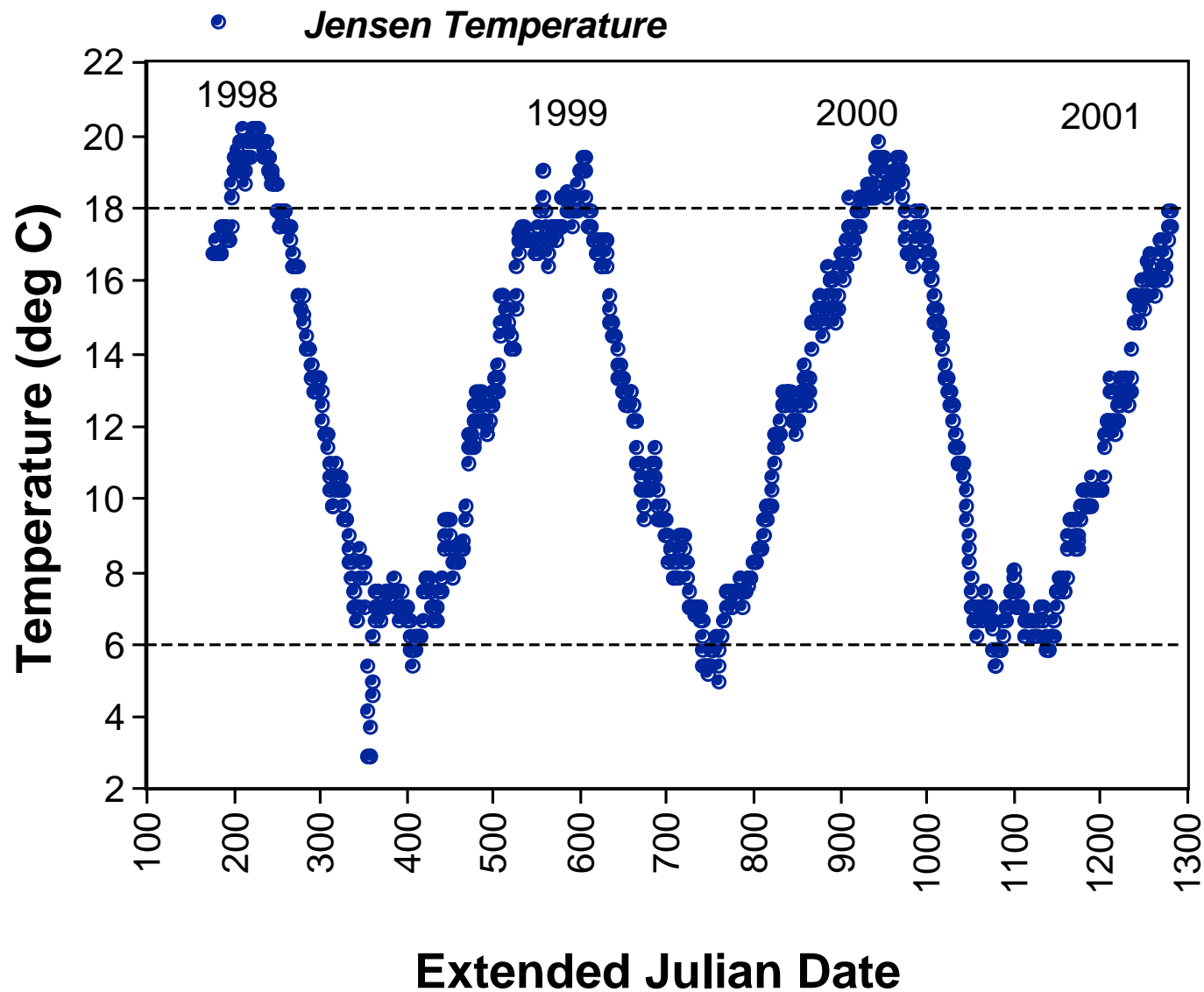


**Biomass increased
~5X
between
1998 and
2000**



**Flower production
increased ~35X
between 1998 and
2000**

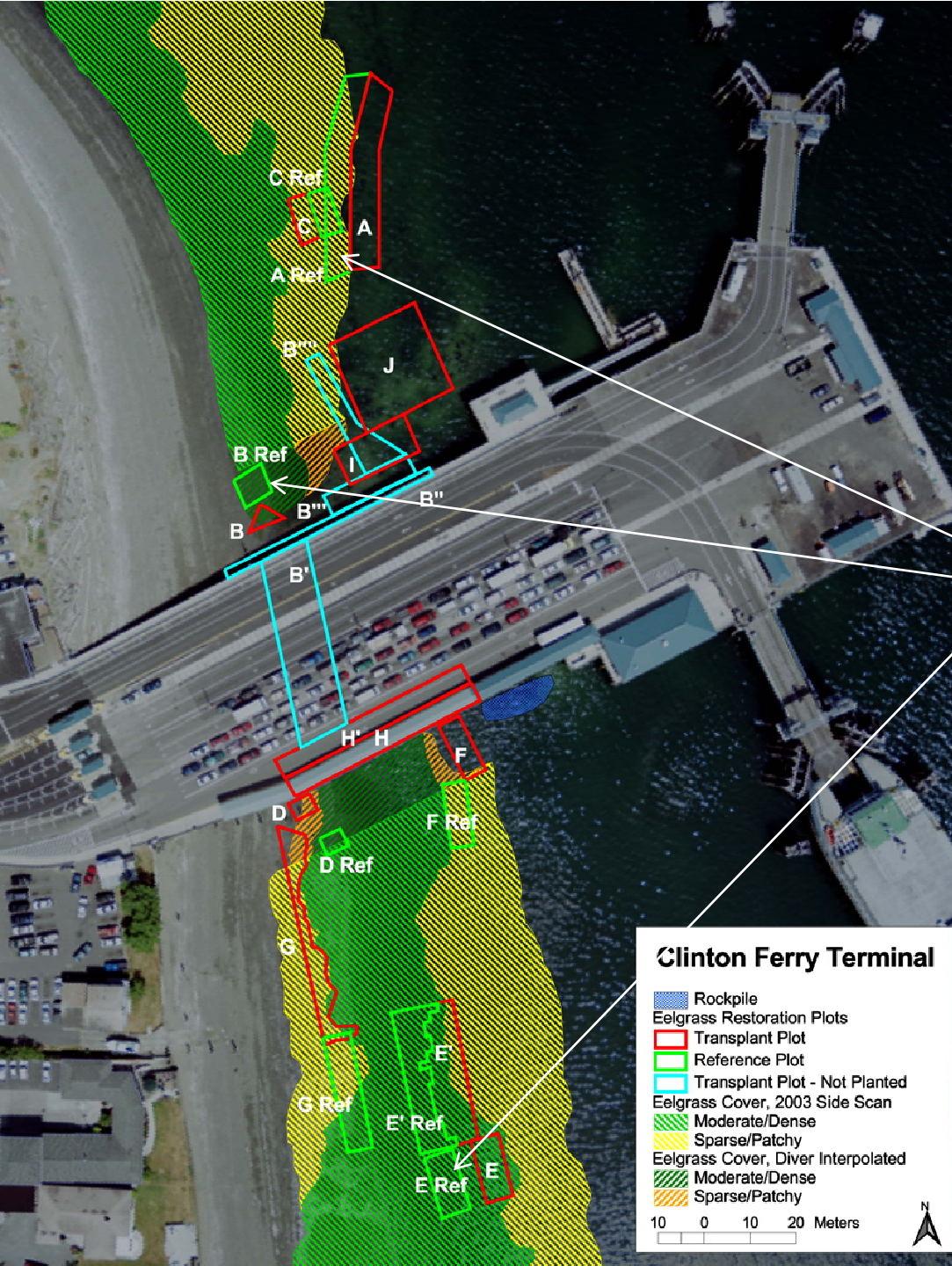


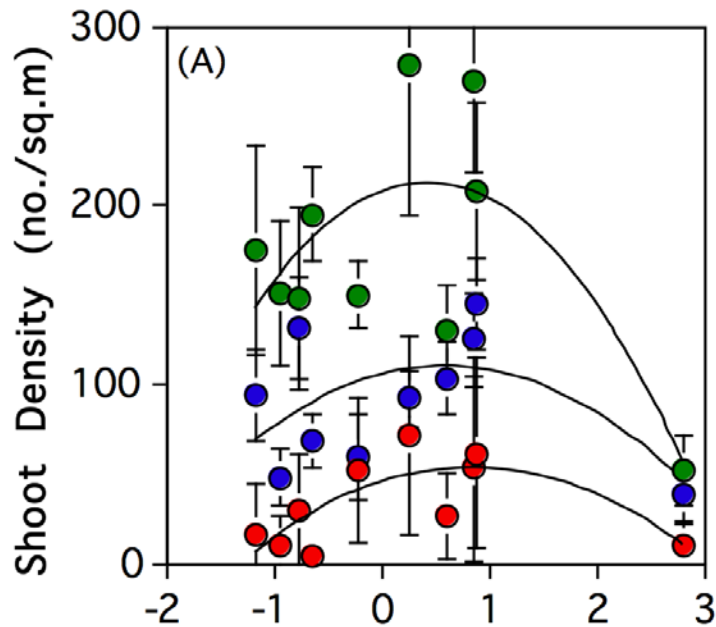


**Warmer
summer and
colder winter
in 1998 - 1999**

Clinton Ferry Terminal Eelgrass Plots

Reference plots



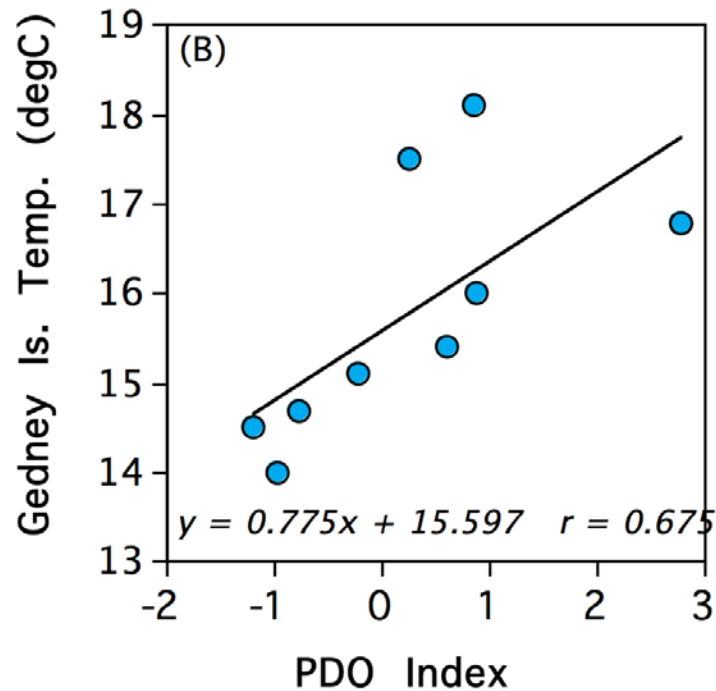


● Plot A: $y = -11.411x^2 + 19.152x + 45.289$
 $r = 0.779$

● 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)



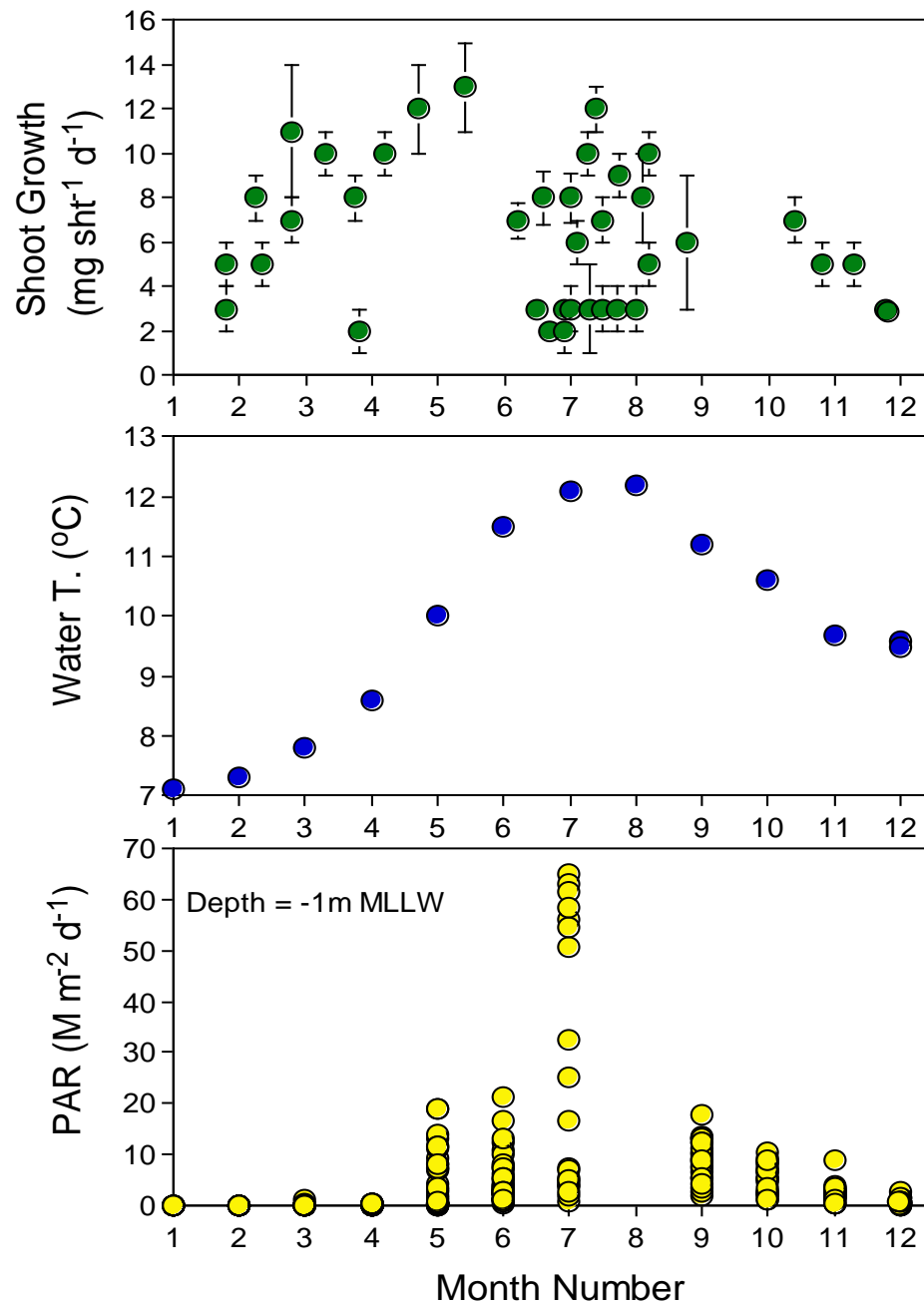
Shoot density greatest at ~neutral PDO

Growth at Sequim Bay (1991-2008)





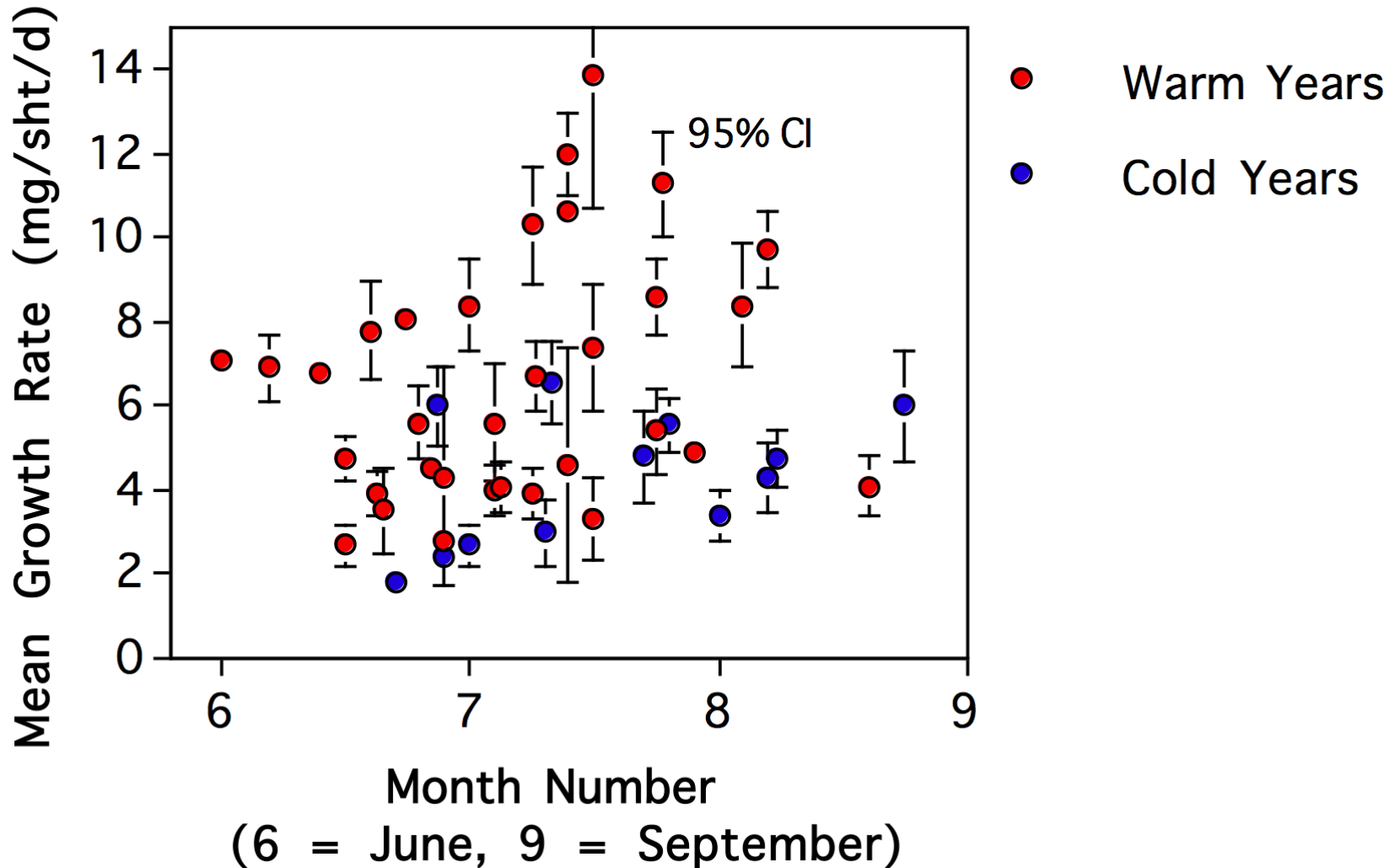
Sampling sites



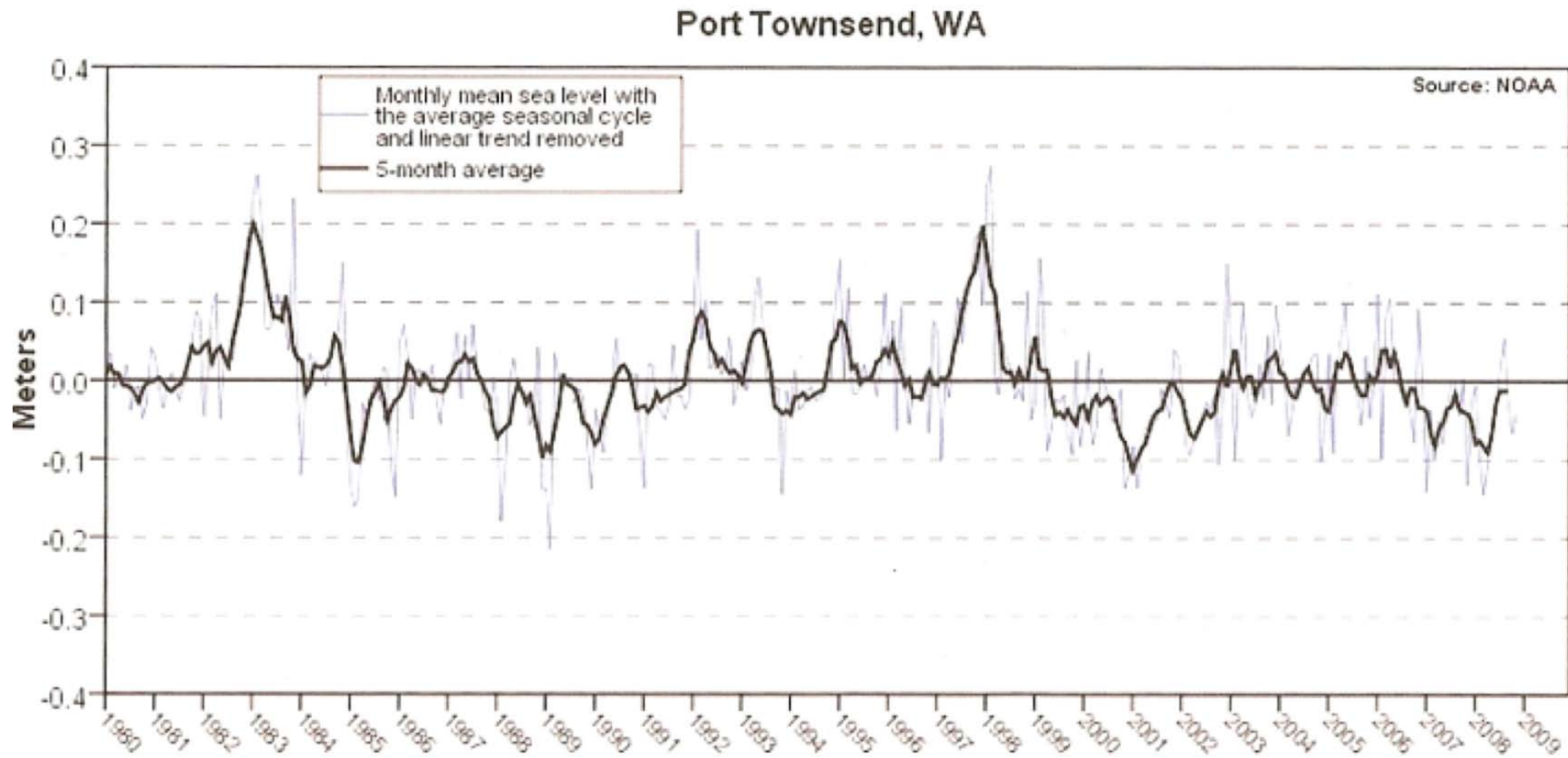
Sequim Bay Seasonal Dynamics ($\text{NPP} = 599 \text{ gC m}^{-2} \text{ y}^{-2}$)

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

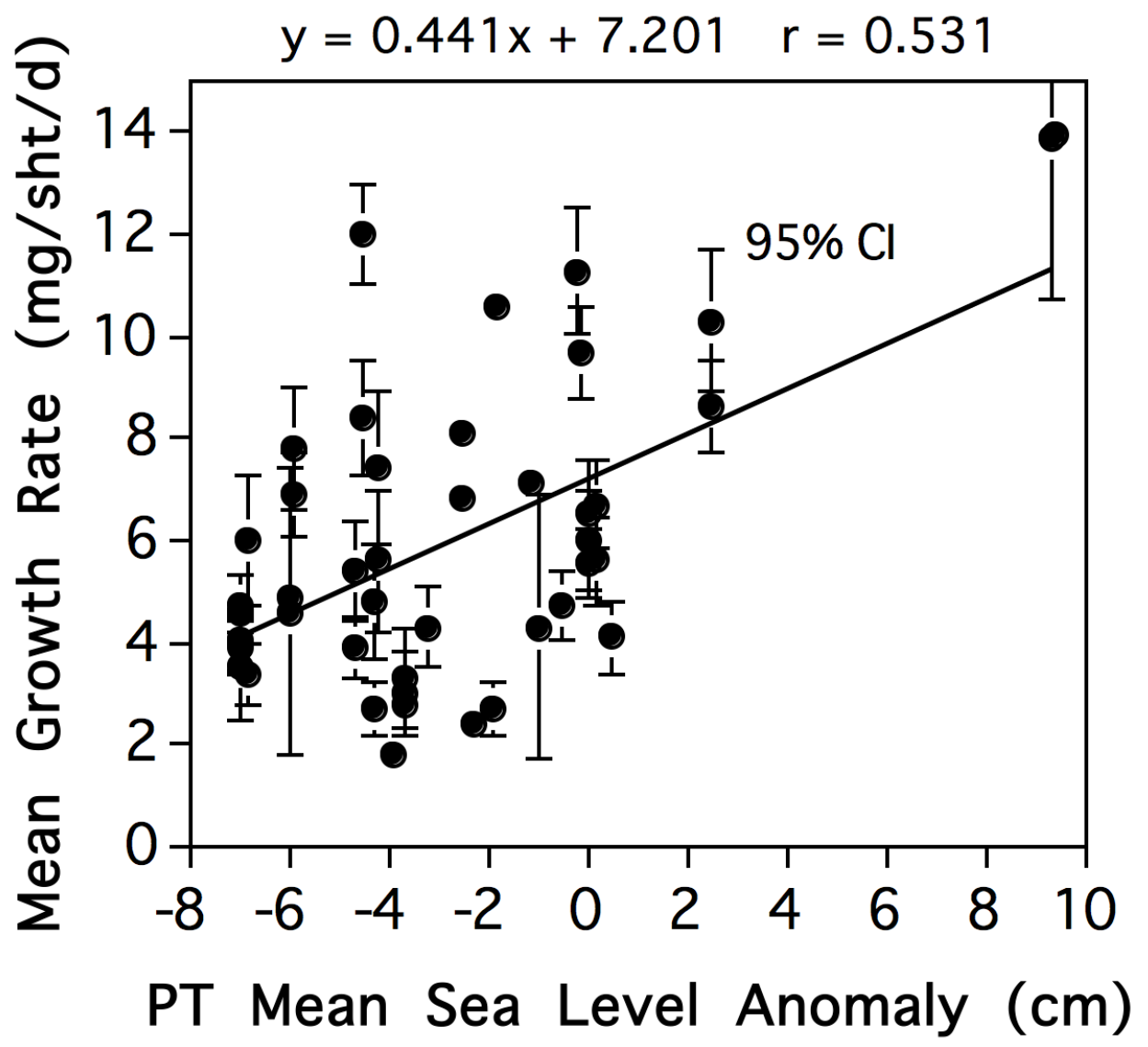
Summer Growth Rates



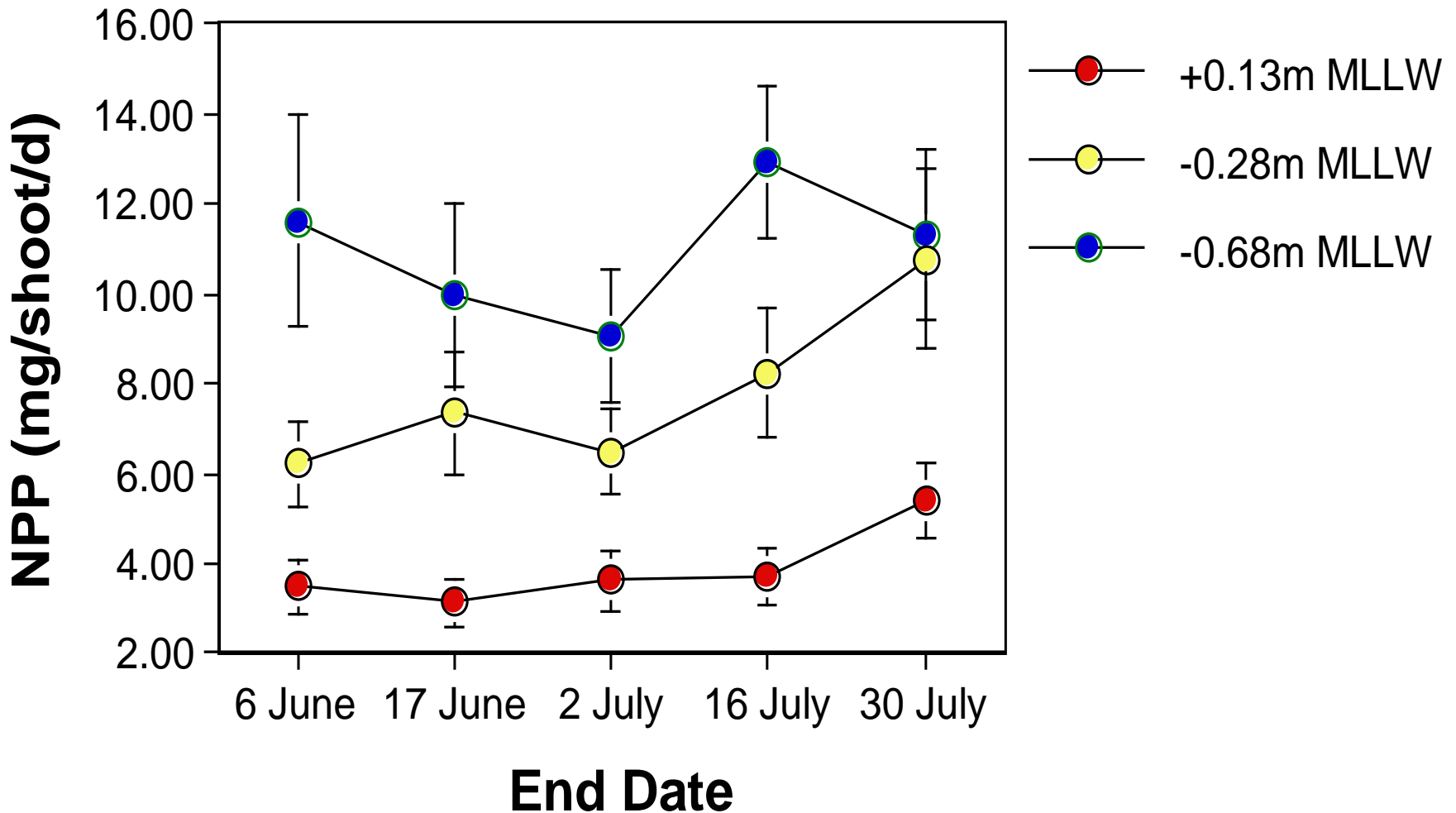
Variation of Mean Sea Level from 1980 to the Present at Port Townsend, Washington



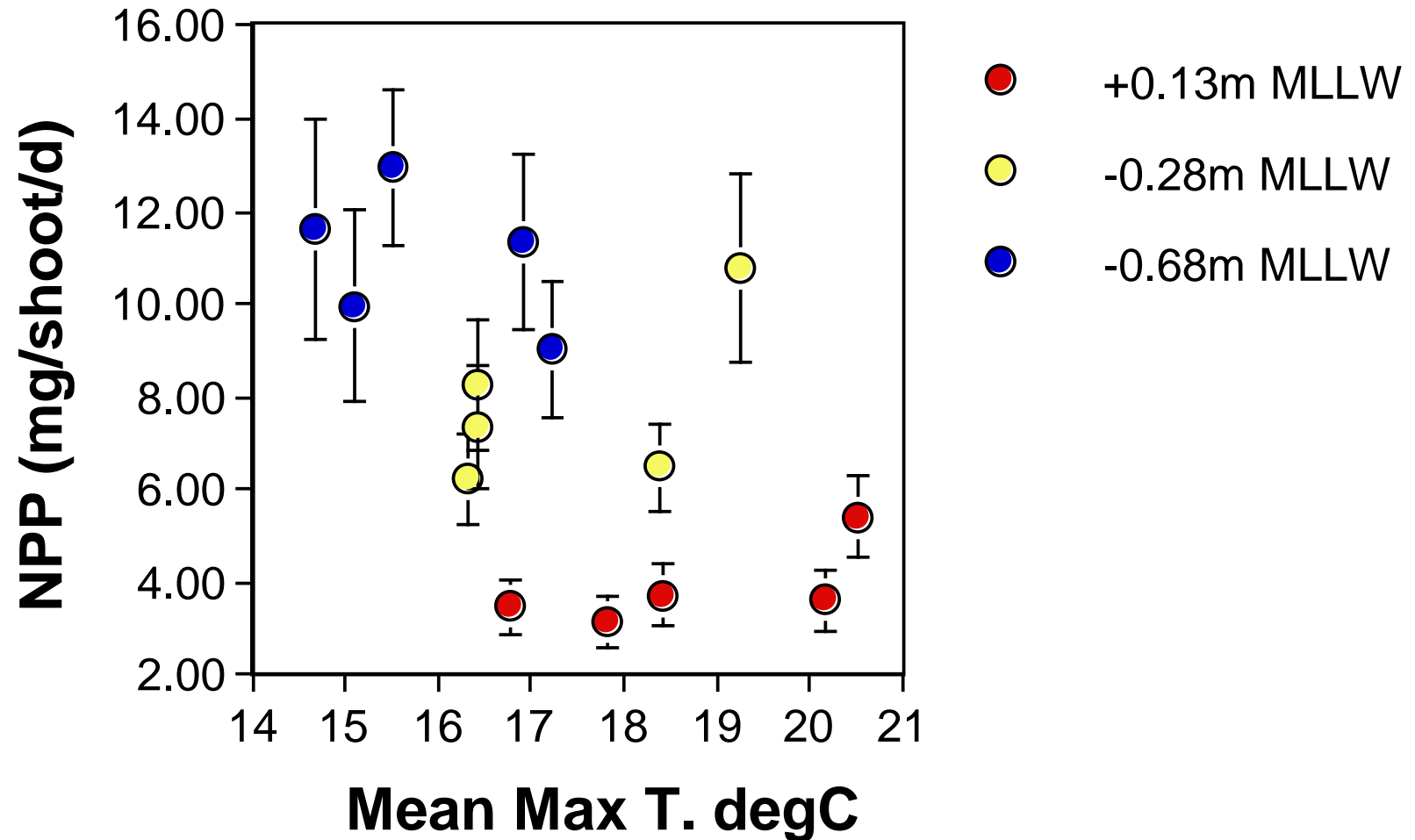
Summer Growth Rates vs Mean Sea Level Anomaly



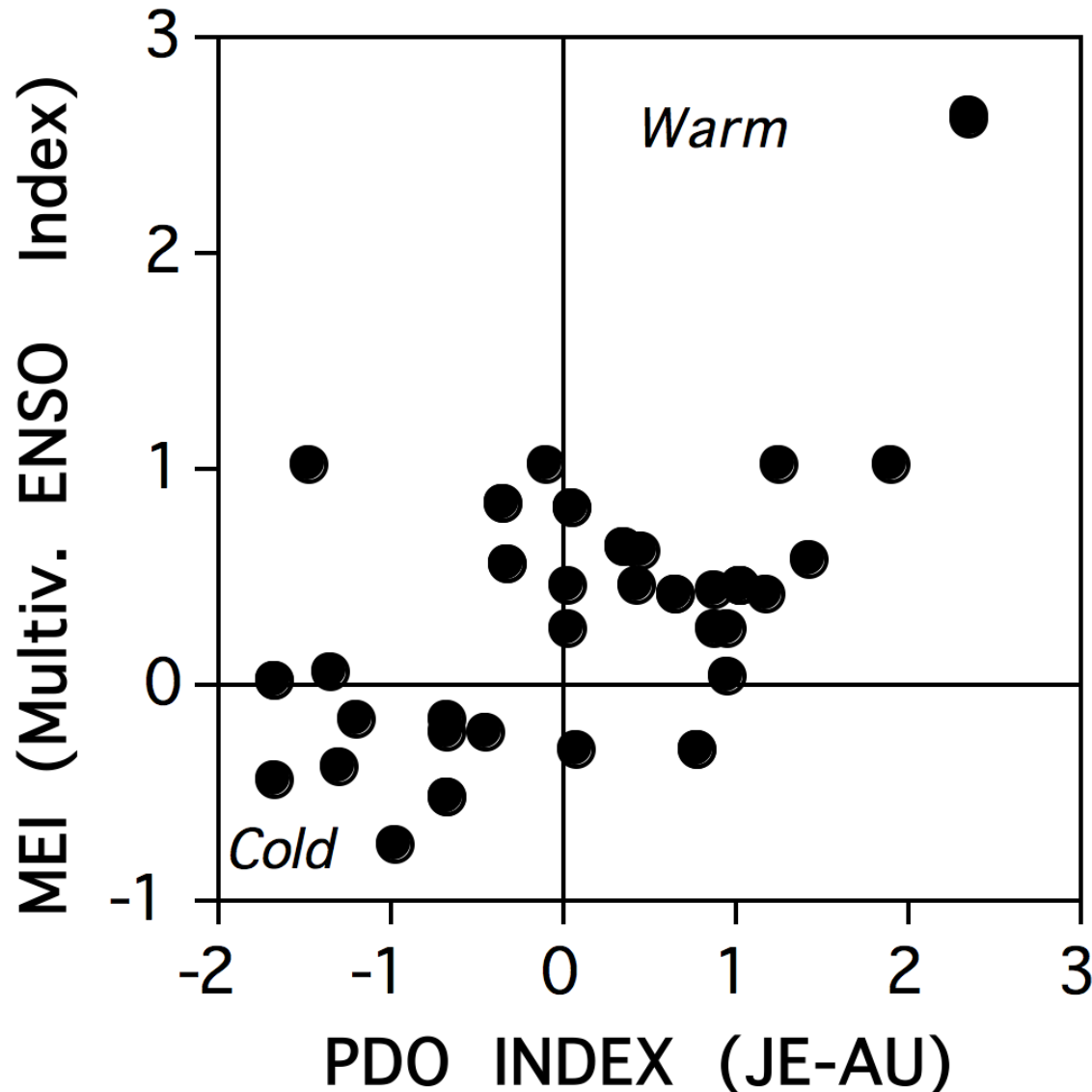
Growth Rates at Three Elevations in Sequim Bay (2004)



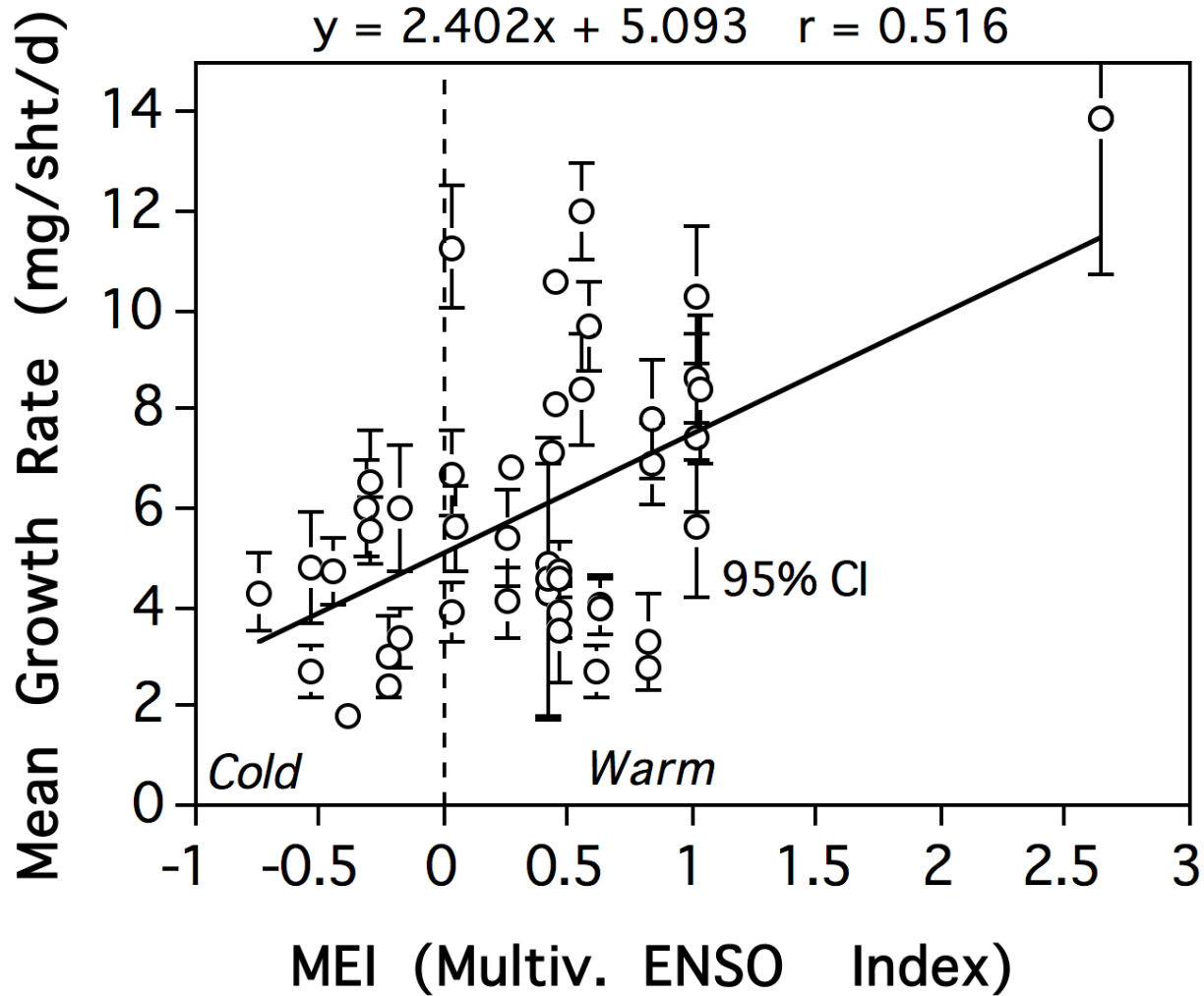
Growth Rates vs Temperature at Three Elevations in Sequim Bay (2004)



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



Summer Growth Rate vs Multivariate ENSO Index



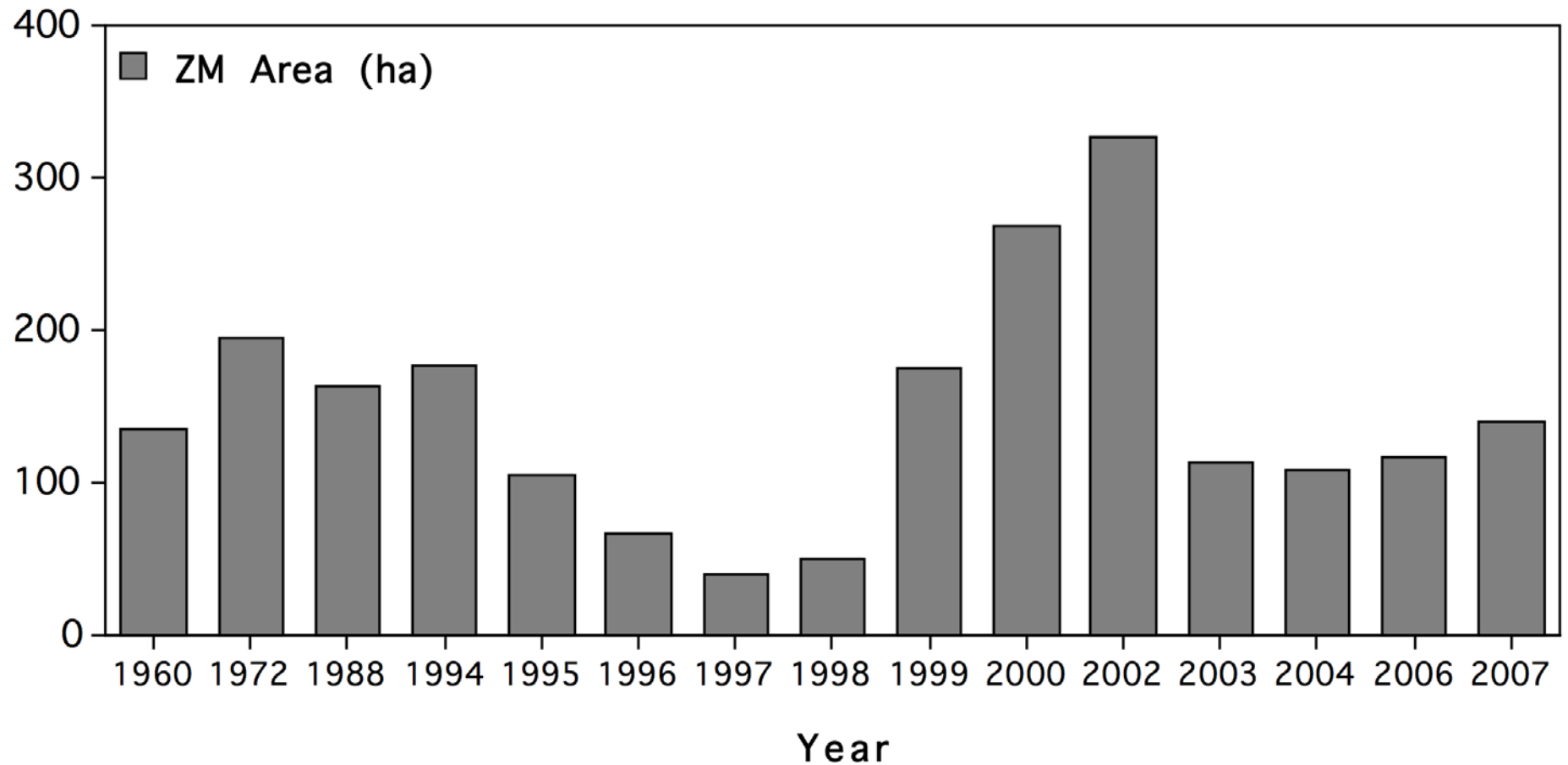
Morro Bay eelgrass

(Data courtesy of Morro Bay National Estuary Program)

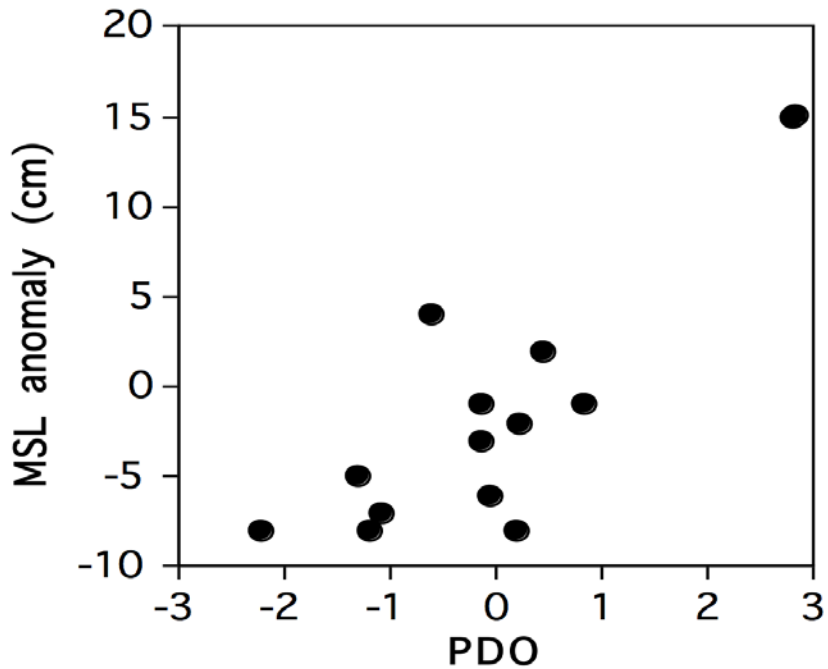
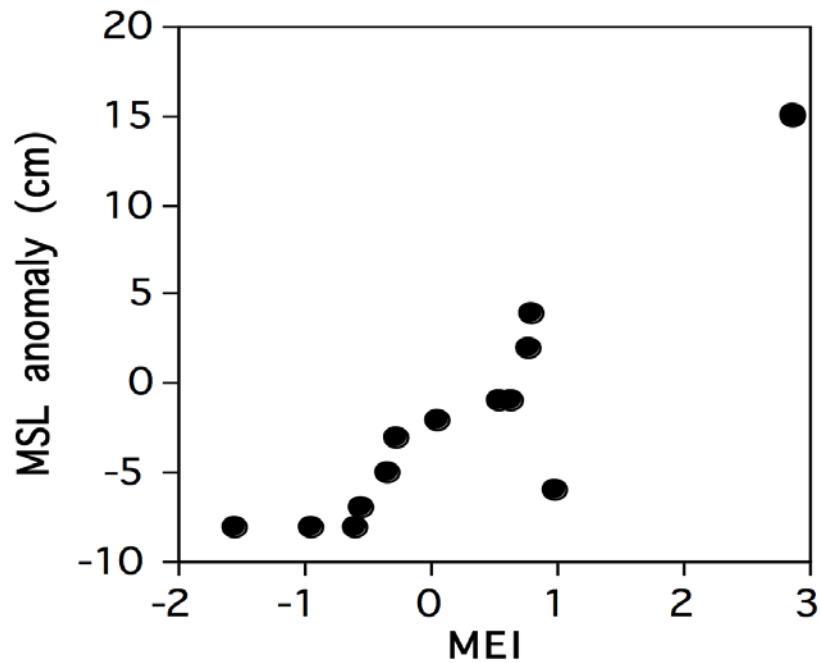




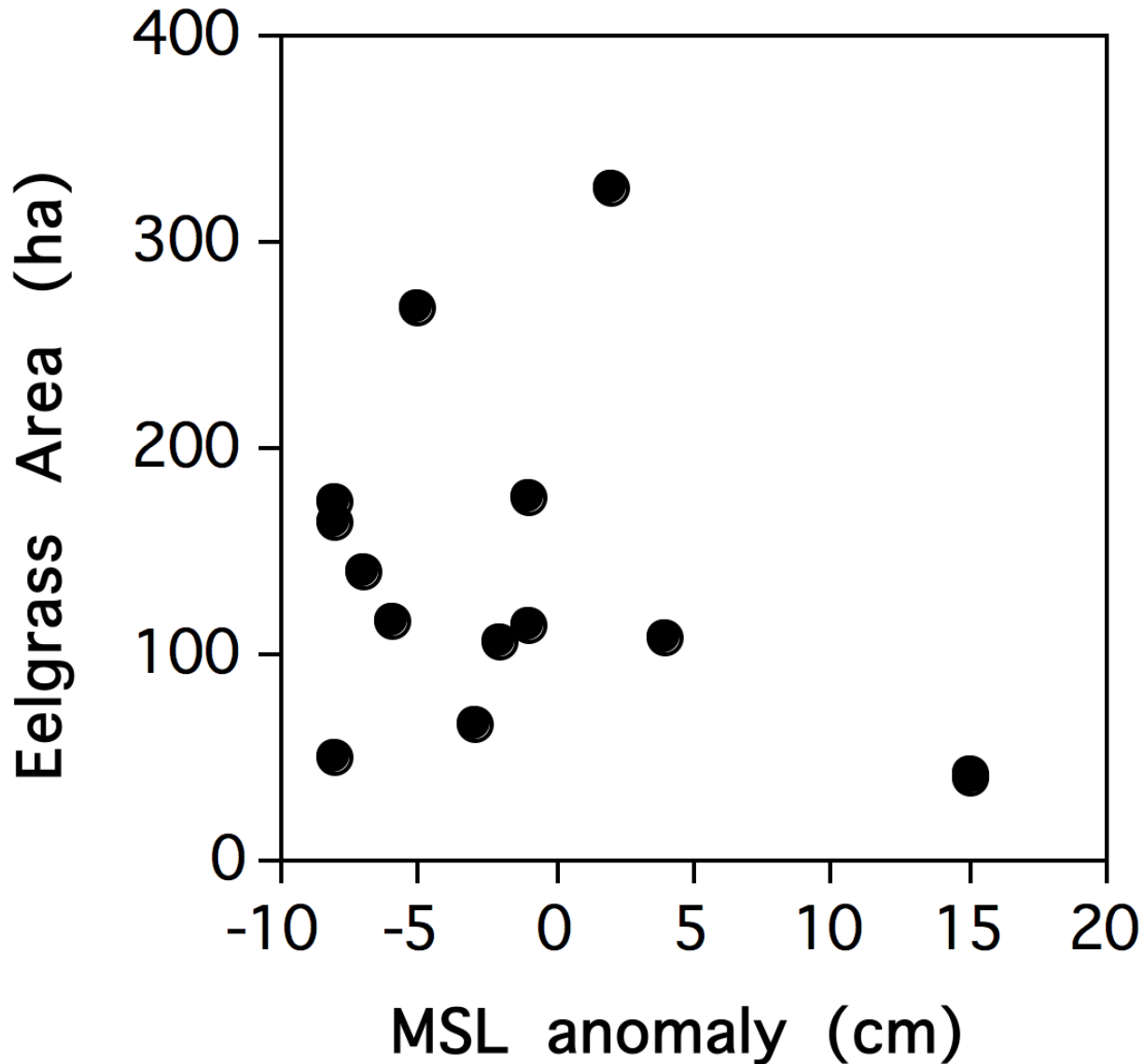
Interannual Variation in Eelgrass Area at Morro Bay



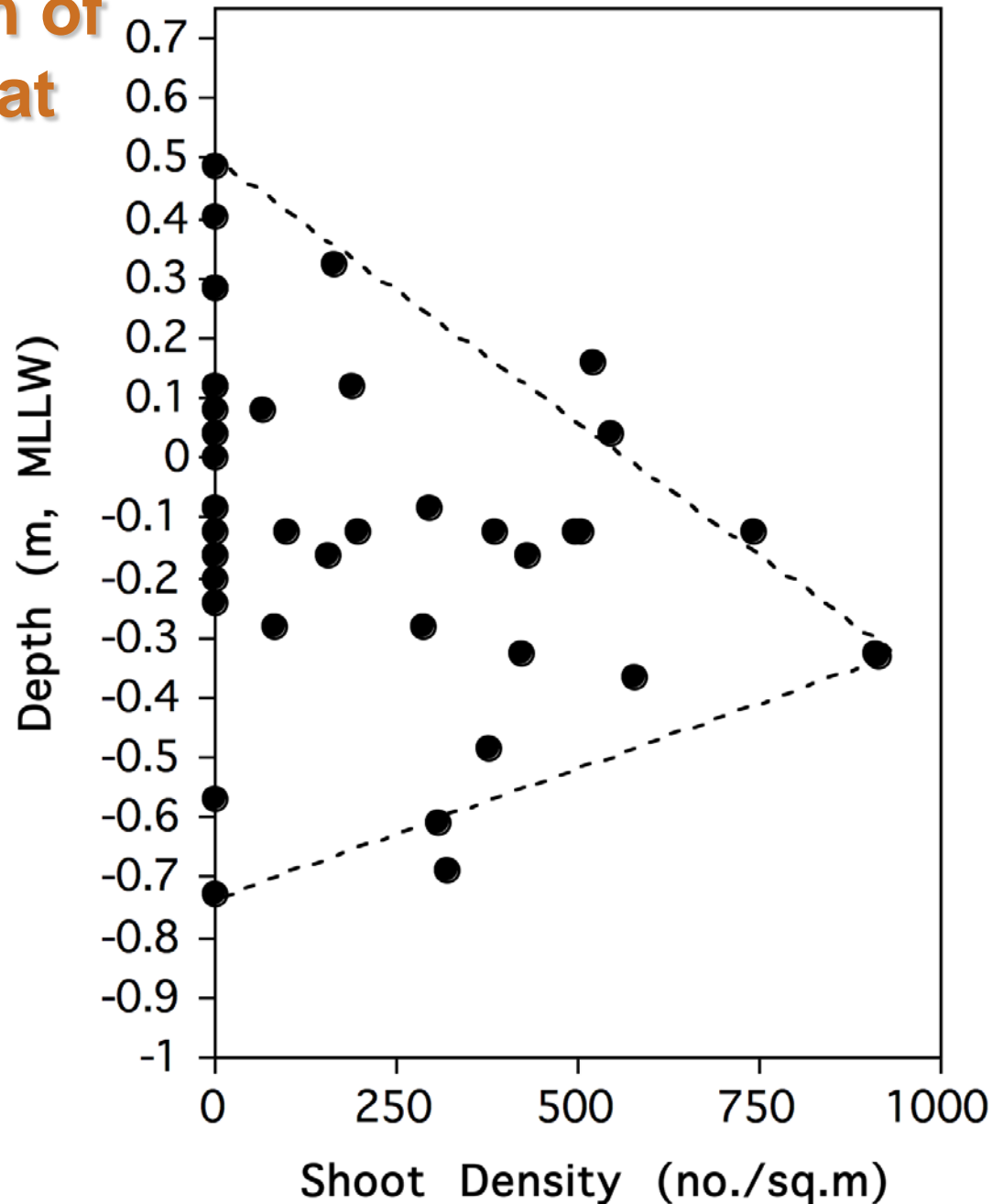
MEI and PDO vs Mean Sea Level 1988-2007 near Morro Bay

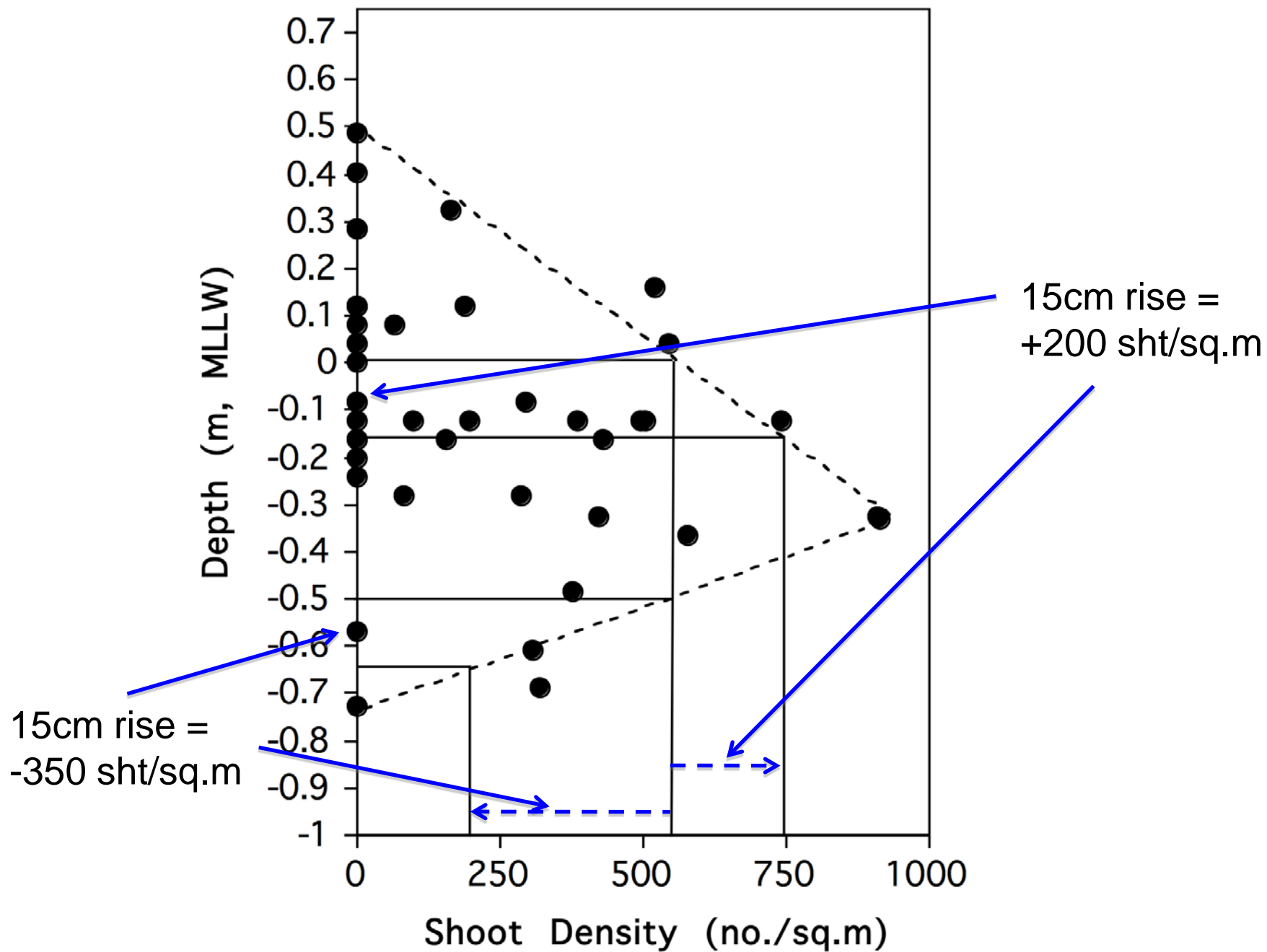


Morro Bay Eelgrass Area vs Mean Sea Level Anomaly



Depth Distribution of Eelgrass Density at Morro Bay (2006)







Slope & substrata break

Beach

Eelgrass

Total Annual NPP Estimates

<i><u>System</u></i>	<i><u>Eelgrass area</u></i>	<i><u>NPP</u></i>
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)

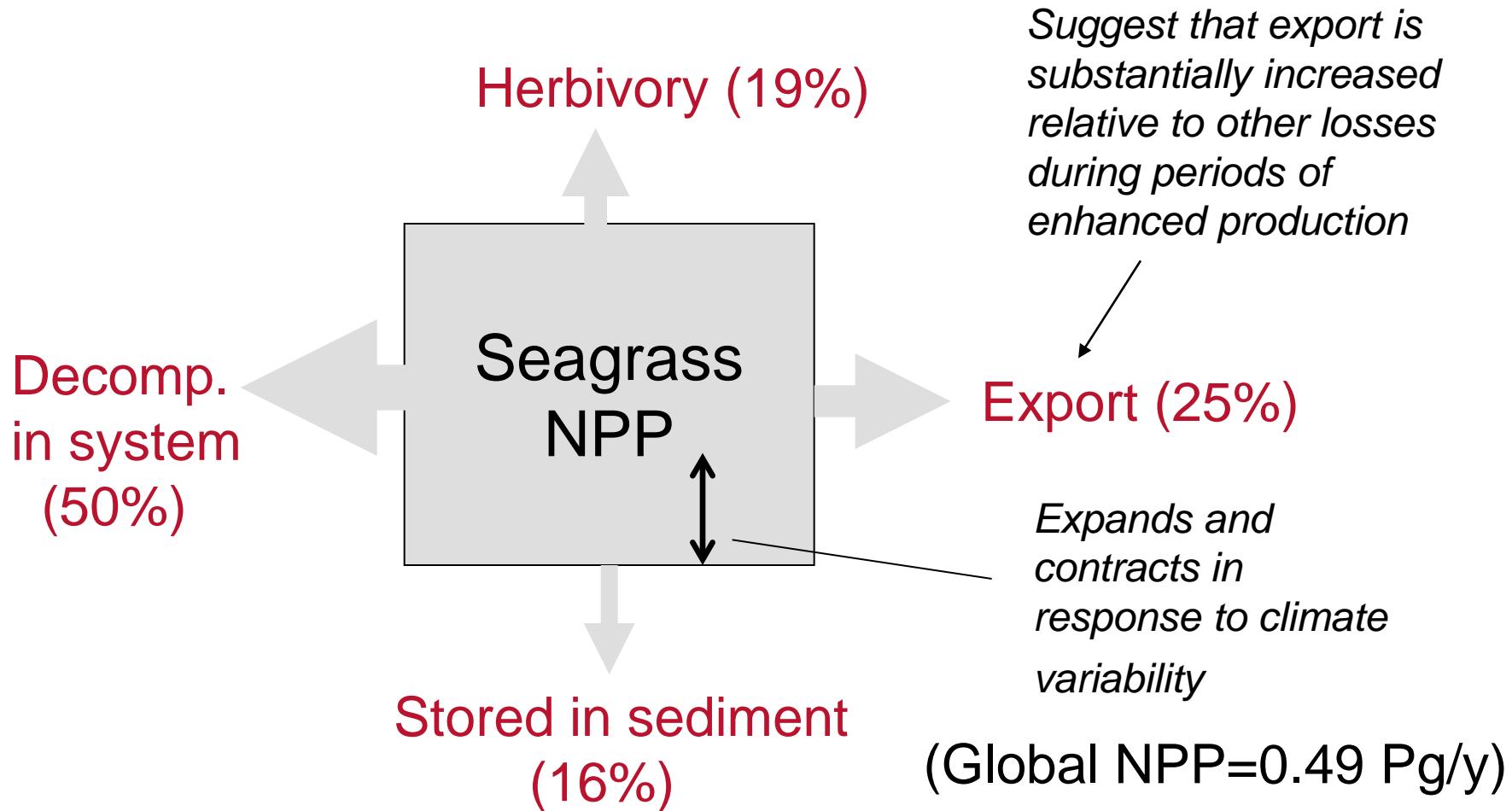
Padilla Bay - eelgrass detritus



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



Fate of Seagrass NPP (after Duarte and Cebrian 1996)



Conclusions (1 of 2)

- ▶ Weather affects plants, seagrasses are no exception
- ▶ Climate anomalies (e.g., ENSO) provide some evidence for forecasting climate change impacts
- ▶ 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, Holmes 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 (e.g., rhizomes, seeds), (2) pathways for dispersal (i.e., genetic stock), and (3) space for recruitment (Gunderson 2000)
- ▶ Manage resilience through conservation and other measures (Bjork et al. (2008)
- ▶ Argue for more emphasis on the coastal ecosystem in the global carbon budget

This opportunity to share information and learn is very much appreciated!



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