Studies of climate effects on pelagic food-web dynamics in the California Current Ecosystem

Michael Landry

Integrative Oceanography Division
Scripps Institution of Oceanography

… and many CCE-LTER contributors

CCE LTER

NSF LTER (Long-Term Ecological Research) Network

26 sites: Terrestrial, Aquatic & Urban Ecosystems

CCE

California
Current
Ecosystem

Started:
Sept. 2004

California Current Ecosystem-LTER

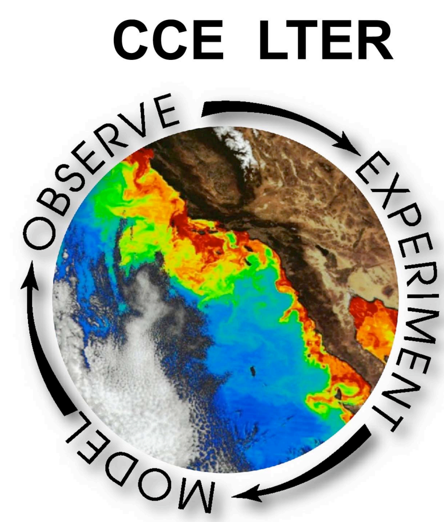
<u>FOCUS</u>: Mechanistic understanding of ecosystem transitions and long-term climate impacts

<u>MAJOR RESEARCH ELEMENTS</u>:

1. Long-term, systematic observations
   CalCOFI, satellites, Stn M traps, gliders

2. Experimental process studies
   community dynamics, relationships
   biogeochemical interactions

3. Modeling - ROMS, ecosystem
   Hypotheses, synthesis, bridge scales



CCE PIs & Associated Researchers

Name	Role	Institution	Interests
Mark Ohman	Lead PI	SIO	Mesozooplankton Ecology
Lihini Aluwihare	Co-PI	SIO	Dissolved Organic Matter
Karen Baker	Co-PI	SIO	Information Management
Katherine Barbeau	Co-PI	SIO	Iron Geochemistry
David Checkley	Co-PI	SIO	Mesozooplankton & Ichthyoplankton
Peter Franks	Co-PI	SIO	Biophysical Modeling
Ralf Goericke	Co-PI	SIO	Phytoplankton Ecology
Michael Landry	Co-PI	SIO	Food-Web Structure and Function
Art Miller	Co-PI	SIO	Physical Oceanography; Modeling
Greg Mitchell	Co-PI	SIO	Remote Sensing and Bio-optics
George Sugihara	Co-PI	SIO	Nonlinear Modeling
Farooq Azam	Associate	SIO	Bacteria/Microbial Food Webs
Steven Bograd	Associate	PFEL	Physical Oceanography
Ron Burton	Associate	SIO	Molecular Probes for Protists
Dan Cayan	Associate	SIO	Atmospheric Physics
Teresa Chereskin	Associate	SIO	ADCP Currents
Emanuel DiLorenzo	Associate	Georgia T.	Biophysical Modeling
Russ Davis	Associate	SIO	Physical Oceanography
David Hyrenbach	Associate	Duke	Seabird Ecology
Brian Palenik	Associate	SIO	Microbial Diversity
Dan Rudnick	Associate	SIO	Mesoscale Ocean Physics
Tony Koslow	Associate	SIO	Planktivorous Fishes
Beth Simmons	E&O Coord.	SIO	Education and Outreach
Ken Smith	Associate	MBARI	Deep-sea Benthic Ecology
Bill Sydeman	Associate	PRBO	Seabird Ecology; Marine Mammals
Elizabeth Venrick	Associate	SIO	Phytoplankton Floristics

Presentation Outline

New Perspectives on Old Problems

CalCOFI - sardines, zooplankton

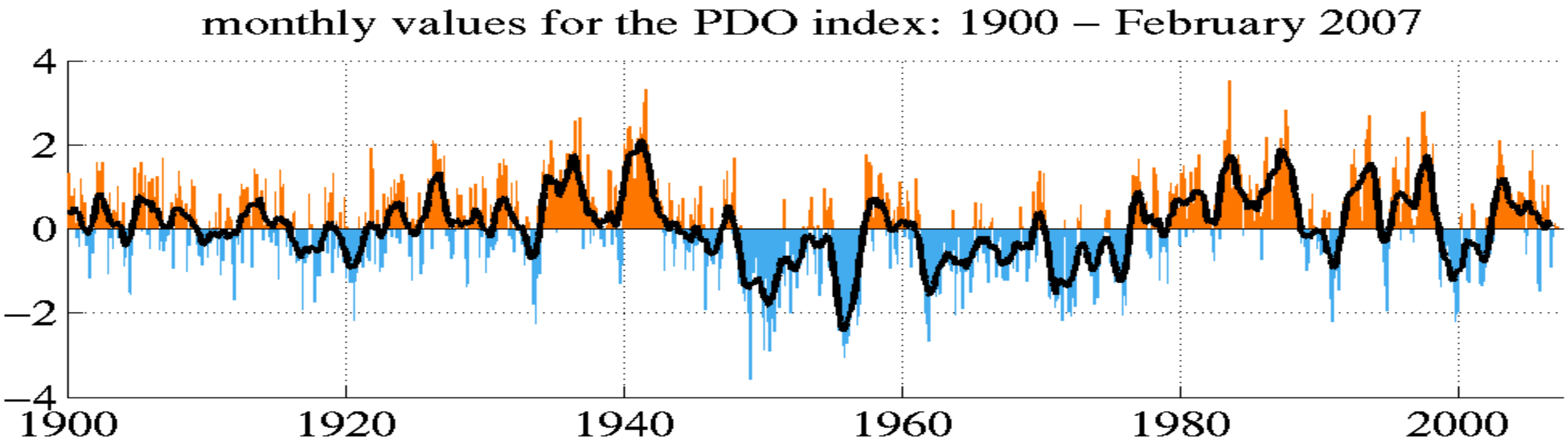
Climate variability, PDO, upwelling

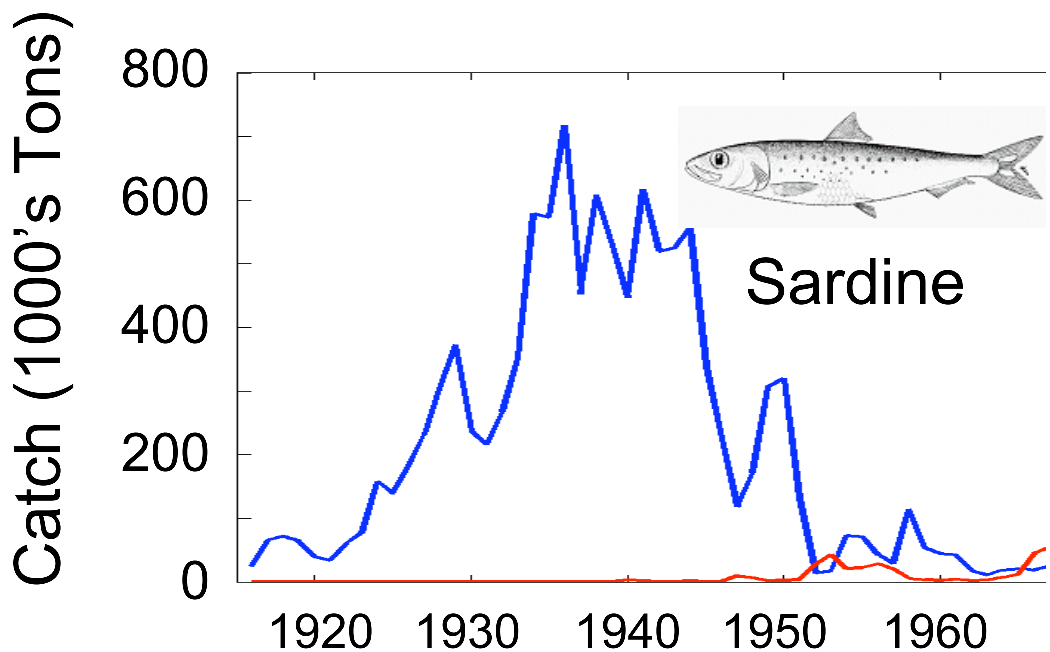
CCE Process Studies

Dynamics of lower trophic levels

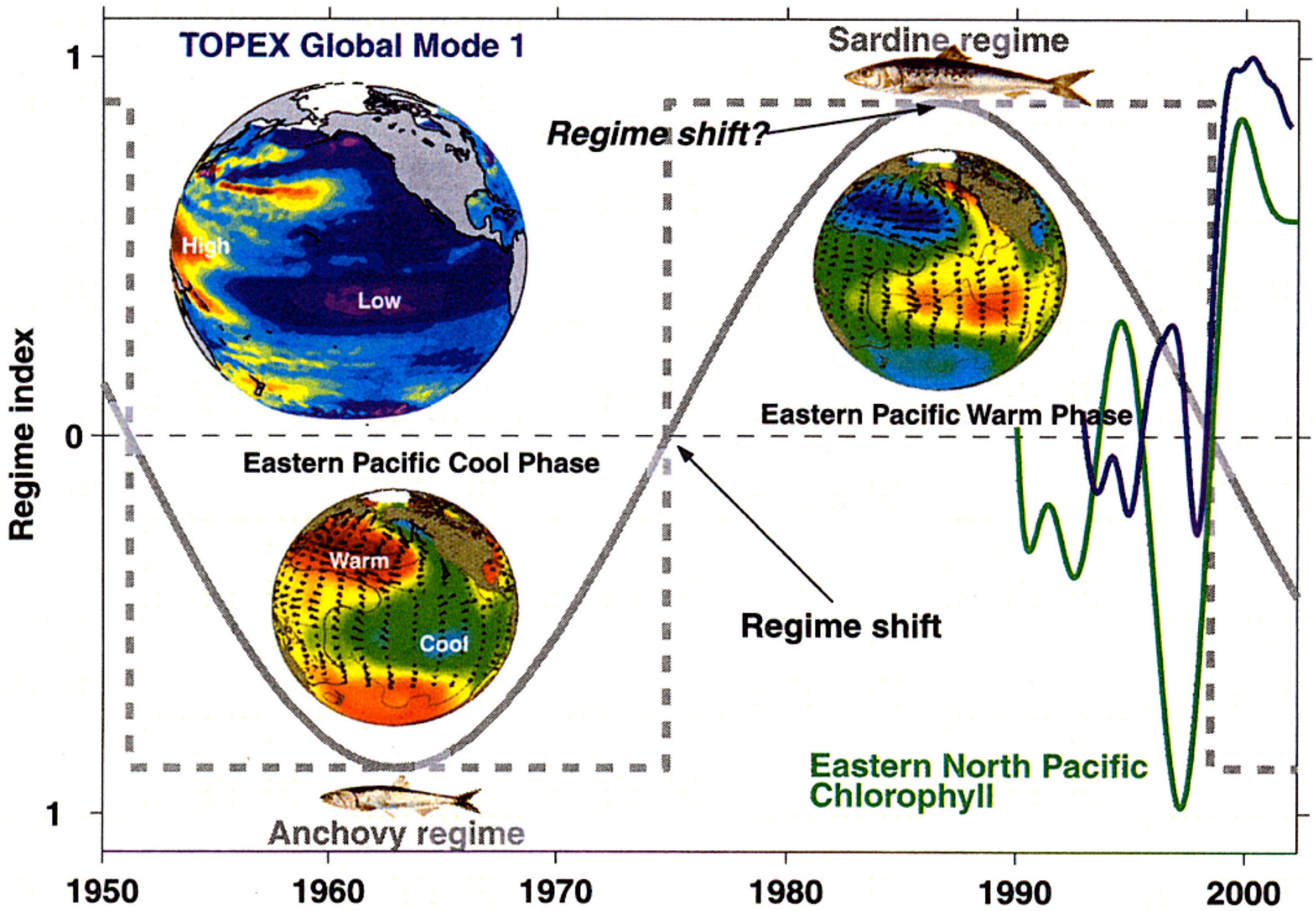
Trophic constraints on export flux

Cyclical oscillations of pelagic fish



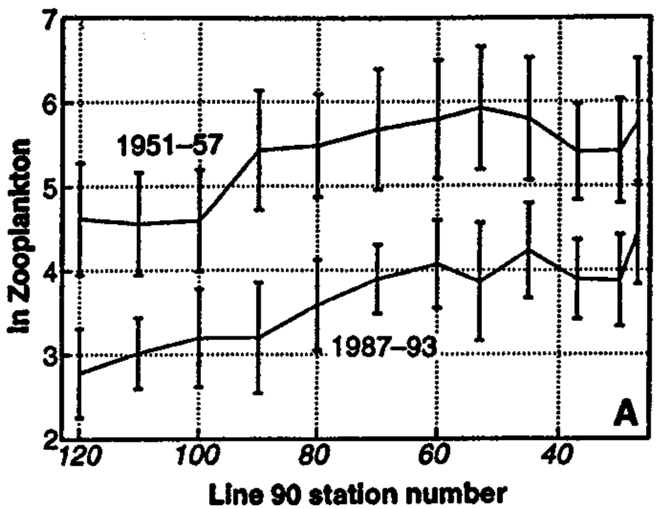


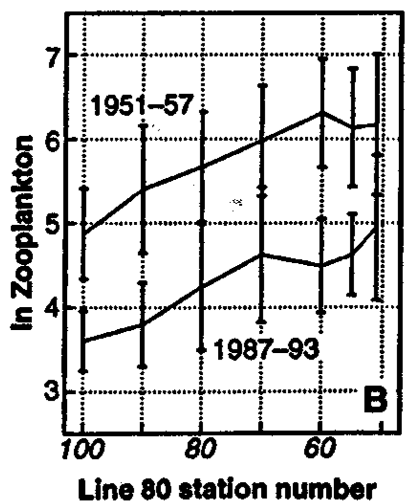
Sardine & Anchovy Regimes



Chavez et al. 2003. Science.

Zooplankton in the California Current



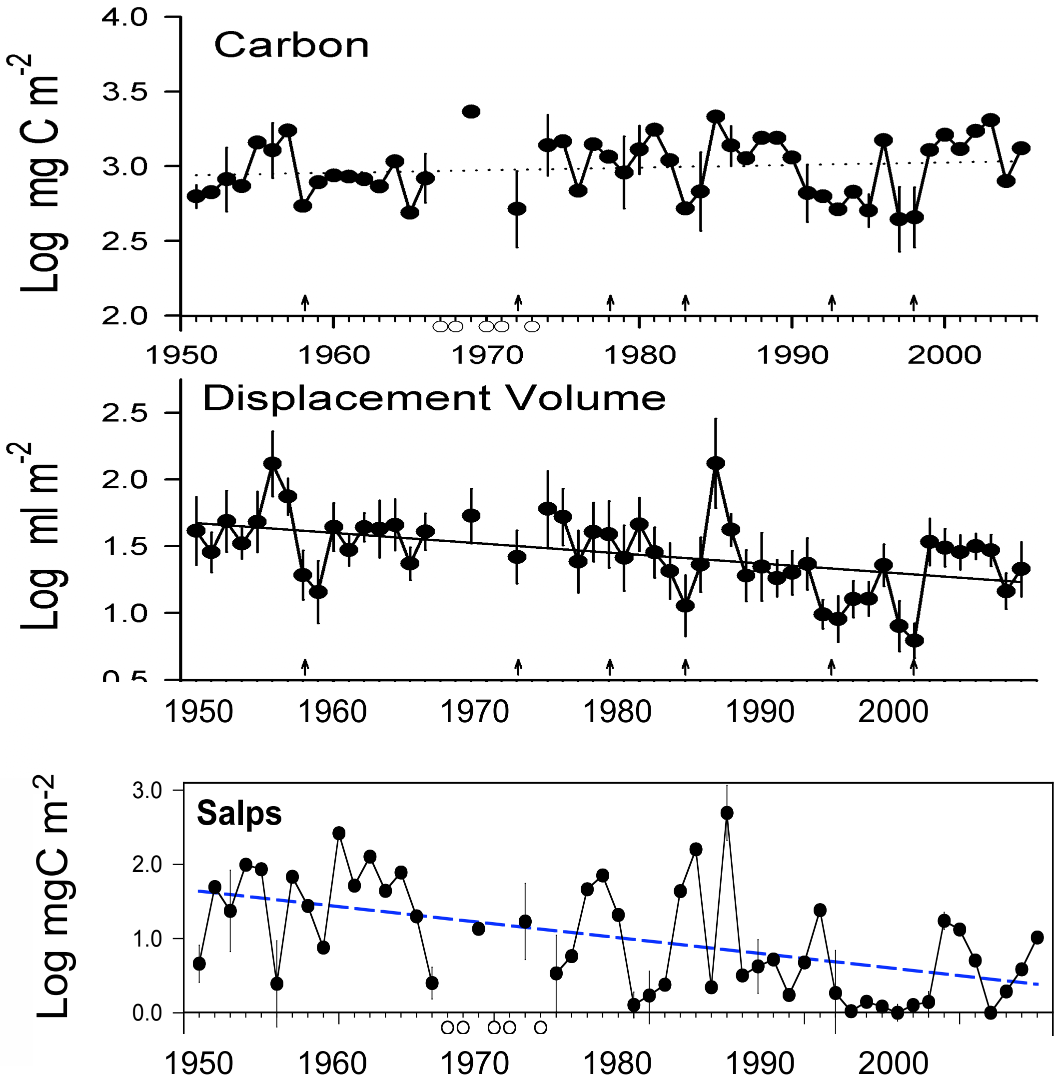


<u>PDO Trend</u>

Displacement volume of large zooplankton (500-μm mesh net) were 5X higher during cold phase of PDO (1950's) compared to warm phase (1980s).

Roemmich & McGowan. 1995. Science.

Salps and Zooplankton Volume



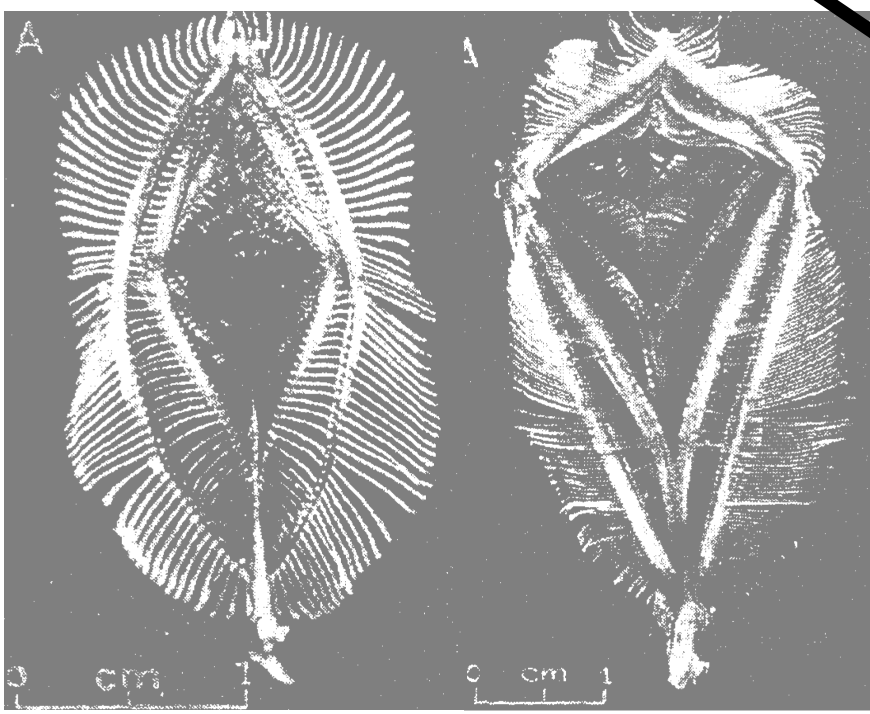
MesoZoo carbon (top), displacement volume (middle), and salps (bottom. Arrows are El Ninos.

Lavaniegos & Ohman (2007)

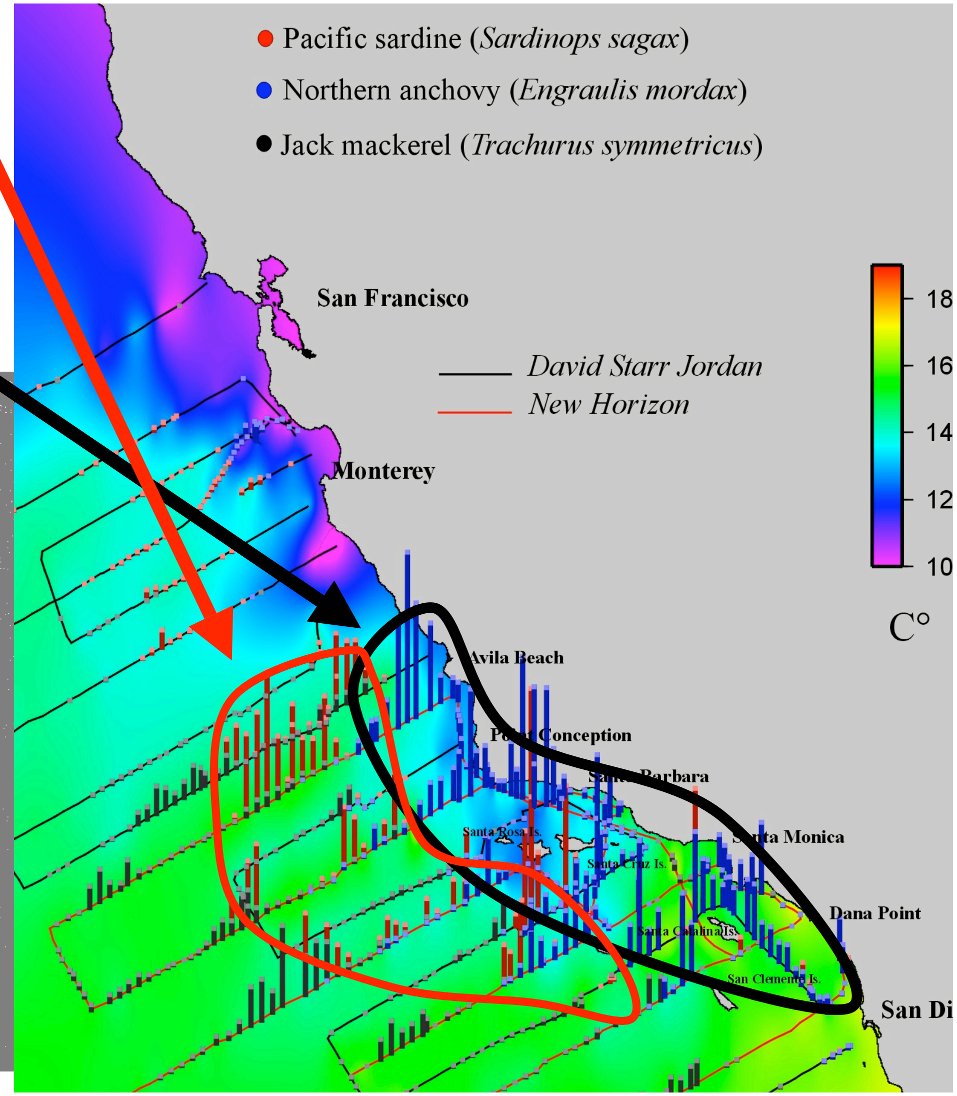
Habitat Preferences of Sardine & Anchovy

Sardine: live offshore and eat smaller prey

Anchovy: live nearshore and eat larger prey



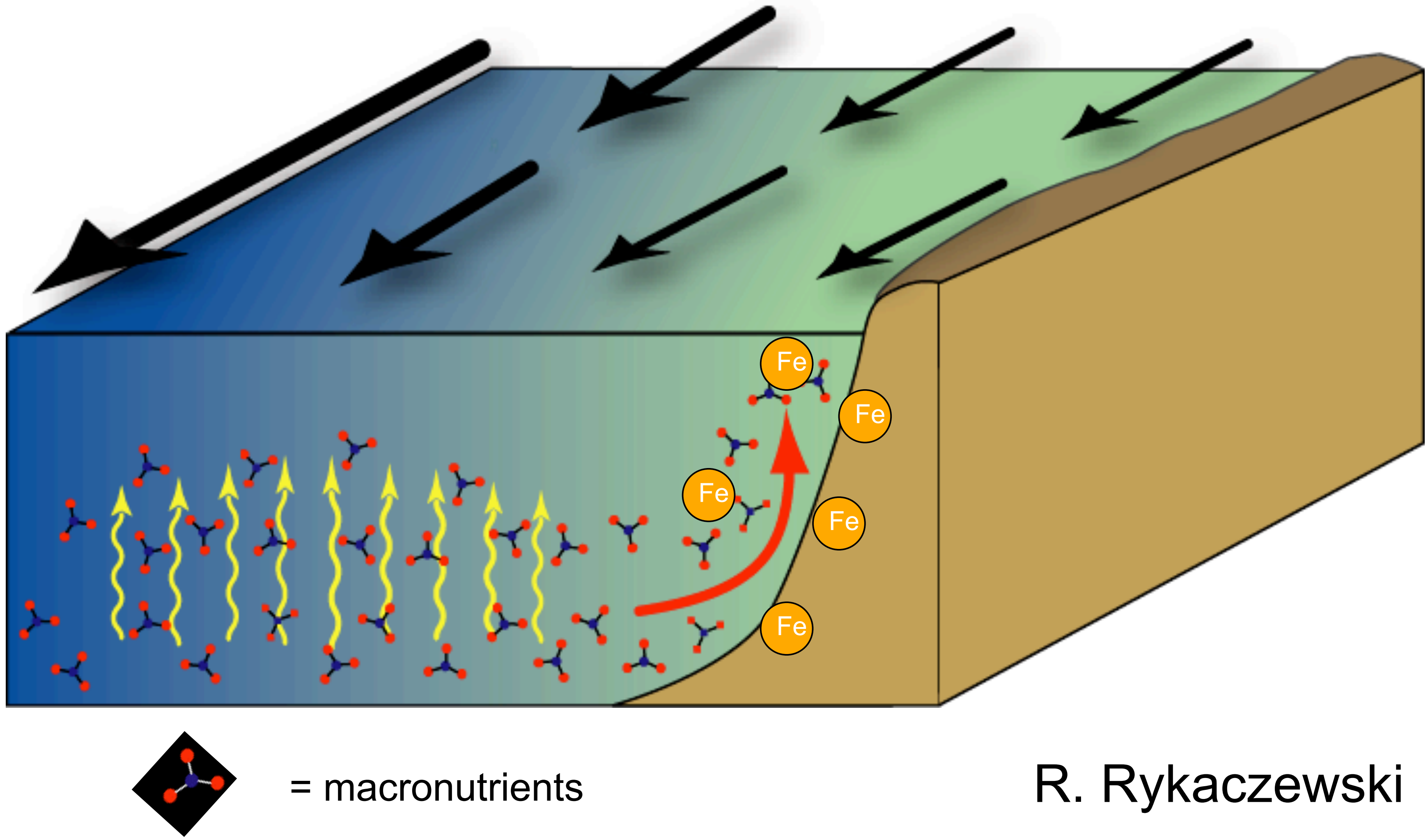
Engraulis sp. *Sardinops* sp.



R. Rykaczewski

Upwelling Mechanisms

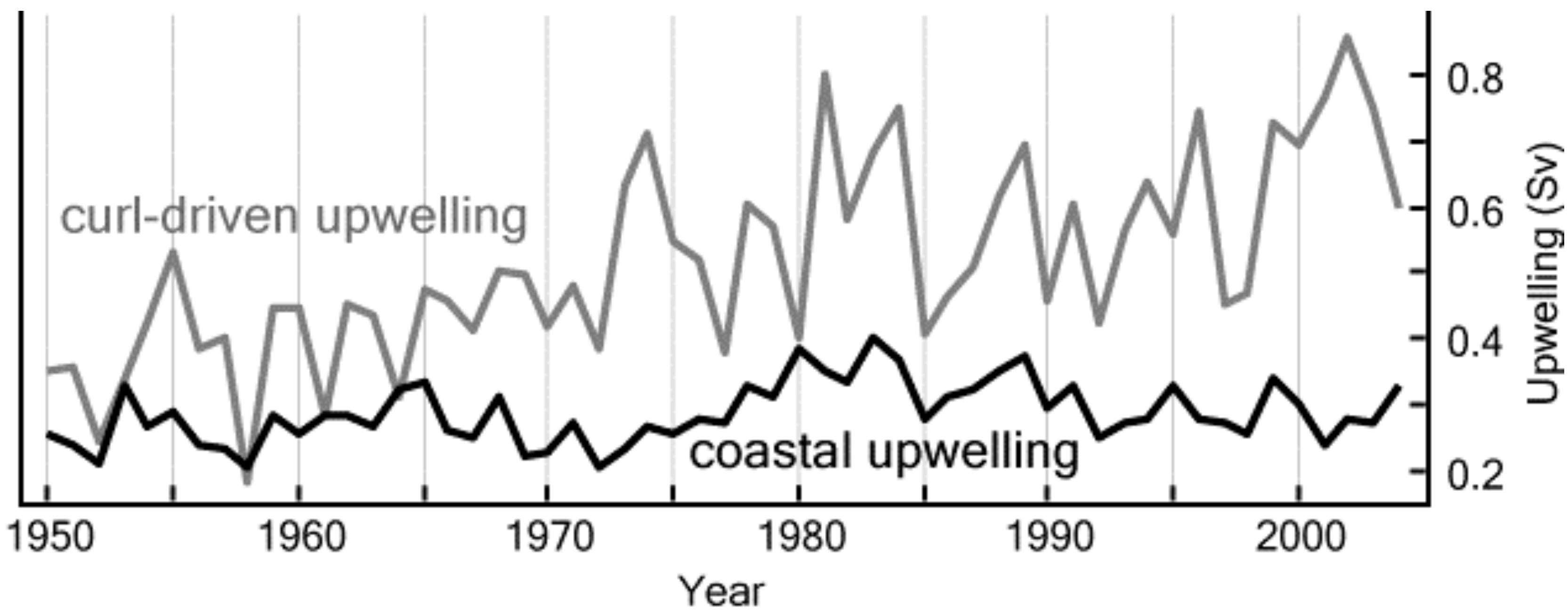
Coastal vs Wind Stress Curl



R. Rykaczewski

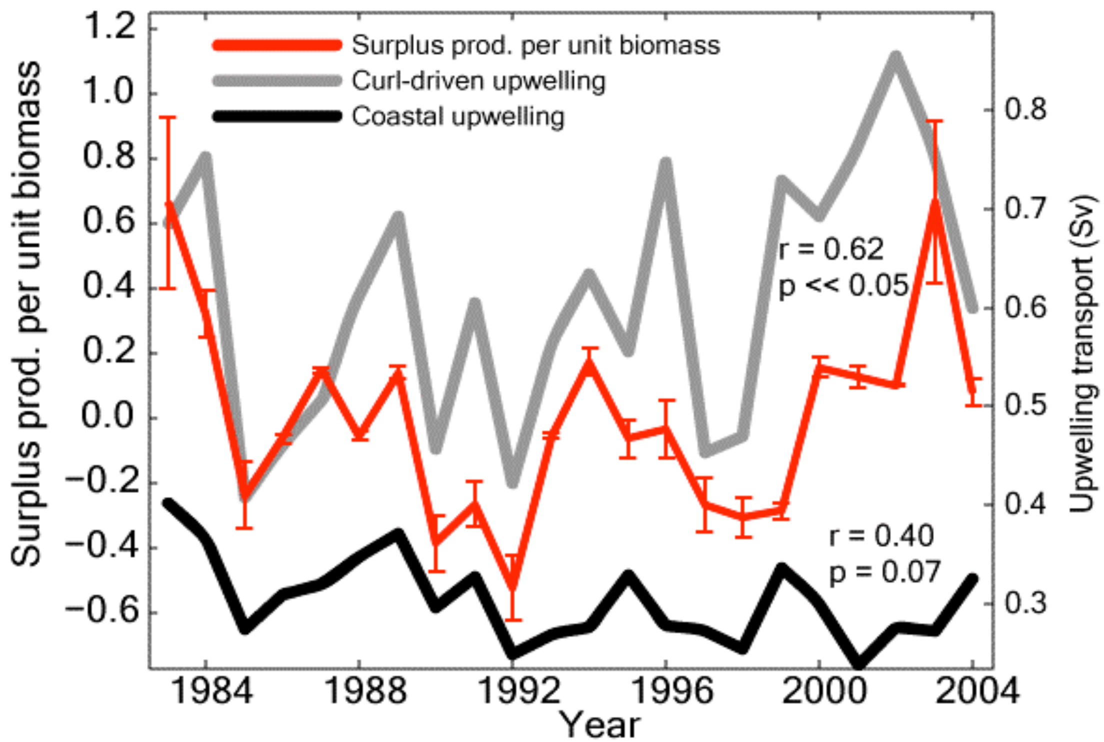
Retrospective Analysis

Monthly-averaged winds
NCEP/NCAR CaRDs10 model

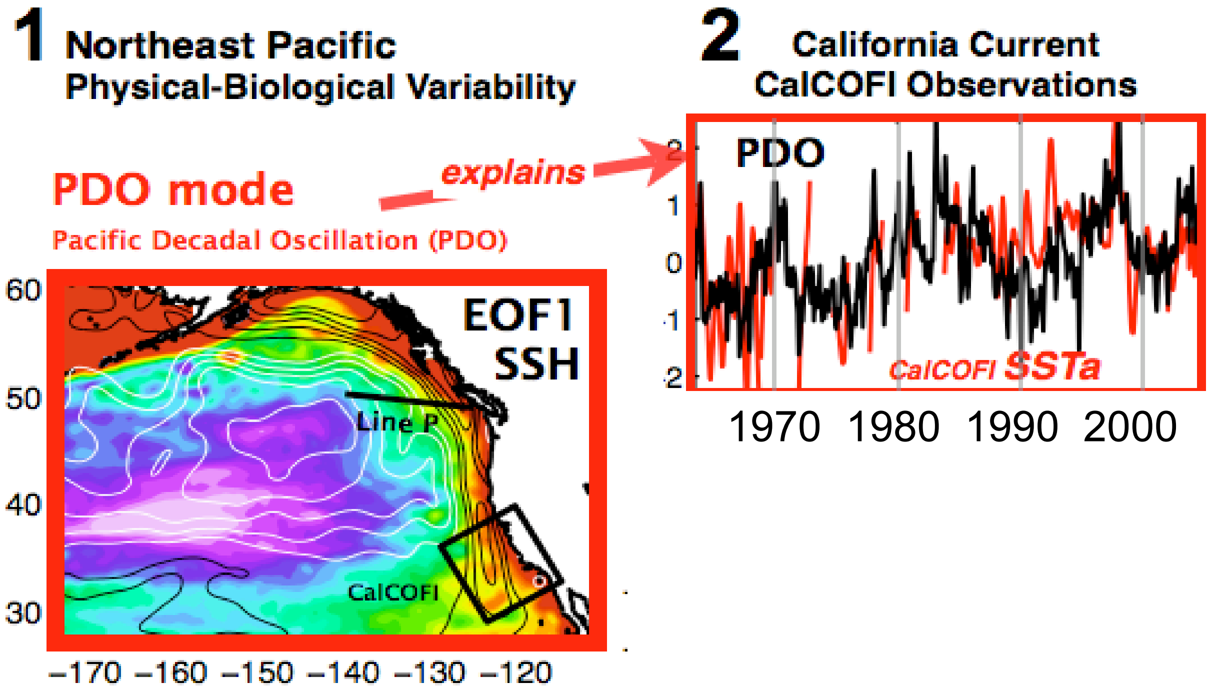


Rykaczewski & Checkley. 2008 PNAS

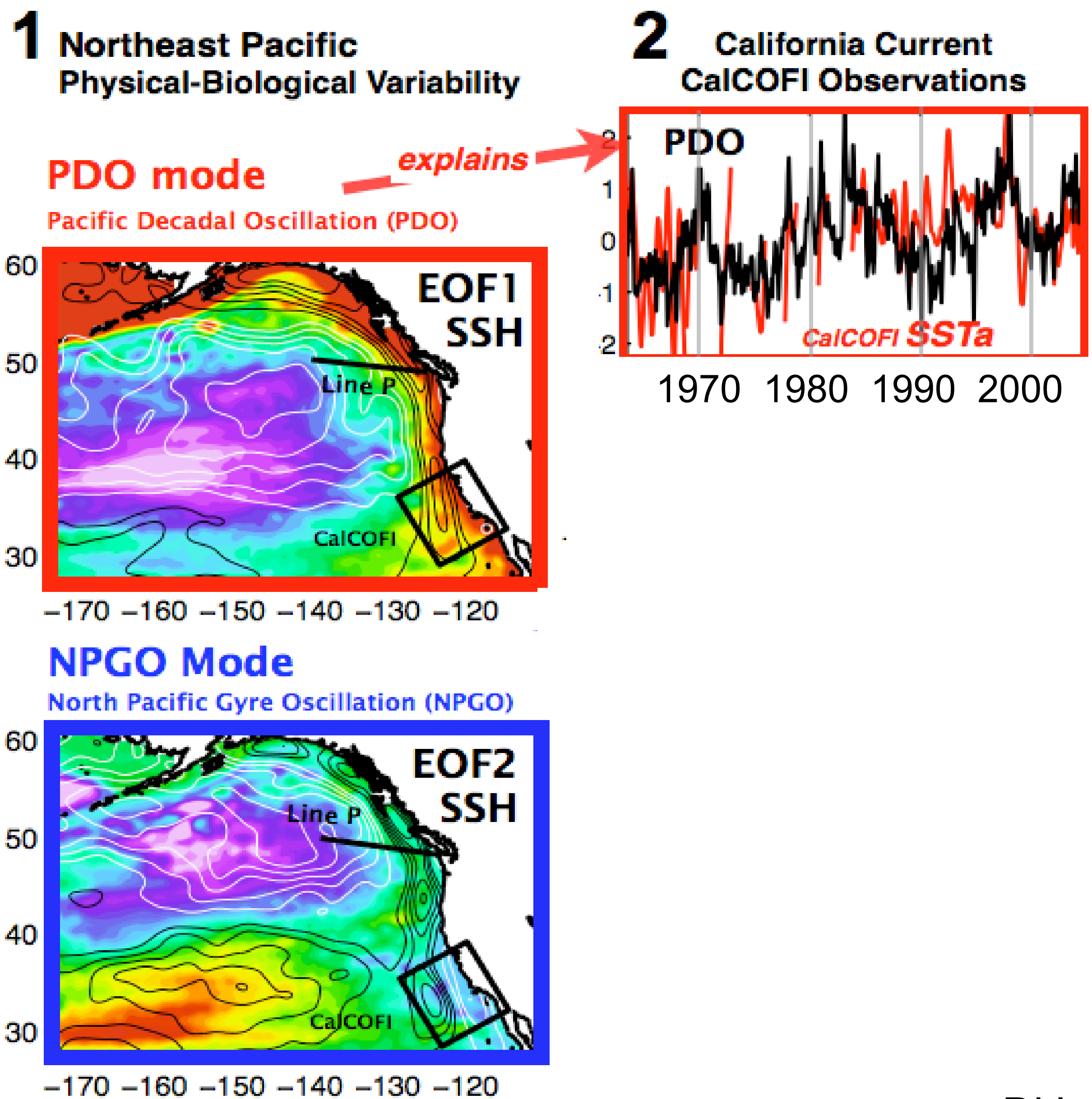
Sardine Surplus Production



Rykaczewski & Checkley. 2008 PNAS



Di Lorenzo *et al.* 2008. GRL



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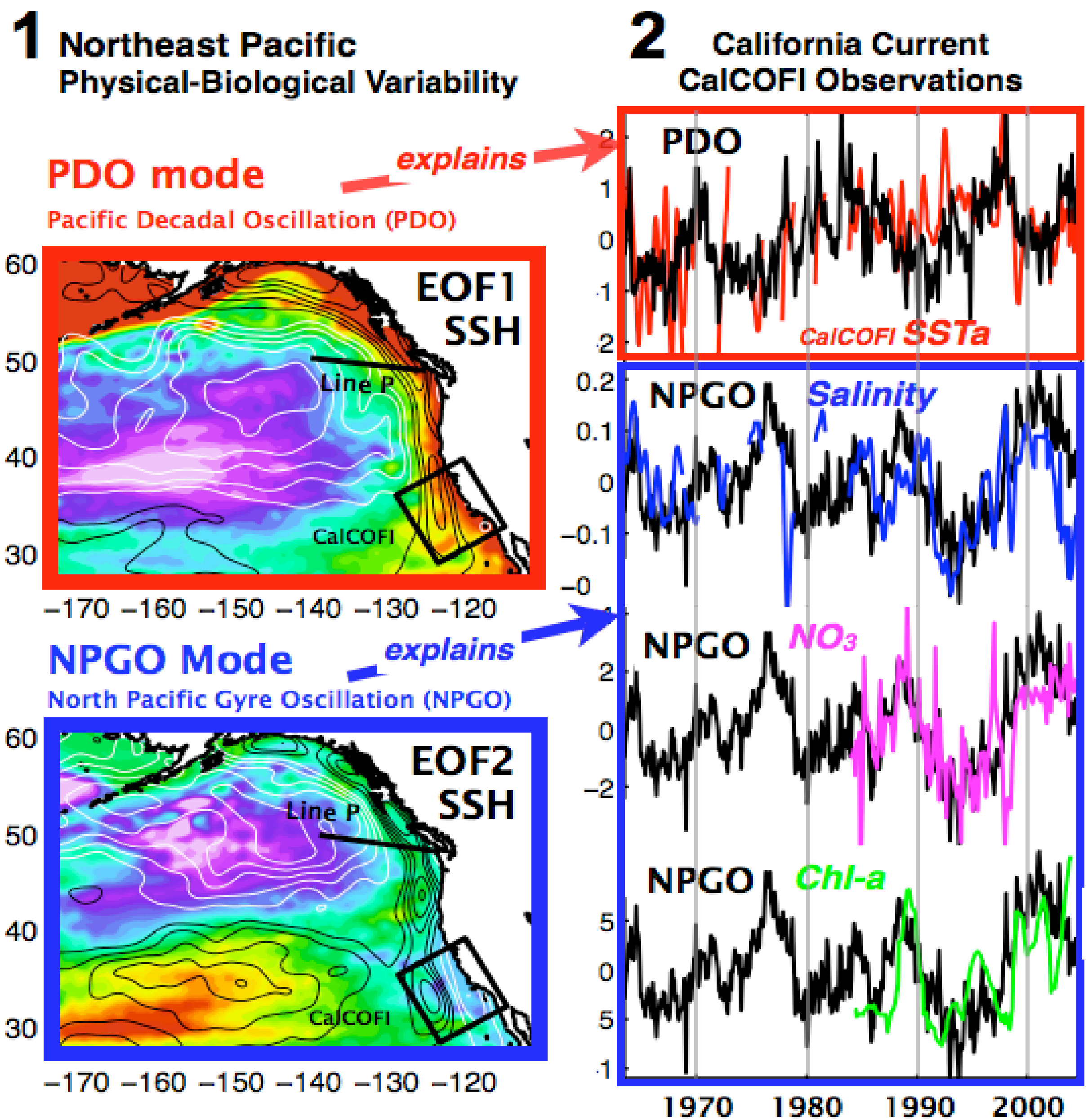

Di Lorenzo *et al.* 2008.

New Perspectives

Biomass of large zooplankton has NOT shown a significant decadal trend

Sardine production related to the level of weak curl-driven upwelling, NOT coastal upwelling

PDO may NOT be the climate mode that regulates the processes of interest - upwelling enhancement of nitrate, chlorophyll and small zooplankton

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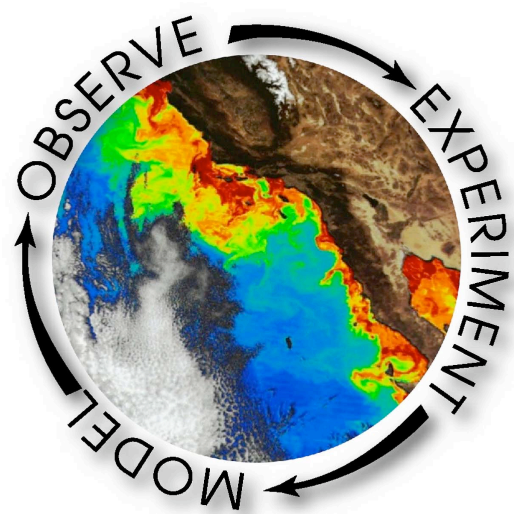
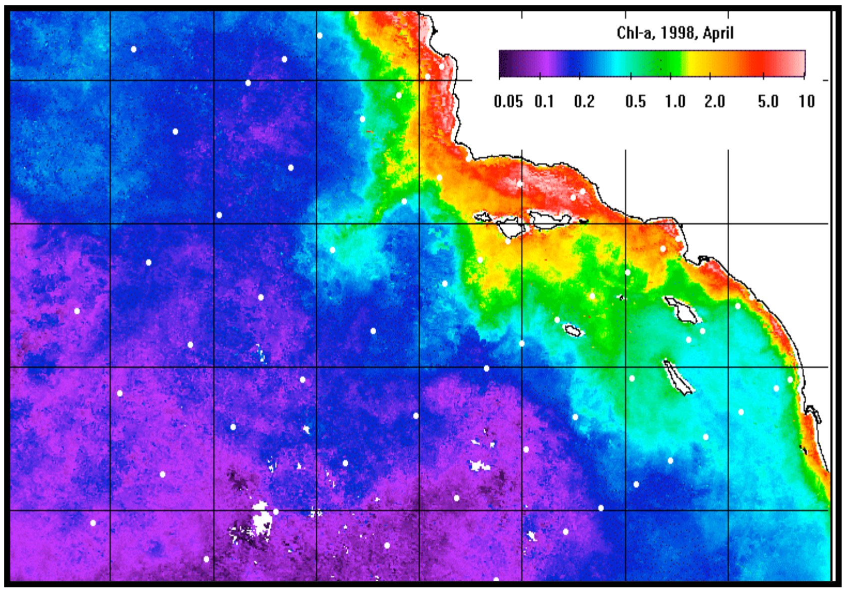
CCE LTER



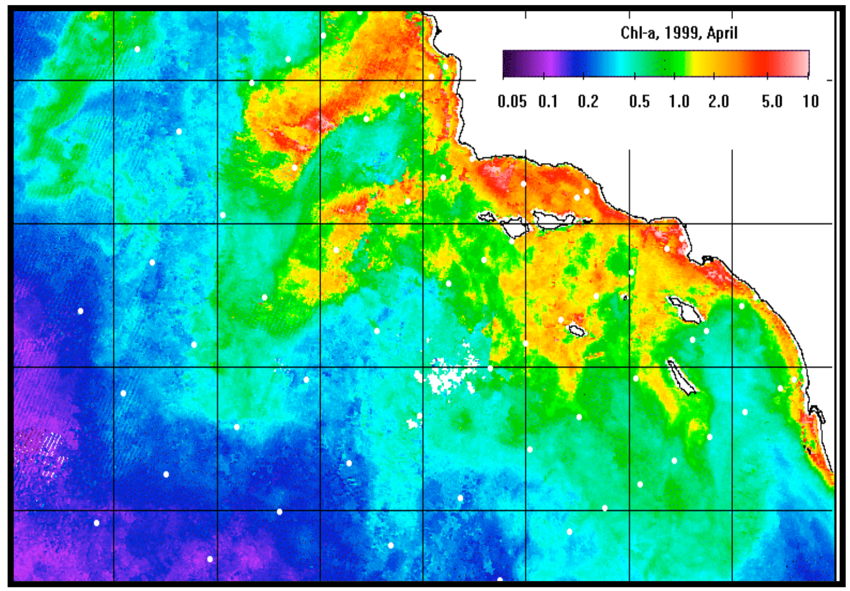
Spatial Scale

We exploit the broad range of conditions that exist spatially in the contemporaneous ocean as analogs of expanding/ contracting system variability that occurs in time.

El Niño - April 1998

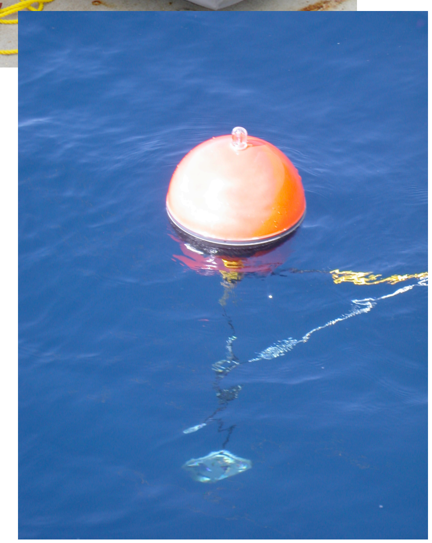


La Niña - April 1999



Lagrangian-designed Process "Cycles"

Drifter w/ drogue (12-17 m)



CCE Process cruises are organized around activity cycles of several days (mean = 4 days) that follow the path of a satellite-tracked drifter.

Each cycle is a coordinated suite of measurements to elucidate process rates and relationships as the community evolves in the marked patch of water.

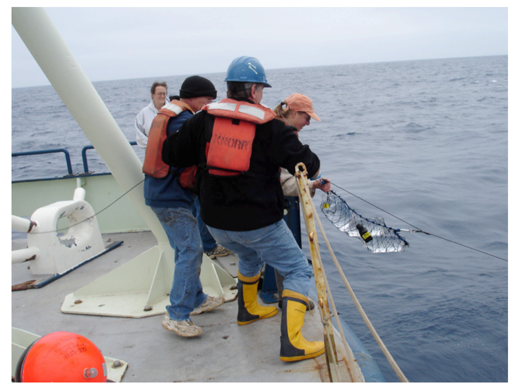
Experimental Concept

Sum of "measurable" processes account for "observed" net rates of community change in the ambient environment

<u>Observed</u> = <u>Measured Process Rates</u>

Net Rate of Change	=	Phytopl Growth	-	MicroZ Grazing	-	MesoZ Grazing	-	Export

In Situ Experiments



<u>CTD sampling - 8 euphotic depths</u>

Environment: T, S, O_2
Light: daily intgr PAR, noon bio-opt
Nutrients: P, N, Si
Particulates: transm, POC, PN, BSi
Community: FCM, HPLC, EPI

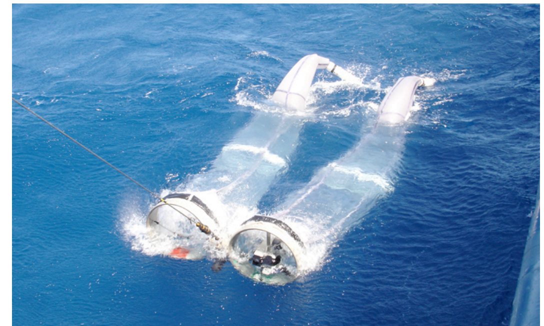
<u>Experimental Rates</u>

^{14}C-primary prod (light+dark)
2-bottle dilution - specific μ & micro-graz
^{14}C-pigment labeling - taxon-specific μ

Lagrangian design (net rates measured daily in bottles & field)
Every rate has full community & environmental data

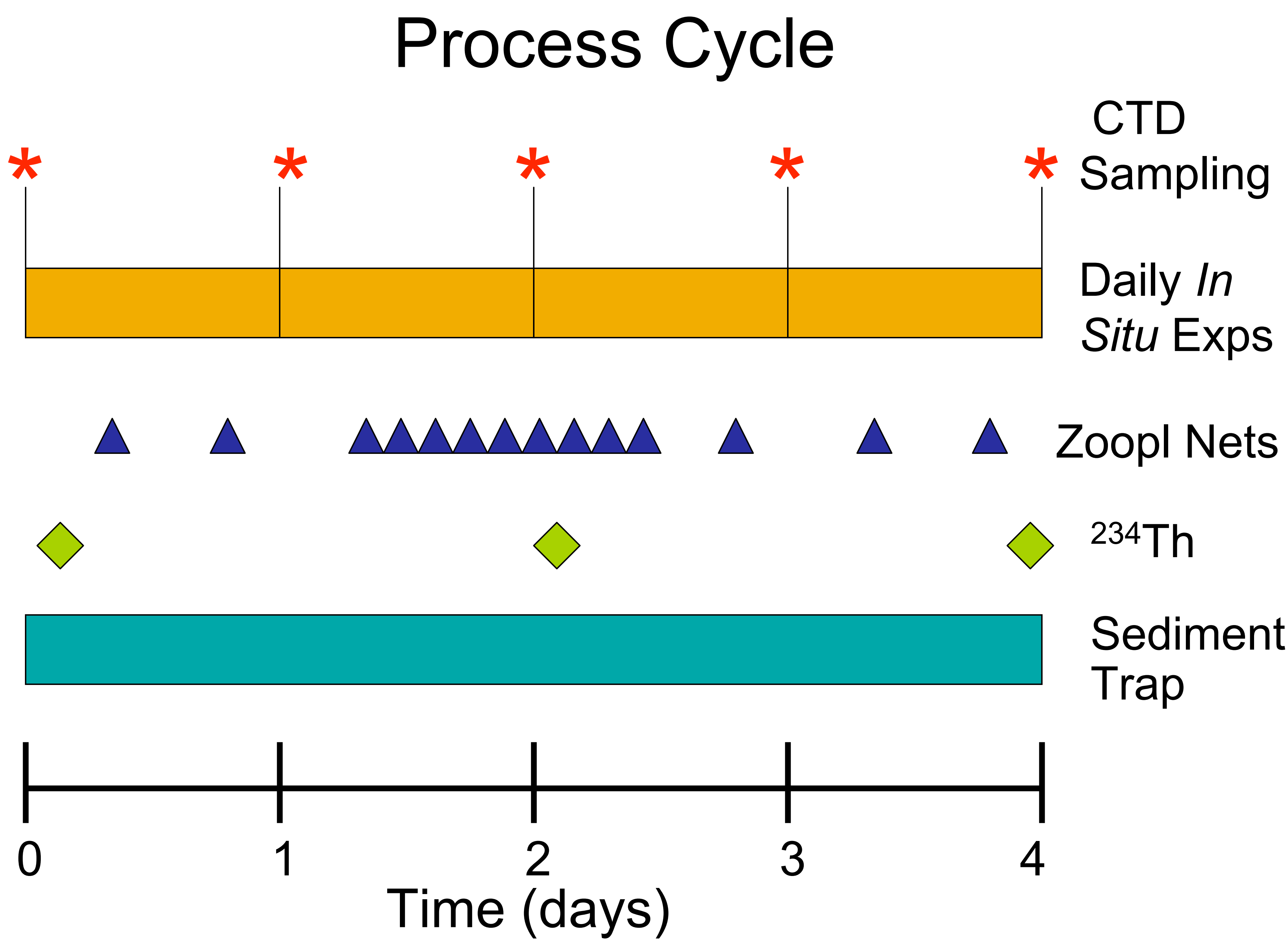
Zooplankton + Export

<u>Bongo Net</u>: Rykaczewski, Ohman
mid-day, mid-night, 24-h diel
size-fract mesozoo biomass
gut fluorescence
laser OPC size spectra



<u>MOCNESS</u>: Ohman
mid-day, mid-night, 3 pairs/cycle
depth-stratified to 450 m
ZOOSCAN size analysis

<u>Passive Export</u> (Stukel)
Th:U disequilibrium
Sediment traps (100 m)
  drift array
  beginning-end of cycle

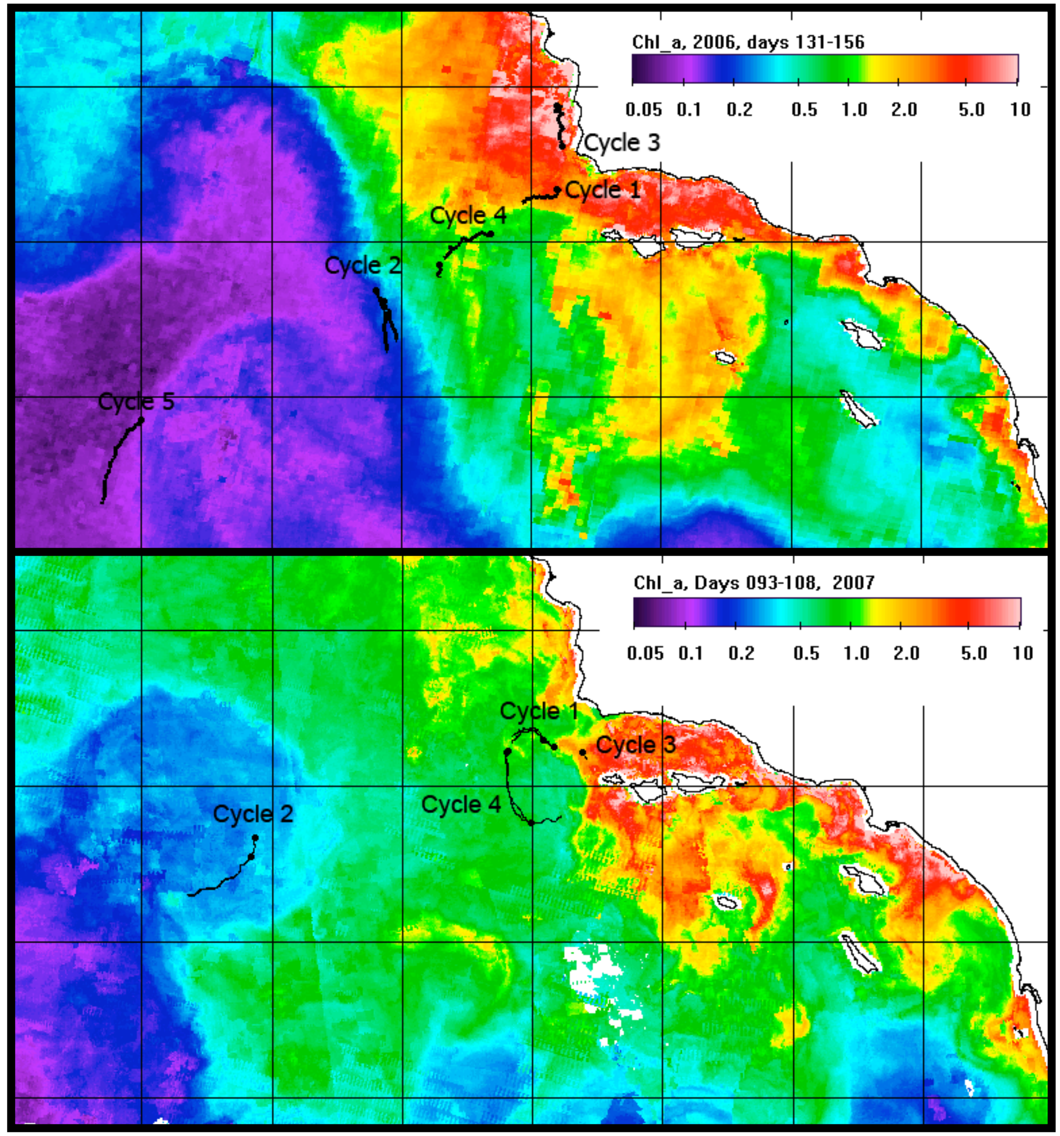

Process Cycle
CTD Sampling
Daily *In Situ* Exps
Zoopl Nets
^{234}Th
Sediment Trap
0
1
2
3
4
Time (days)

Process Cruise Drifter Tracks

P0605
May-June 2006

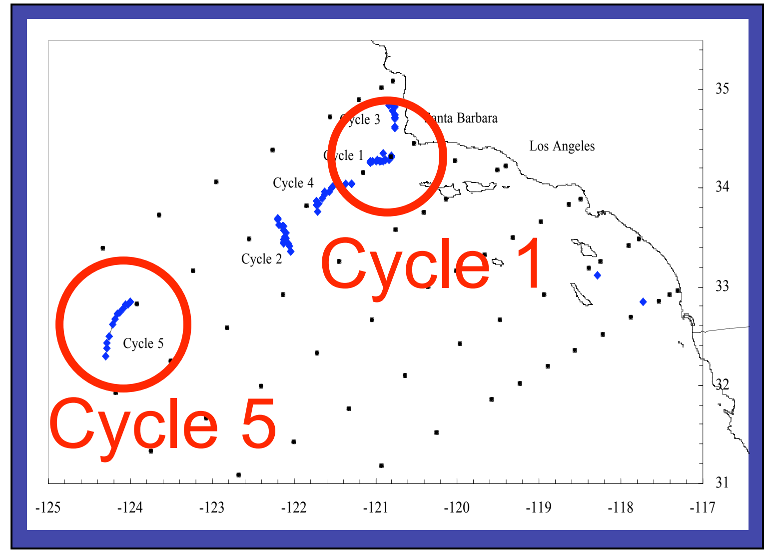
P0704
April 2007

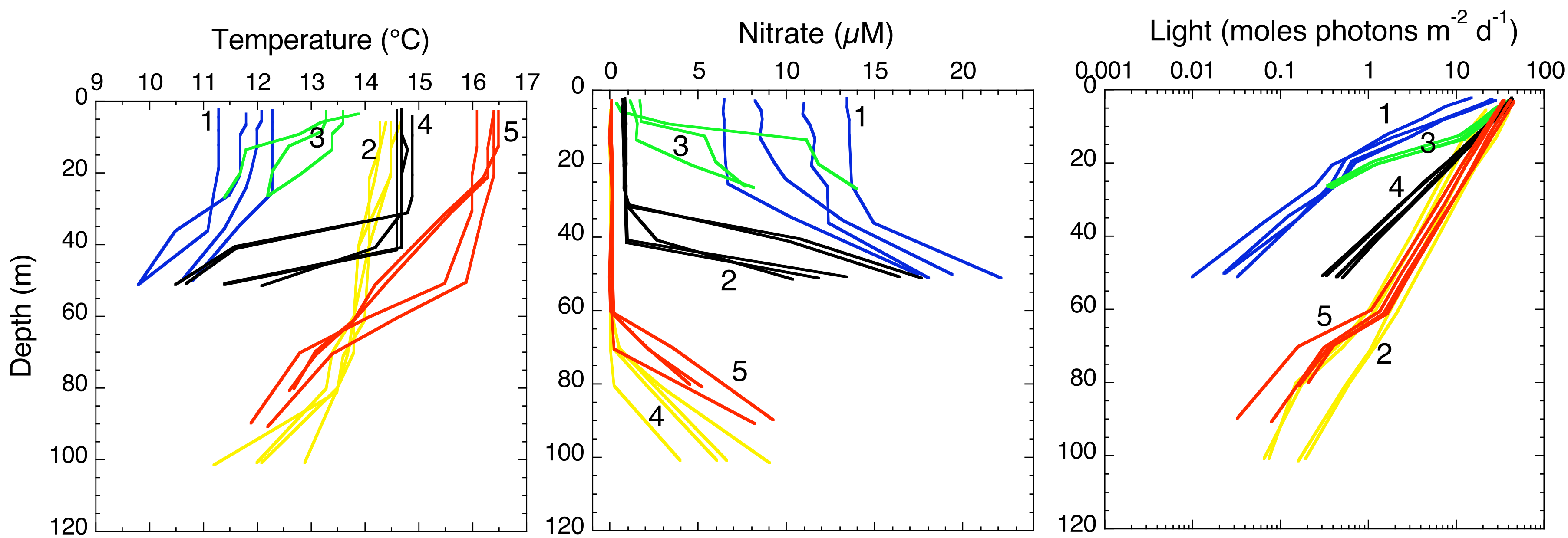
CCE-P0605
MODIS-Aqua Chla w/ Globalstar drifter tracks



M. Kahru

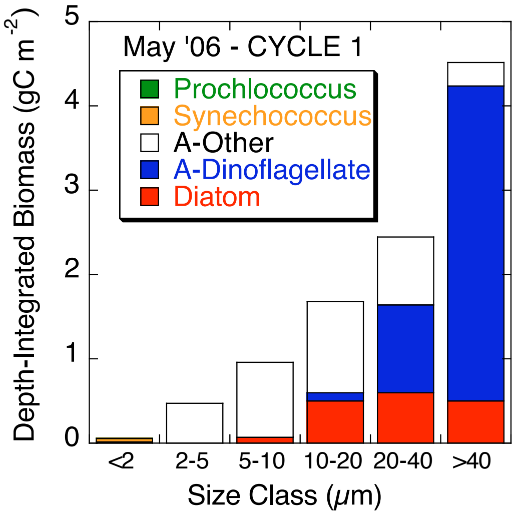
System Variability
May-June 2006

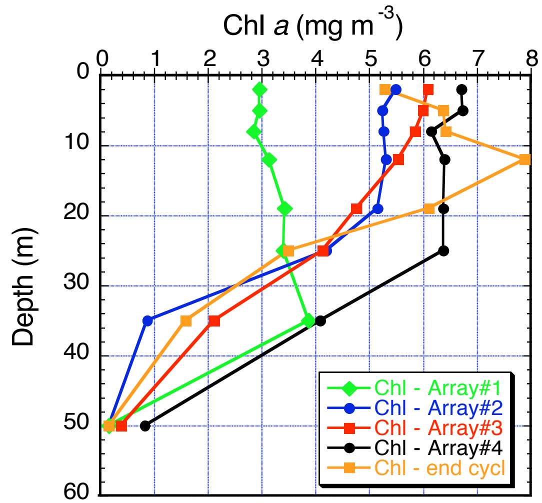




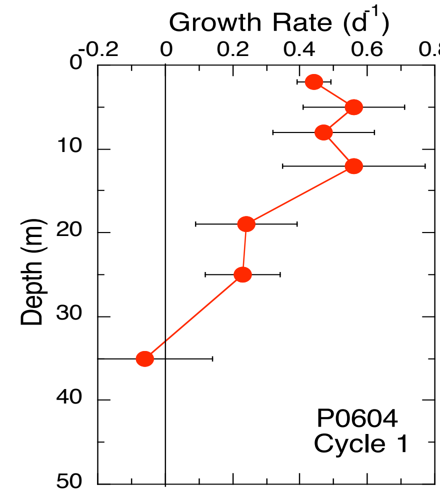
Phytoplankton Biomass & Growth

Coastal - 8.3 µM NO_3

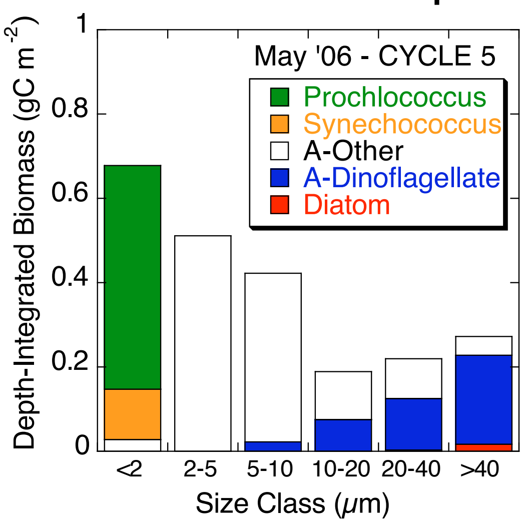


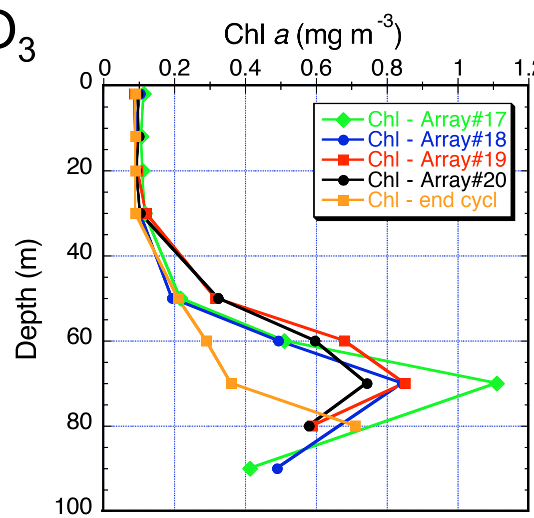


Cycle #1 - *In situ* Chl *a*
(start of array incubation)

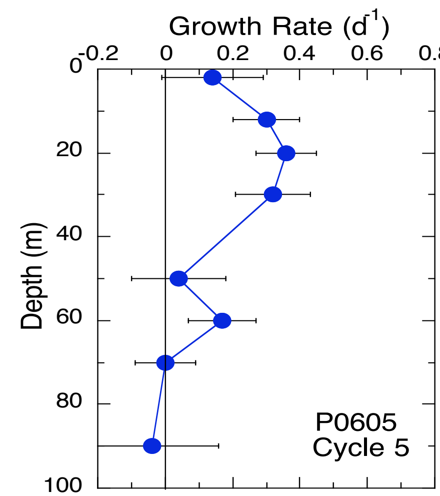


Oceanic - 0.12 µM NO_3

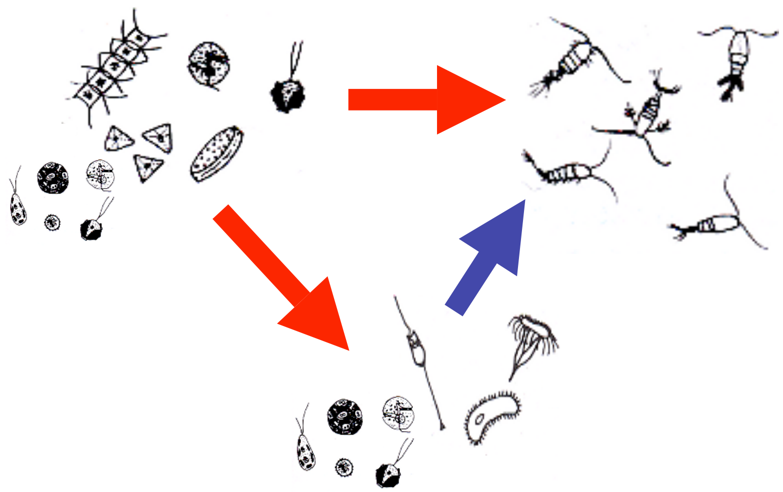




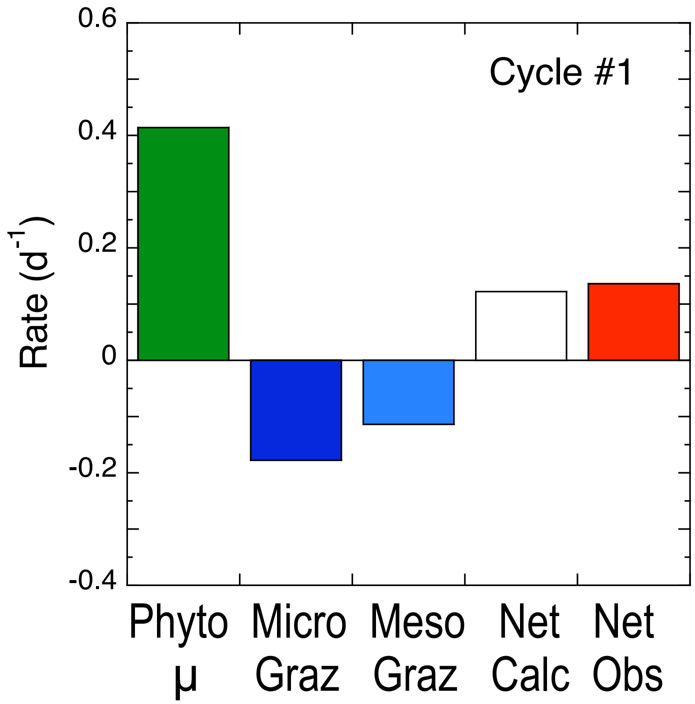
Cycle #5 - *In situ* Chl *a*
(start of array incubation)



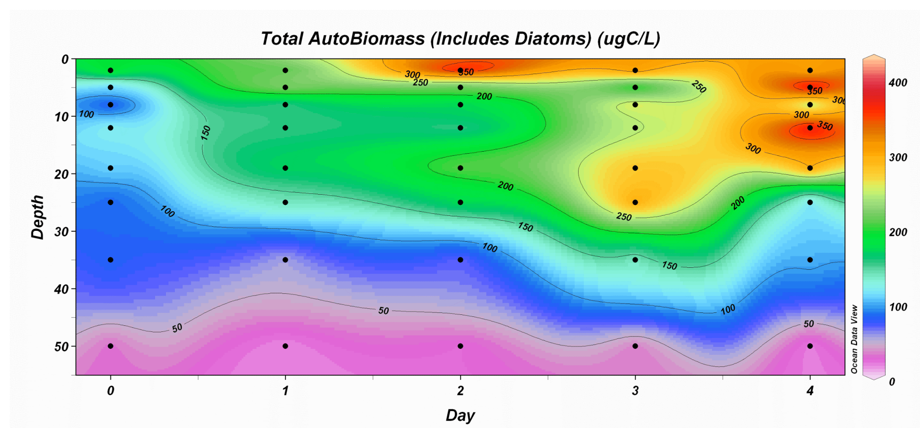
In situ Drifter Results



All rates based on Chl *a*

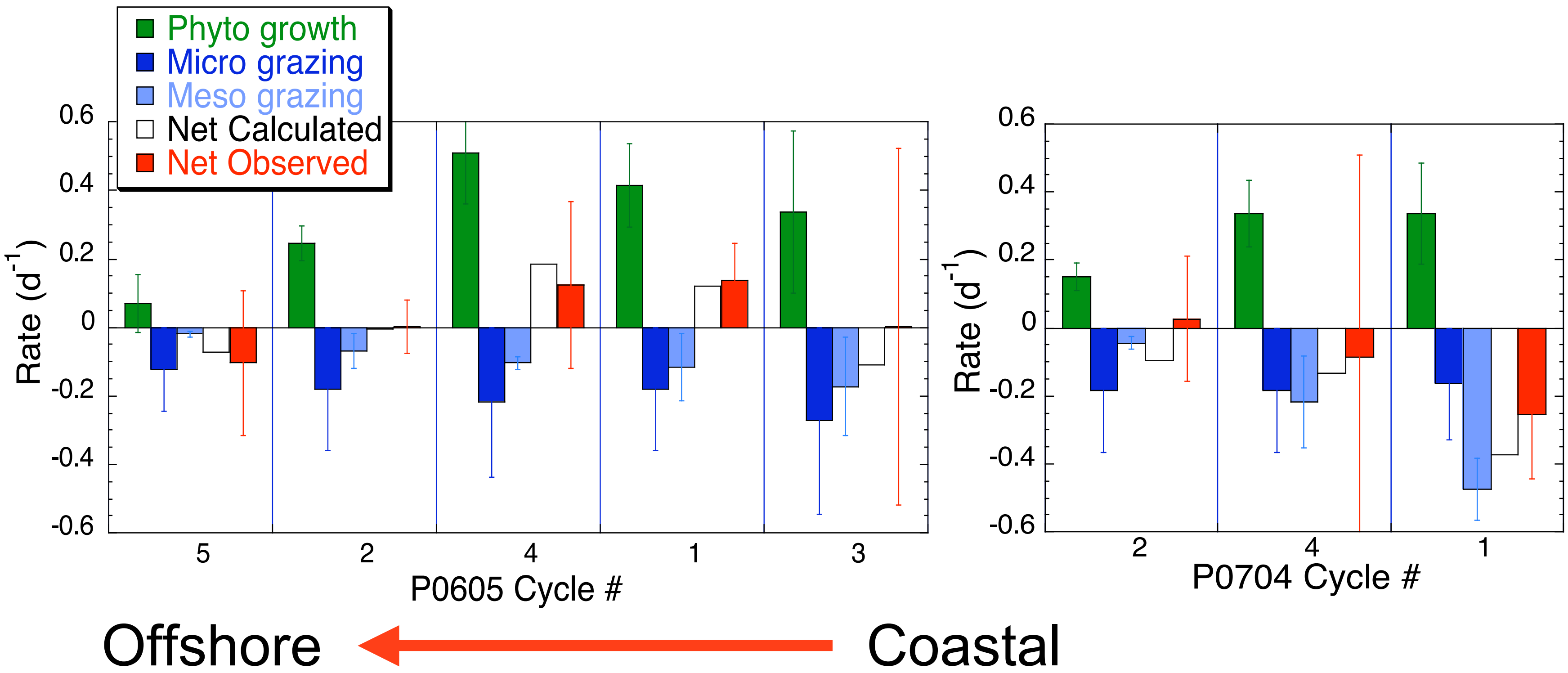


“Net Obs” is measured as the rate of change in the ambient water (Lagrangian design).



Drift Arrays: Fate of Primary Production

All rates based on fluorometric Chl a
depth-integrated for the euphotic zone

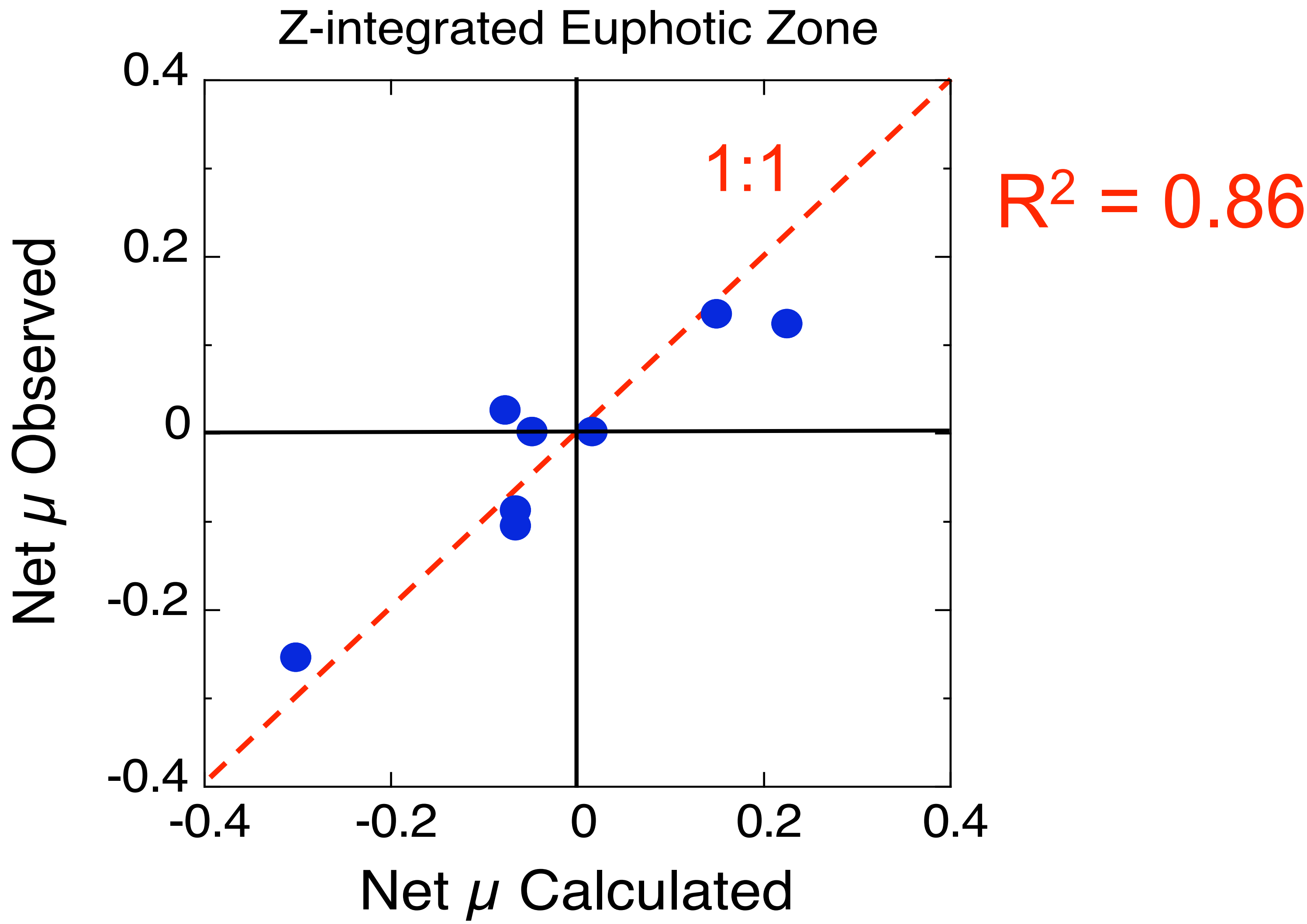


System trends: growth, total grazing, ratio of meso:micro

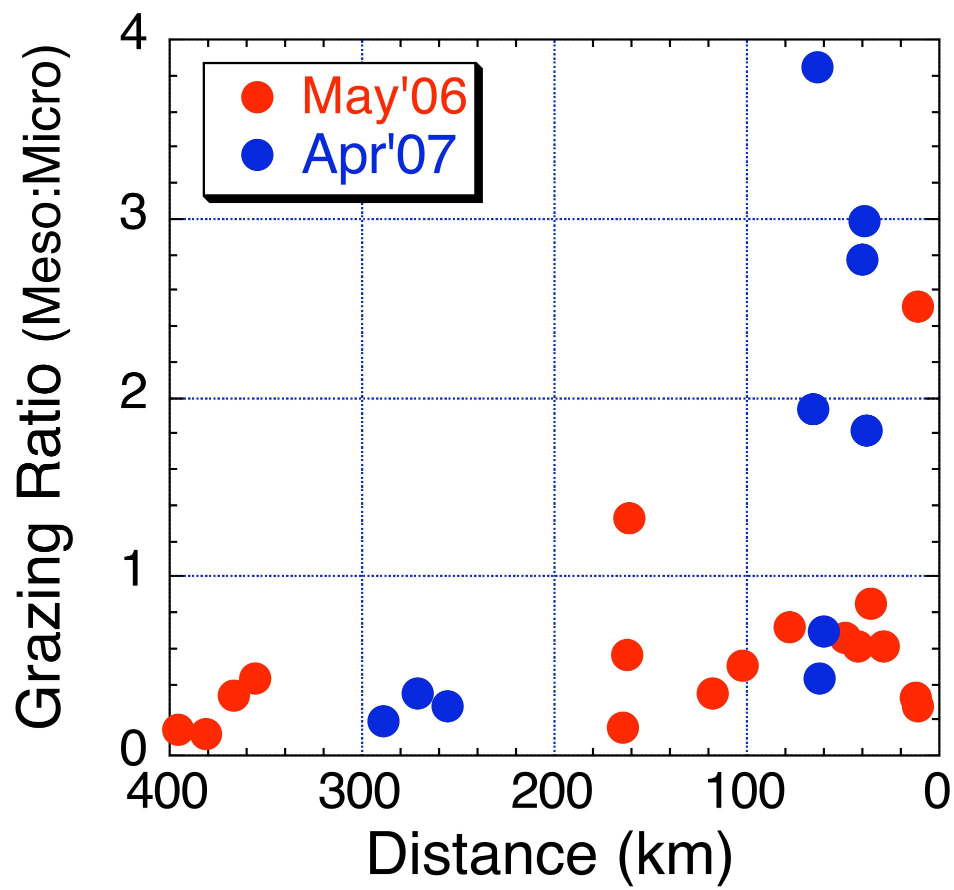
P0605 - positive net growth; P0704 - negative net growth

Experimental Concept/Assumption

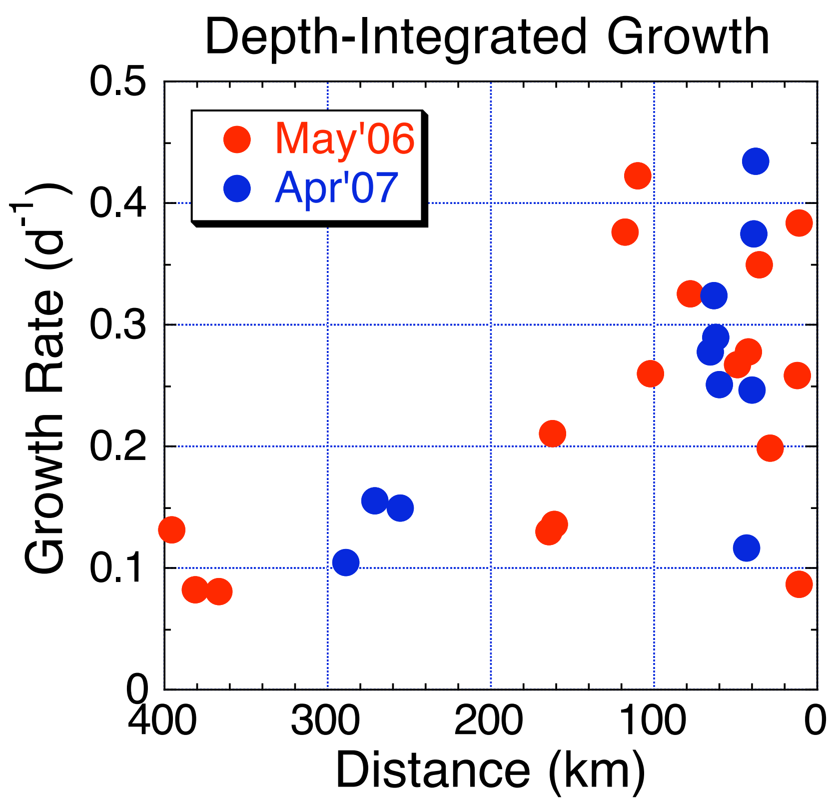
Sum measured processes = ambient "net" observed

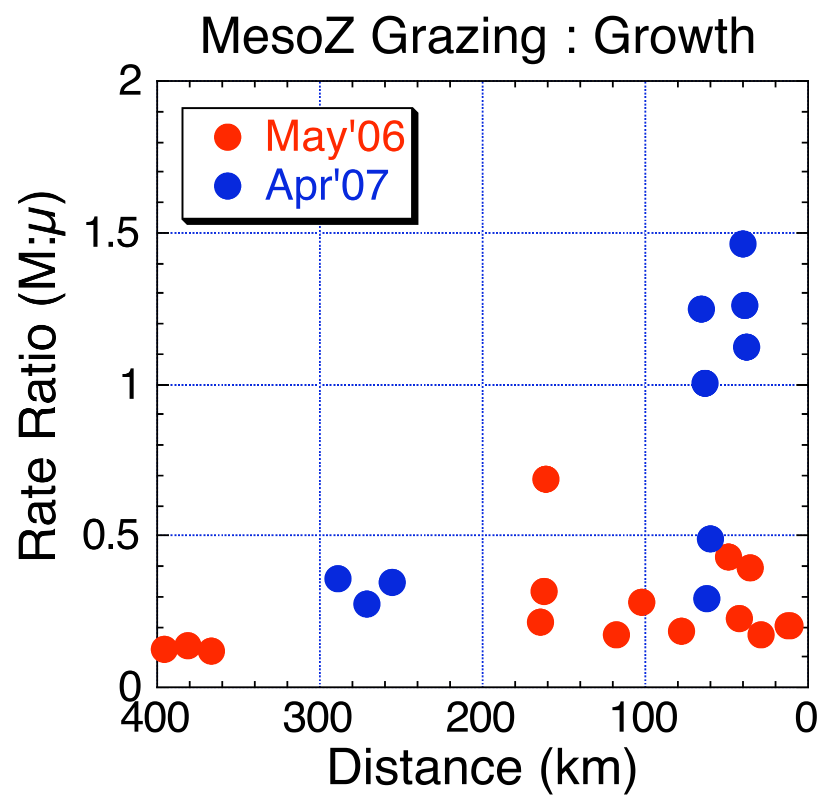


Relative Grazer Roles

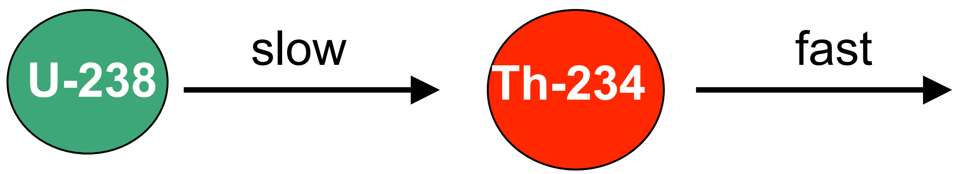


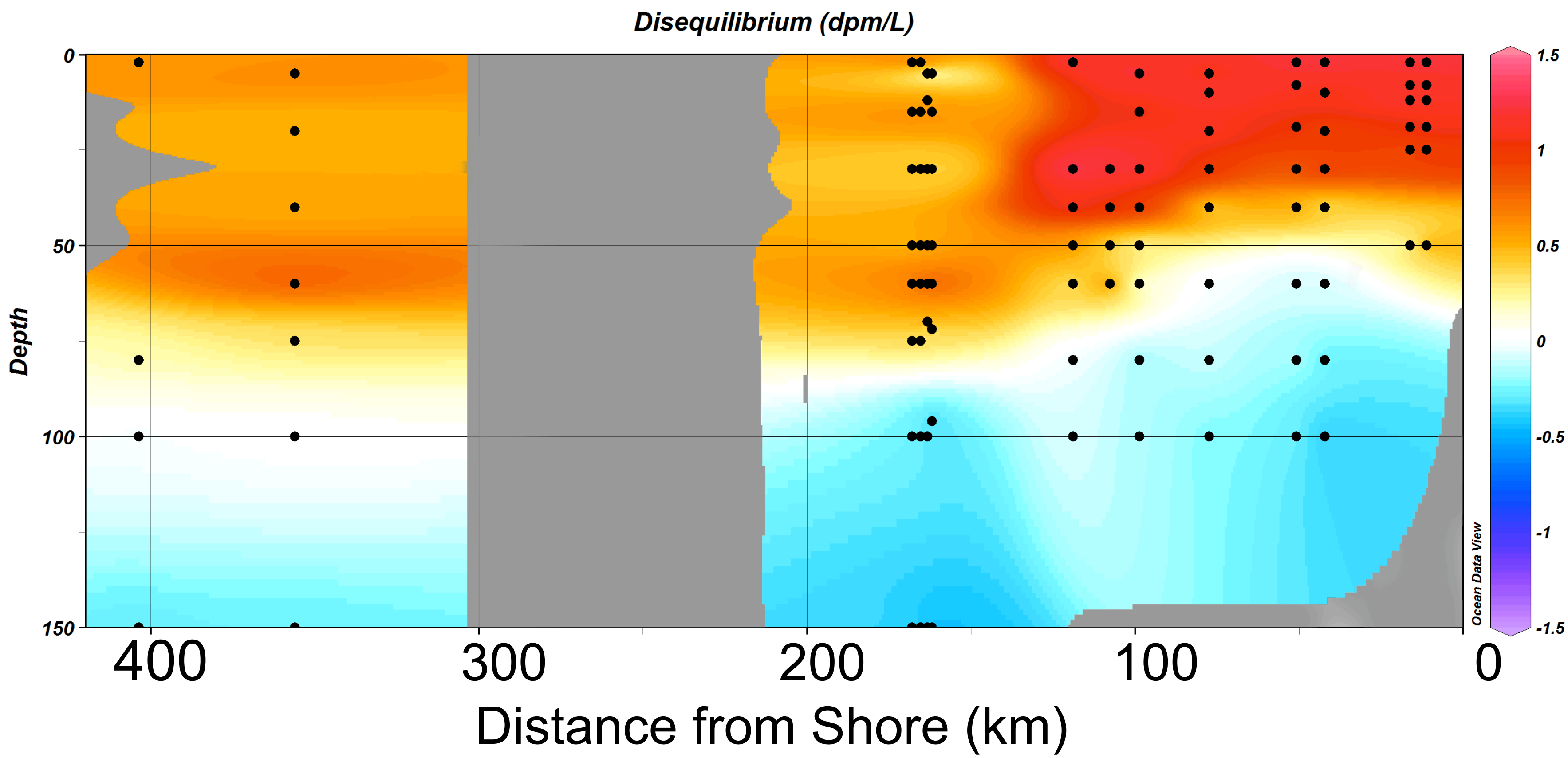
Relative Grazer Roles





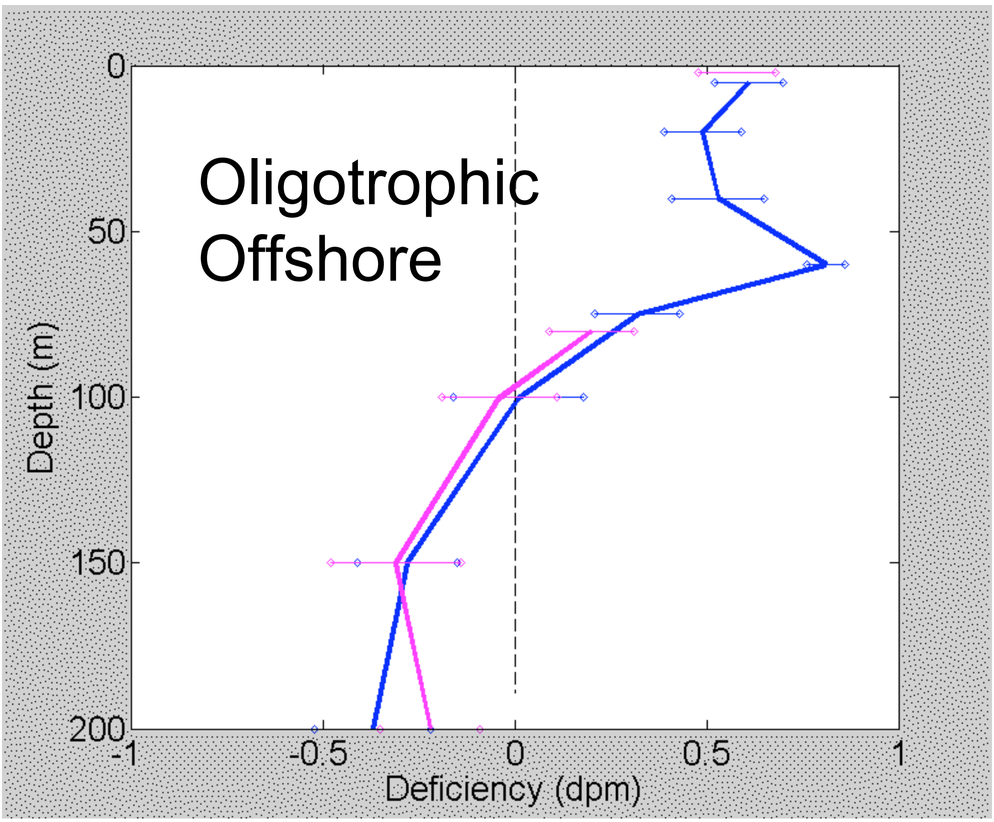
Export Flux -- Thorium Deficiency

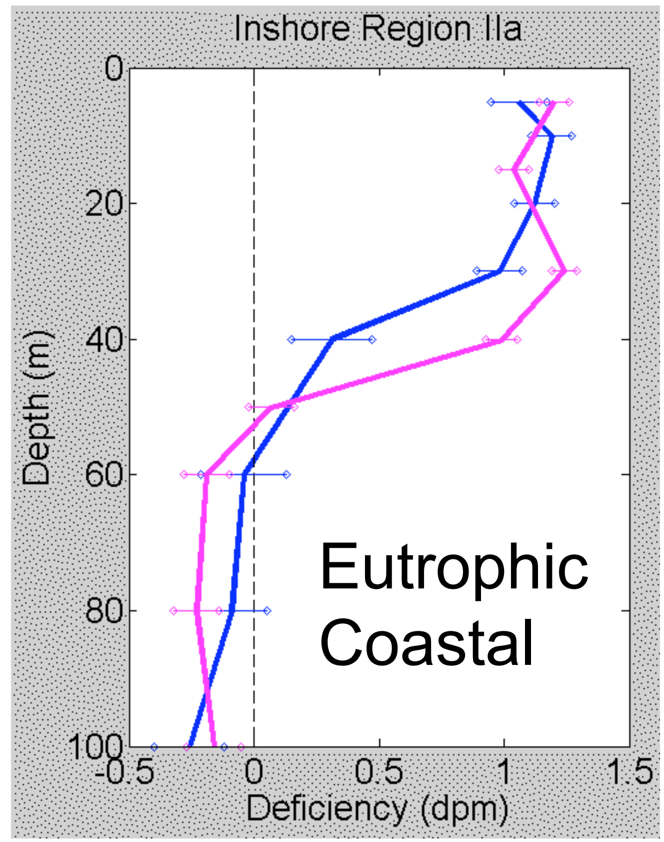




M. Stukel & C. Benitez-Nelson

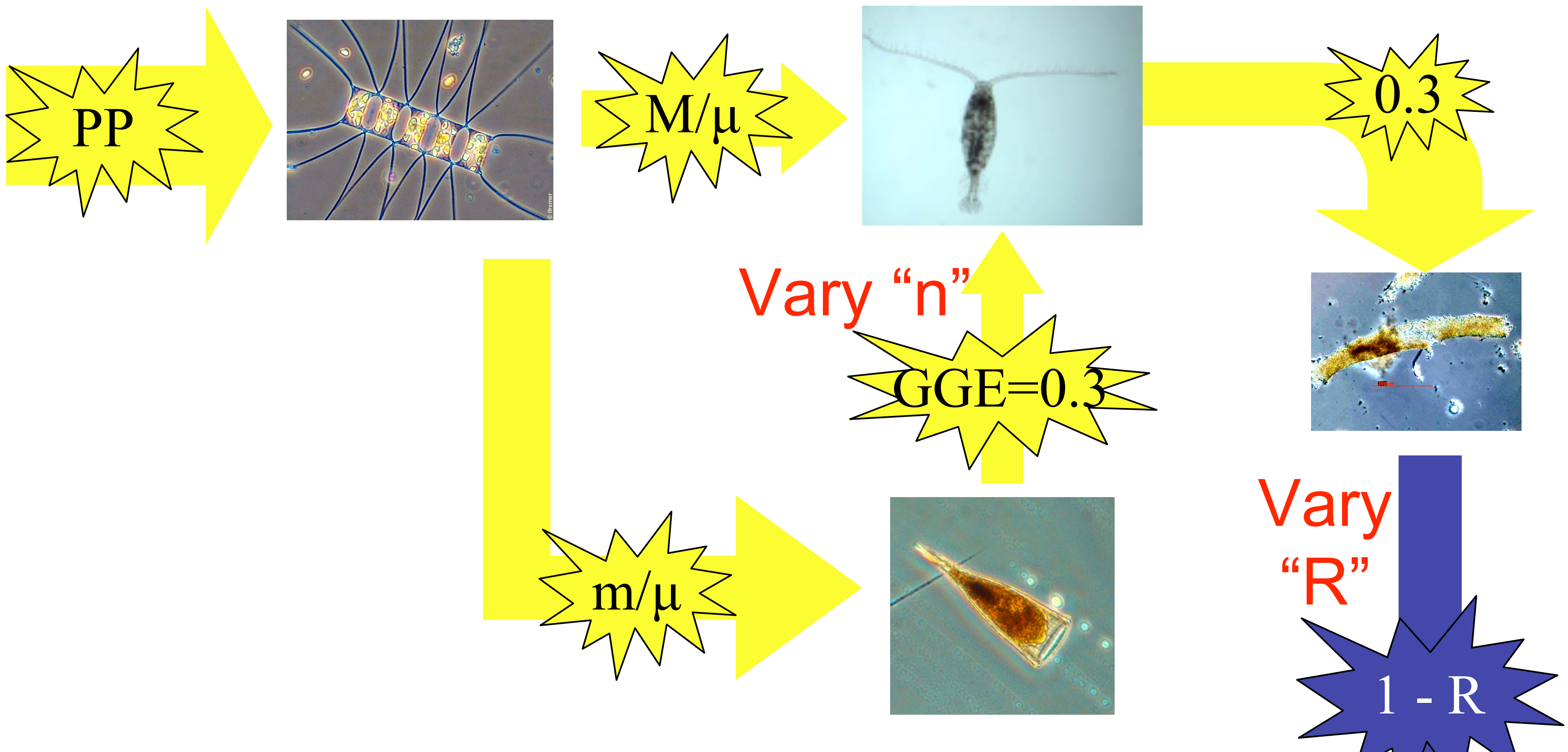
Carbon-based Export Estimates





ThE ratio: 0.14 0.07

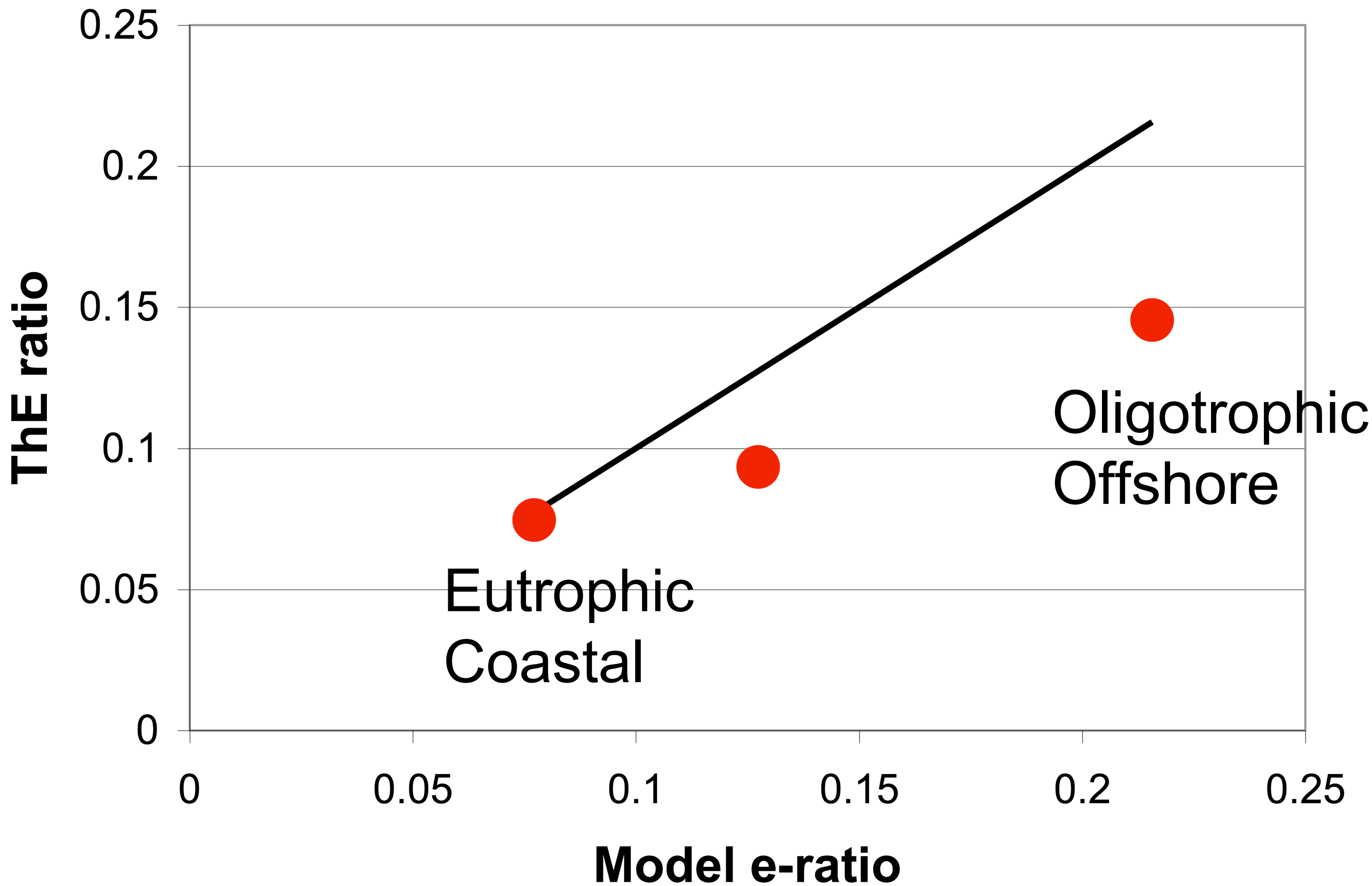
Simple Food-Web Flux Model



$$\text{E-ratio} = 0.3\left(\frac{M}{\mu} + (0.3)^n \frac{m}{\mu}\right)(1 - R)$$

Flux Model Prediction

Line = 1:1



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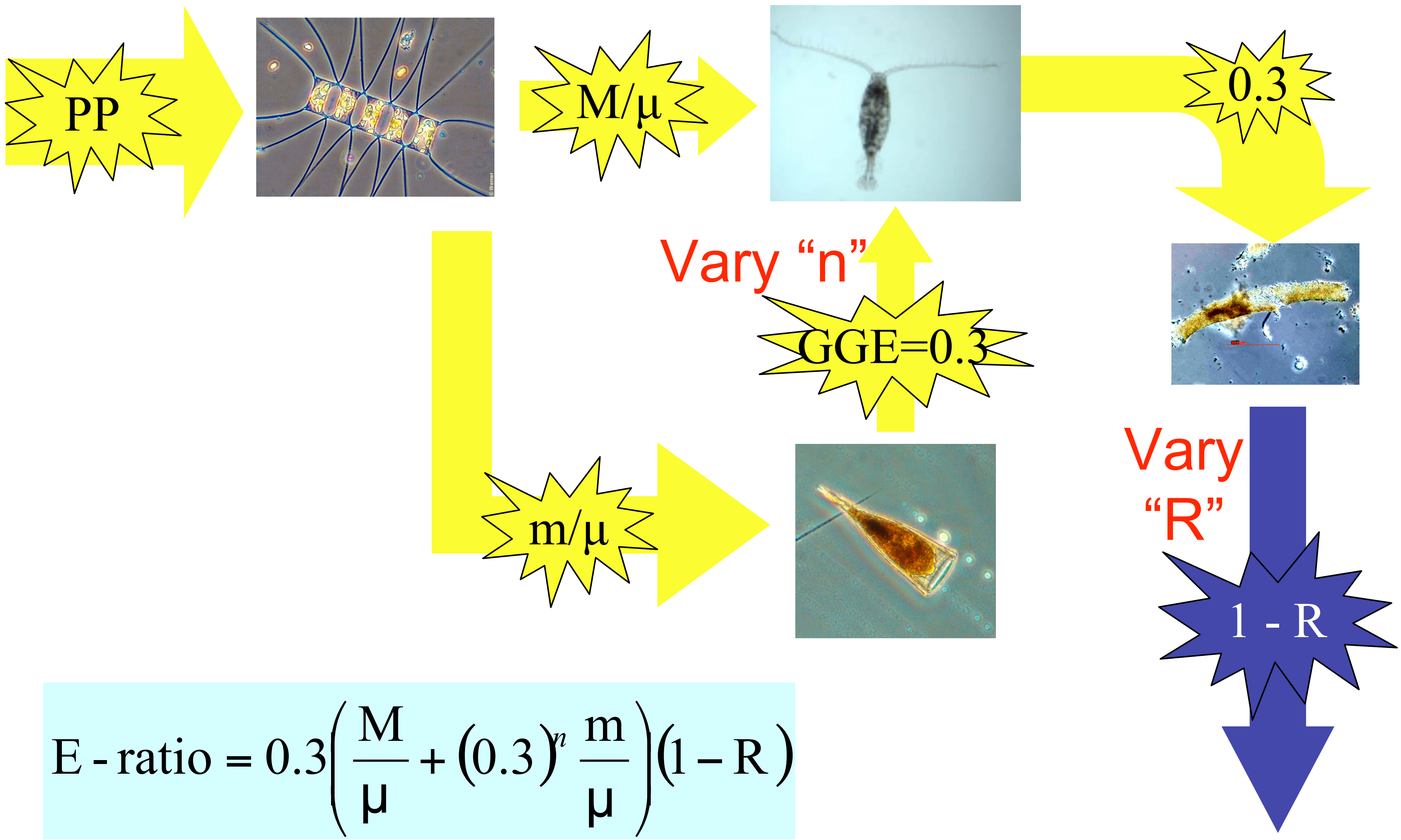

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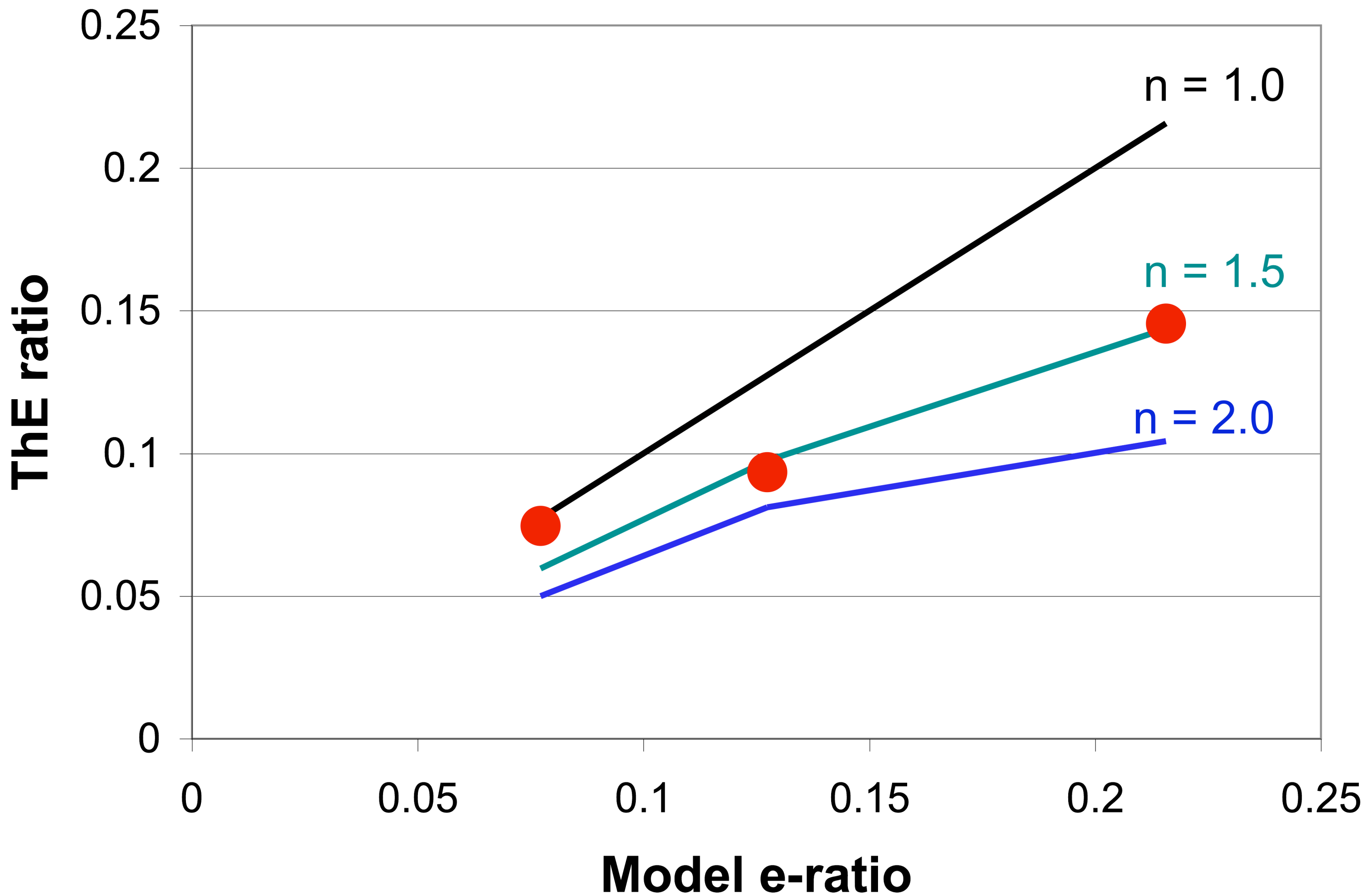
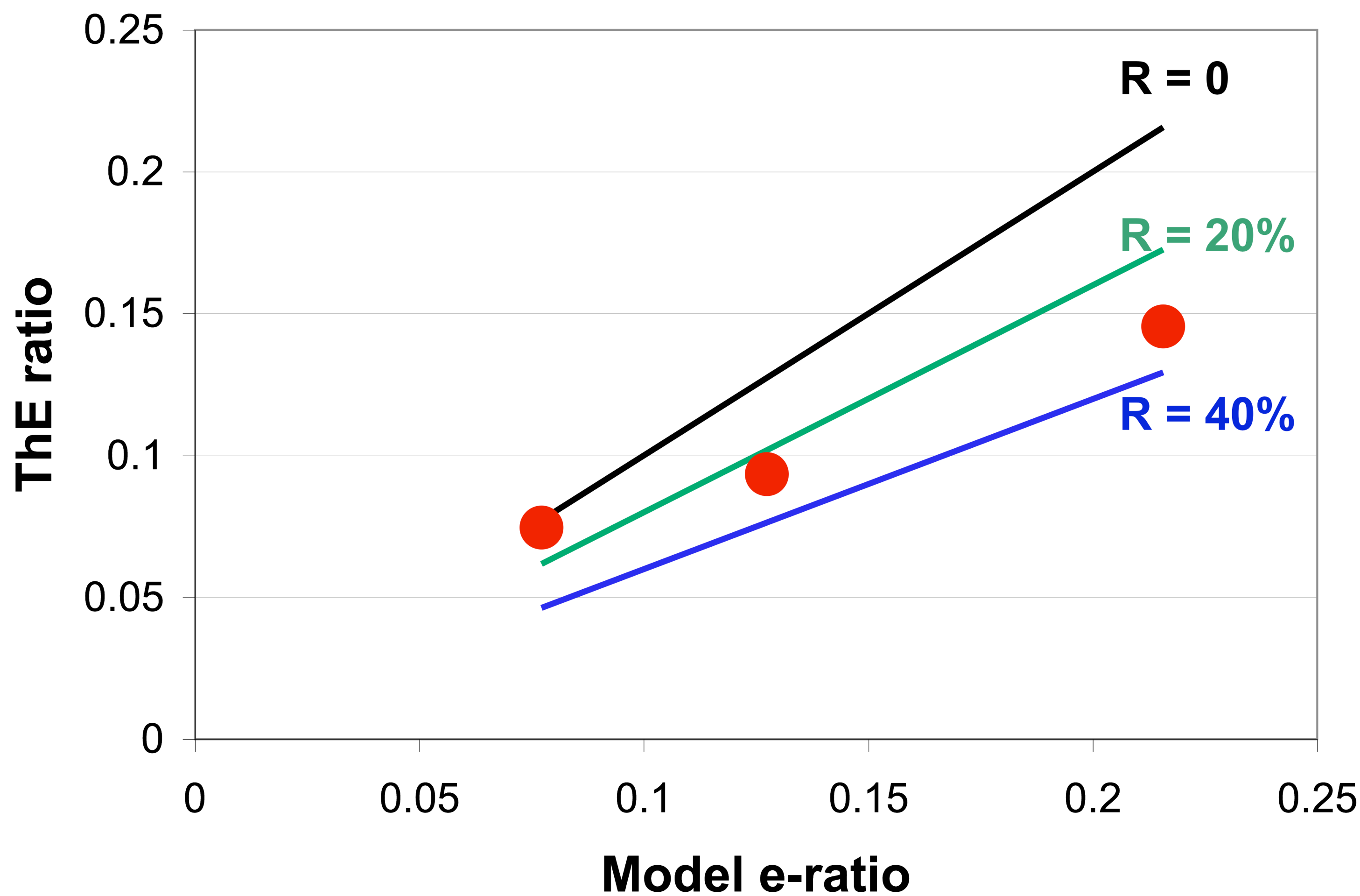
Varying MicroZoo Trophic Linkages



Pellet Remineralization



CCE Process Experiments

Lagrangian design allows study of short-term temporal dynamics in a spatially complex system

- *Resolve ambient changes from sum of measured rates*
- *System patterns in biomass, growth and grazing*
- *Strong and variable role of mesozooplankton*
- *Simple food-web export model*

Future directions …

- *Comparative seasonal cruise (Oct 2008)*
- *Taxon-specific analysis, size relationships*
- *Model development - parameterization, validation*

Summary

CCE has shed new light on old issues

- Zooplankton biomass trends
- Sardines & wind-curl upwelling
- New mode of Pacific climate variability - NPGO

Process Experiments: lower food-web dynamics

- Measurement-constrained budgets of PP fate
- Coupling to ocean biogeochemistry (cycling & export)
- Parameterization of ecosystem models