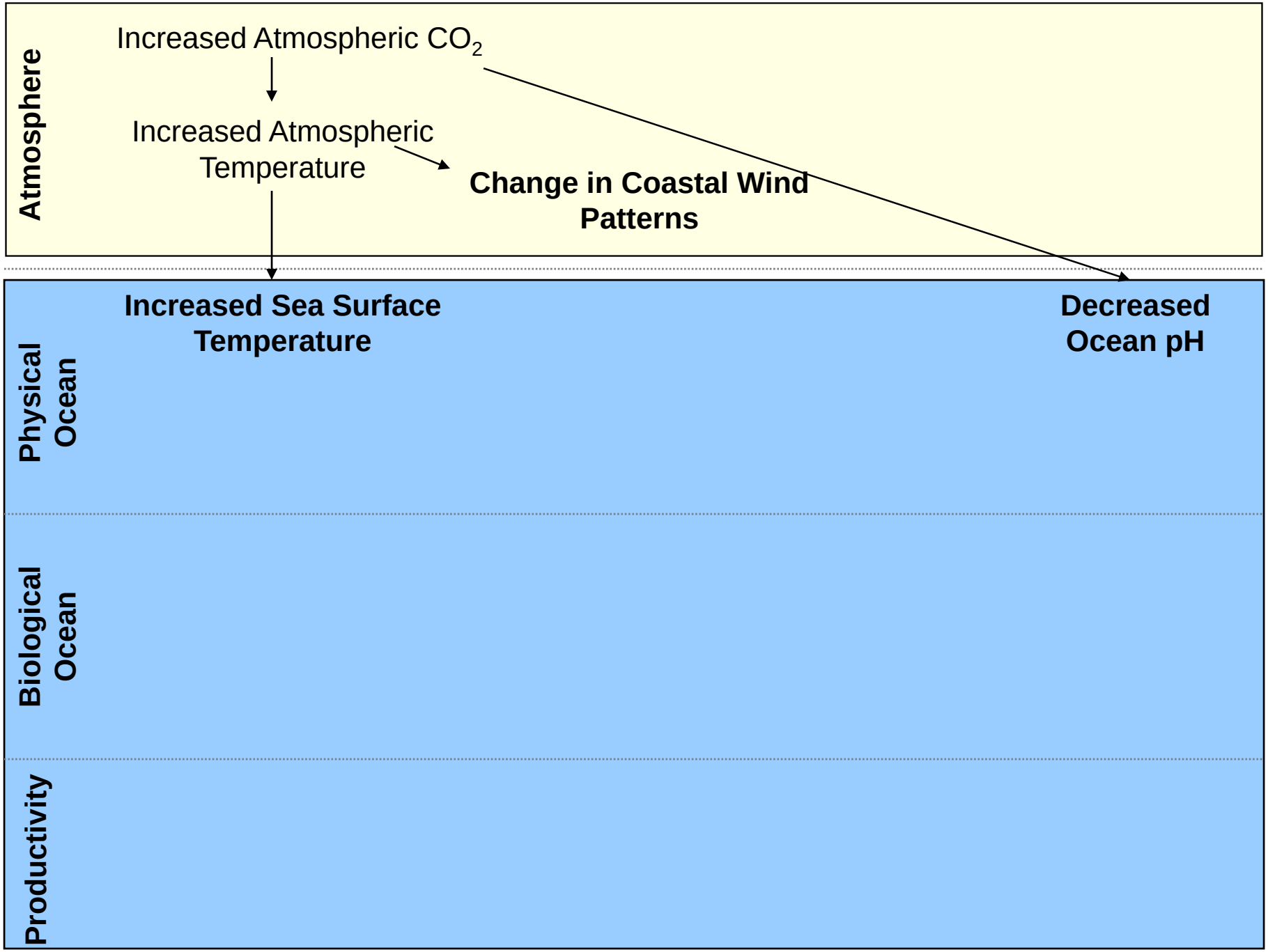
Climate Change Impacts on the Biological Productivity of the Coastal Ocean

Jeffrey Dorman

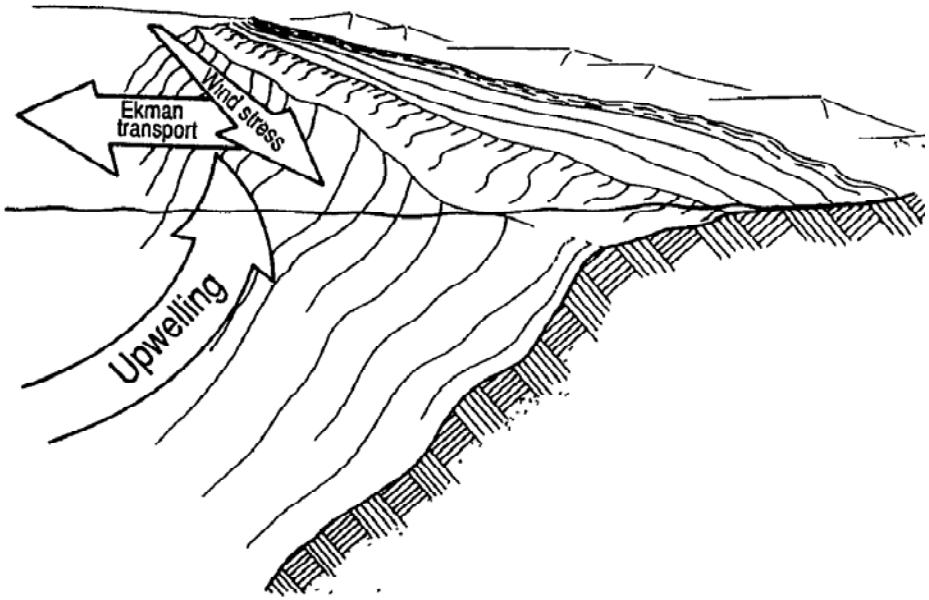
University of California, Berkeley

BICCCA

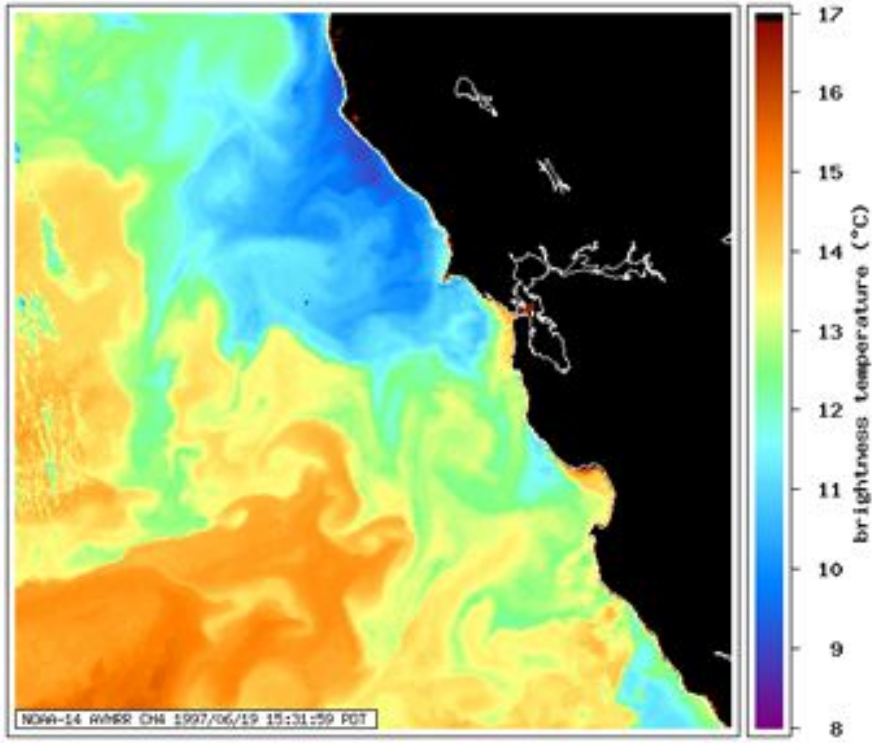
BIOLOGICAL IMPACTS OF CLIMATE CHANGE IN CALIFORNIA


Atmosphere
Increased Atmospheric CO_2
Increased Atmospheric Temperature
Change in Coastal Wind Patterns
Physical Ocean
Increased Sea Surface Temperature
Decreased Ocean pH
Biological Ocean
Productivity

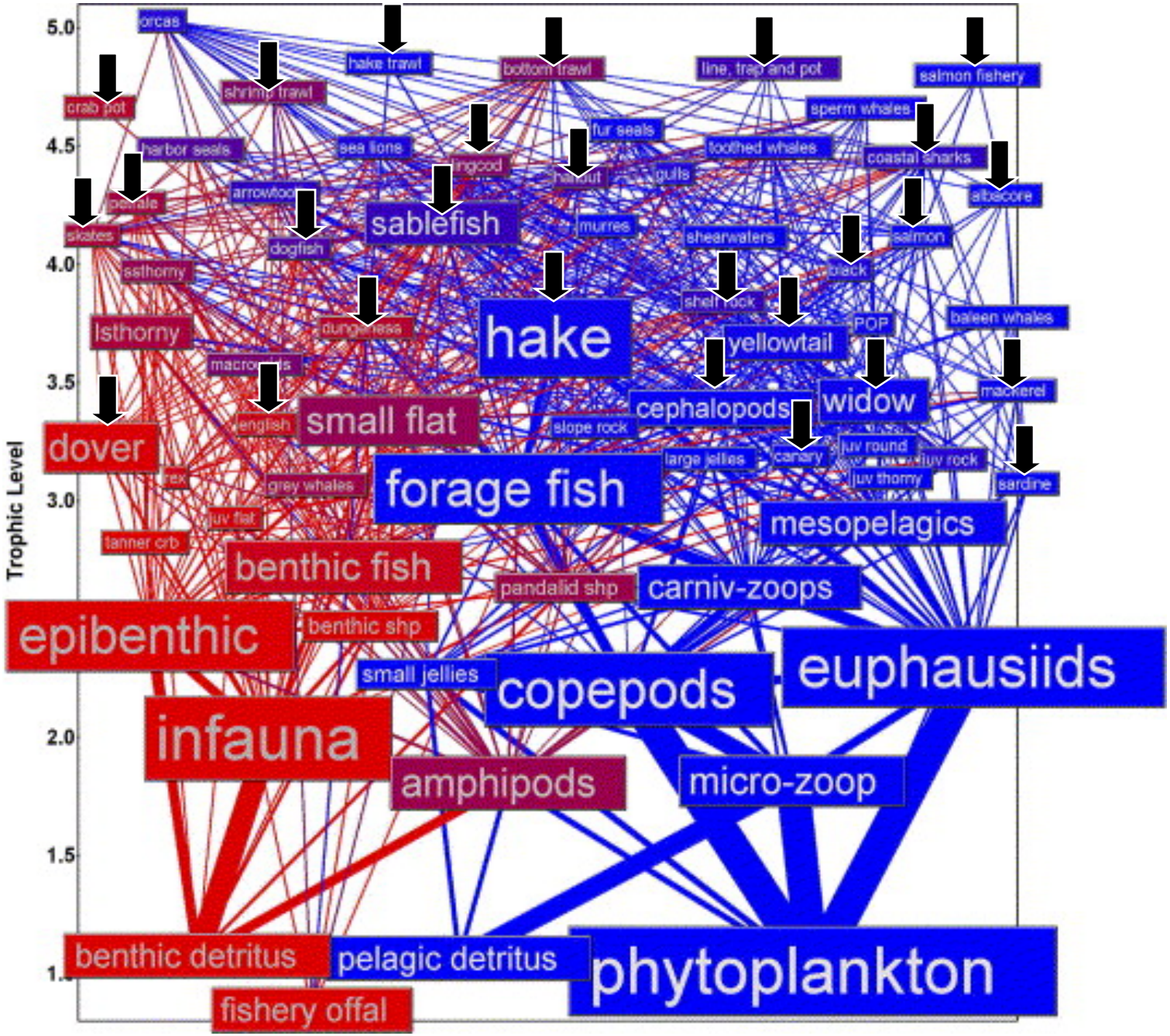
Coastal Upwelling Regions and Productivity



(Bakun A Science 1990 247:198-201)



(NOAA, AVHRR, Sea Surface Temperature Data)



(Field JC et al., Prog Ocean, 2006 68:238-270)

Atmosphere

Increased Atmospheric CO_2

Increased Atmospheric Temperature

Change in Coastal Wind Patterns

CO_2

Physical Ocean

Increased Sea Surface Temperature

$$CO_2 + 2H_2O + CO_3^{-2}$$

$$2HCO_3^{-2} \quad 2H^+$$

Decreased Oceanic pH

Biological Ocean

Change in Calcareous Organisms

Productivity

Results at 560 ppm CO_2

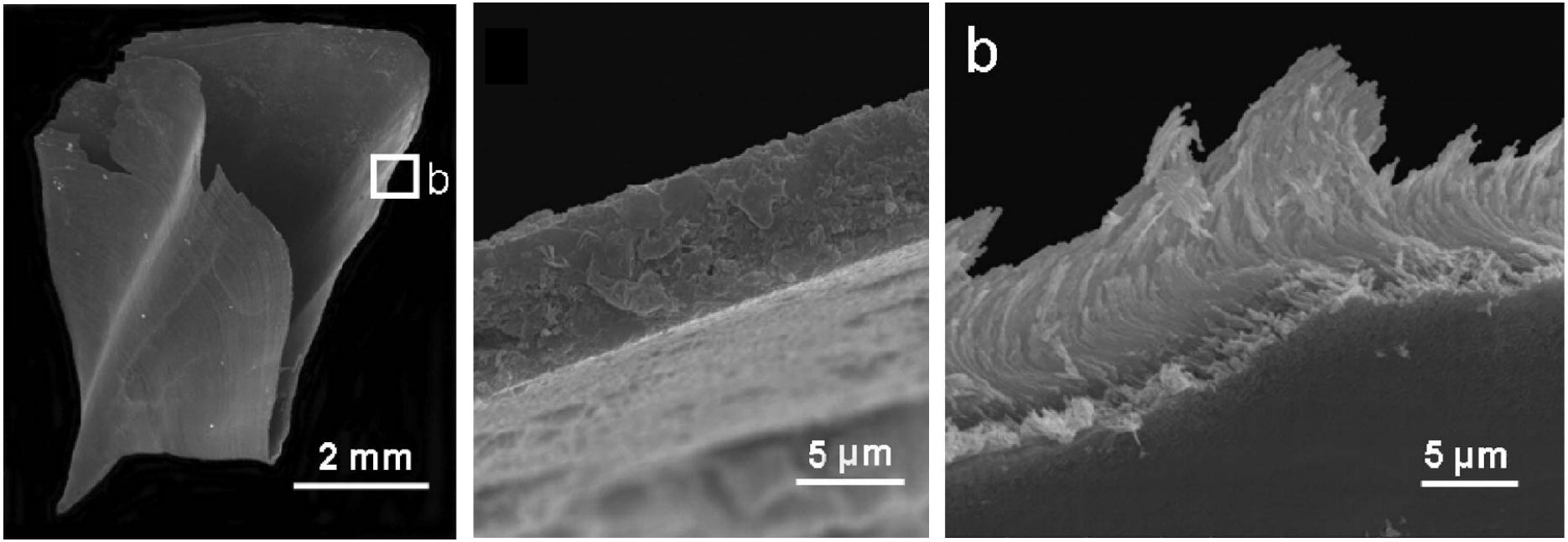
pH decreases by 0.25

CO_3^{-2} decreases by 34%

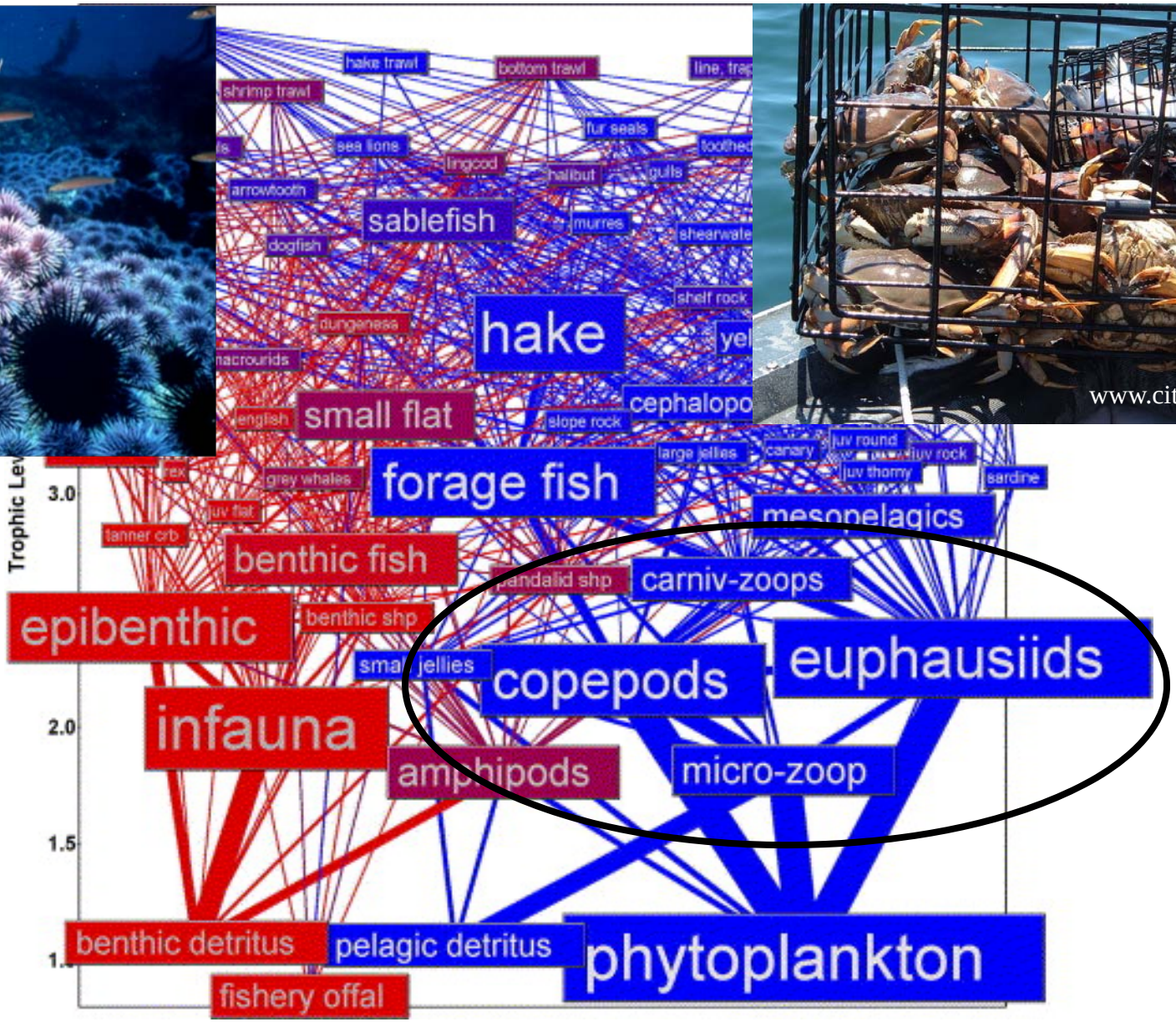
(Fabry VJ et al., ICES J Mar Sci, 2008 65:414-432)

Ocean Acidification: Impact on marine ogranisms

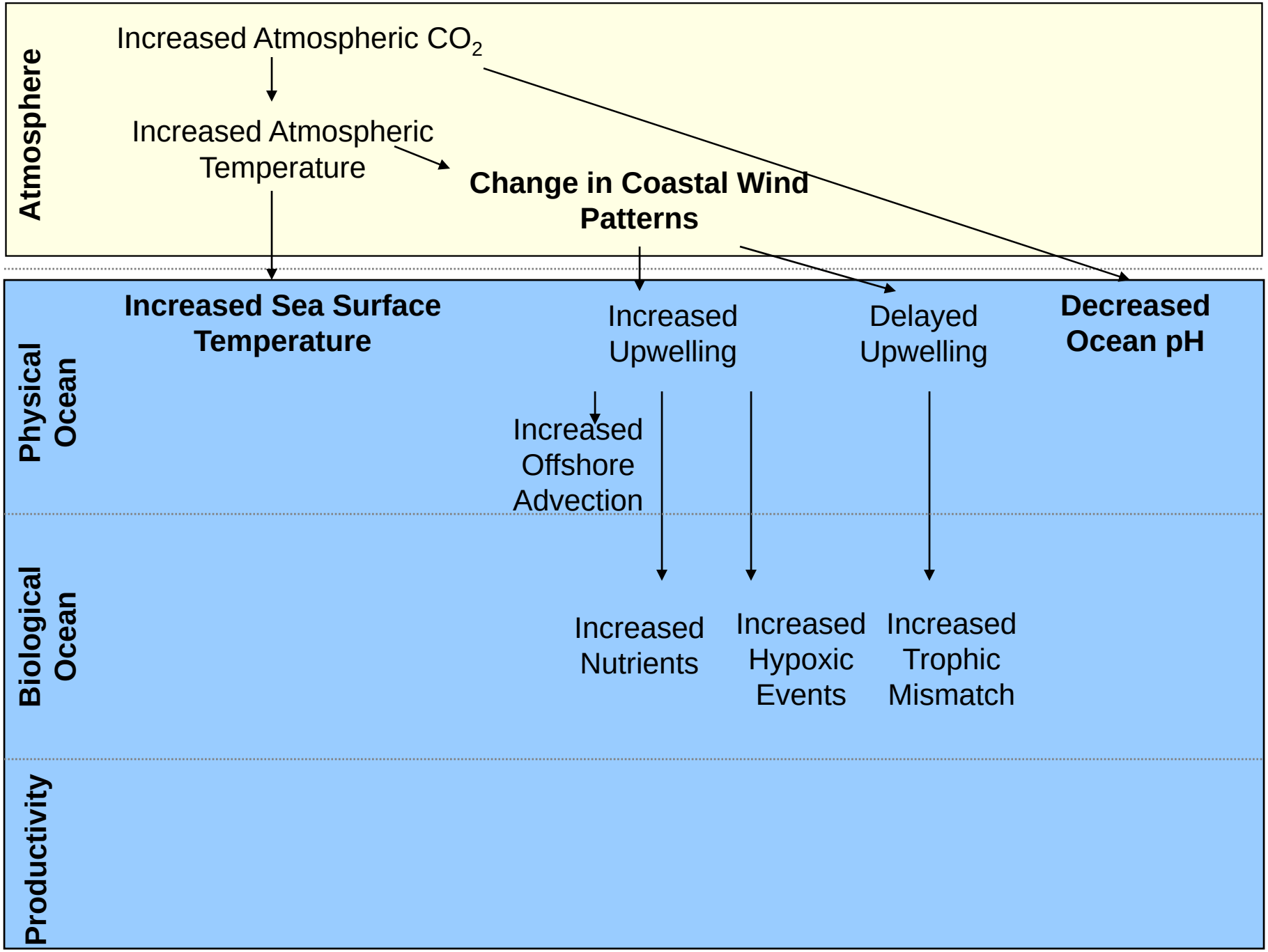
SEM photographs of the shell of the pteropod Clio pyramidata



(Fabry VJ et al., ICES J Mar Sci, 2008 65:414-432)



(Field JC et al., Prog Ocean, 2006 68:238-270)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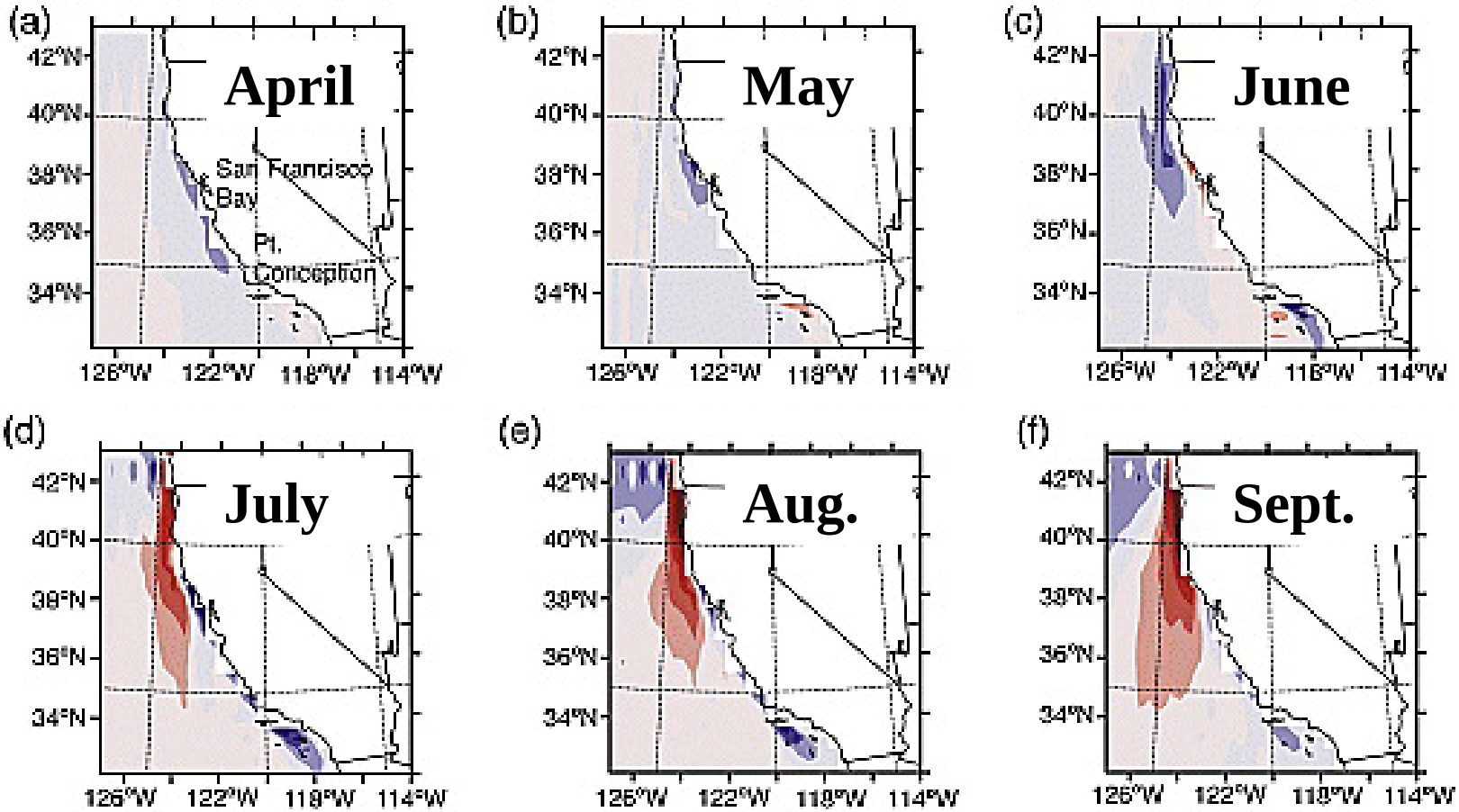
Biological Ocean
Increased Nutrients
Increased Hypoxic Events
Increased Trophic Mismatch
Productivity

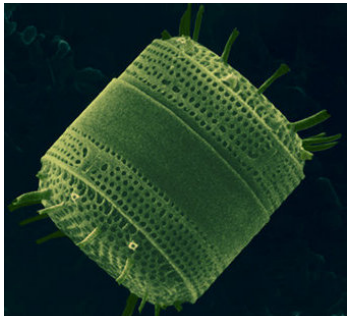
Increased Upwelling Favorable Winds/ Delayed Winds



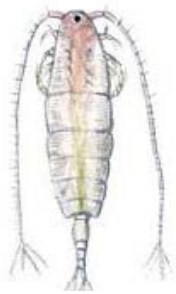
(Snyder MA et al., Geophy Res Letters 2003 30(15):1823; doi:10.1029/2003GL017647)

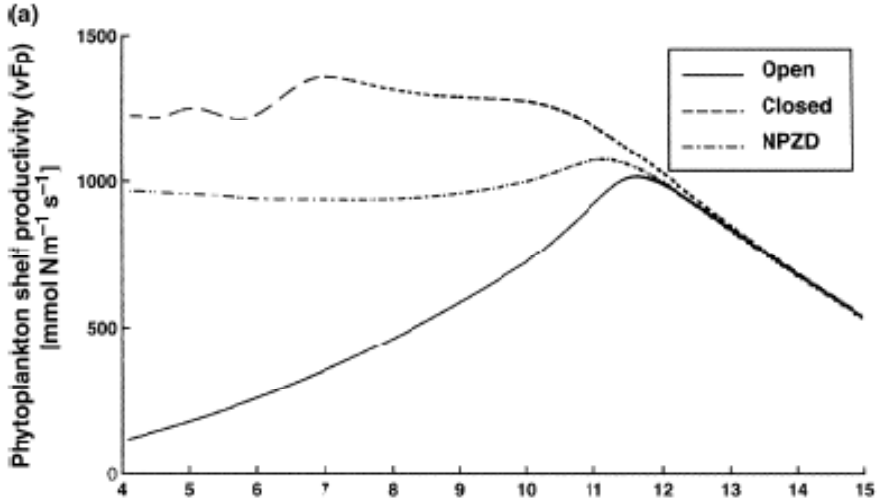
Increased Upwelling Favorable Winds: Increased Nutrients vs. Increased Advection

Impacts on Phytoplankton

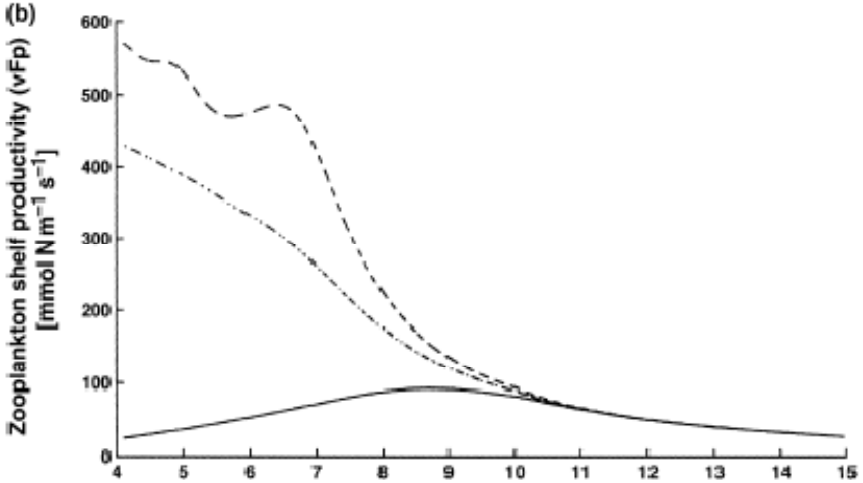


Impacts on Zooplankton





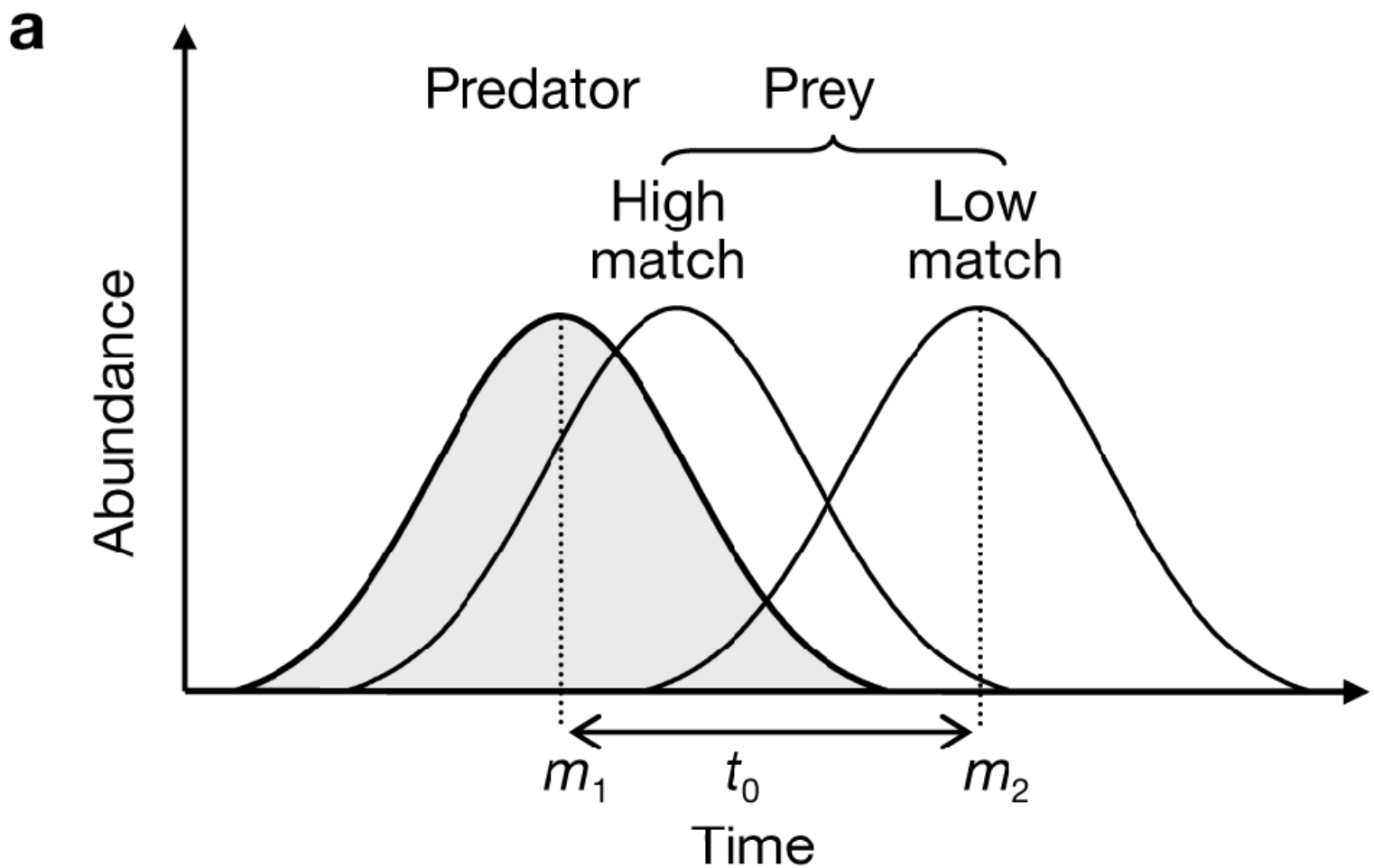
Wind Speed (m/s)



Wind Speed (m/s)

(Botsford LW et al., Fish Ocean, 2003 12:245-259)

Delayed Winds:
Increased Trophic Mismatch



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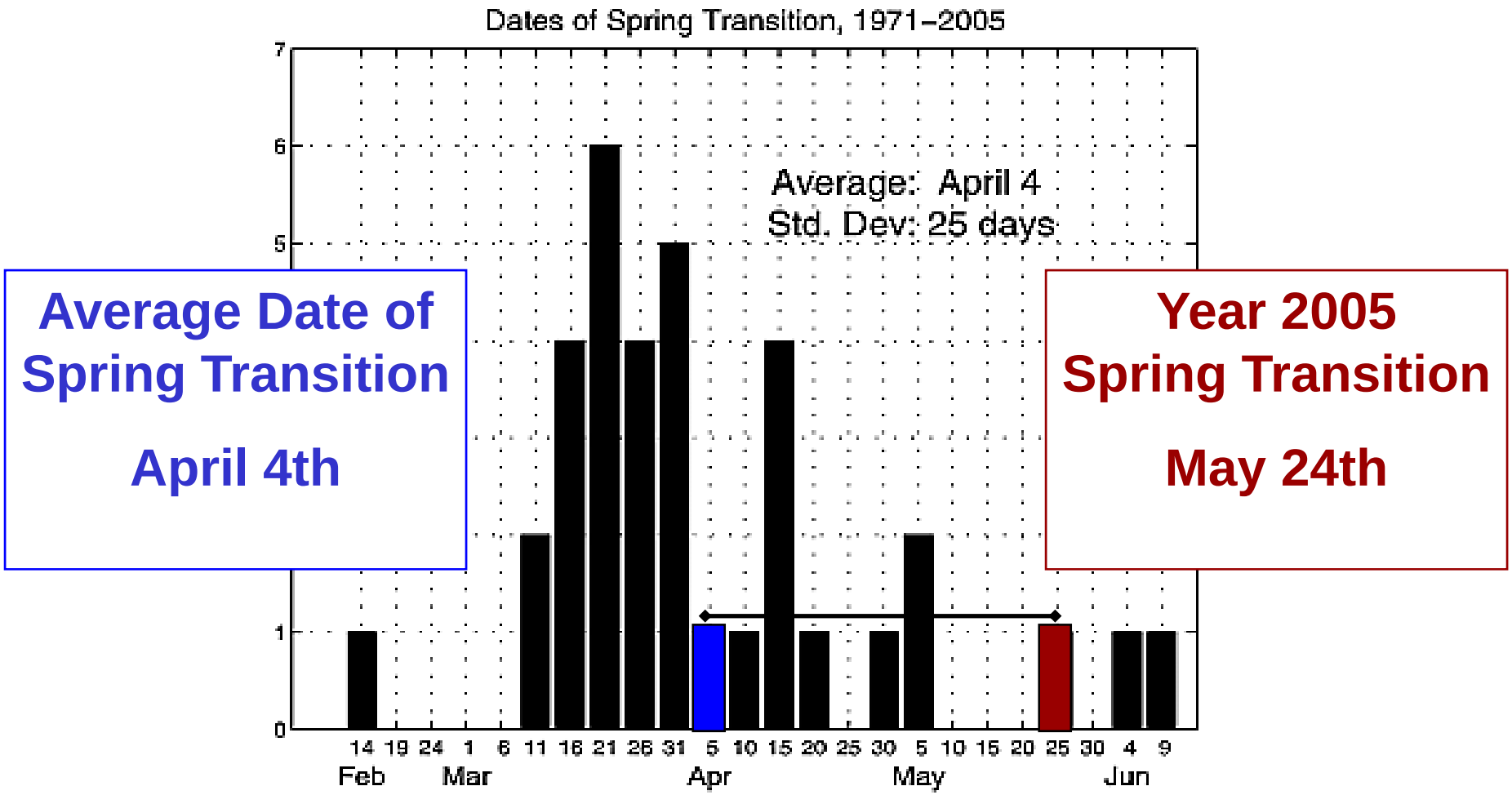
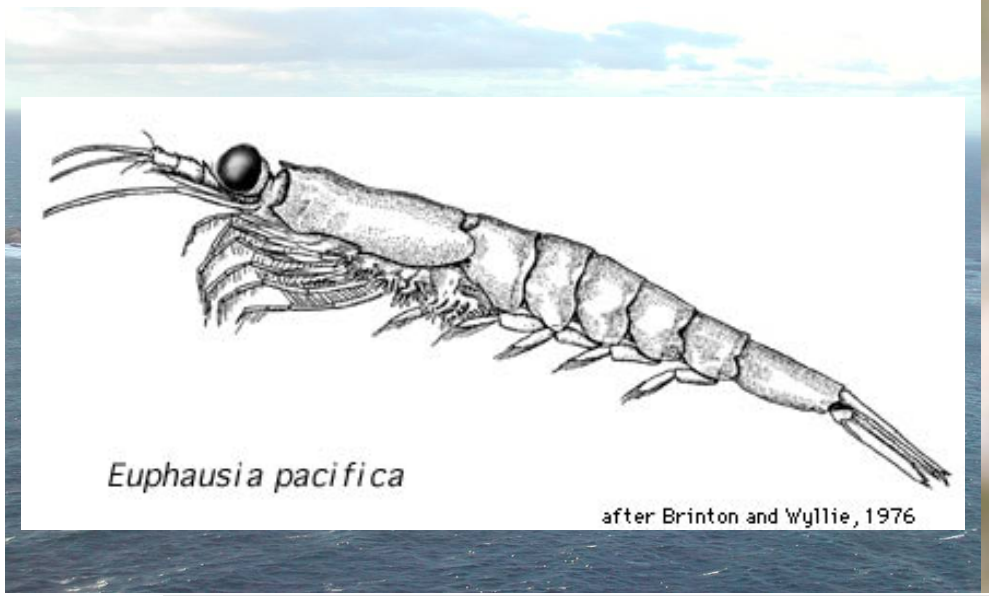
(Durant JM et al., Clim Res, 2007 33:271-283)

Delayed Winds: Increased Trophic Mismatch

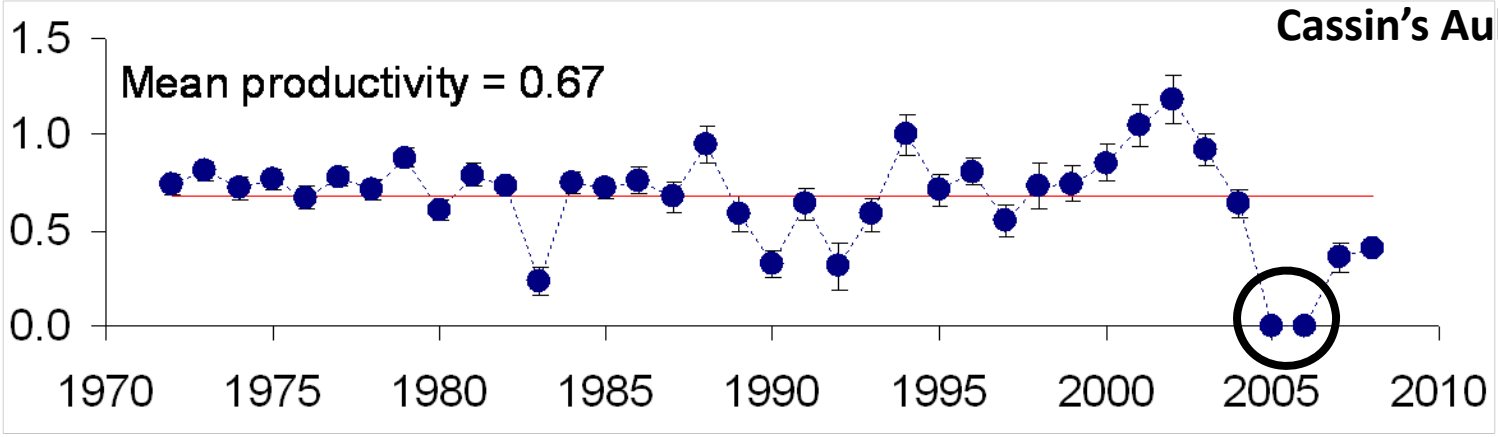


(Kosro PM et al., Geophys Res Letters, 2006 33:L22S03; doi:10.1029/2006GL027072)

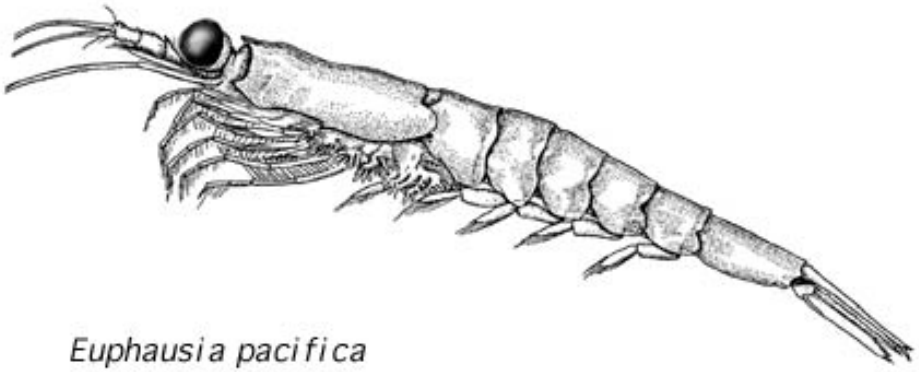
Delayed Winds:
Increased Trophic Mismatch



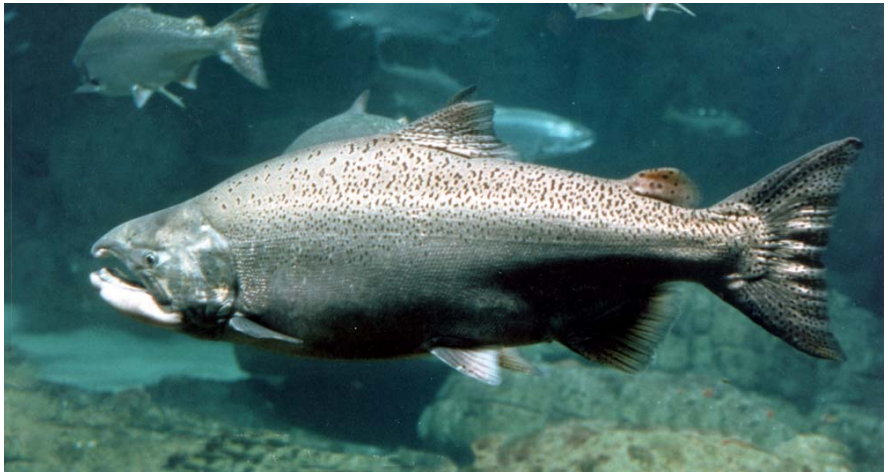
Cassin's Auklet

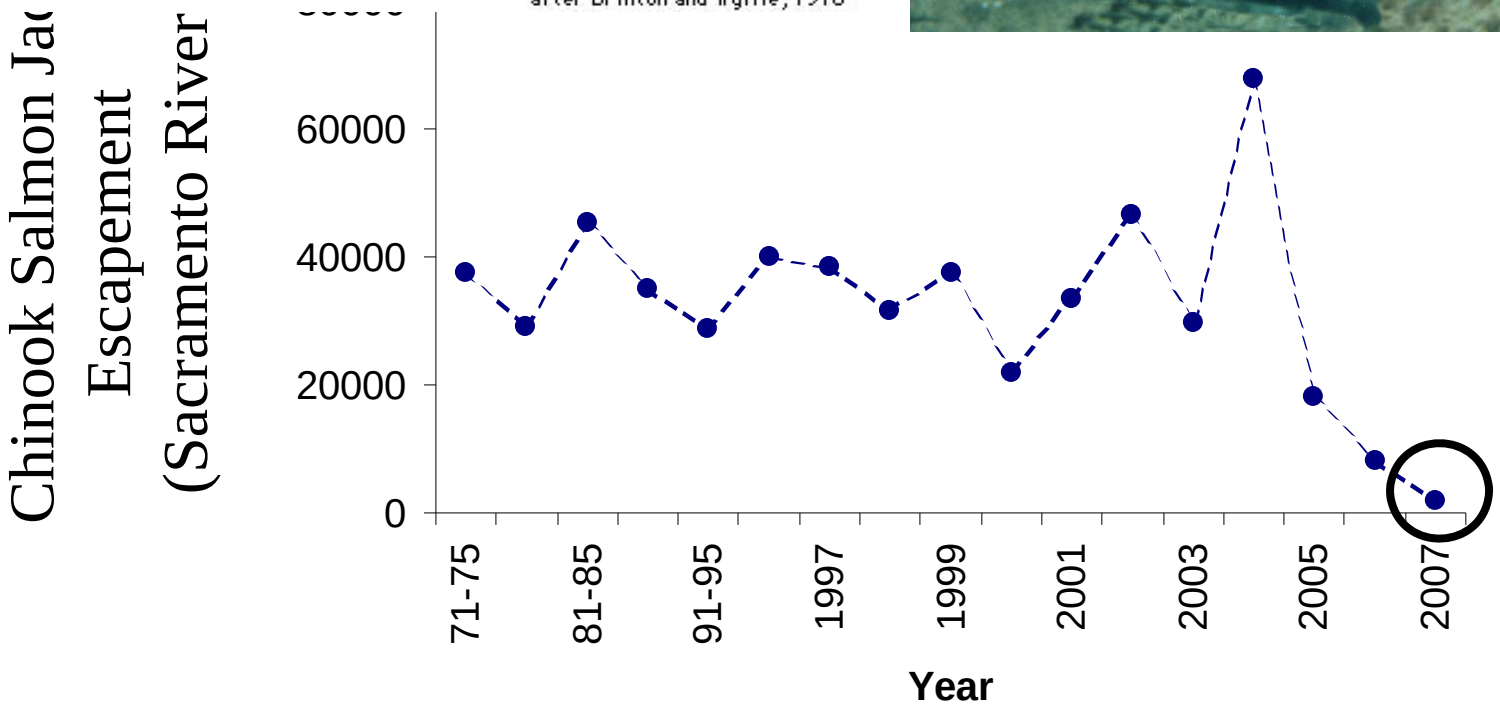


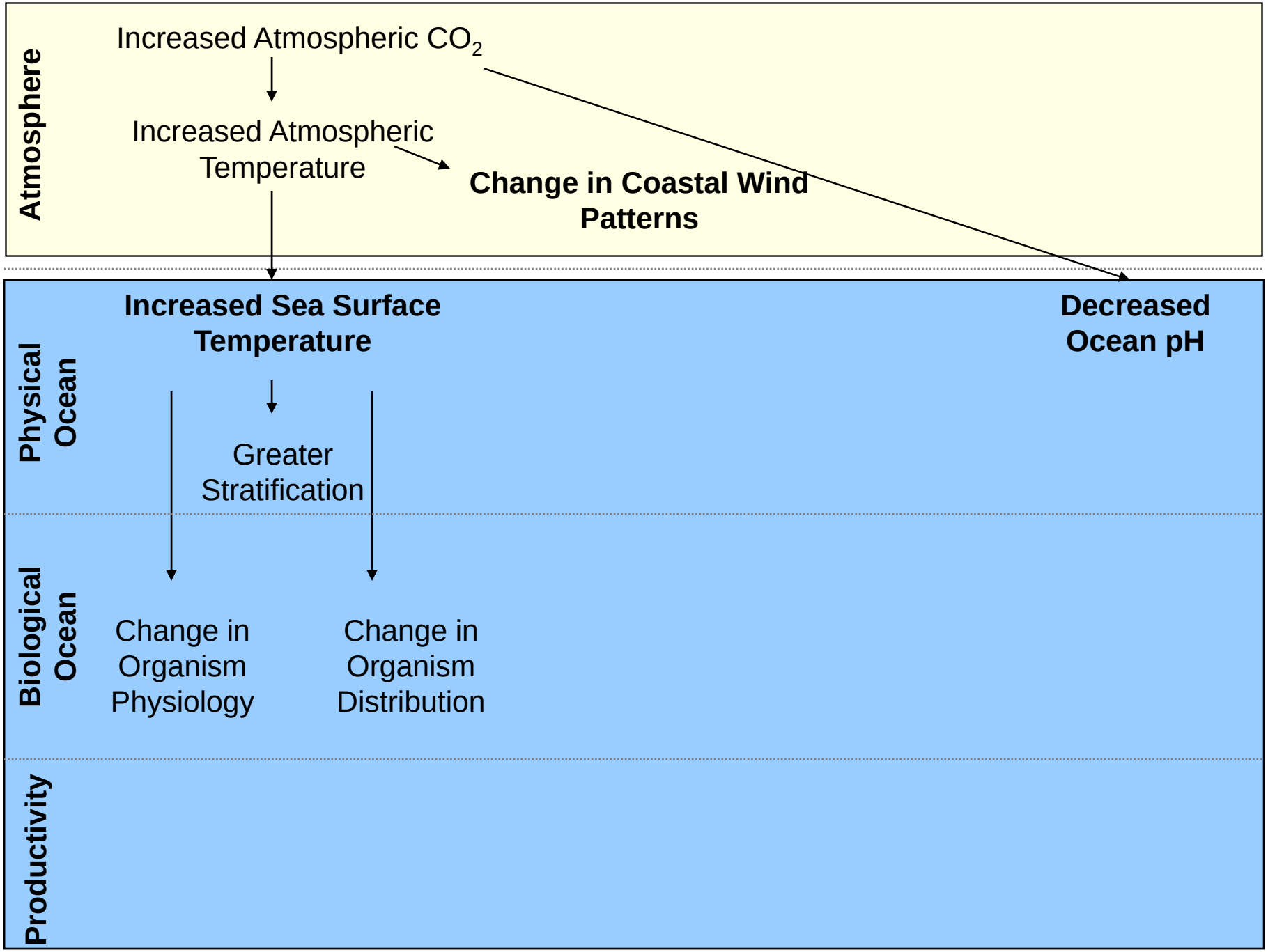
Delayed Winds:
Increased Trophic Mismatch



after Brinton and Wyllie, 1976



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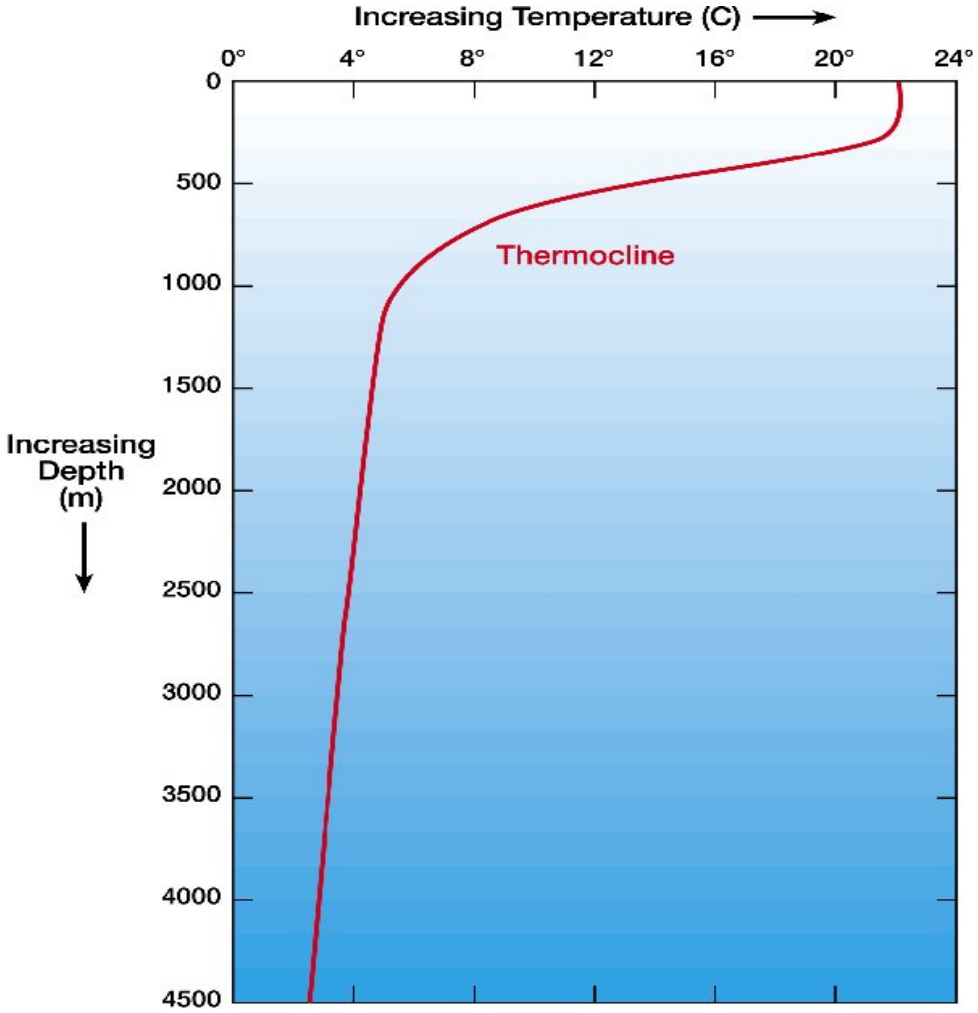
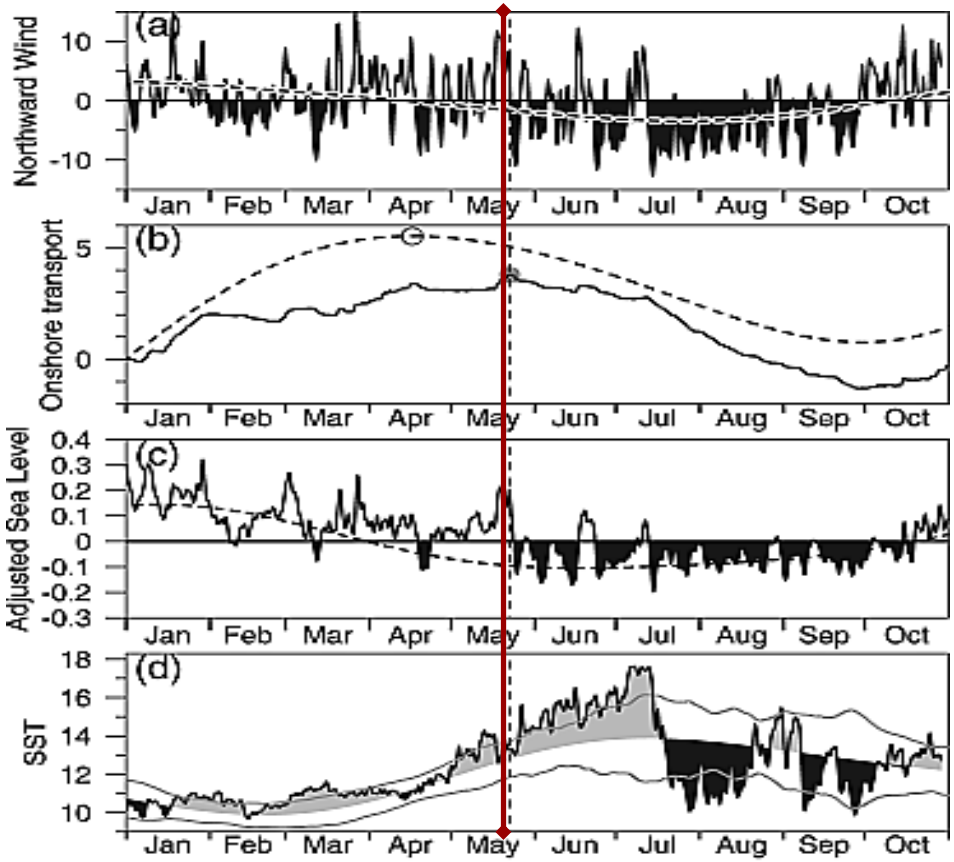
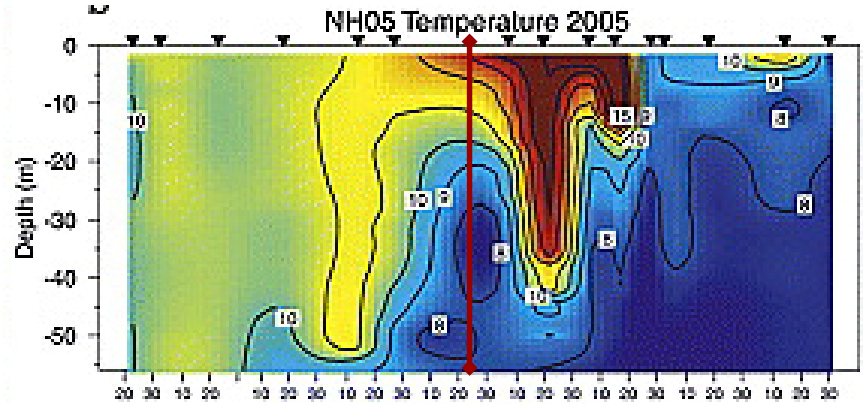
Increased Sea Surface Temperature
Decreased Ocean pH
Greater Stratification
Biological Ocean
Change in Organism Physiology
Change in Organism Distribution
Productivity

Increased Sea Surface Temperature: Greater Stratification



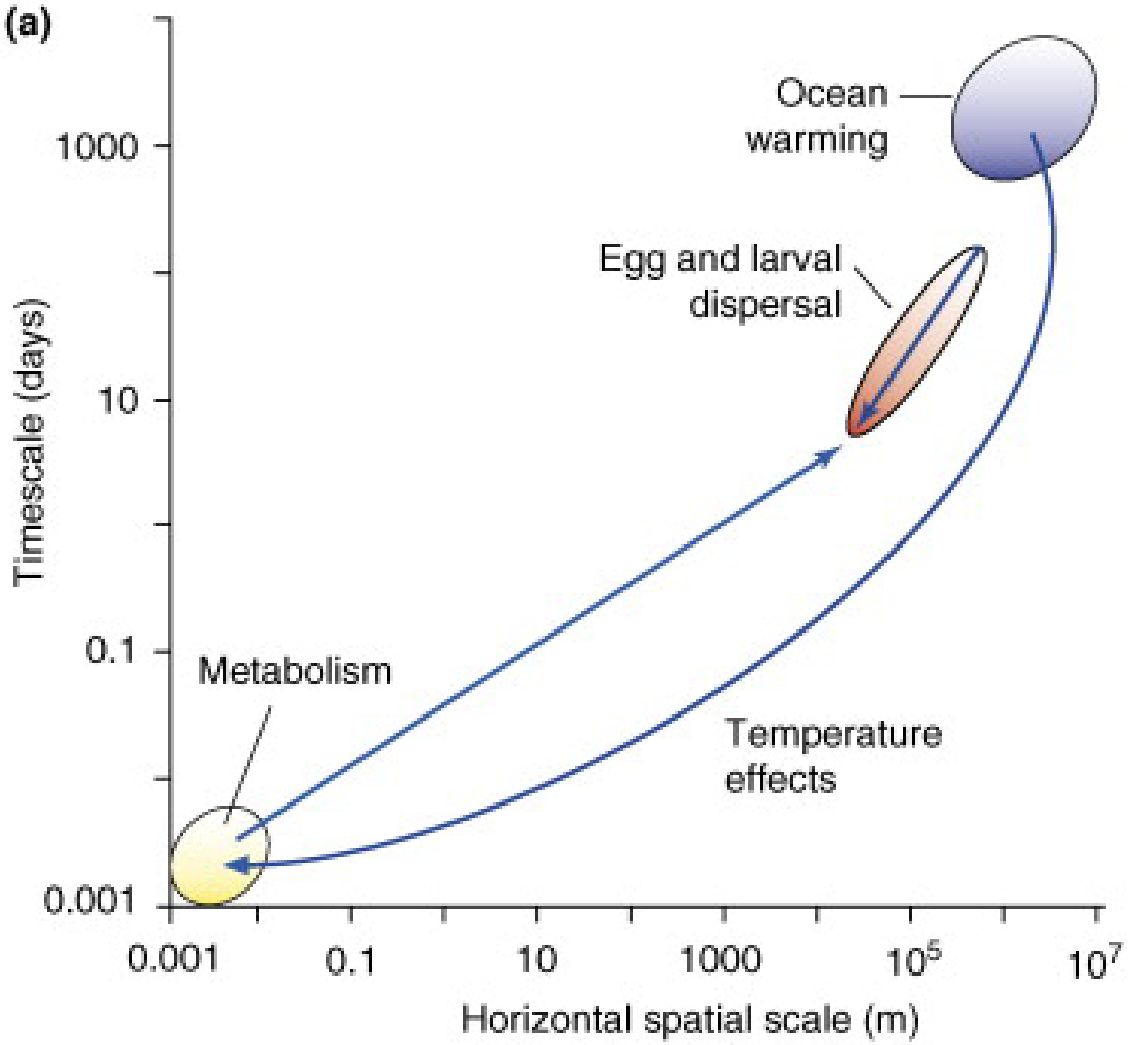
(http://www.windows.ucar.edu/tour/link=/earth/Water/temp.html)





(Kosro PM et al., Geophys Res Letters, 2006 33:L22S03; doi:10.1029/2006GL027072)

Increased Sea Surface Temperature: Change in Organism Physiology



(Duarte CM, Trends Ecol Evo, 2007 22(7); doi:10.1016/j.tree.2007.04.001)

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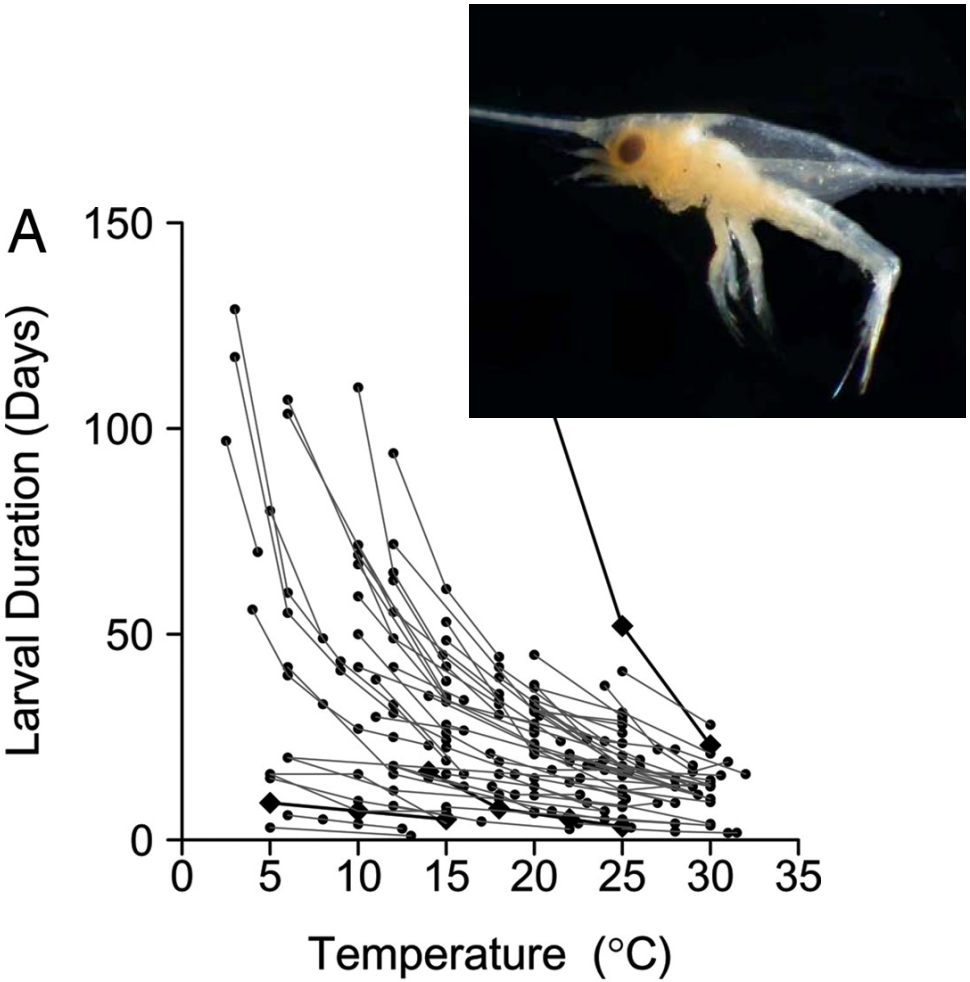
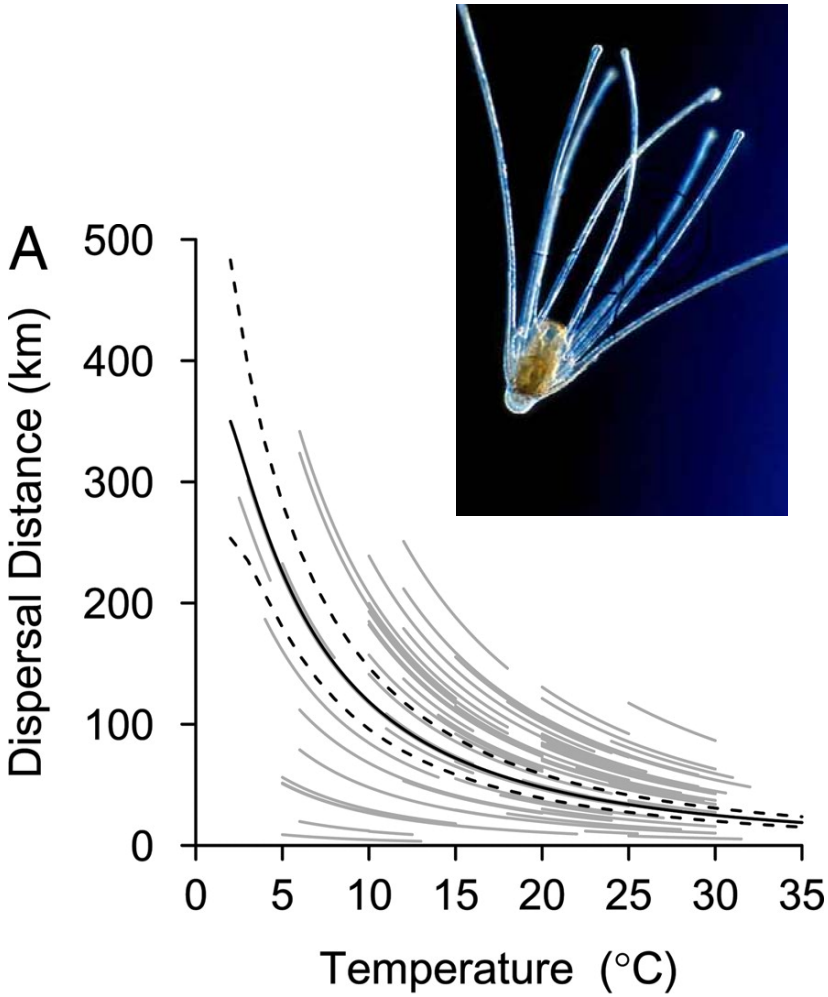


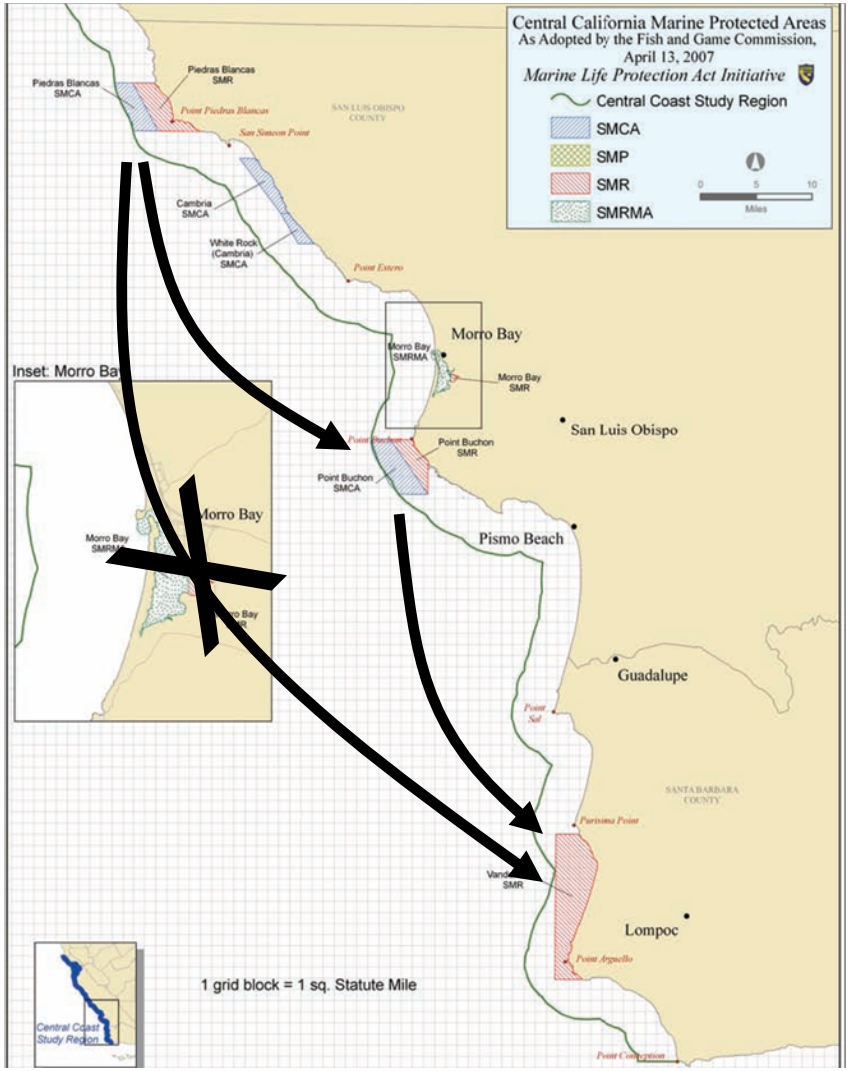


(O'Connor MI et al., PNAS, 2007 104:1266-1271)

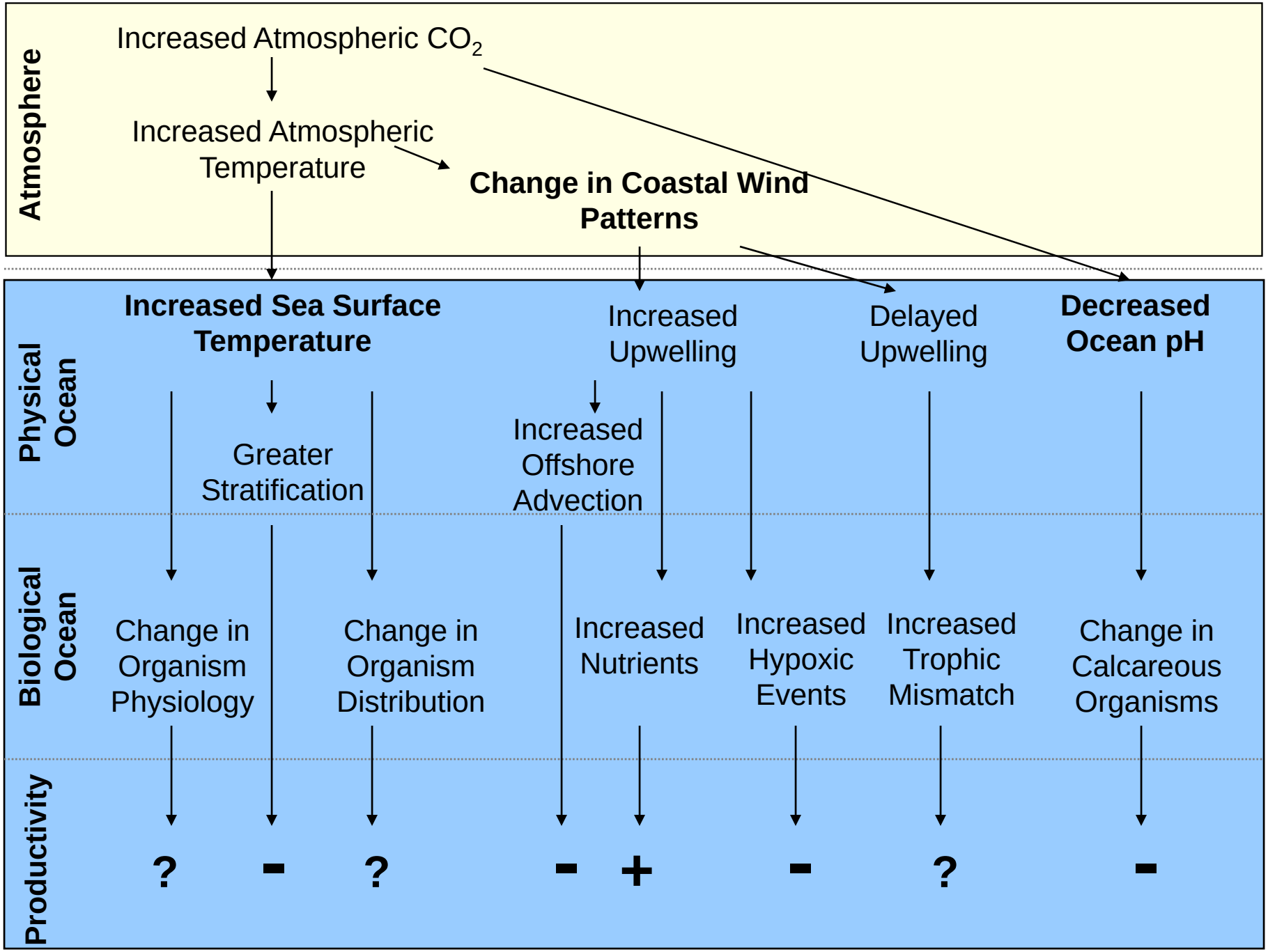
Increased Sea Surface Temperature: Change in Organism Physiology

Loss of Connectivity

Population Genetic Diversity



(Guide to Central California MPAs; California Dept. of Fish and Game)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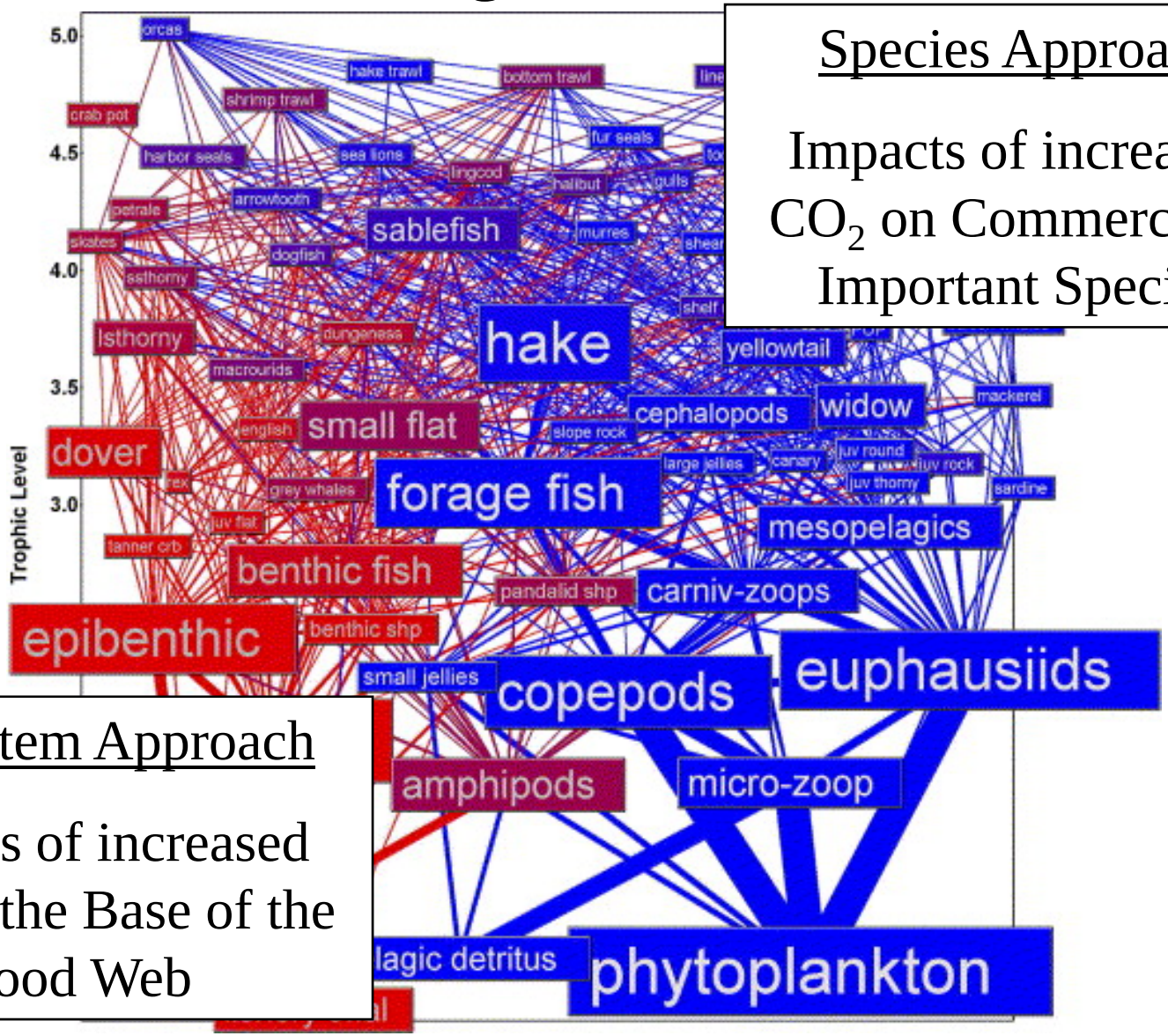
We Need a Better Understanding of the Impacts of Climate Change on the Coastal Ocean



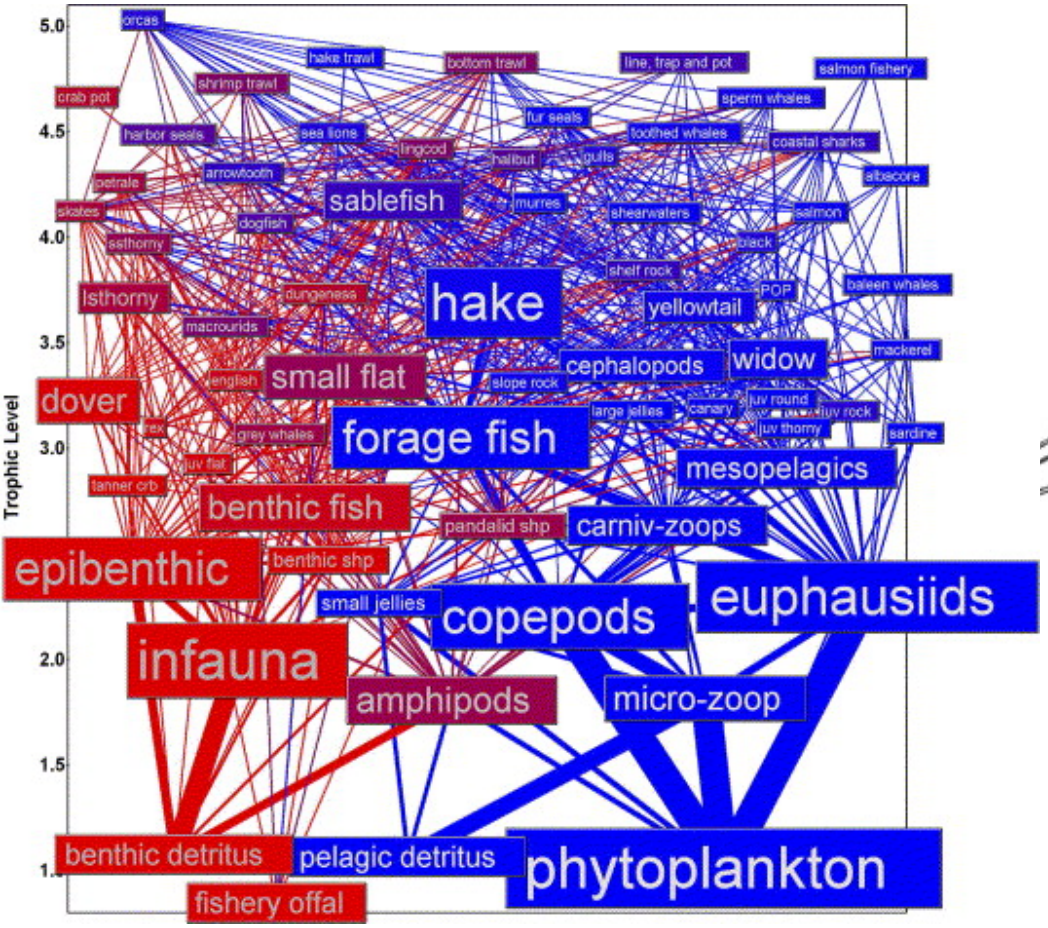
Species Approach

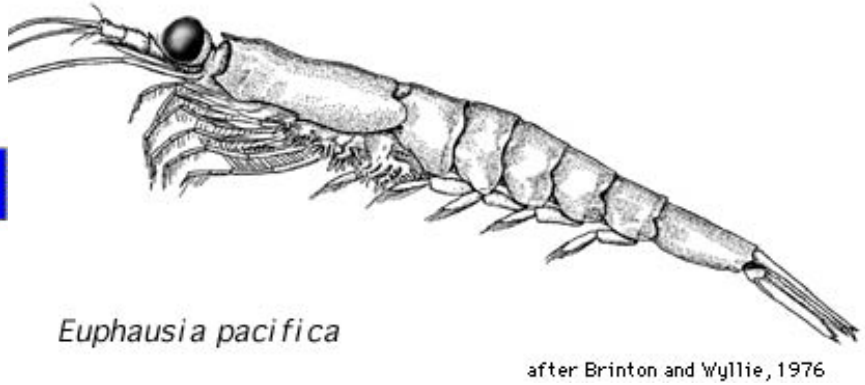
Impacts of increased CO_2 on Commercially Important Species

Ecosystem Approach

Impacts of increased CO_2 on the Base of the Food Web

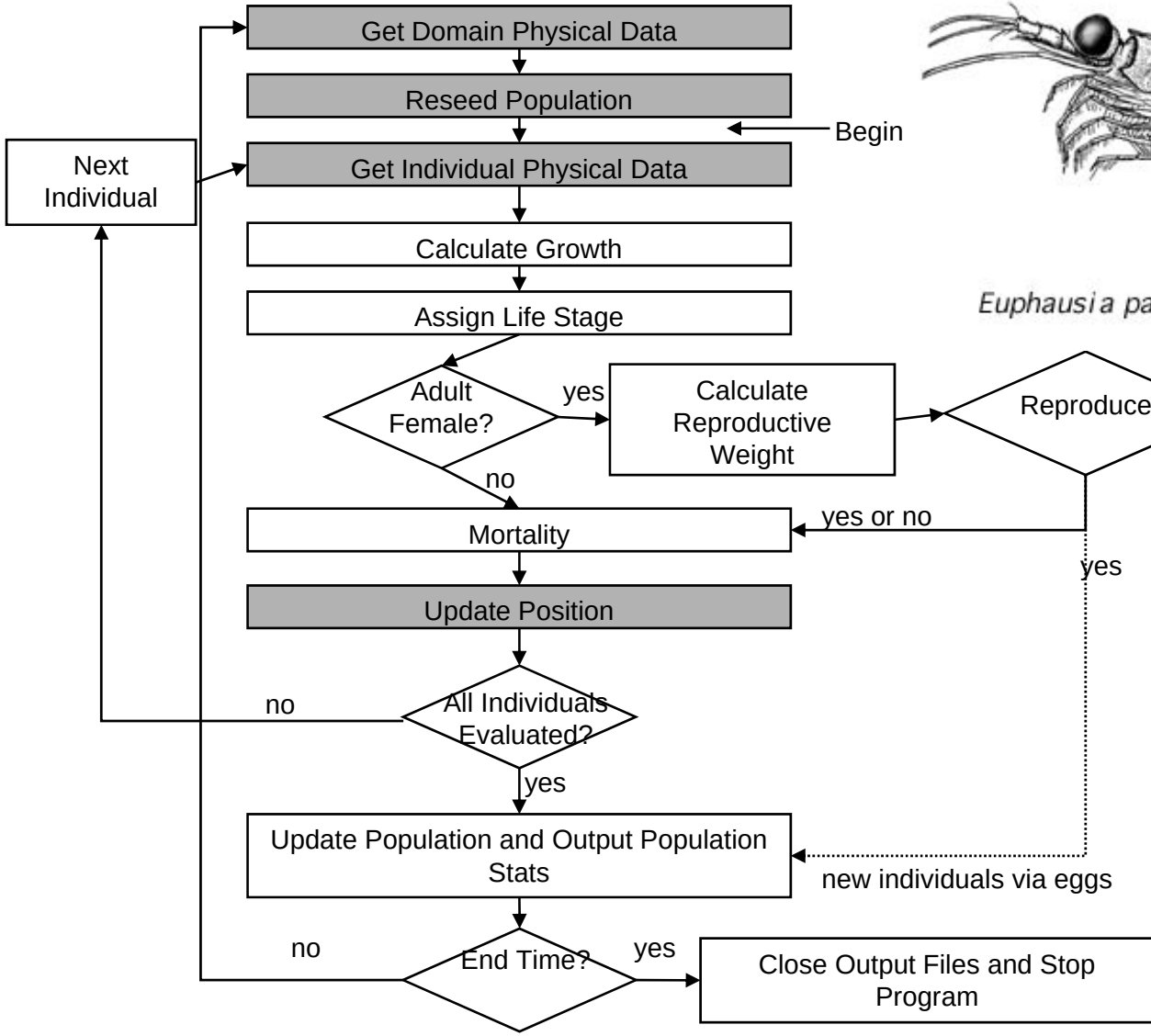
Modeled Impacts of Climate Change on *Euphausia pacifica*

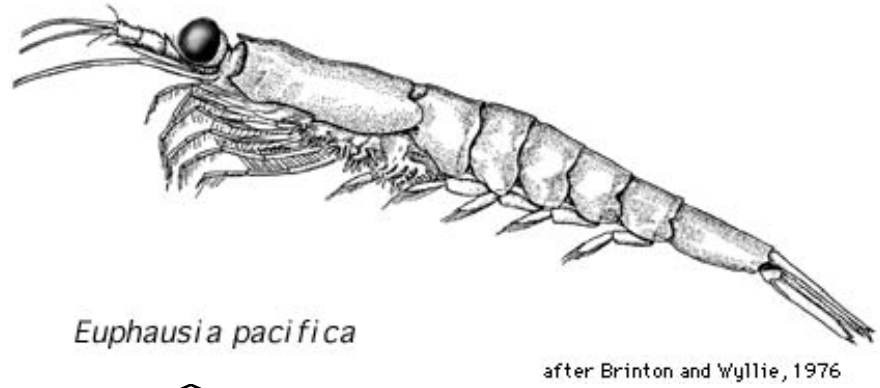




(Field JC et al., Prog Ocean, 2006 68:238-270)

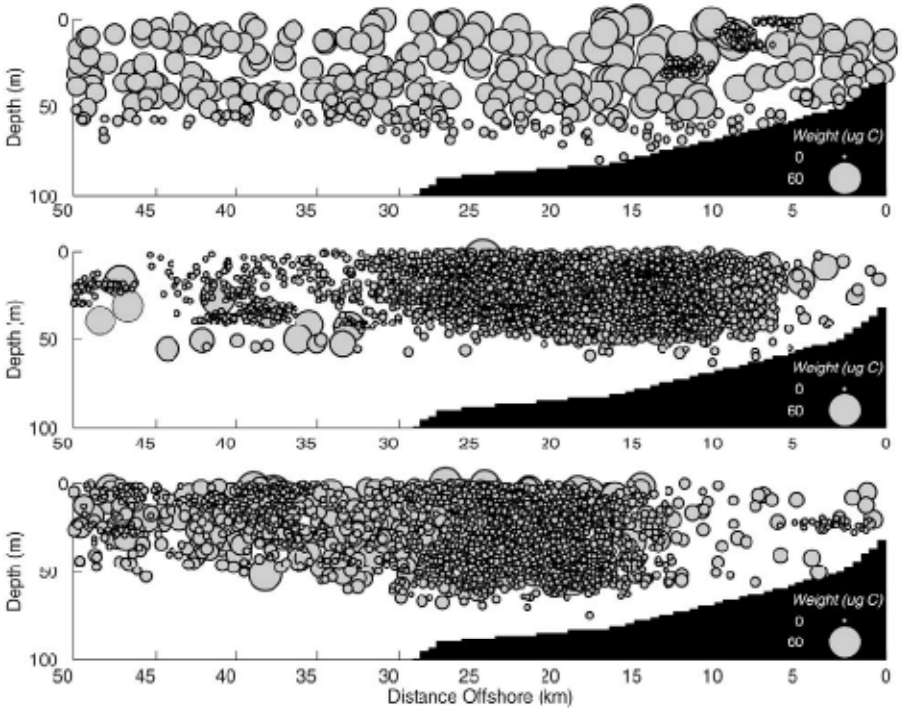
Individual-Based Model of *Euphausia pacifica*



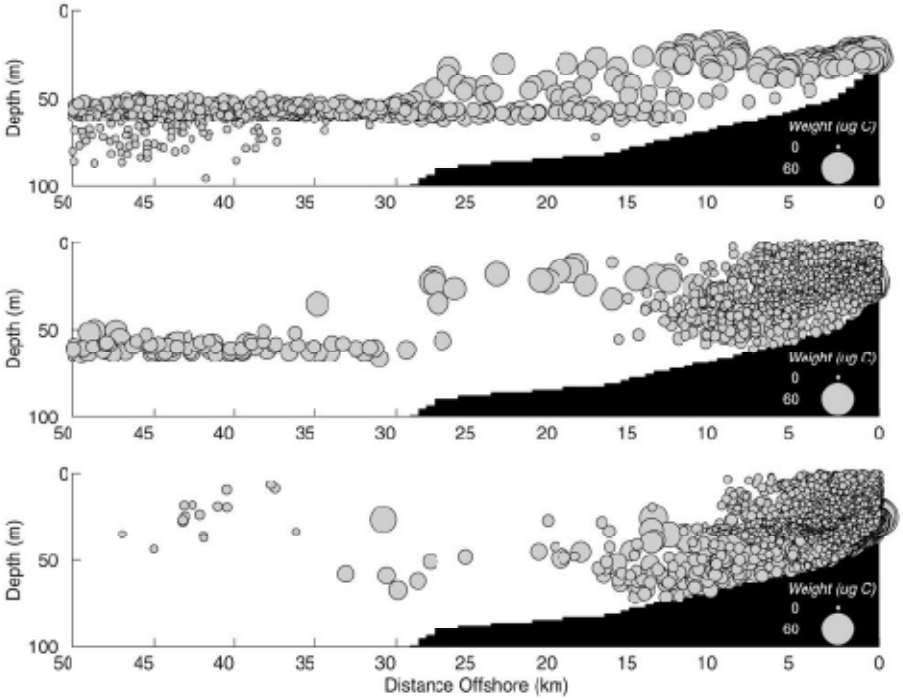


Impacts of Behavior on Zooplankton Retention

Without Diel Vertical Migration

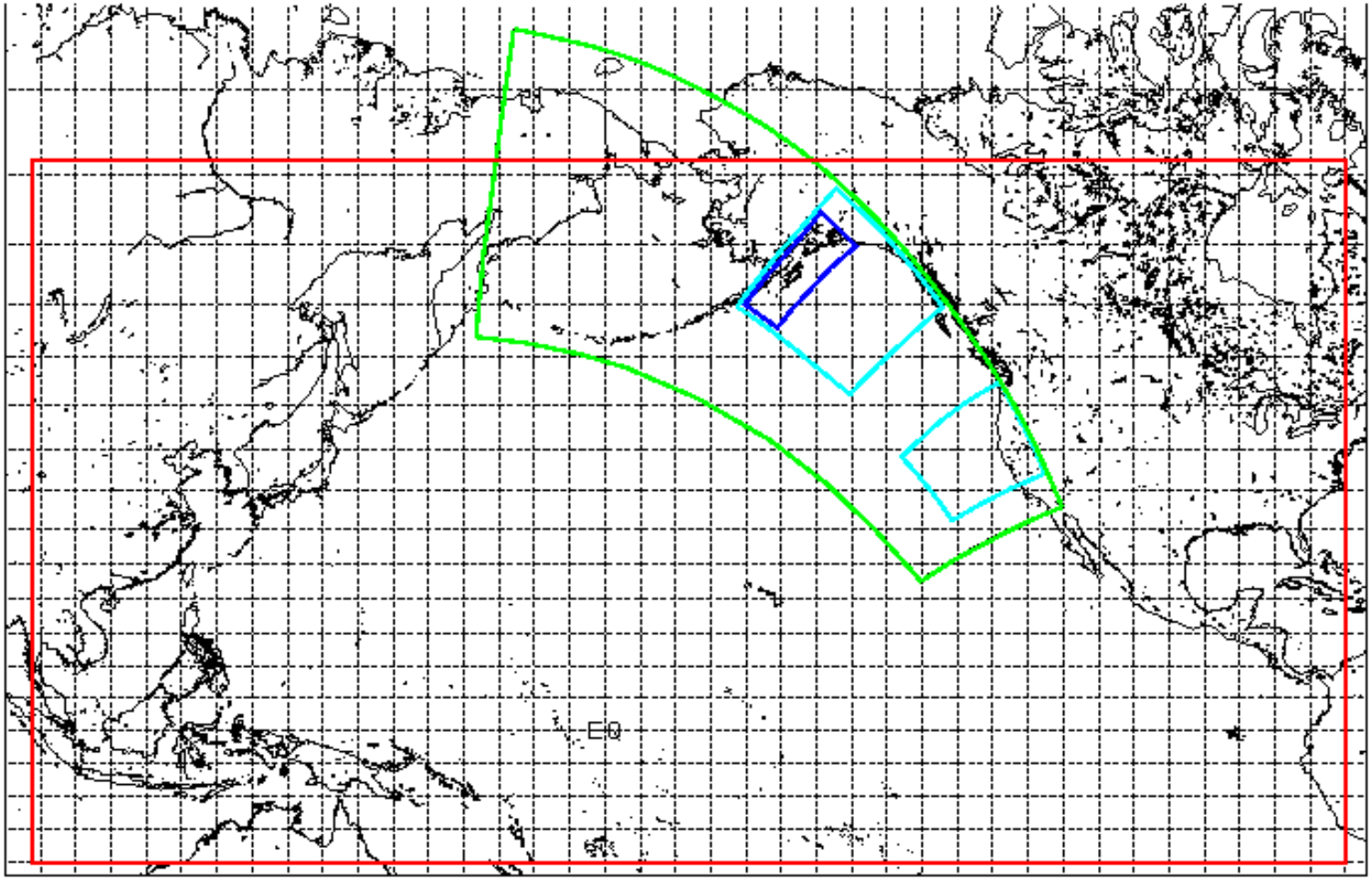


With Diel Vertical Migration

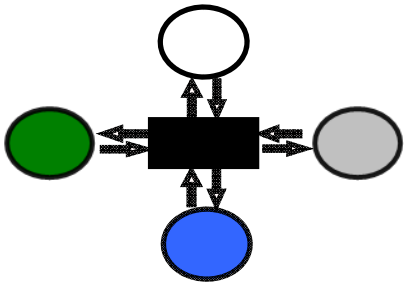


(Batchelder HP et al., Prog Ocean, 2002 53:307-333)

Regional Ocean Modeling System (ROMS)

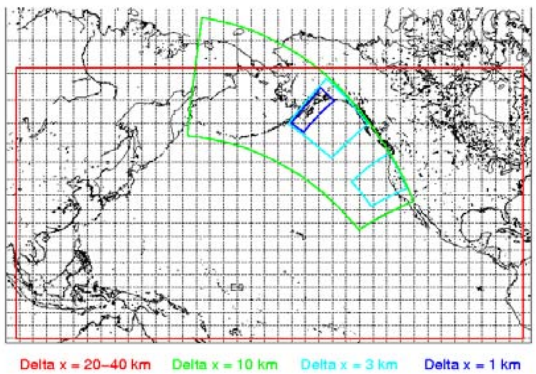


Delta x = 20–40 km Delta x = 10 km Delta x = 3 km Delta x = 1 km



ATMOSPHERE

Wind Velocity
Surface Heat Flux



OCEAN

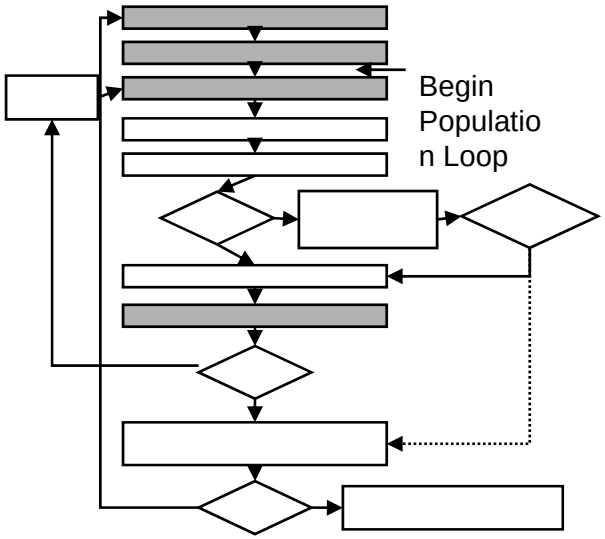
Water Velocity
Diffusivity, T, S

Water
Velocity

ORGANISM

ECOSYSTEM

P,Z



$$\frac{\partial N}{\partial t} + \mathbf{u} \cdot \nabla N = \delta D + \gamma_n GZ - UP + \frac{\partial}{\partial z}\left(k_v \frac{\partial N}{\partial z}\right),$$

$$\frac{\partial P}{\partial t} + \mathbf{u} \cdot \nabla P = UP - GZ - \sigma_d P + \frac{\partial}{\partial z}\left(k_v \frac{\partial P}{\partial z}\right),$$

$$\frac{\partial Z}{\partial t} + \mathbf{u} \cdot \nabla Z = (1 - \gamma_n) GZ - \zeta_d Z + \frac{\partial}{\partial z}\left(k_v \frac{\partial Z}{\partial z}\right),$$

$$\frac{\partial D}{\partial t} + \mathbf{u} \cdot \nabla D = \sigma_d P + \zeta_d Z - \delta D + w_d \frac{\partial D}{\partial z} + \frac{\partial}{\partial z}\left(k_v \frac{\partial D}{\partial z}\right).$$

Acknowledgements

Thomas Powell – UC Berkeley

BICCCA Terry Root, Kim Hall Mark Herzog, Chrissy Howell

Ed Dever, Oregon State Univ.
John Largier, UC Davis
Bill Peterson, NOAA