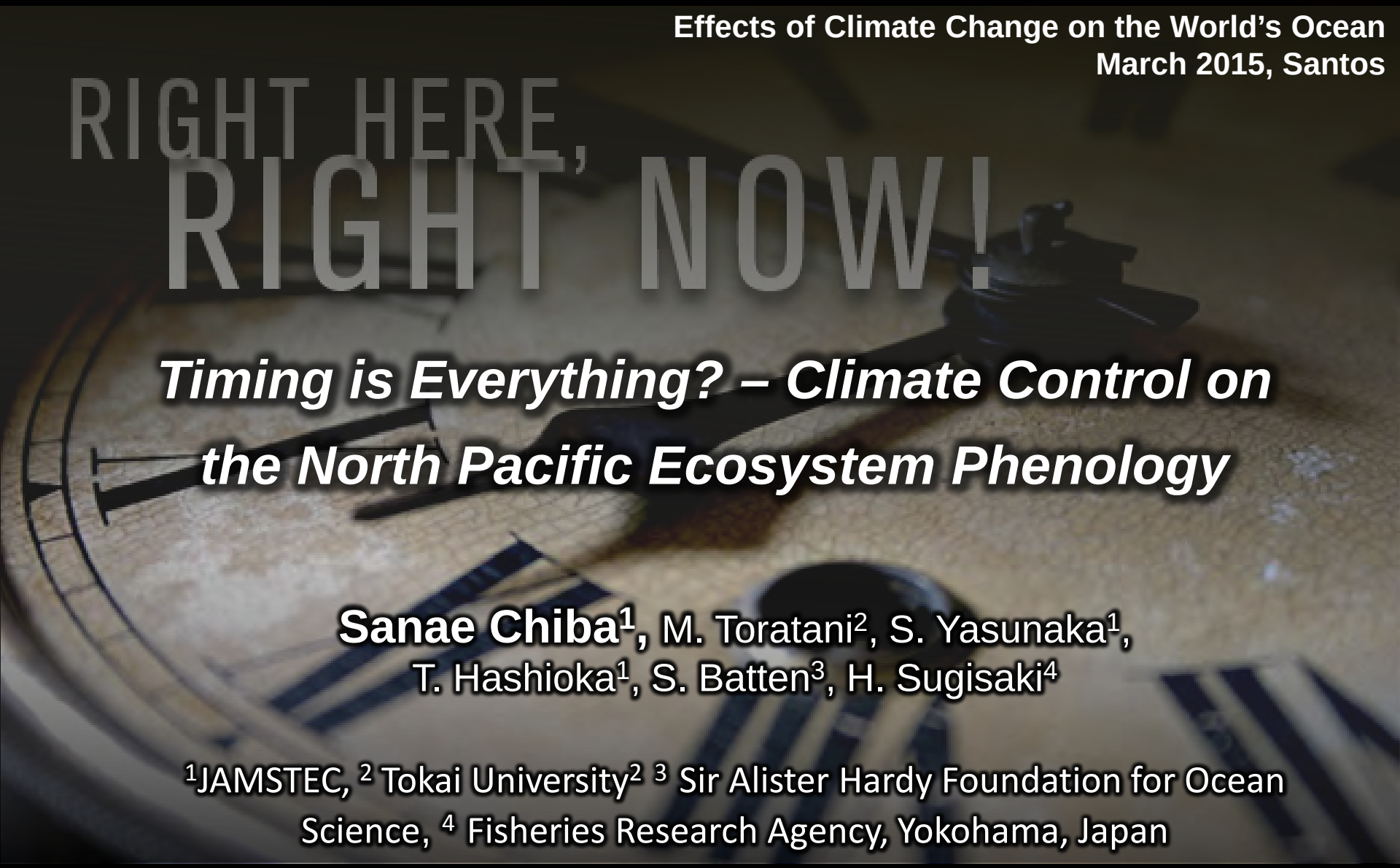
Effects of Climate Change on the World's Ocean
March 2015, Santos



Timing is Everything? – Climate Control on the North Pacific Ecosystem Phenology

Sanae Chiba[1], M. Toratani[2], S. Yasunaka[1],
T. Hashioka[1], S. Batten[3], H. Sugisaki[4]

[1]JAMSTEC, [2] Tokai University[2] [3] Sir Alister Hardy Foundation for Ocean Science, [4] Fisheries Research Agency, Yokohama, Japan

JAMSTEC

CONTINUOUS PLANKTON RECORDER SURVEY
SAHFOS

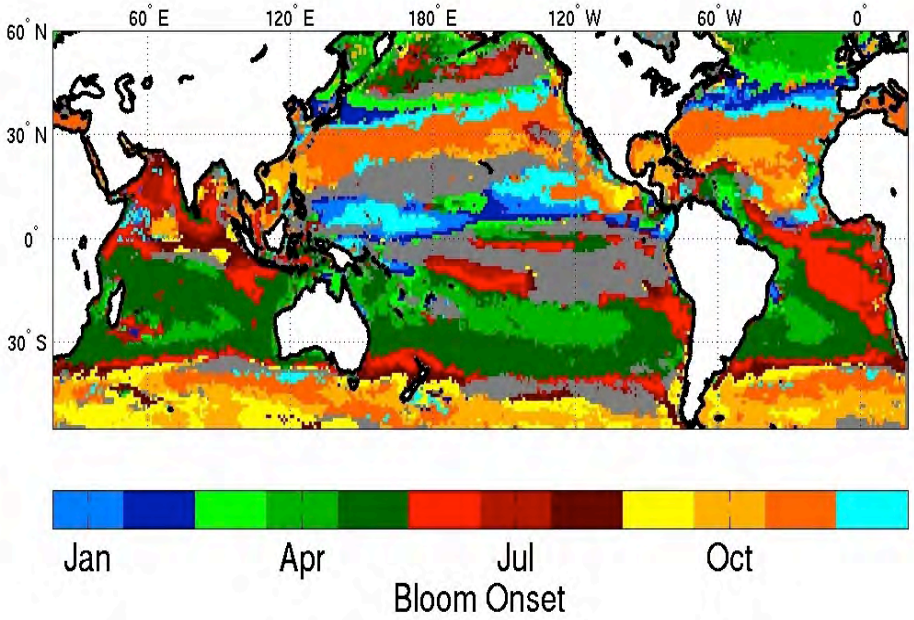
FRA
Fisheries Research Agency

TOKAI UNIVERSITY

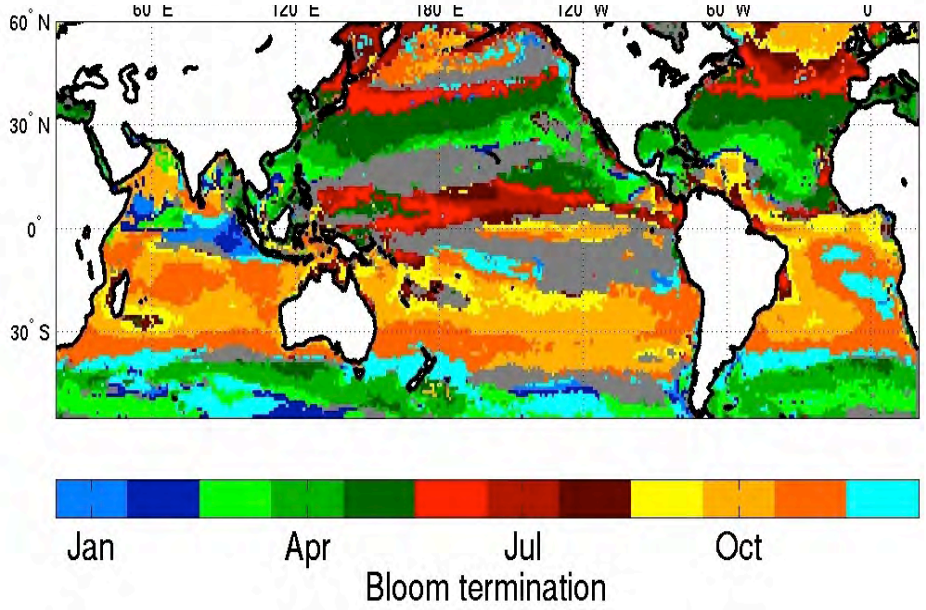
NEOPS
New Ocean Paradigm
on Its Biogeochemistry, Ecosysytem and Sustainable Use

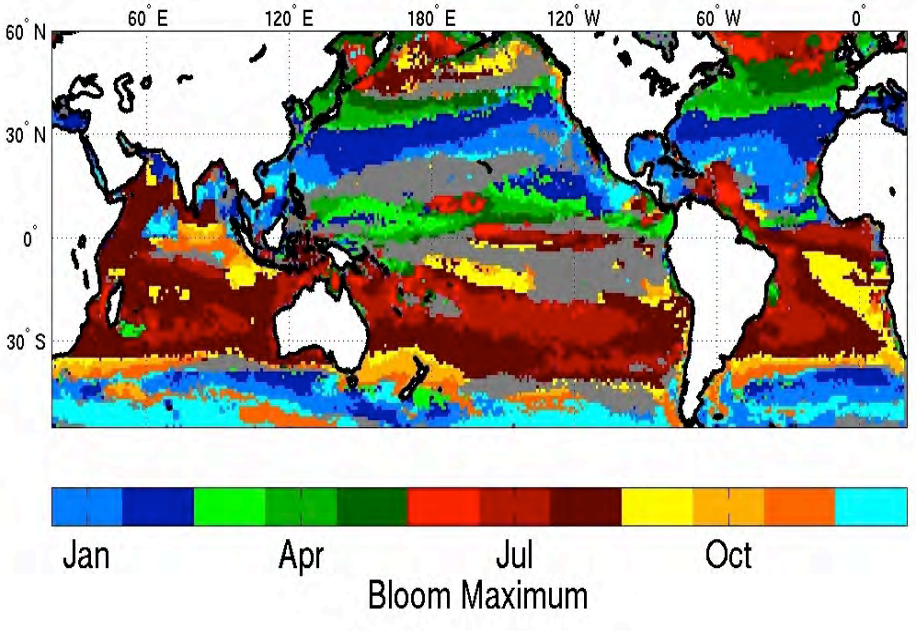
Cherry blossom in Tokyo, March 20th 2015

Global Climatology of Phytoplankton Phenology

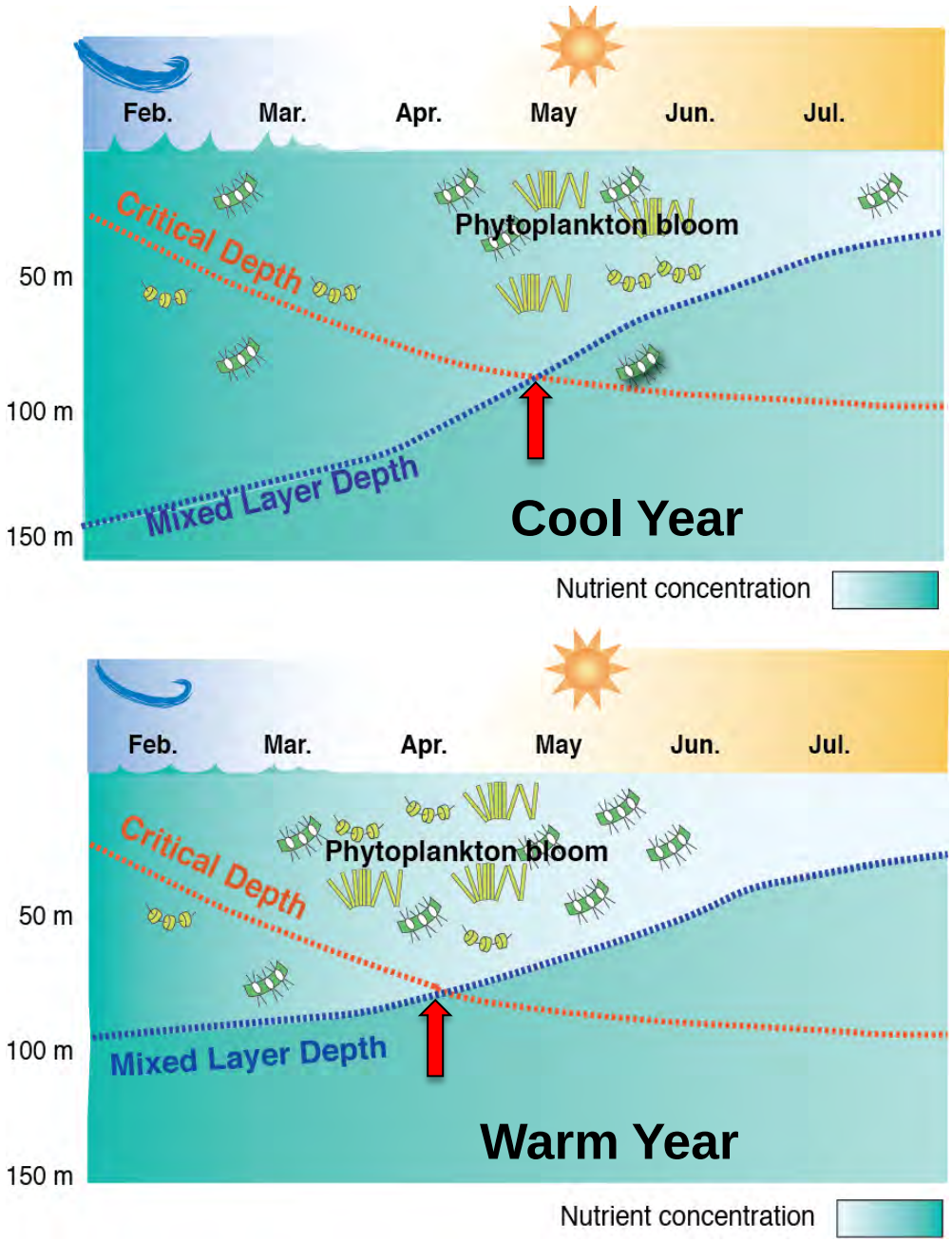


Global climatology of marine phytoplankton phenological characteristics based on the SeaWiFS chlorophyll concentrations dating from Sept. 1997 to Dec. 2007. (Sapiano et al., 2012, JGR)





Seasonal Mixed Layer Process and Onset of Spring Bloom



Future Projection of Phytoplankton Phenology

Earlier when Warmer in mid-high latitudinal region

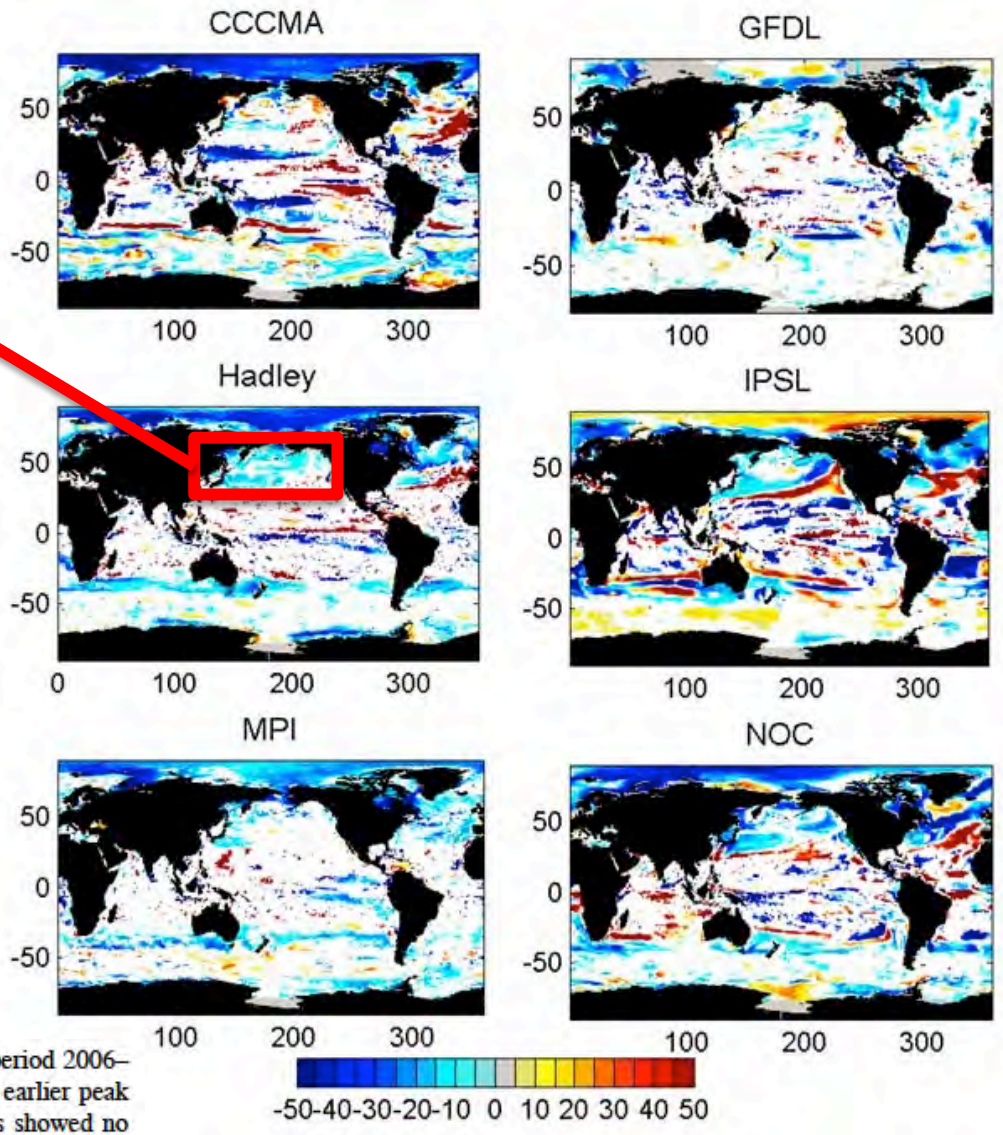


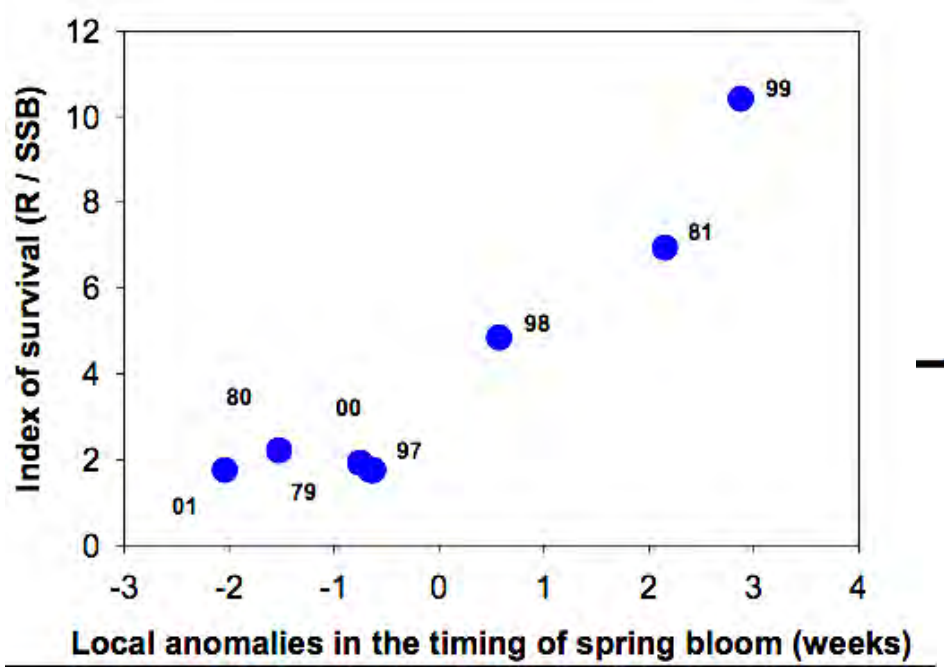
Fig. 4. Difference in timing of peak PP between the period 2006–2026 and 2081–2100 (where negative values indicate earlier peak timing). Only points where a 1-way ANOVA analysis showed no significant difference in the means of the 2 periods (significance at 5 % level) are plotted.

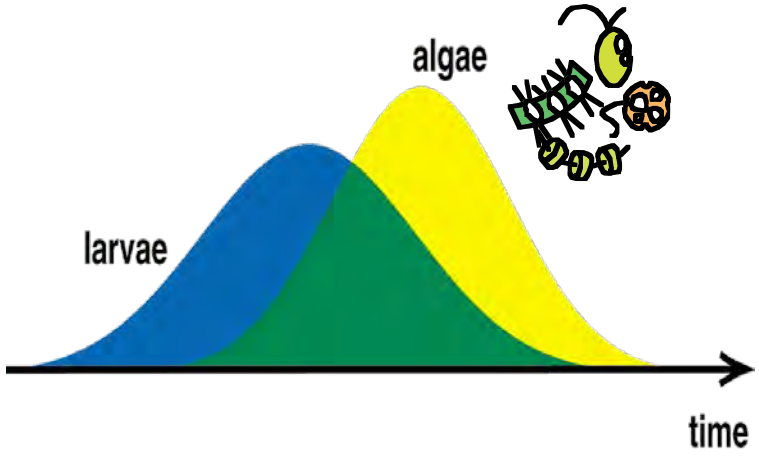
(Henson et al. 2013, Biogeoscience)

Why Does Plankton Phenology Matter?

Trophic Match-Mismatch

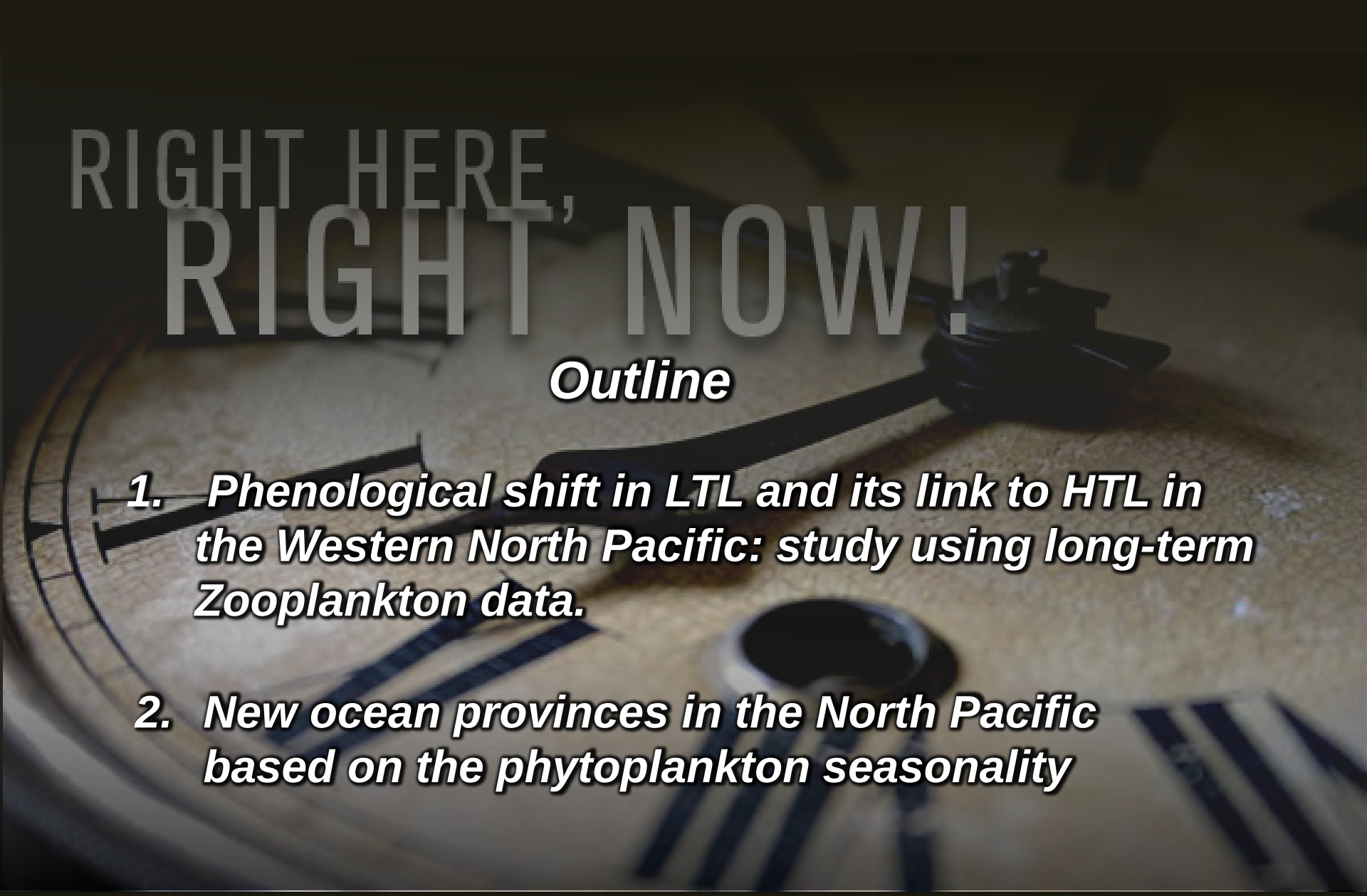
Timing of spring bloom and the Eastern Scotian Shelf outer banks haddock fishery (Platt et al. 2003**)**





Mechanism: temporal match-mismatch bw/ bloom & larval development

How Does Phytoplankton Phenology Impact Zooplankton, and more?

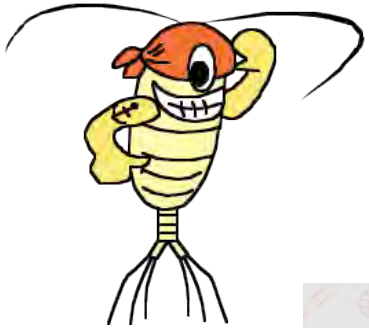


Outline

1. Phenological shift in LTL and its link to HTL in the Western North Pacific: study using long-term Zooplankton data.

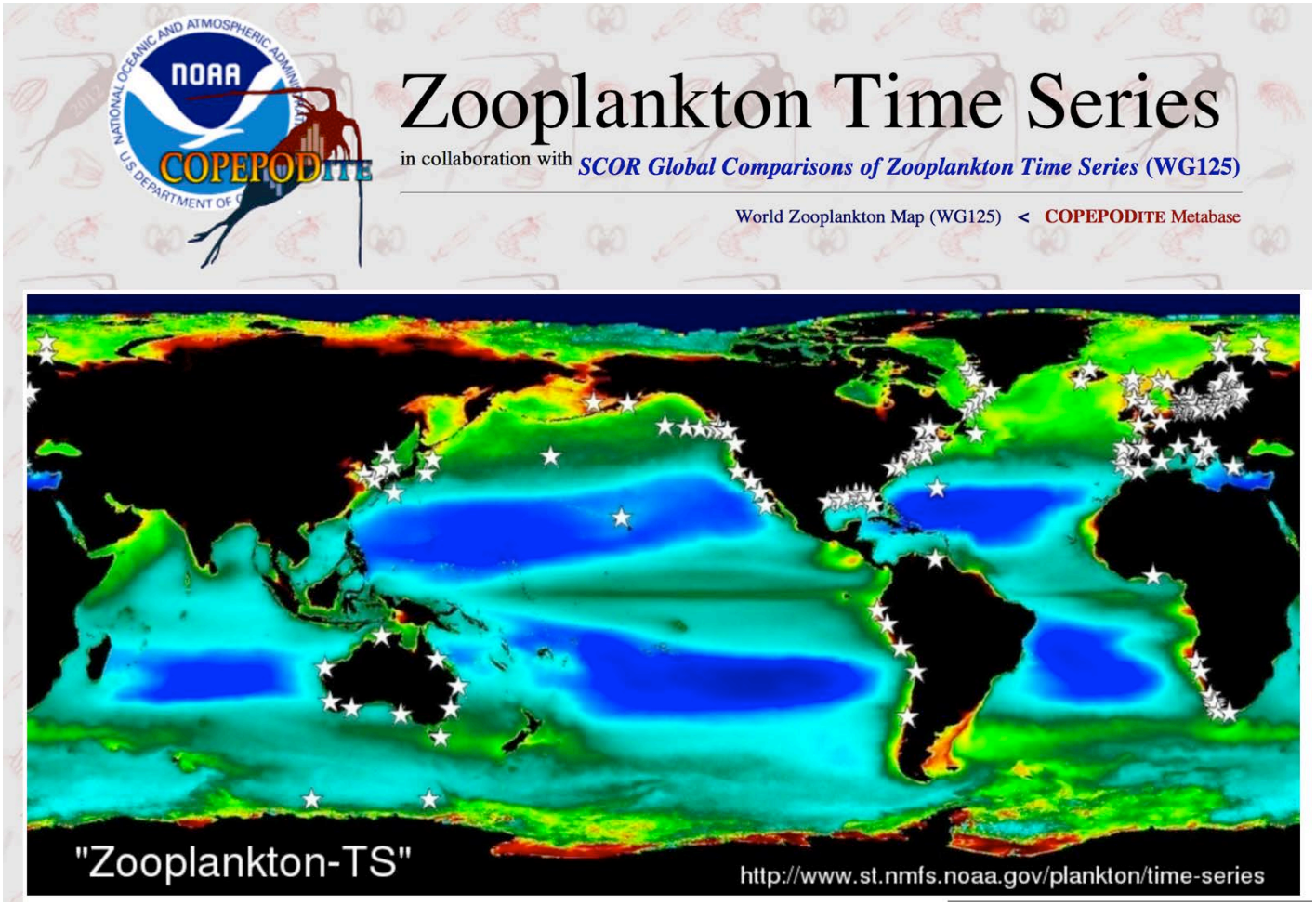
2. New ocean provinces in the North Pacific based on the phytoplankton seasonality

Global Comparison of Zooplankton Time-series: SCOR WG125 (2005~2011)



Advantages in using zooplankton time-series

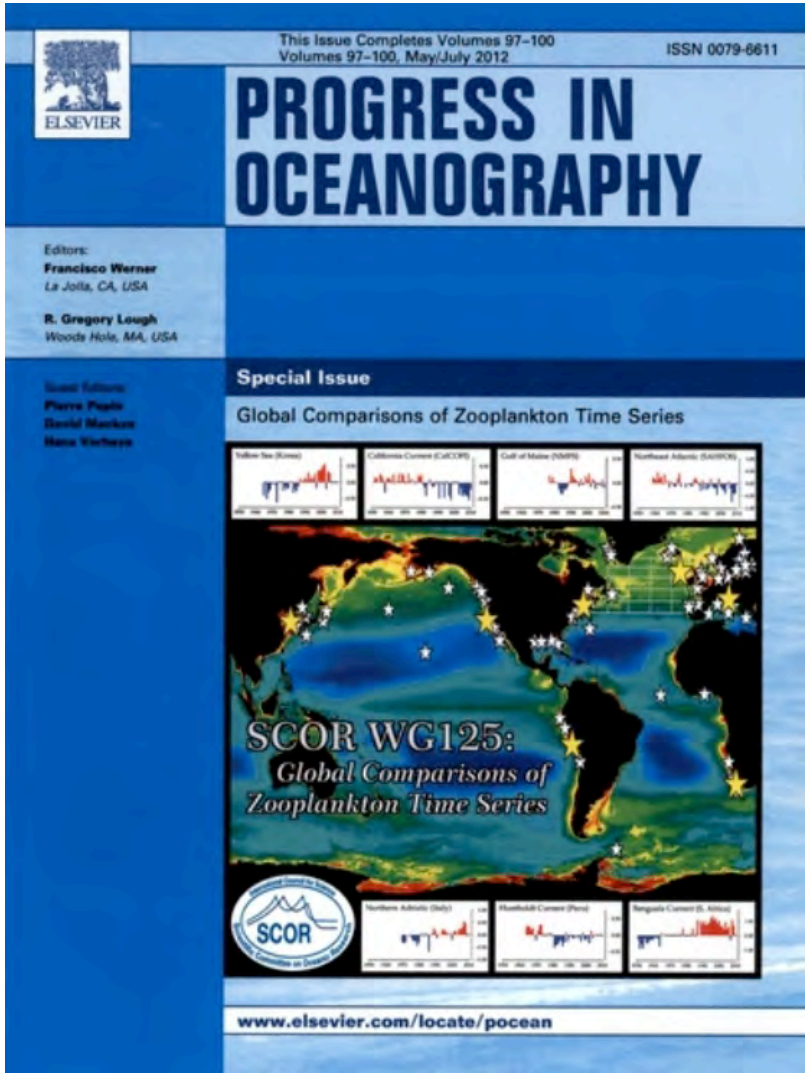
- Samples are preserved for decades
- Biological, chemical compositions of Zooplankton tell us environmental conditions integrated through seasons.



Global Comparison of Zooplankton Phenology

in the SCOR WG 125 Special Issue of Progress in Oceanography

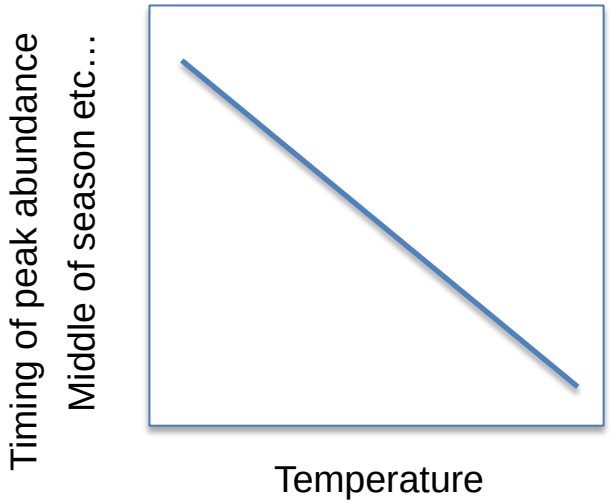
(Mackas et al., 2012)



Temperature dependence of Zooplankton Phenology

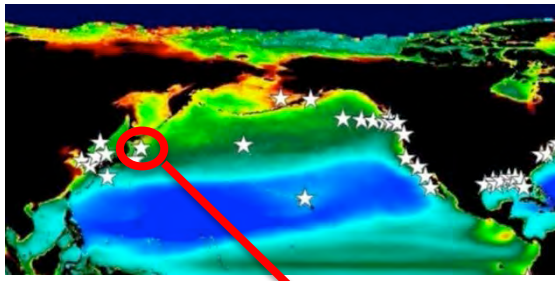
"The most common phenology correlate is water temperature during and before the growing season, and the most common phenologic response to temperature is.."

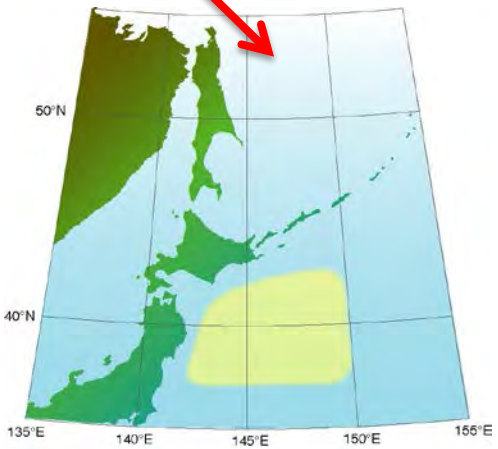
"***Earlier when and where warmer"….***



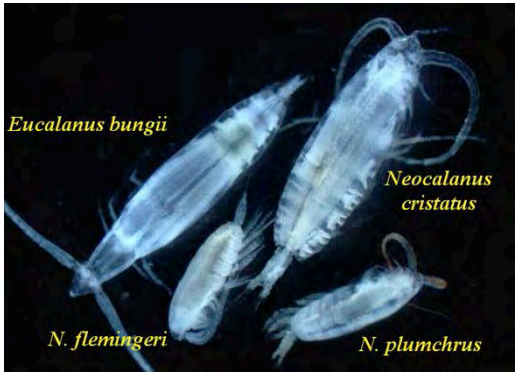
Long-term Study in the Western North Pacific Zooplankton Phenology (1960s-1990s)

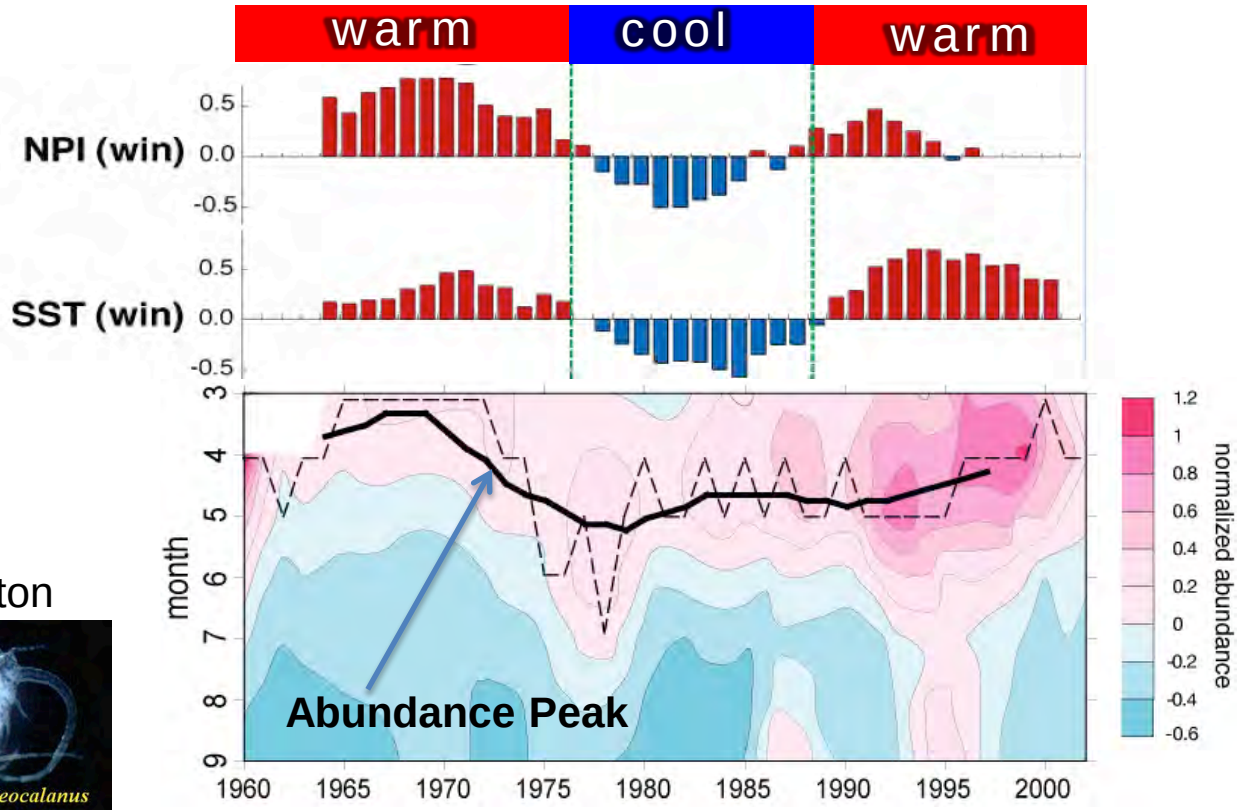
Odate Collection Data sets





Dominant Zooplankton





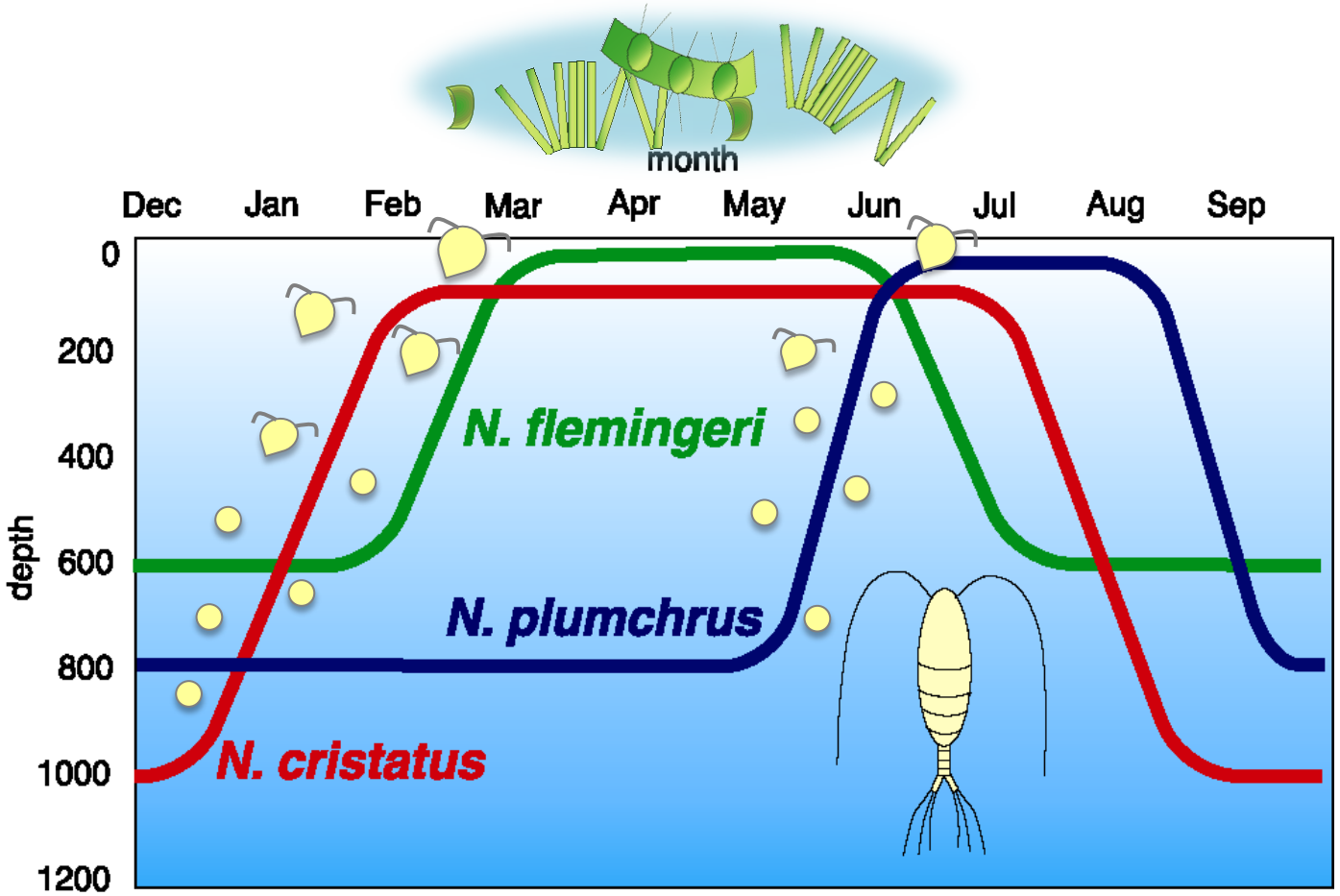
Peak Abundance Timing of Spring Zooplankton community

(Chiba et al, 2006, GCB)

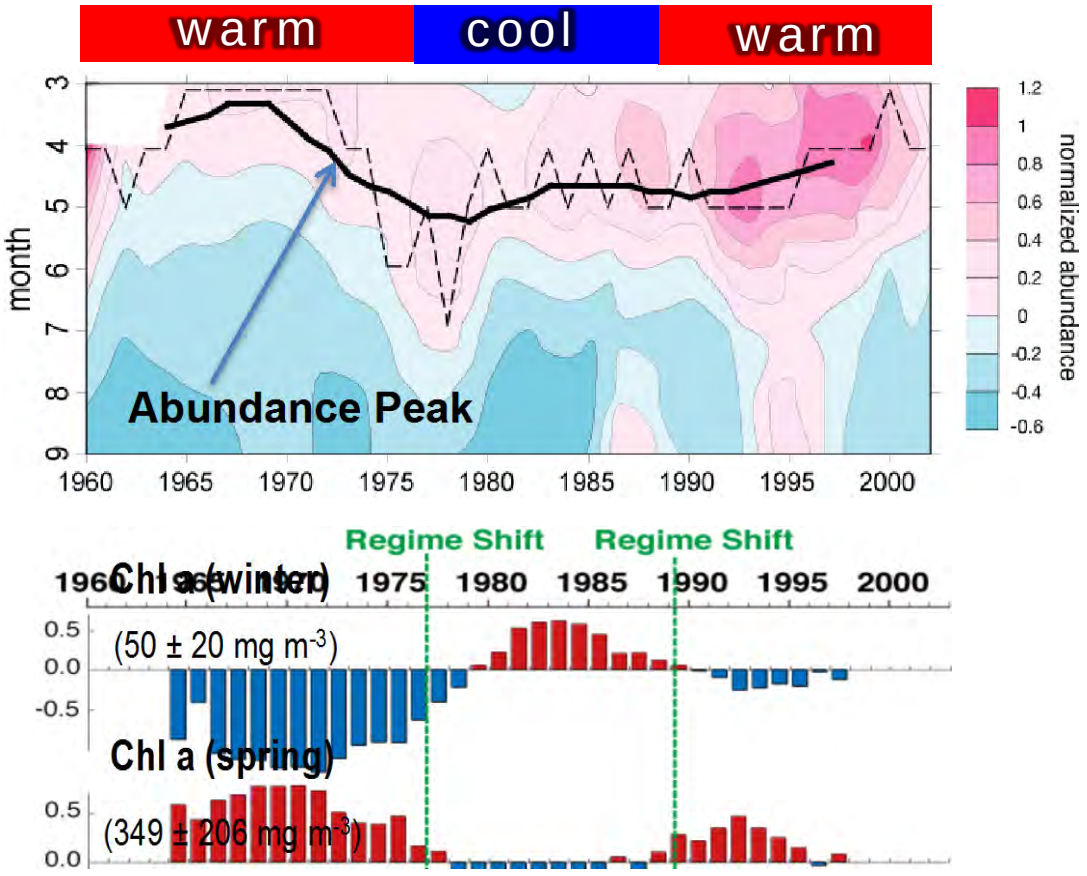
Long-term Study in the Western North Pacific
Ontogenetic vertical migration of Neocalanus Copepods

Neocalanus species: mesopelagic spawning
=> Peak biomass is likely controlled by seasonal phytoplankton availability

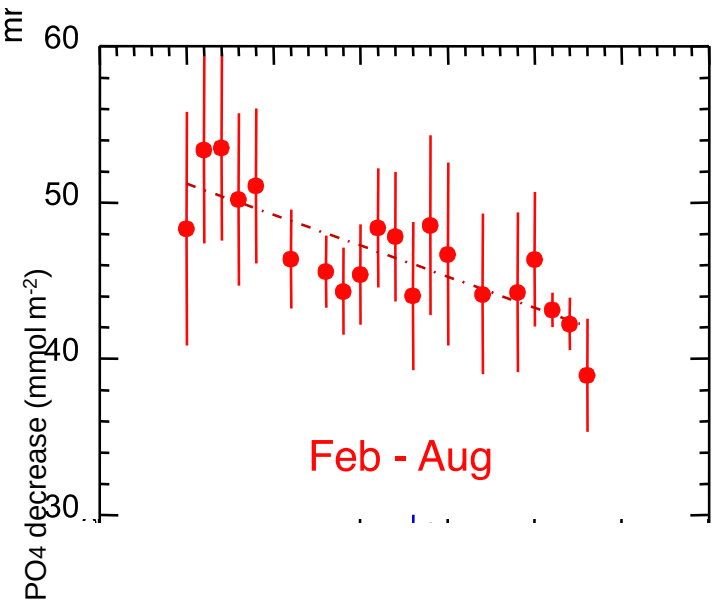
Match or Mismatch?



Long-term Study in the Western North Pacific



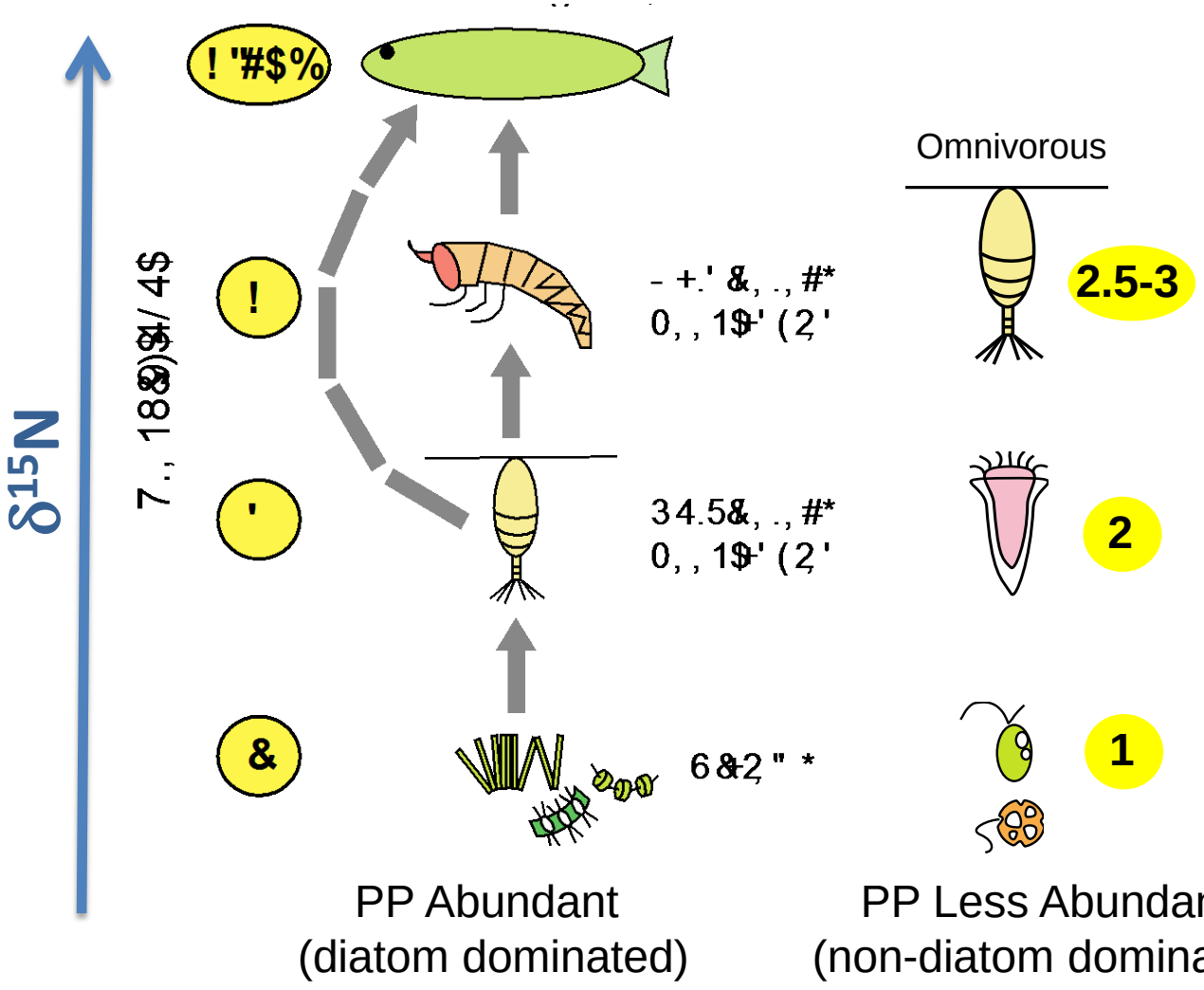
Min. **Net Community Production**
(NCPmin)
= decrease of MLPO4 inventory



H: Early bloom (longer bloom season) was "Good Match"
For* Neocalanus *reproduction in the 90s.

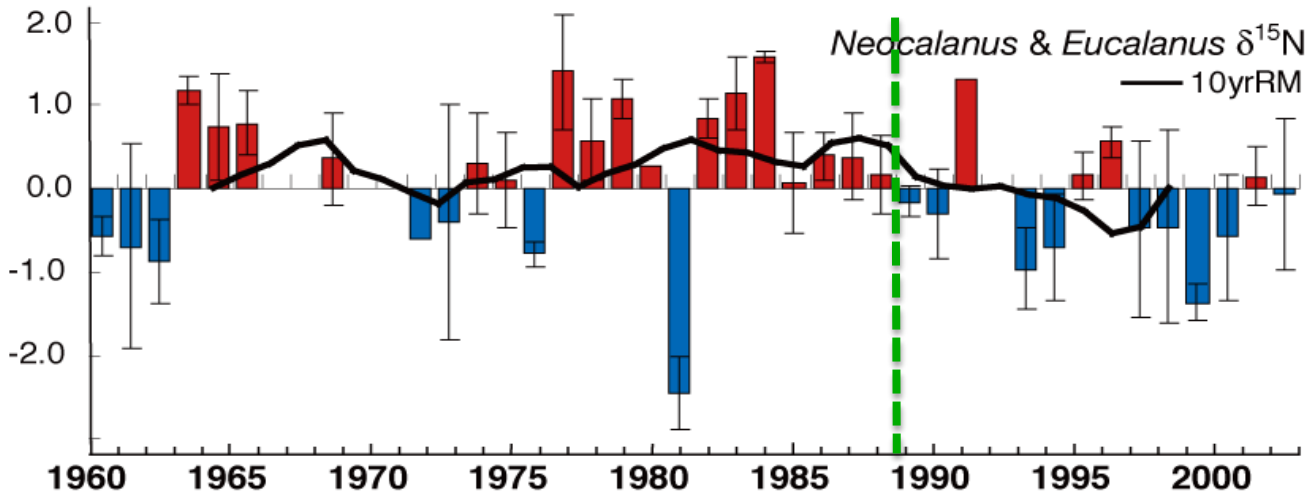
Trophic Link Study using zooplankton Nitrogen Stable Isotope

$\delta^{15}N$: Indicator of Trophic Levels .. and of PP availability as ZP food.



Long-term Study in the Western North Pacific
Nitrogen Stable Isotope Analysis

***Neocalanus* δ^{15}N declined ca. 3 ‰ decline = 1 trophic level**



Indicating….

1. More Nitrate available in the 1990s

2. Copepods become more herbivorous and less omnivorous

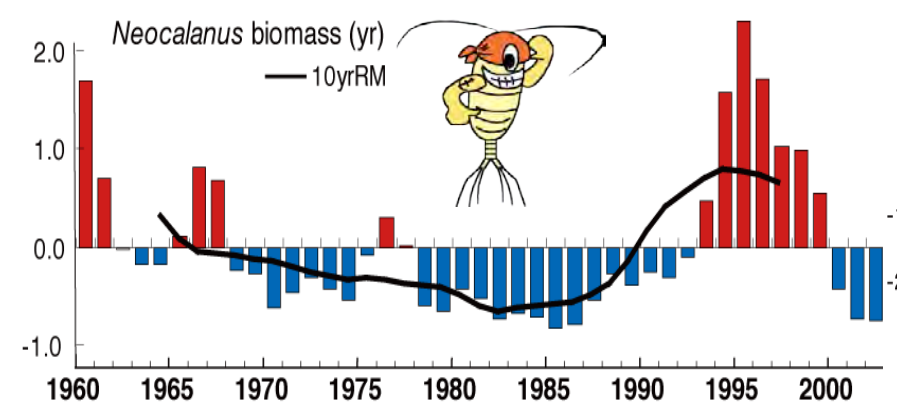
= <u>more phytoplankton available</u>

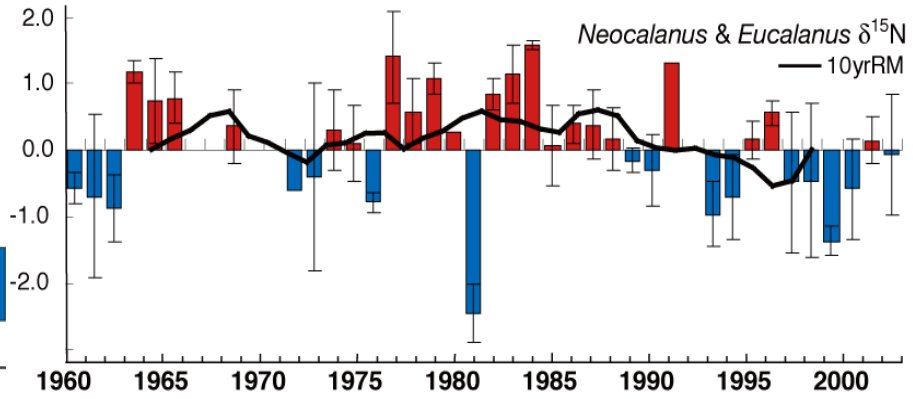
(Chiba 2012, NPAFC Tech. Rep.)

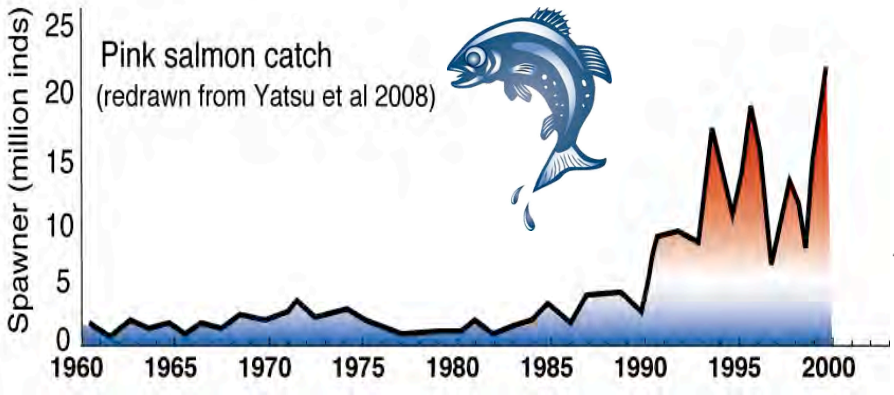
Long-term Study in the Western North Pacific
Nitrogen Stable Isotope Analysis
Link to HTL (Pink Salmon)

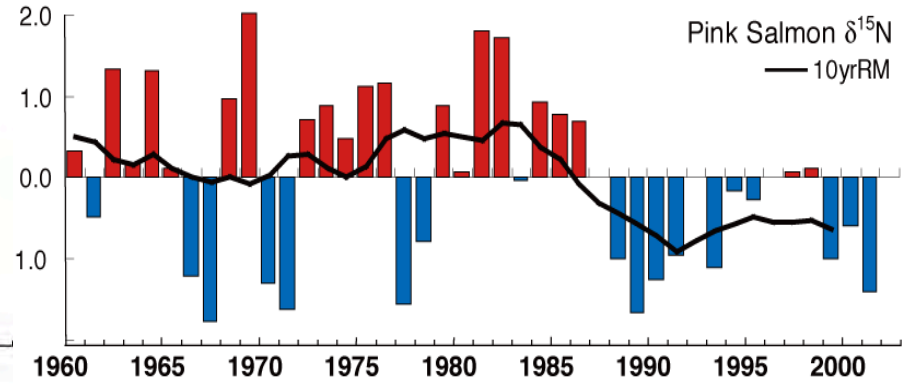
BIOMASS

$\delta^{15}N$









(Chiba 2012, NPAFC Tech. Rep.)

Summary

Plankton Phenology and Trophic Good Match in WNP during the 1990s

AL-PDO

Warming *Good Match* *Good Match*

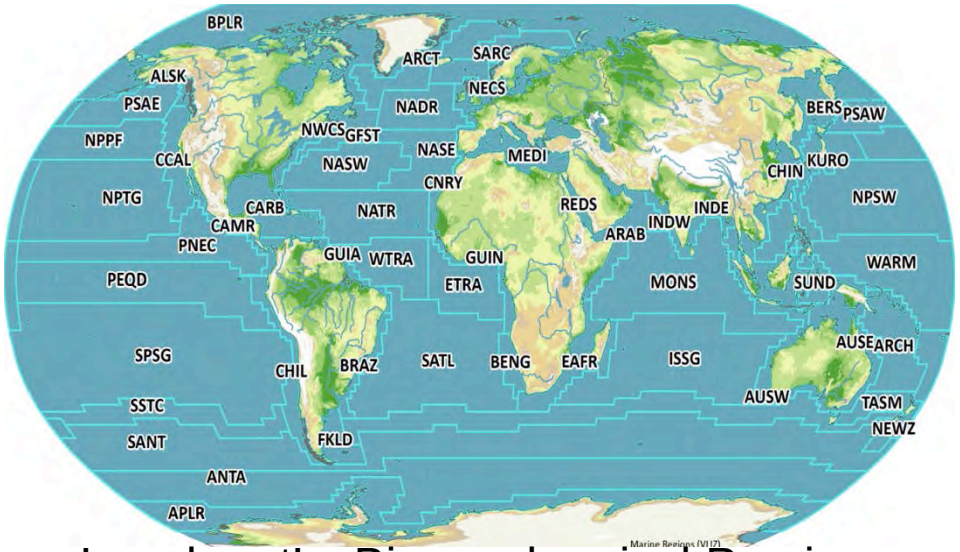
Outline

2. New ocean provinces in the North Pacific based on the phytoplankton seasonality

New Ocean Paradigm on Its Biogeochemistry, Ecosystem and Sustainable Use

NEOPS
New Ocean Paradigm
on Its Biogeochemistry, Ecosystem and Sustainable Use

*To develop **a new ocean provinces** based on ecological and biogeochemical properties*



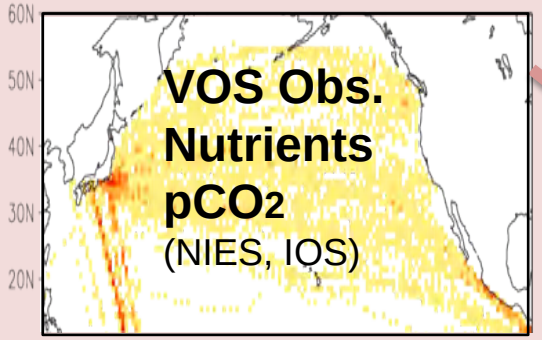
Longhurst's Biogeochemical Provinces

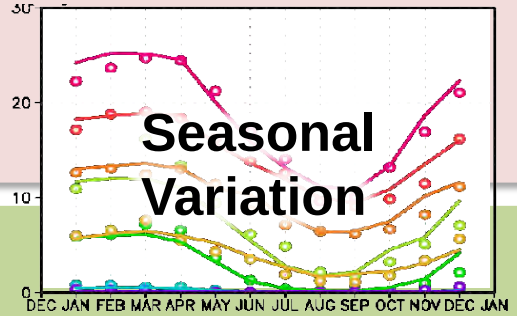
North Pacific

JSPS Grant-in Aid for Scientific Research FY2012-2016

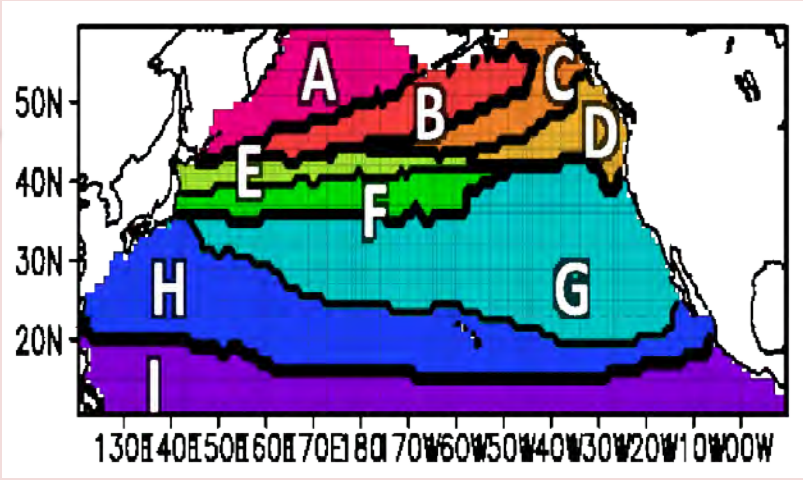
NEOPS New Ocean Provinces

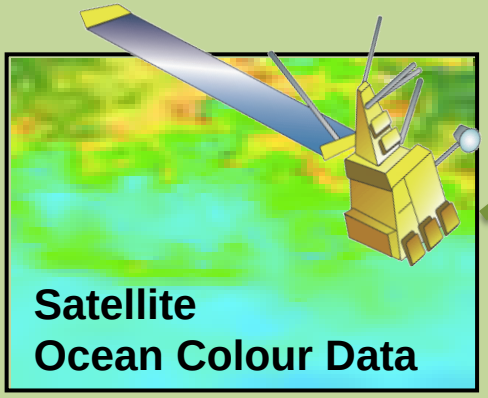
GOAL: Better management of Marine Ecosystem Services

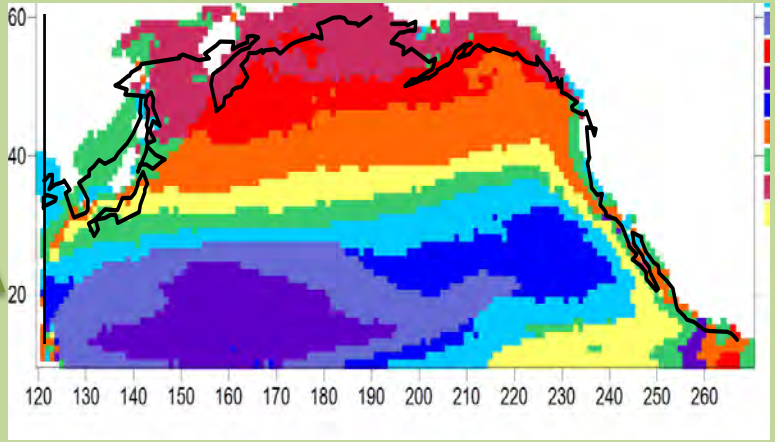




① BGC Provinces



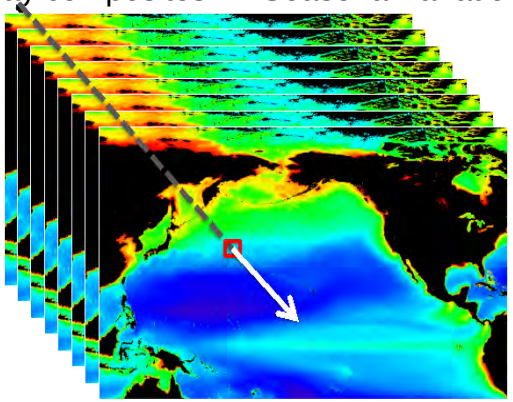




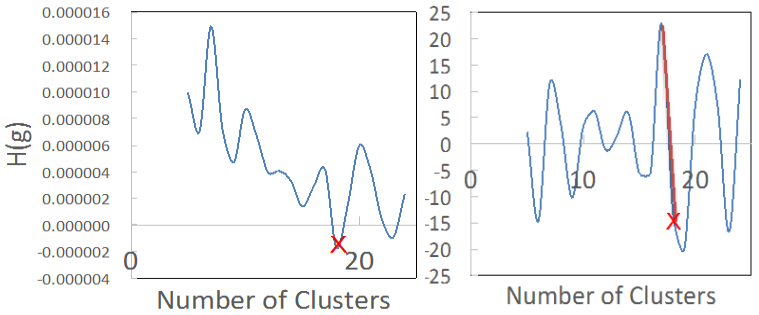
② Phytoplankton Provinces

NEOPS New Ocean Provinces based on the Seasonal Chl a Variation

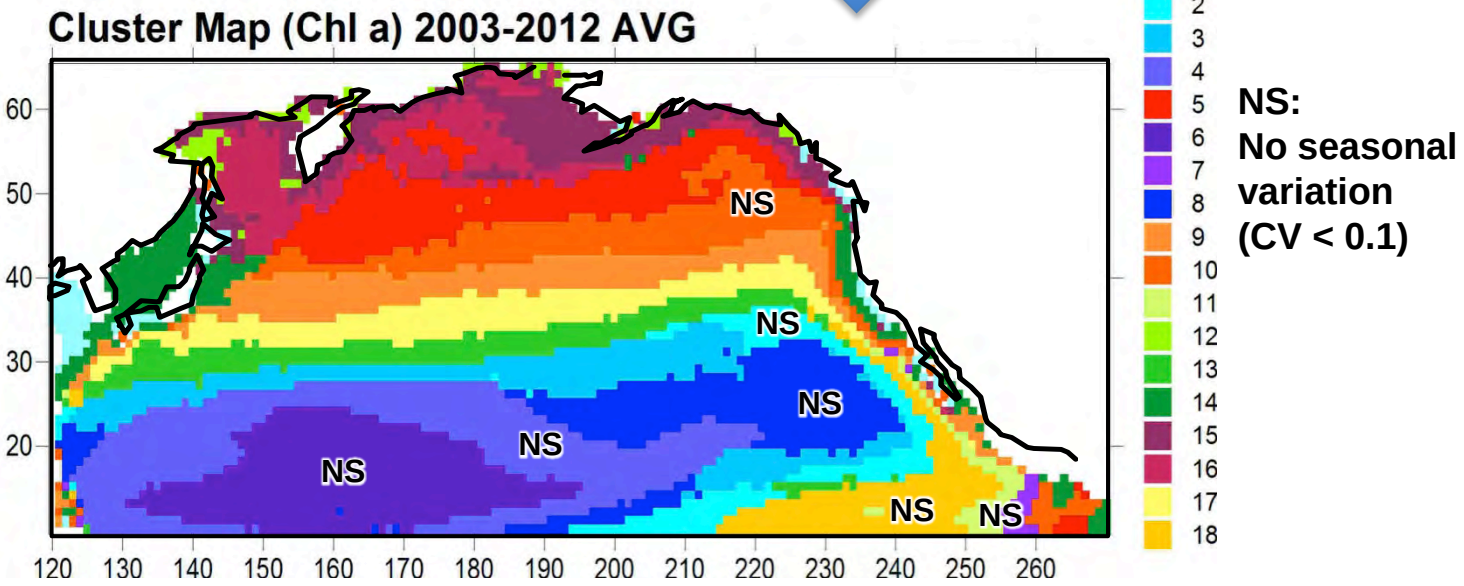
DATA:
MODIS/Aqua (2003-2012),
8-day composites => Seasonal variation



K-means Clustering
w/ methods of Hartigan (1979) and Beale(1969)



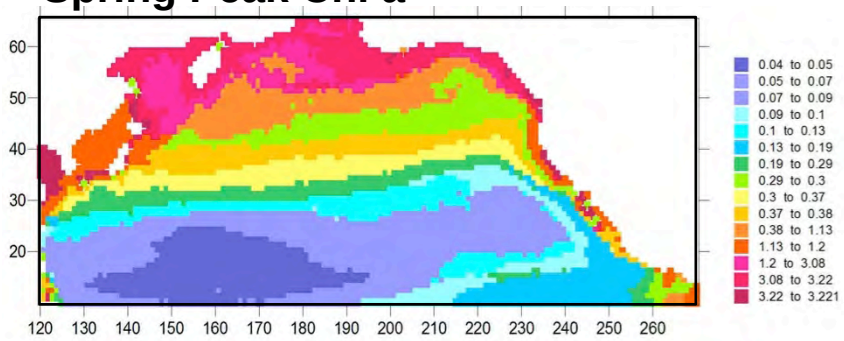
18 clusters



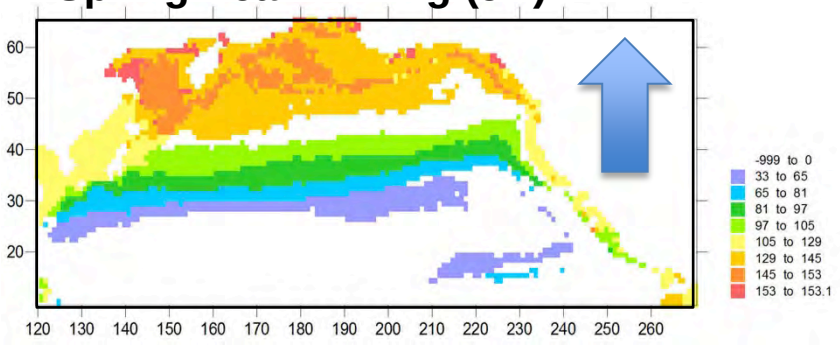
NS:
No seasonal variation
(CV < 0.1)

NEOPS Phytoplankton Provinces: 10 yrs Climatology in Seasonal Timing

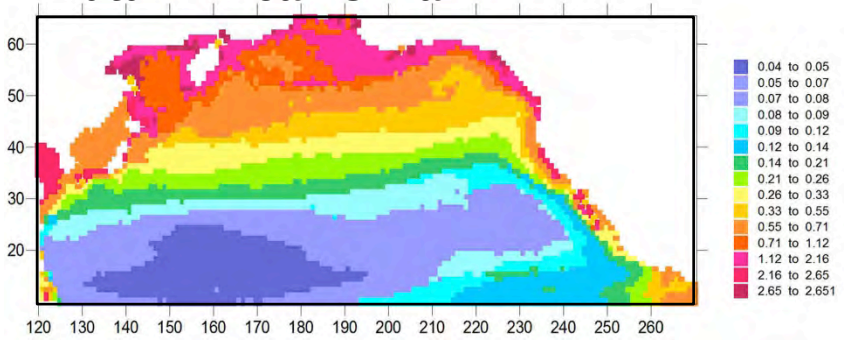
Spring Peak Chl a



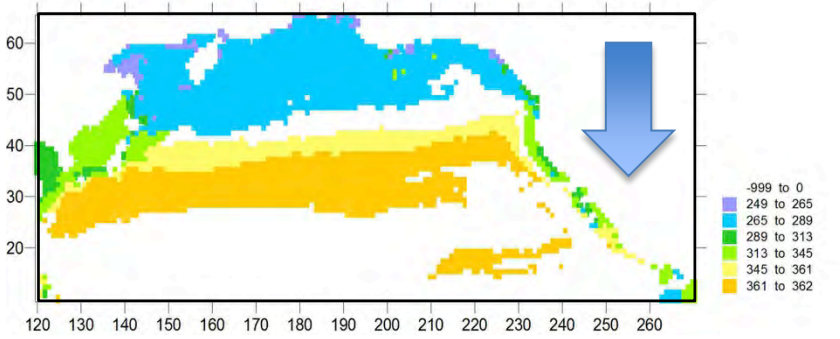
Spring Peak Timing (JD)



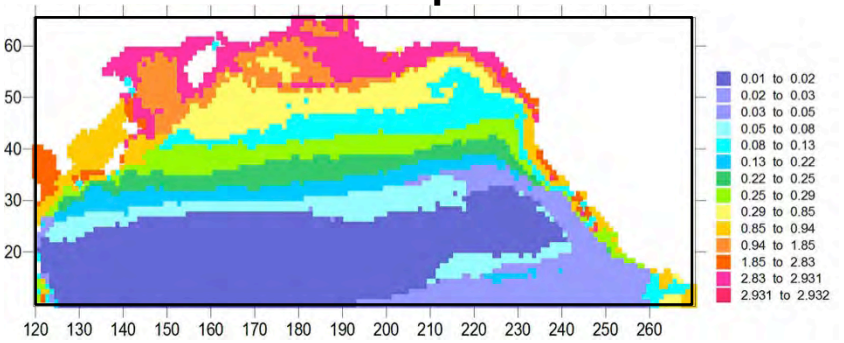
Autumn Peak Chl a



Autumn Peak Timing (JD)



Seasonal Chl a Amplitude



Note: Peak JD Range was examined for only clusters with seasonal variation (CV > 0.1)

NEOPS New Ocean Provinces: Dynamic Boundary

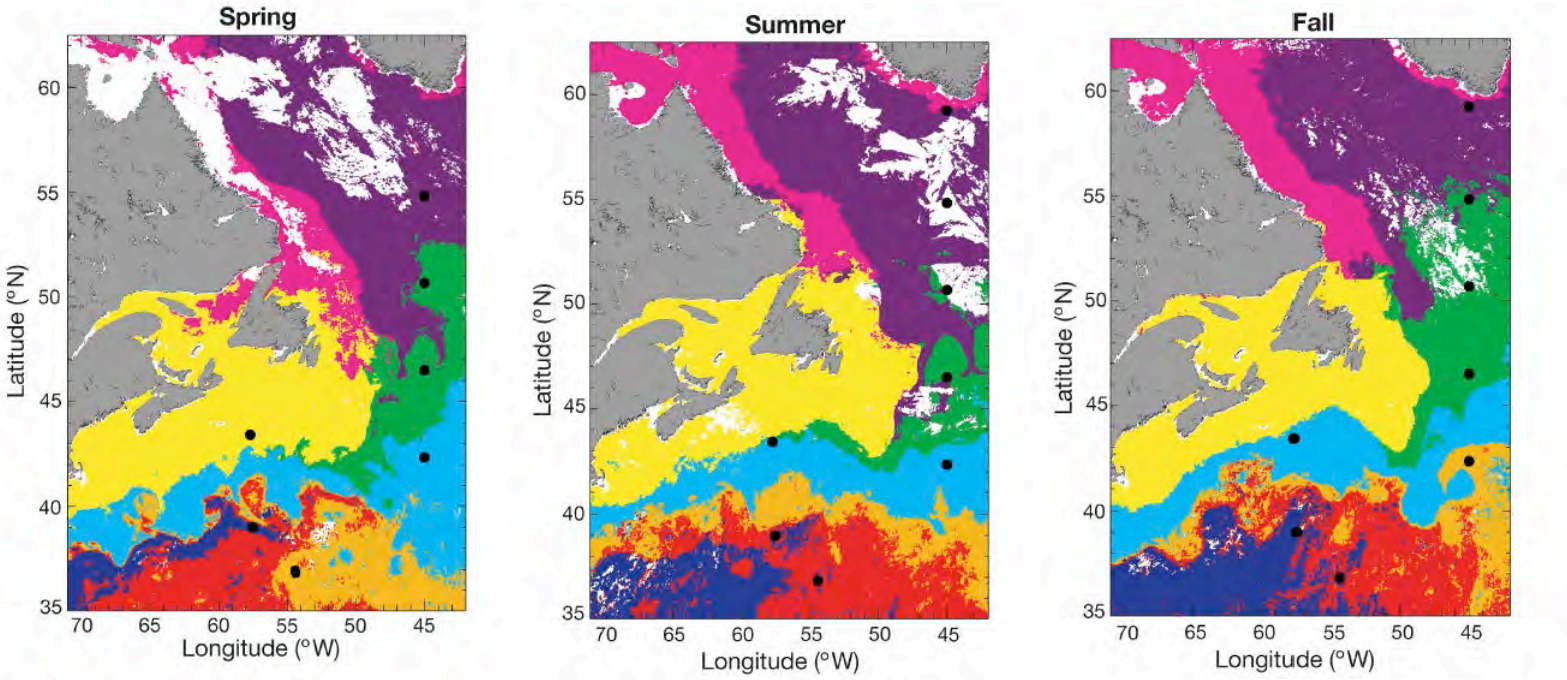
Vol. 346: 1–13, 2007
doi: 10.3354/meps07149

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

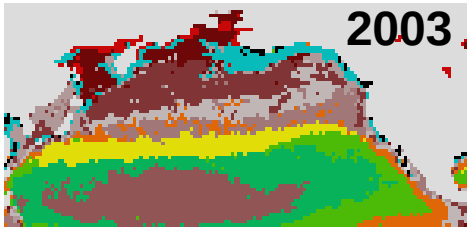
Published September 27

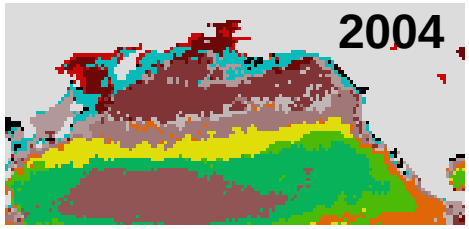
Delineation of ecological provinces using ocean colour radiometry

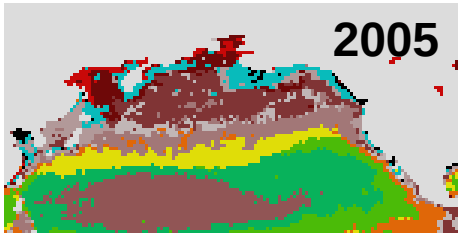
Emmanuel Devred[1,2,*], Shubha Sathyendranath[3], Trevor Platt[2]



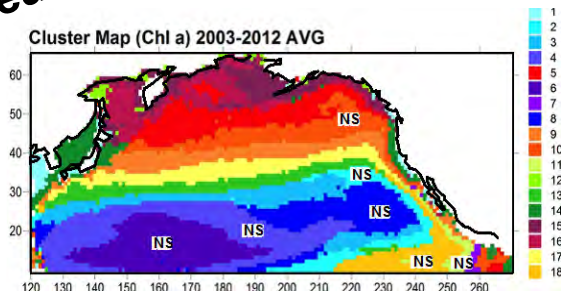
NEOPS New Ocean Provinces: Boundary Shift







10 yr mean



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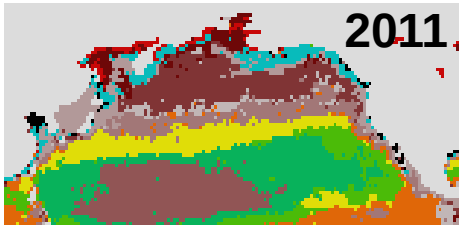
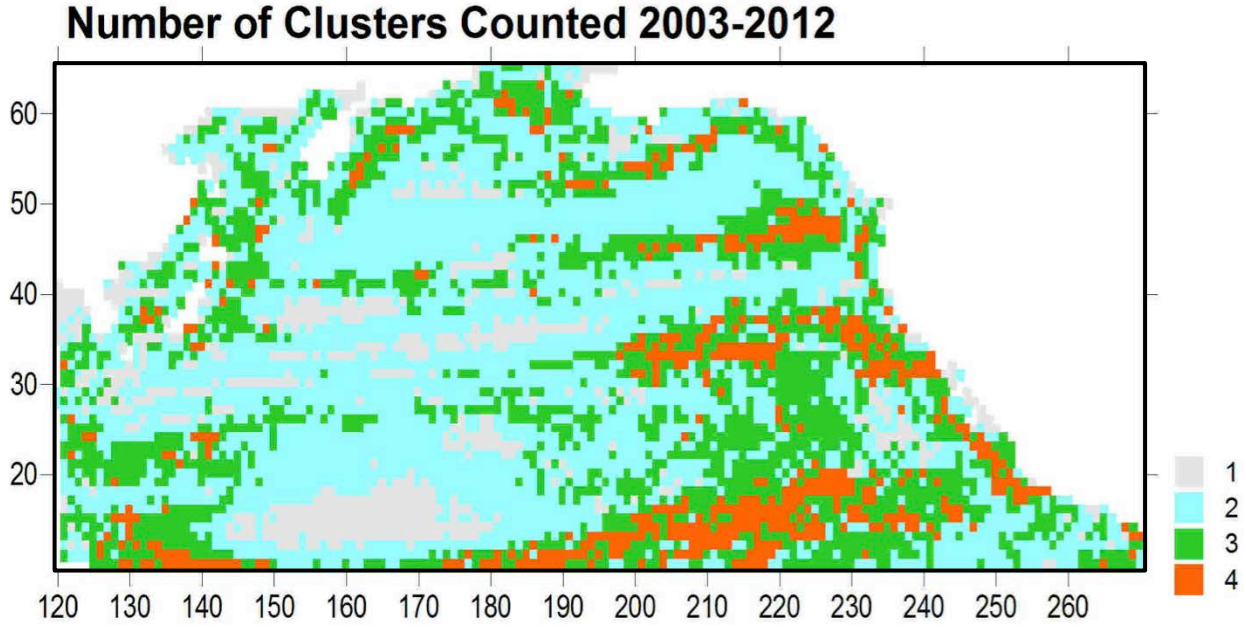
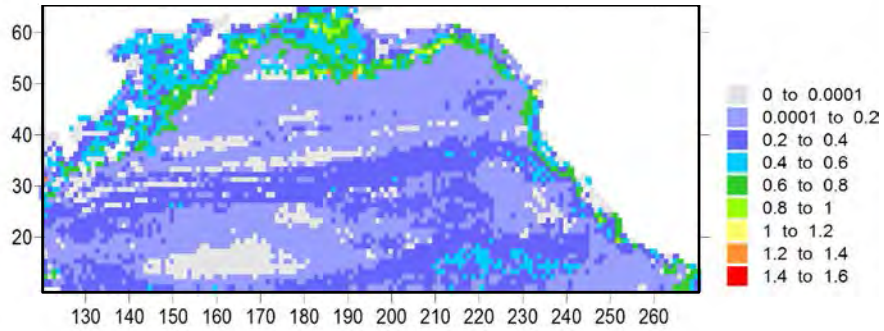




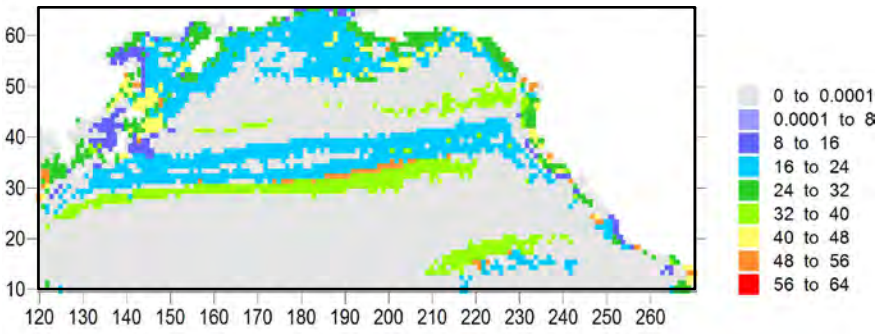
NEOPS New Ocean Provinces: Boundary Shift

Interannual Variation in Phytoplankton Phenology in the Boundary Regions

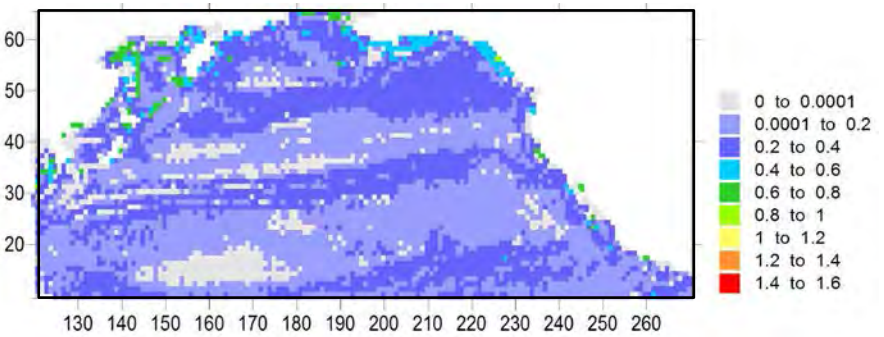
Spring Peak Chl a (CV: area standardized)



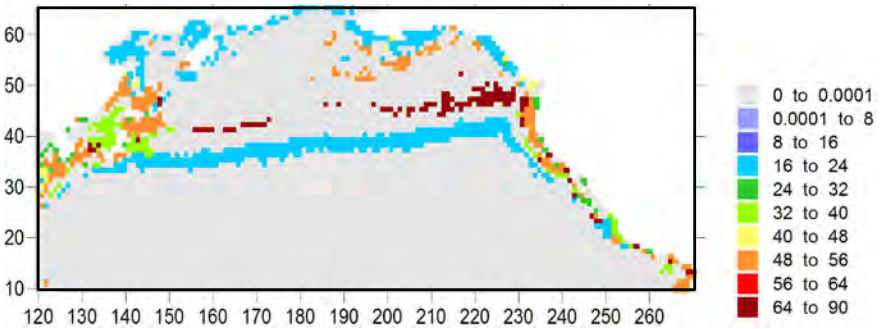
Spring Peak Chl a Timing (JD)



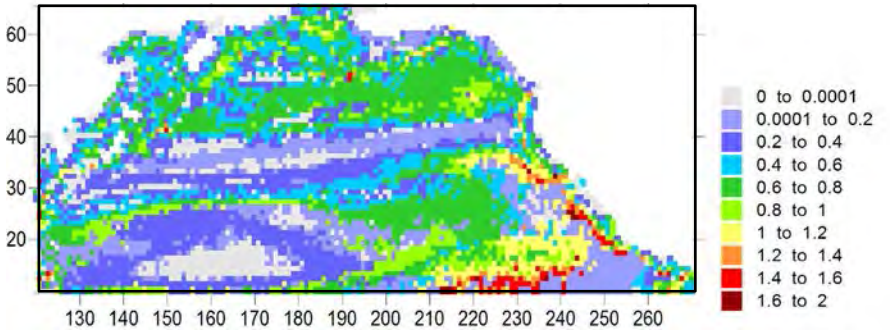
Autumn Peak Chl a (CV: area standardized)



Autumn Peak Chl a Timing (JD)

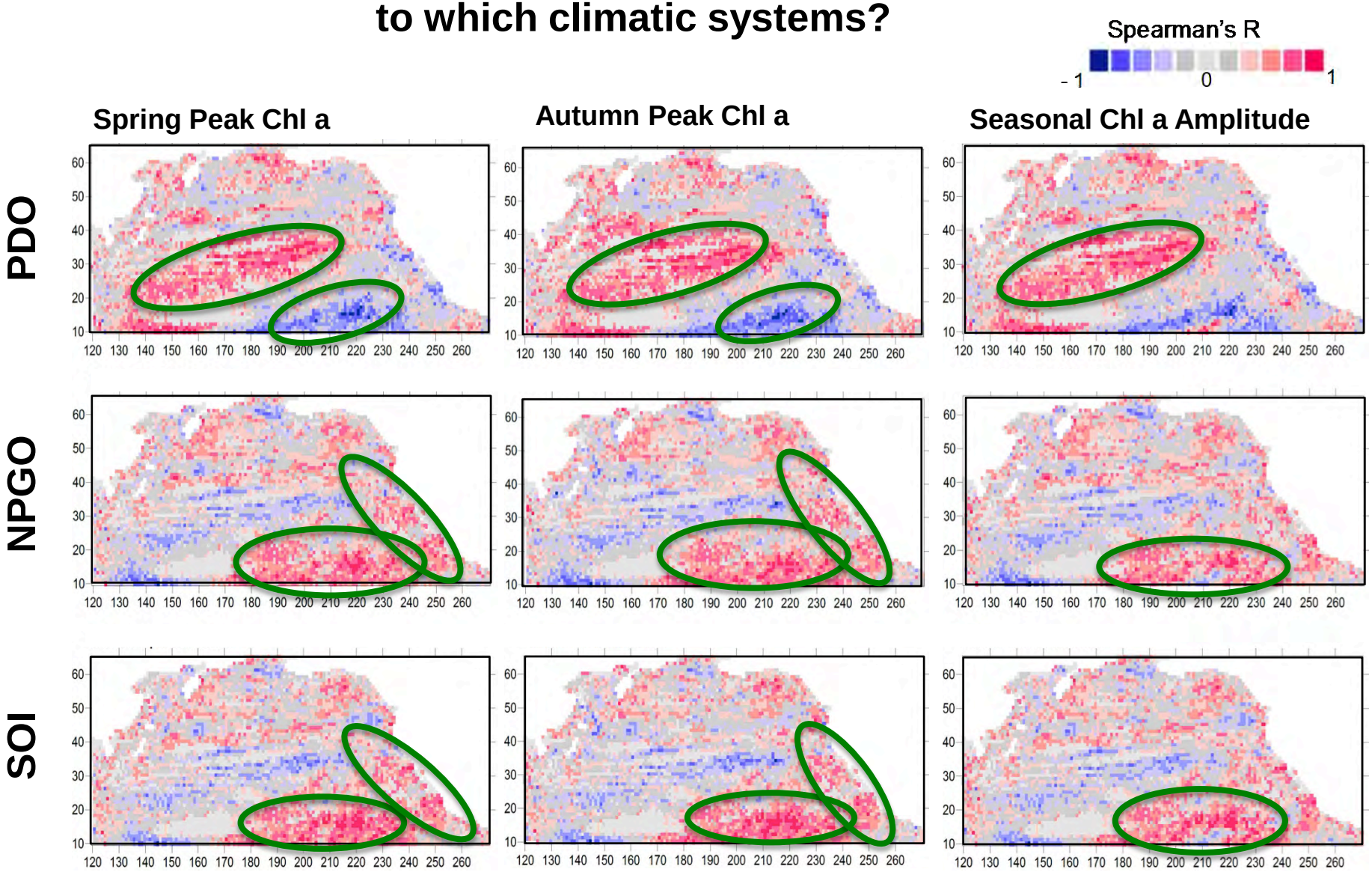


Seasonal Chl a Amplitude (CV: area standardized)



NEOPS New Ocean Provinces: Climate change and Boundary Shift

Which areas are more susceptible to which climatic systems?



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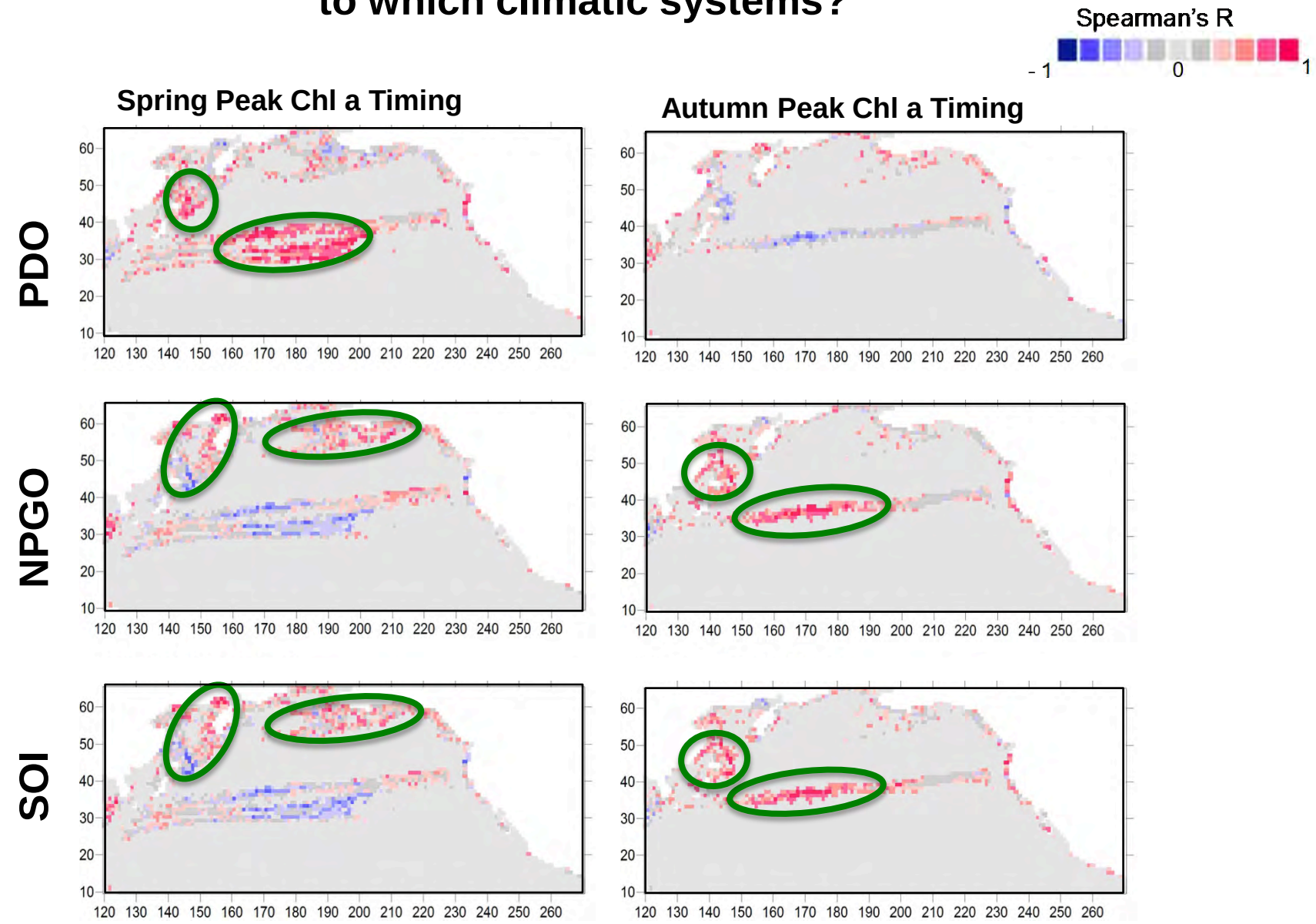
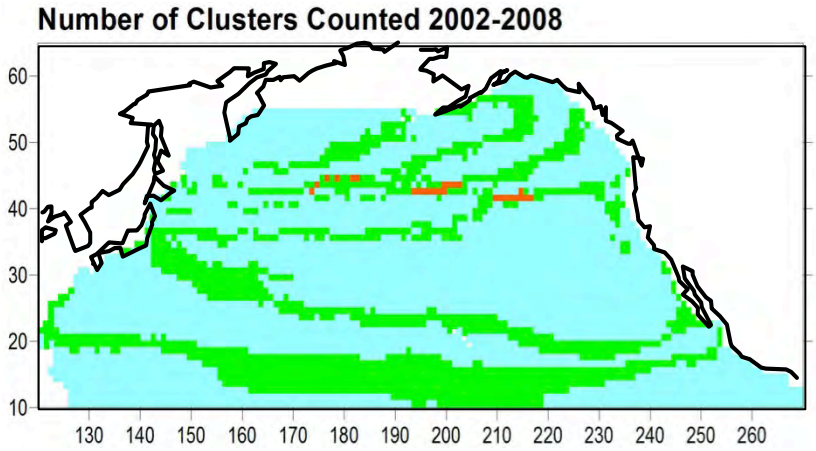


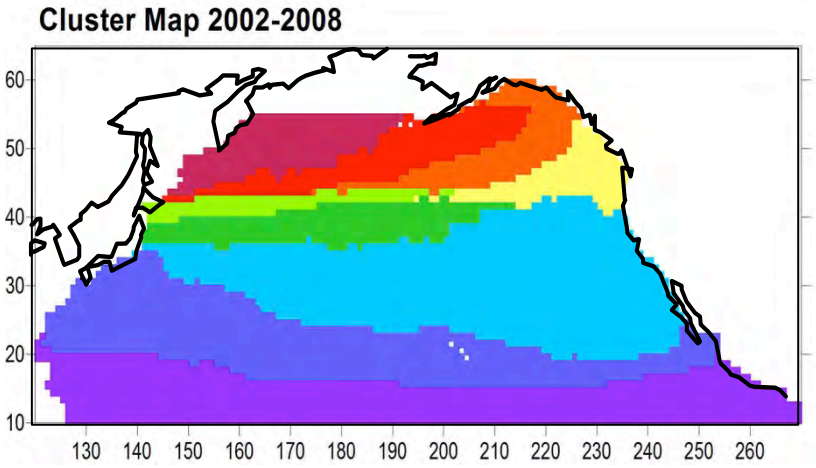
NEOPS New Ocean Provinces: Climate change and Boundary Shift

Ongoing analysis:

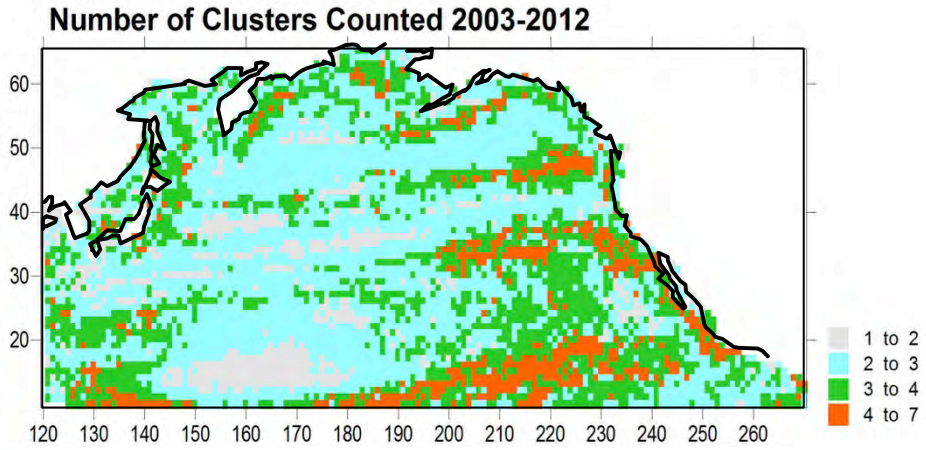
- **Comparison to BGC Provinces**
- **Comparison to zooplankton distribution**

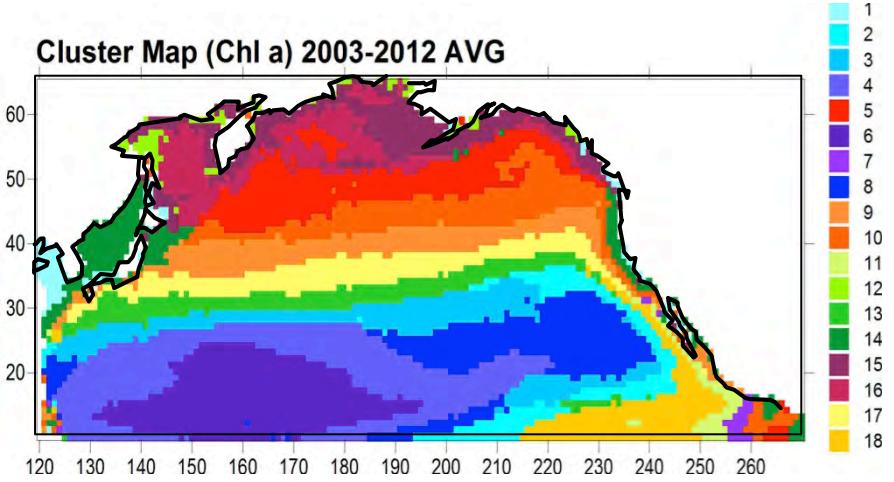
BGC Provinces



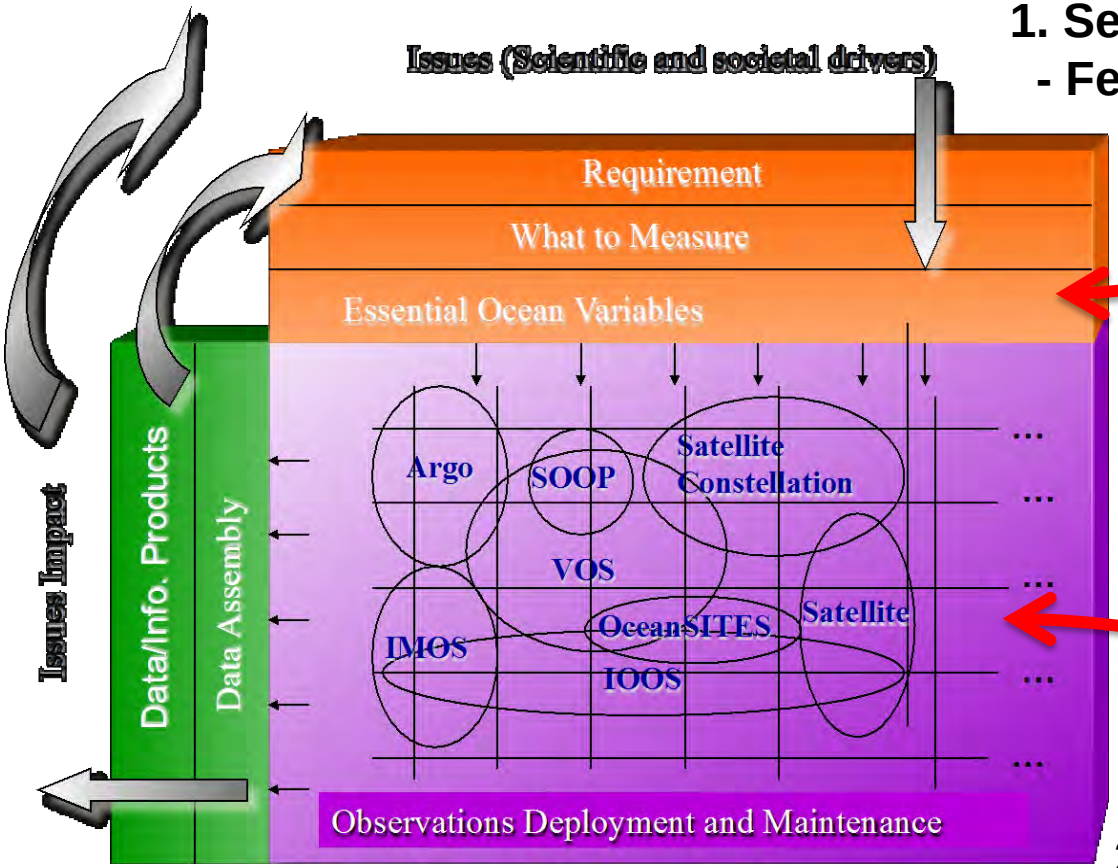


Phytoplankton Provinces





FOO (Framework for Ocean Observing)



1. Setting of Ecosystem EOV
- Feasibility & Importance

2. Designing of Effective Observation Plan

A Framework for Ocean Observing. By the Task Team for an Integrated Framework for Sustained Ocean Observing, UNESCO 2012, IOC/INF-1284 rev., doi: 10.5270/OceanObs09-FOO

Recommendation to Global Ocean Observation of Phenology

1. *Zooplankton $\delta^{15}N$ as an EOV for Trophic Link (incl. phenlogical match-mismatch)*

   ** Amino acid level $\delta^{15}N$ is the best, because it can detect variation in Trophic level regardless of $\delta^{15}N$ variation in phytoplankton and source water (Chikaraishi et al., 2010, Limnology and Oceanography: Method)*

2. *Observation in better spatial and temporal resolution in the boundary regions of the Phytoplankton Province.*

TIMING IS EVERYTHING

Doctor, there's a chronometer in the arboretum that ceased working a year ago. It has been correct twice a day ever since. So you see, I do not doubt that you, too, can be...