Phytoplankton and Upper Ocean Biogeochemical Cycles Along Line P

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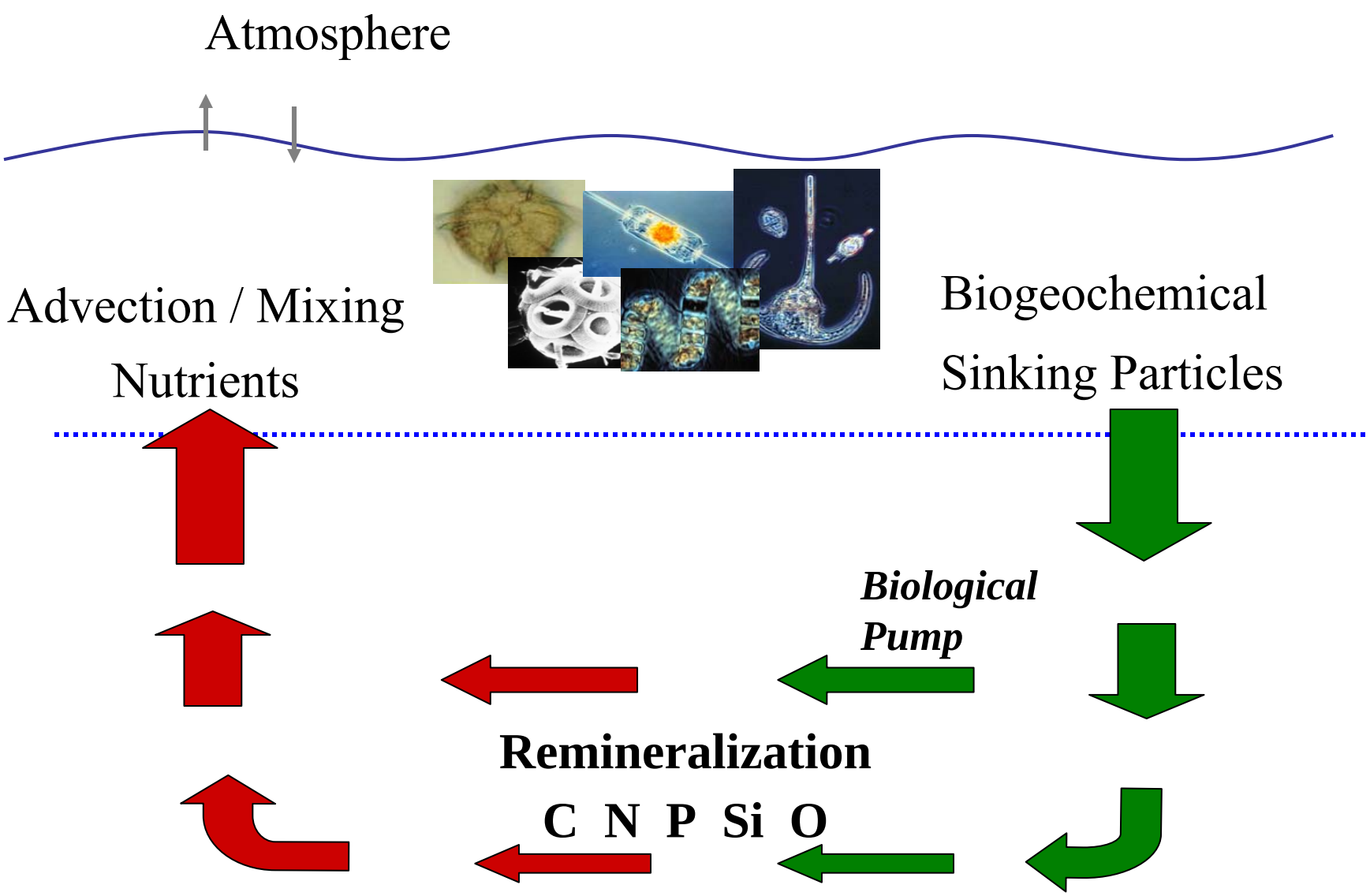
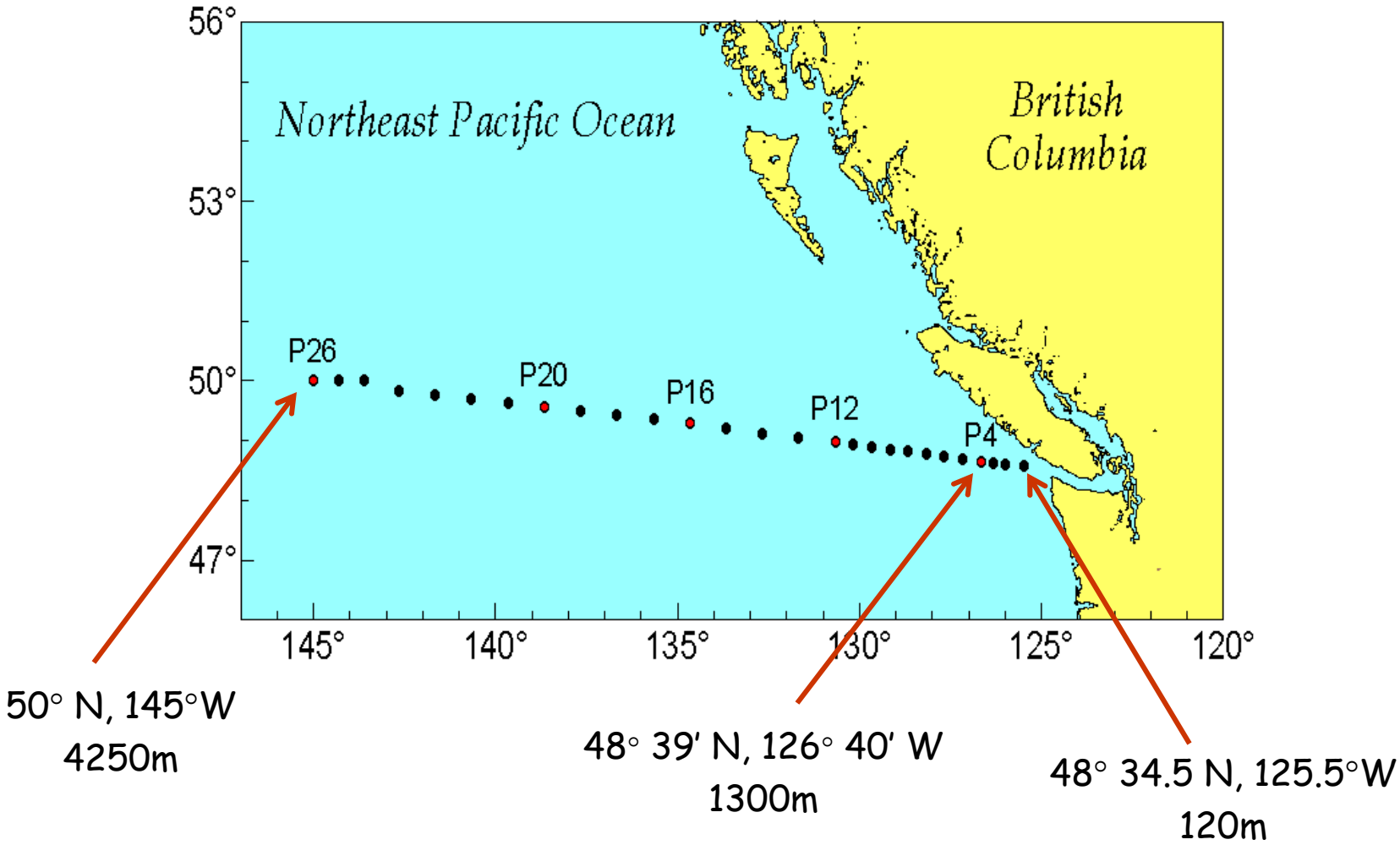
Fisheries and Oceans Canada Pêches et Océans Canada

IOS

Biogeochemical Cycles



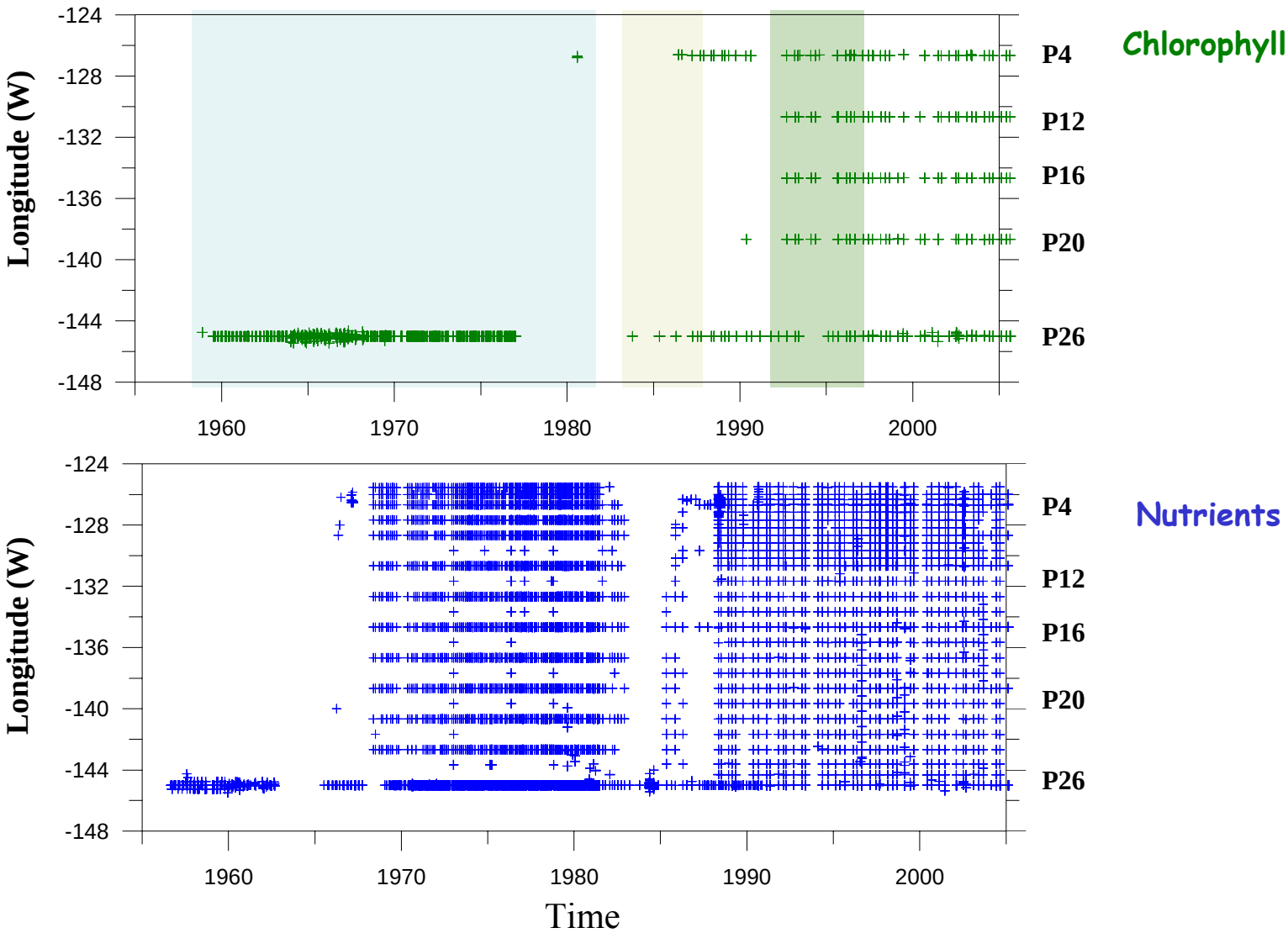
Sampling Stations – Line P



Line-P Sampling

- Weathership era: 1956-1981
- SUPER (Subarctic Pacific Ecosystem Research) program: 1984-88
- VERTEX (Vertical exchange) program
- WOCE (World Ocean Circulation Experiment) 1991-1997
- CJGOFS (Canadian Joint Global Ocean Flux Study) 1992-1997
- SERIES (Subarctic ecosystem response to iron enrichment study) 2002

Sampling along Line P

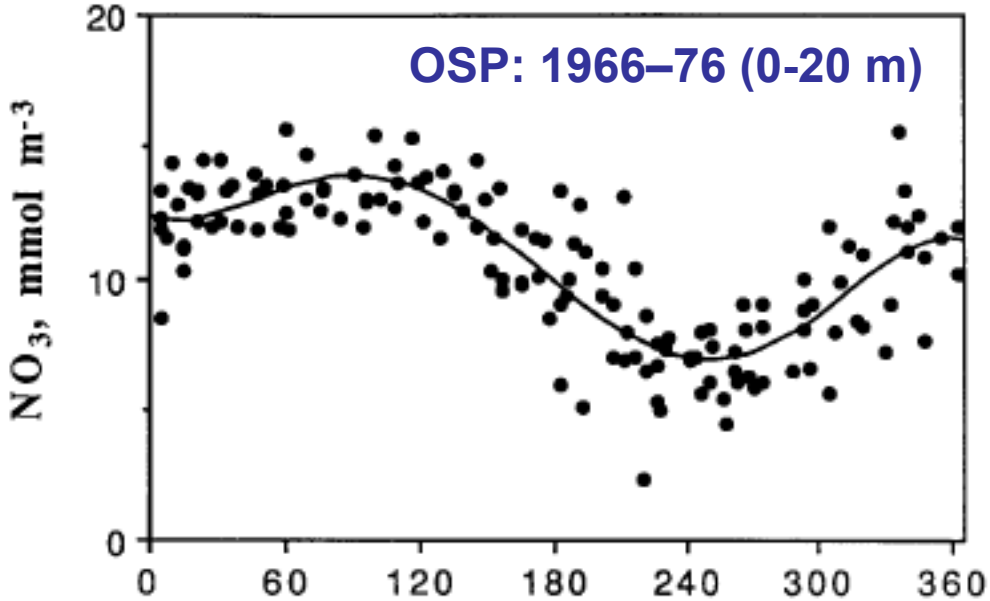


Observations from the weathership era

A High Nitrogen – Low Chlorophyll (HNLC) region

- High nitrate concentration all year around
- Chlorophyll concentration are low all year (<0.5 mg m^{-3}) – no spring bloom
- Modest annual cycle in primary production
- Annual cycle in mesozooplankton abundance
- Surface oxygen supersaturation in spring/summer

NO_3 Minimum ~ ½ Winter Maximum



Frost, 1993, Prog.Ocgy.32.
[adapted from Parslow, 1981]

Recognized as a region of

High Nitrogen – Low Chlorophyll (HNLC)

Chlorophyll *a* at OSP, Weathership Era

- **no spring bloom**
- **average 0.3-0.4 mg-Chl m^{-3}**
- **all obs. < 2 mg-Chl m^{-3}**

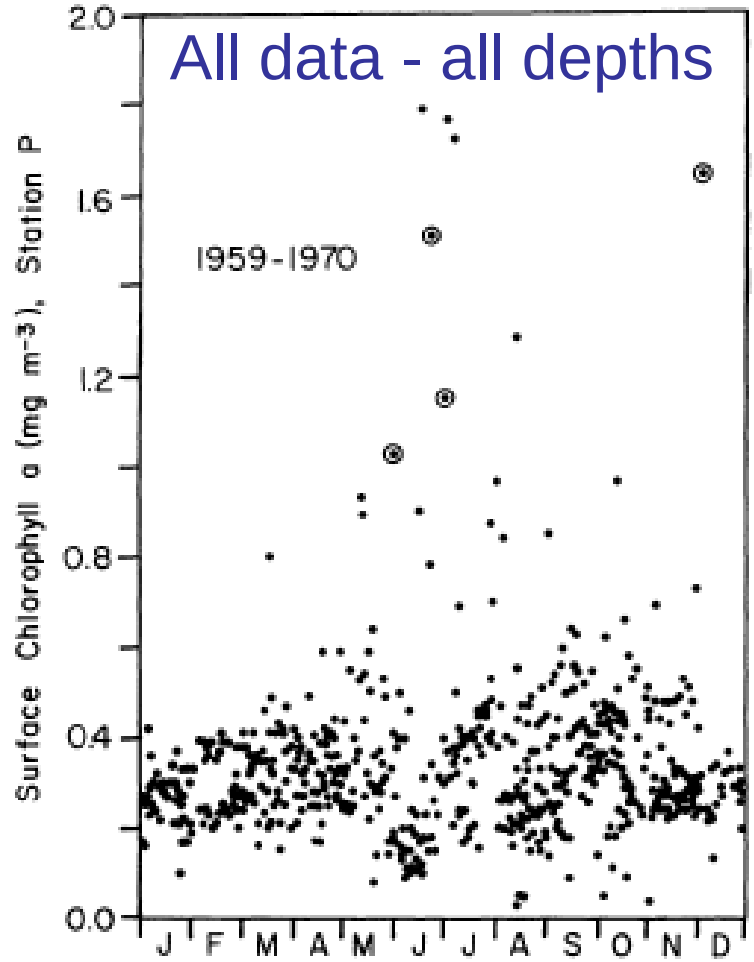


Fig. 3. Cumulative Chl *a* data from Station P over 10 yr. Scale extends only to 2.0 mg m^{-3}. Four circled points are all the values >1.0 m gm^{-3} from 1970 to 1976.

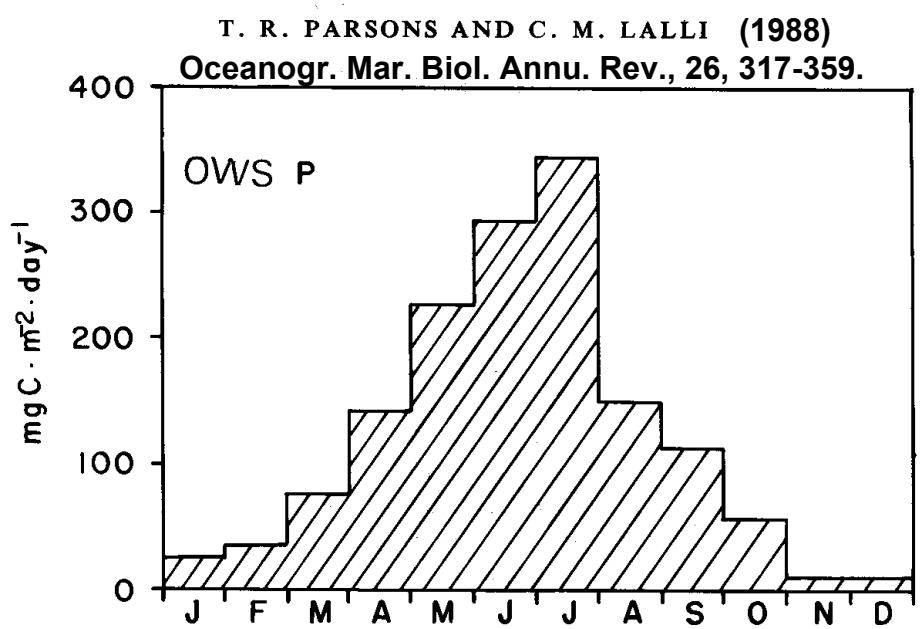
Miller et al., 1991
L&O, 36(8)

(via Parslow, 1981)

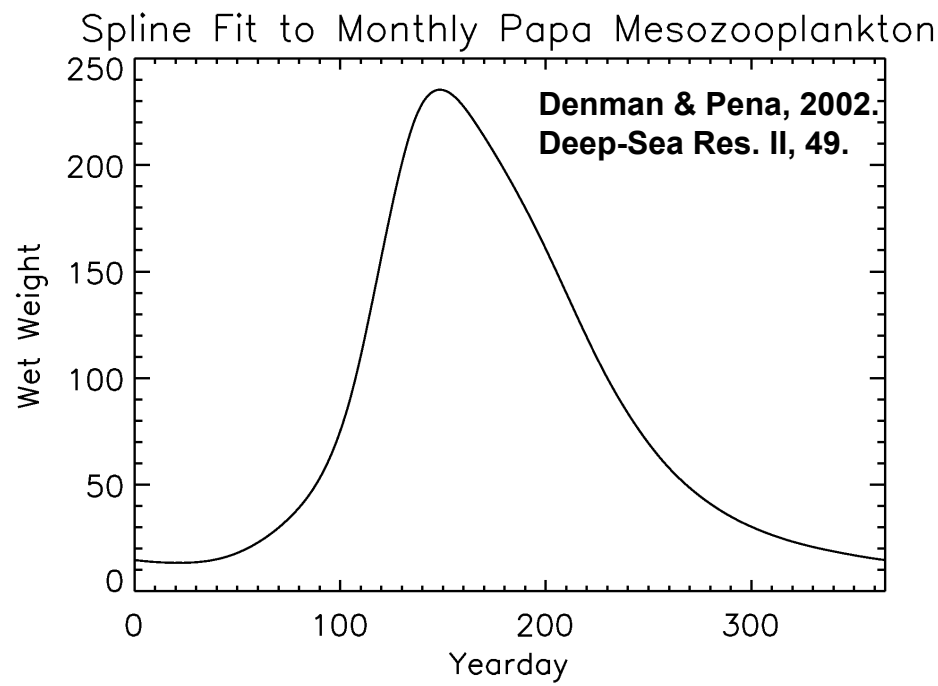
Annual Cycle:

$NO_3^- \rightarrow PP \rightarrow$ Mesozooplankton

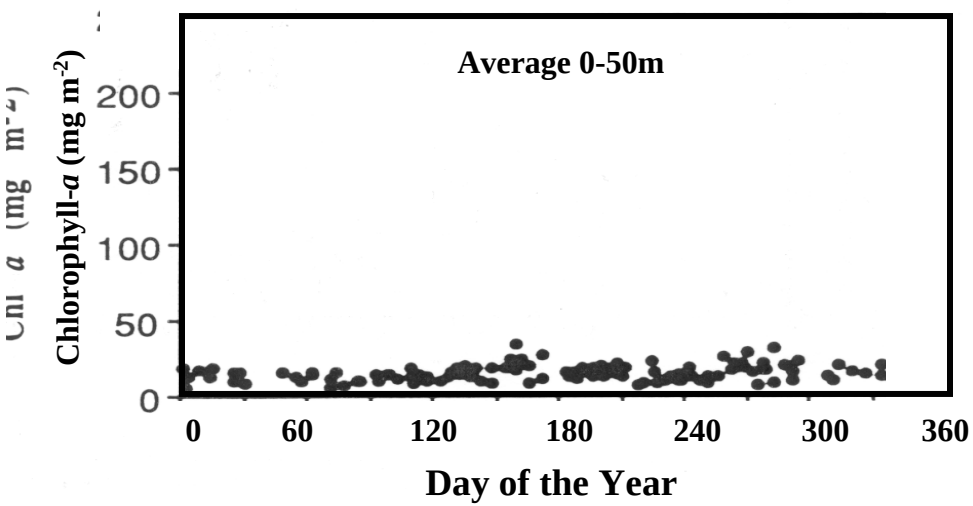
Primary productivity (0-50m) OSP 1960-66, redrawn from:
McAllister, 1969.
J. Fish. Res. Board Can. 26.

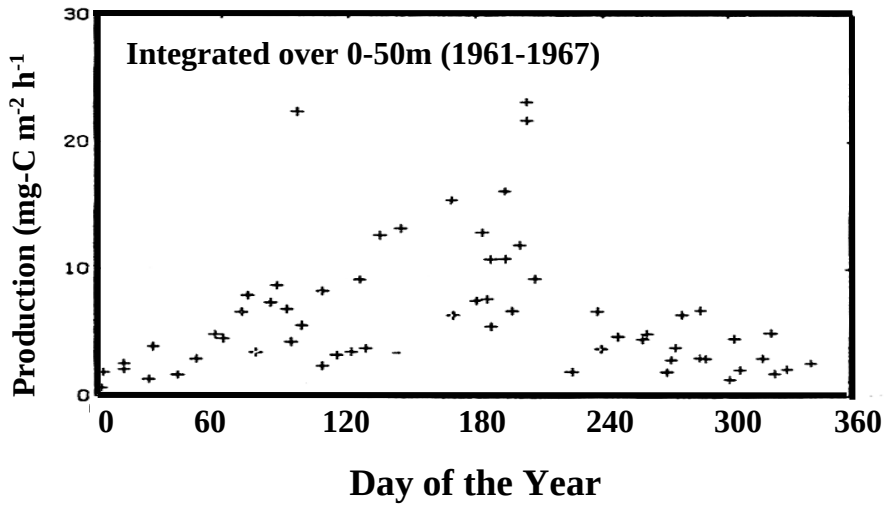


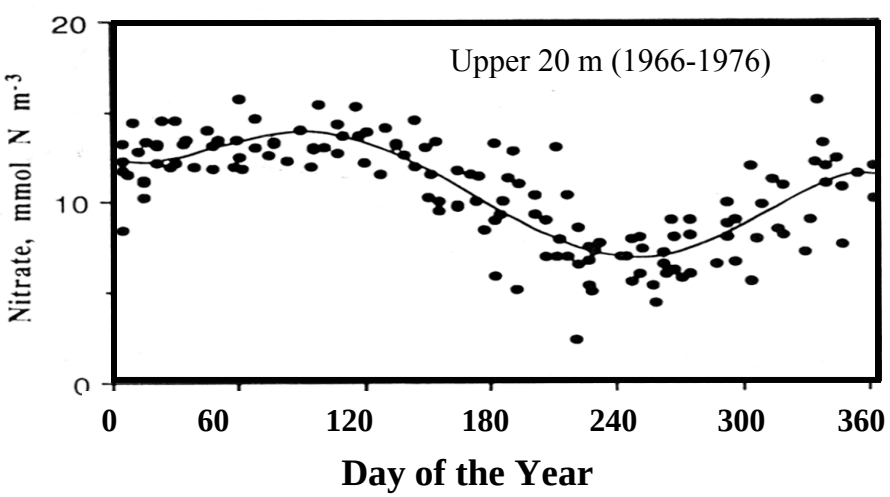
Mesozooplankton wet weight OSP 1956-80, data from:
Fulton, J.D., 1983. Can. Data Rept. Fish. Aquat. Sci. 374.

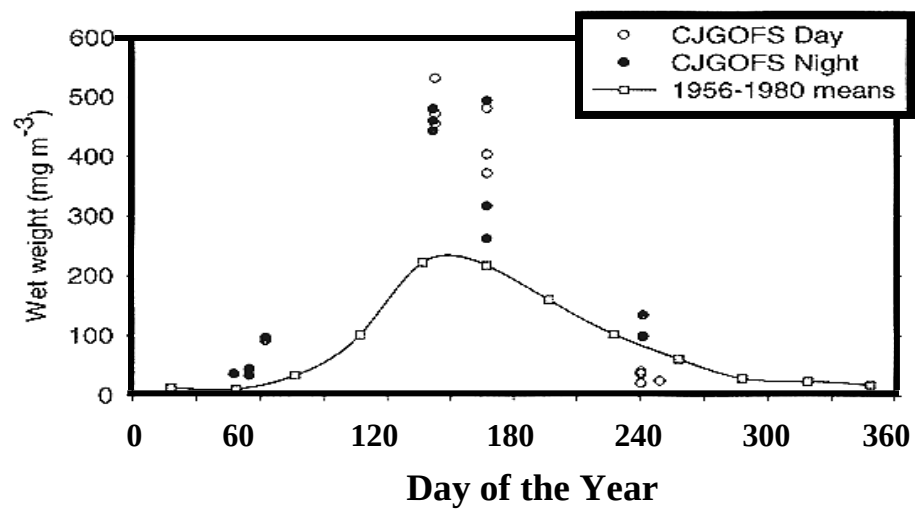


NE Subarctic Pacific – HNLC region









(Frost, 1993)

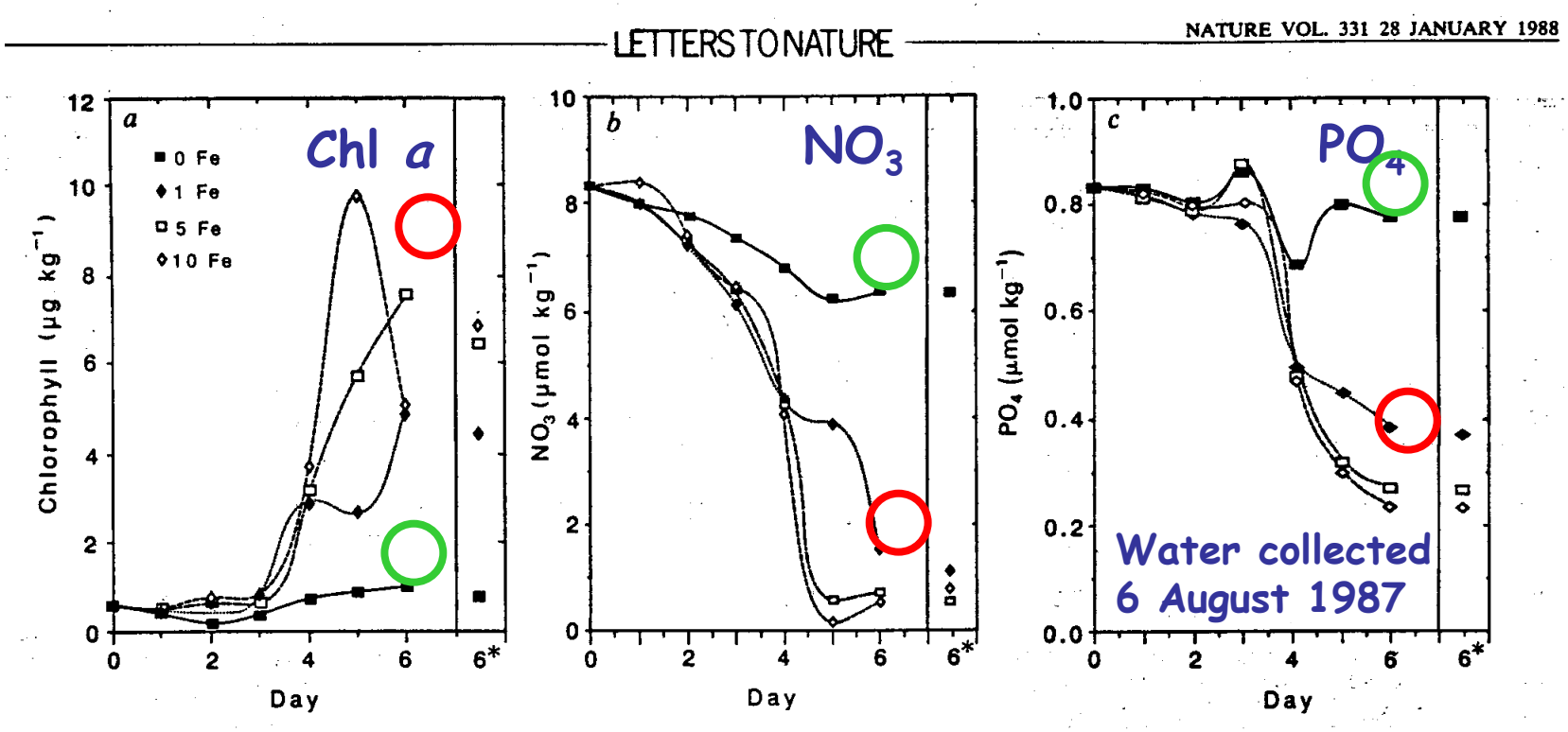
SUPER program

Why there are no phytoplankton blooms in the NE subarctic Pacific?

- Phytoplankton biomass controlled by mesozooplankton grazing – "Major Grazer Hypothesis"
- Mixing and Micrograzer Hypothesis –micrograzers control phytoplankton biomass. This interaction is not broken down by deep mixing in winter months.

Phytoplankton dominated by small-size organism

Fe deficiency limits phytoplankton growth at OSP



No Fe added → little Chl *a* increase, little NO_3 & PO_4 drawdown

5 nmol kg^{-1} Fe added → large Chl *a* increase & NO_3 , PO_4 drawdown

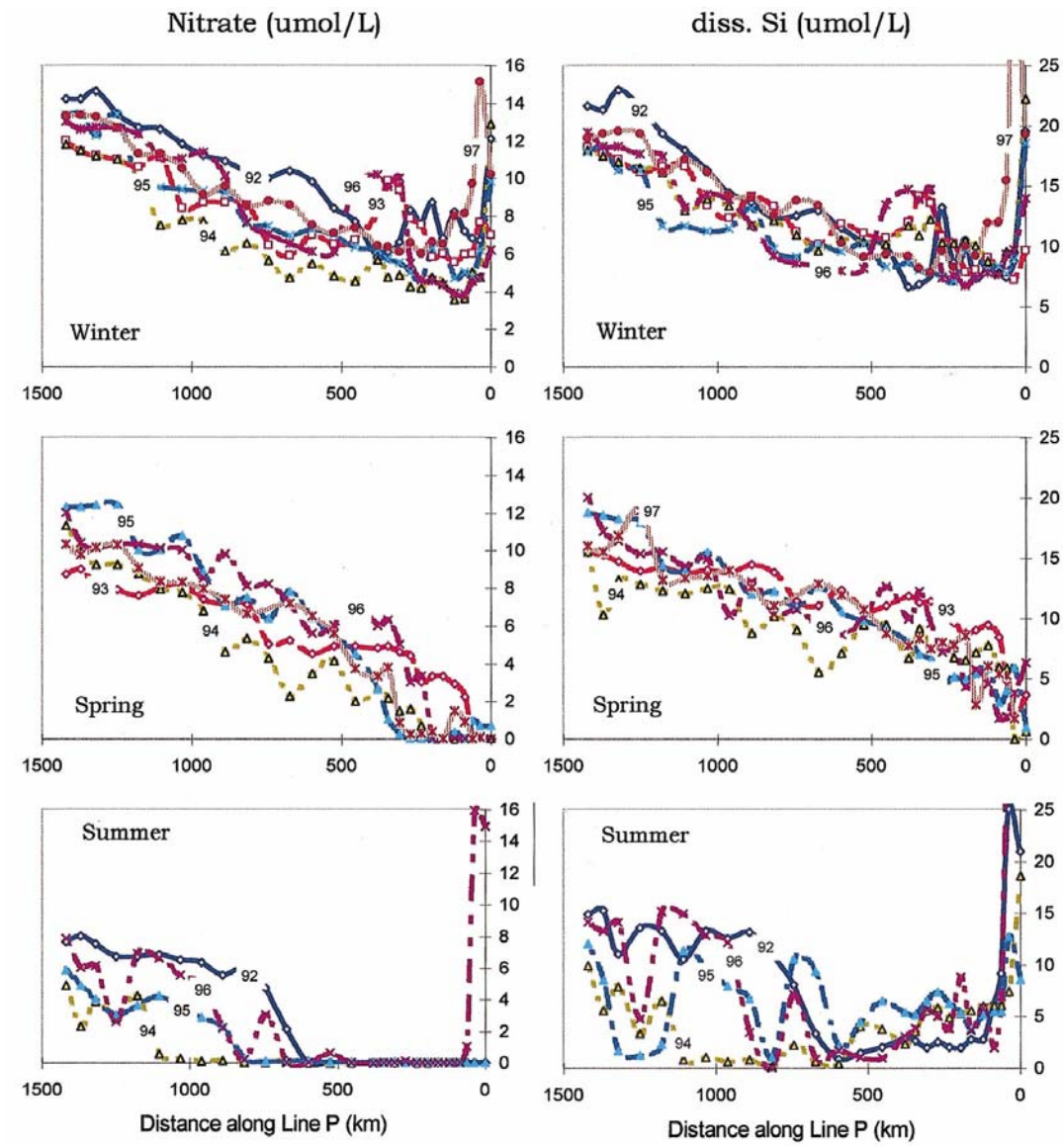
Martin & Fitzwater, 1988. Nature 331.

Canadian JGOFS Program

- Functioning of the pelagic ecosystem
- Iron limitation vs grazing control
- Carried out plankton research along Line P. Sampling at: P4, P12, P16, P20 and P26 (OSP)

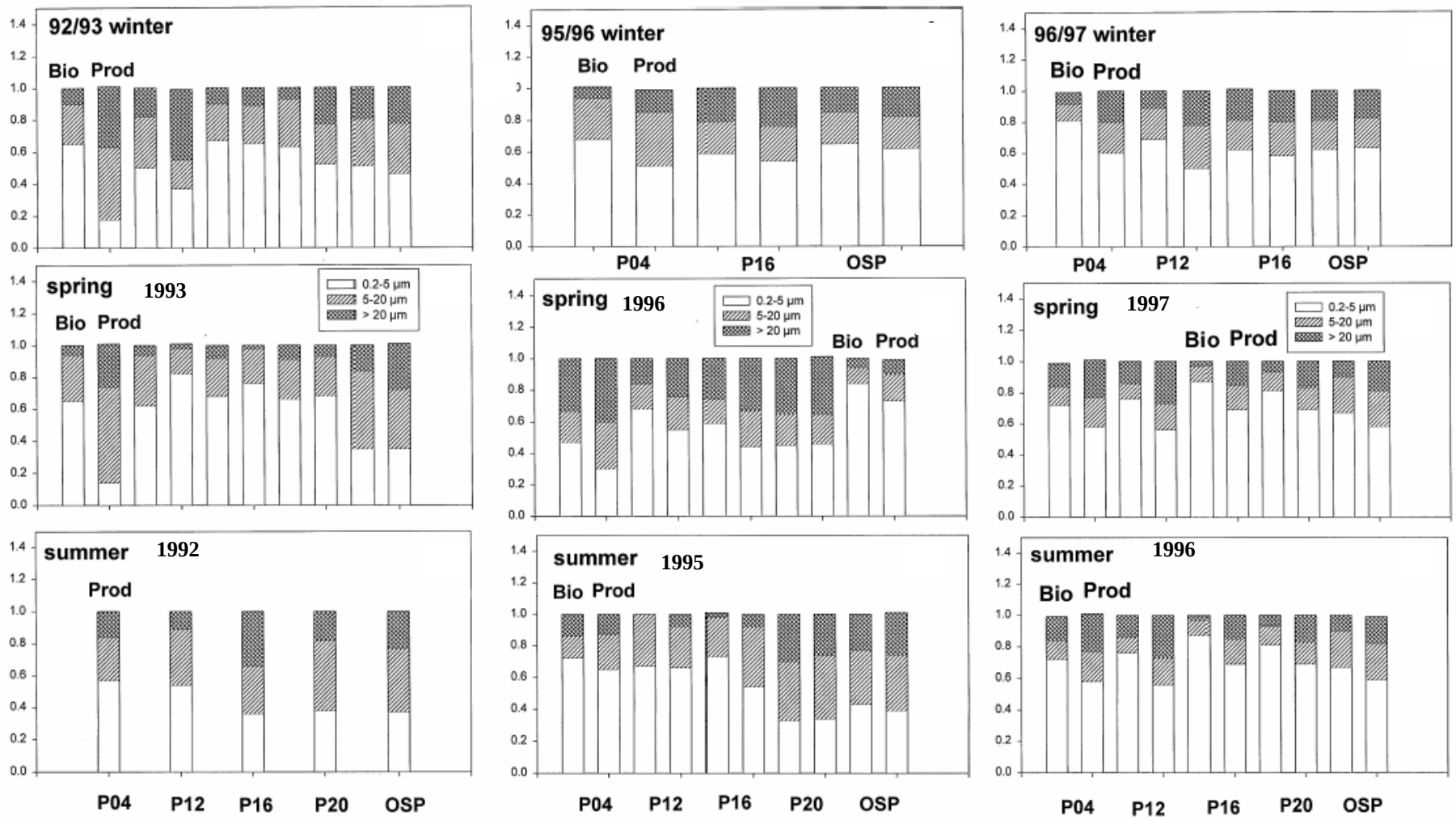
Surface nitrate and silicate along Line P

CJGOFS program 1992-1997



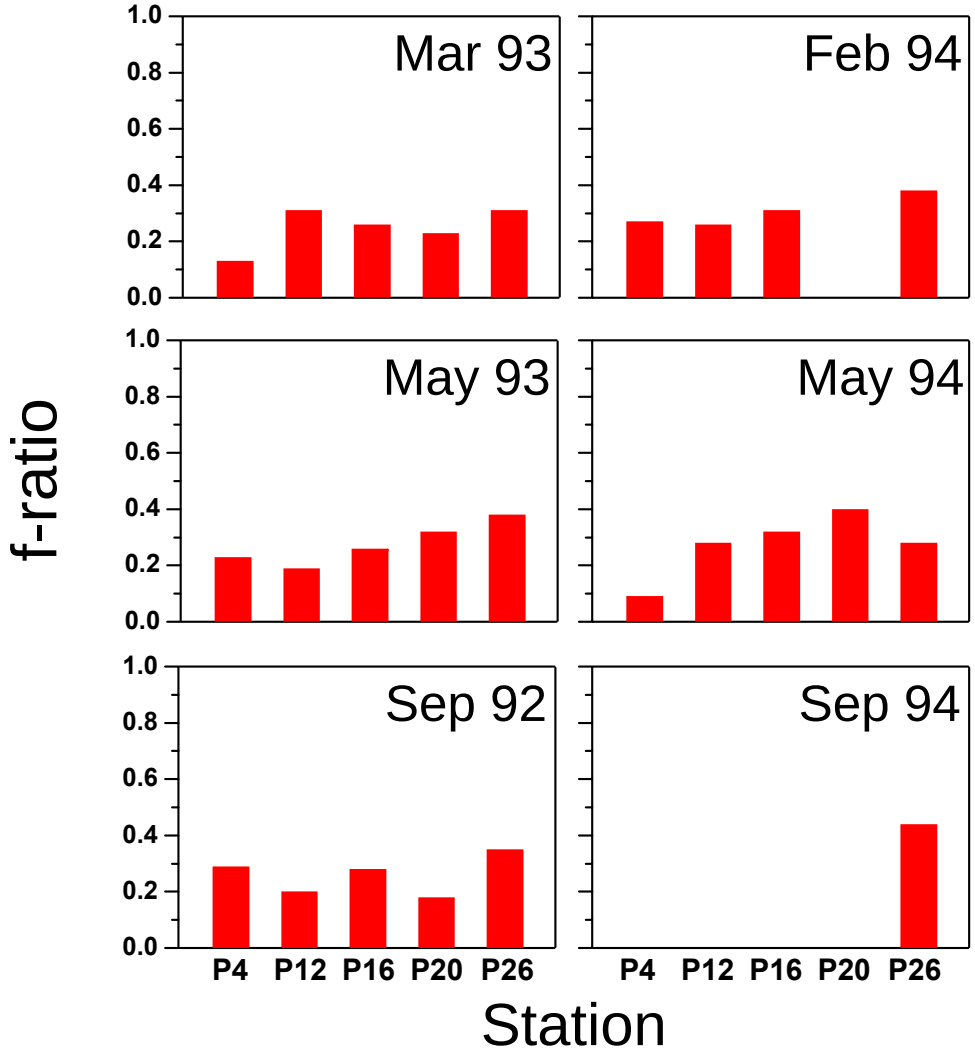
(Whitney and Freeland, 1999)

Size-fractionated phytoplankton biomass and production



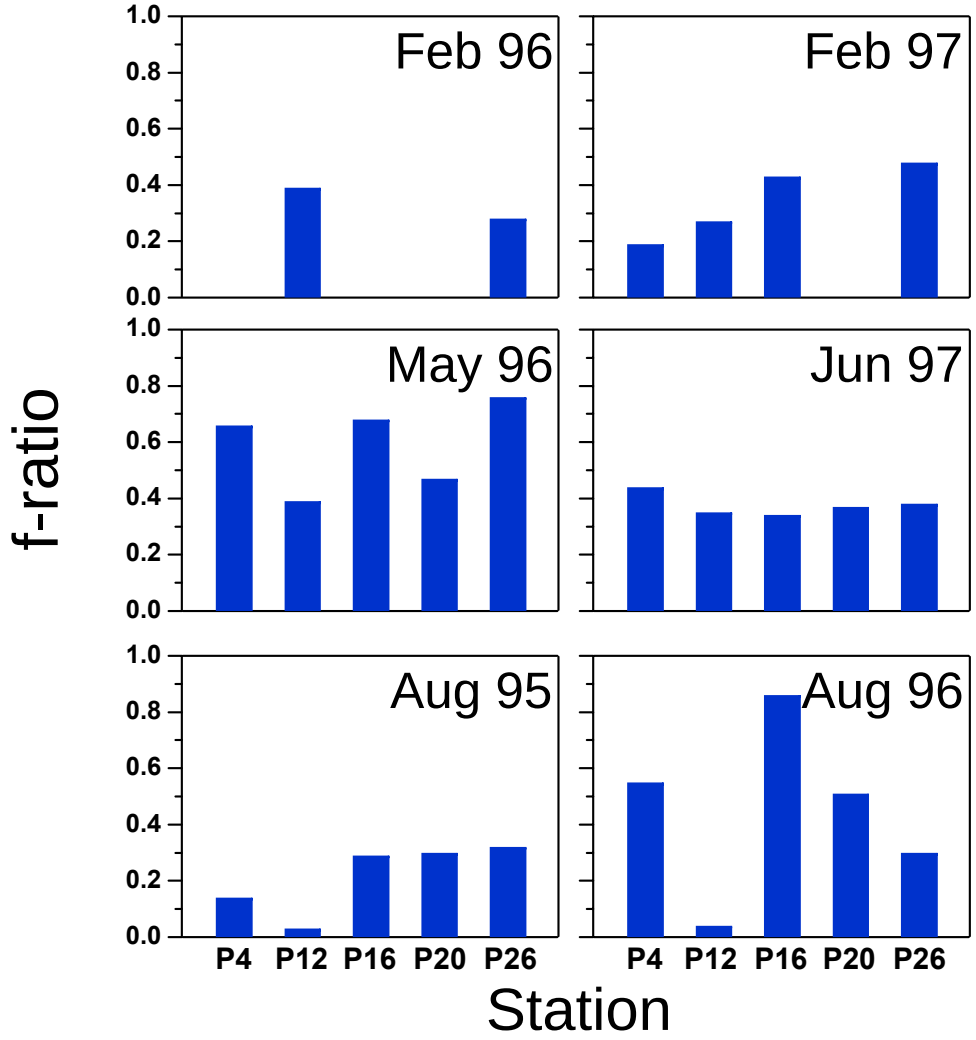
(Boyd and Harrison, 1999)

JGOFS I: 1992-1994



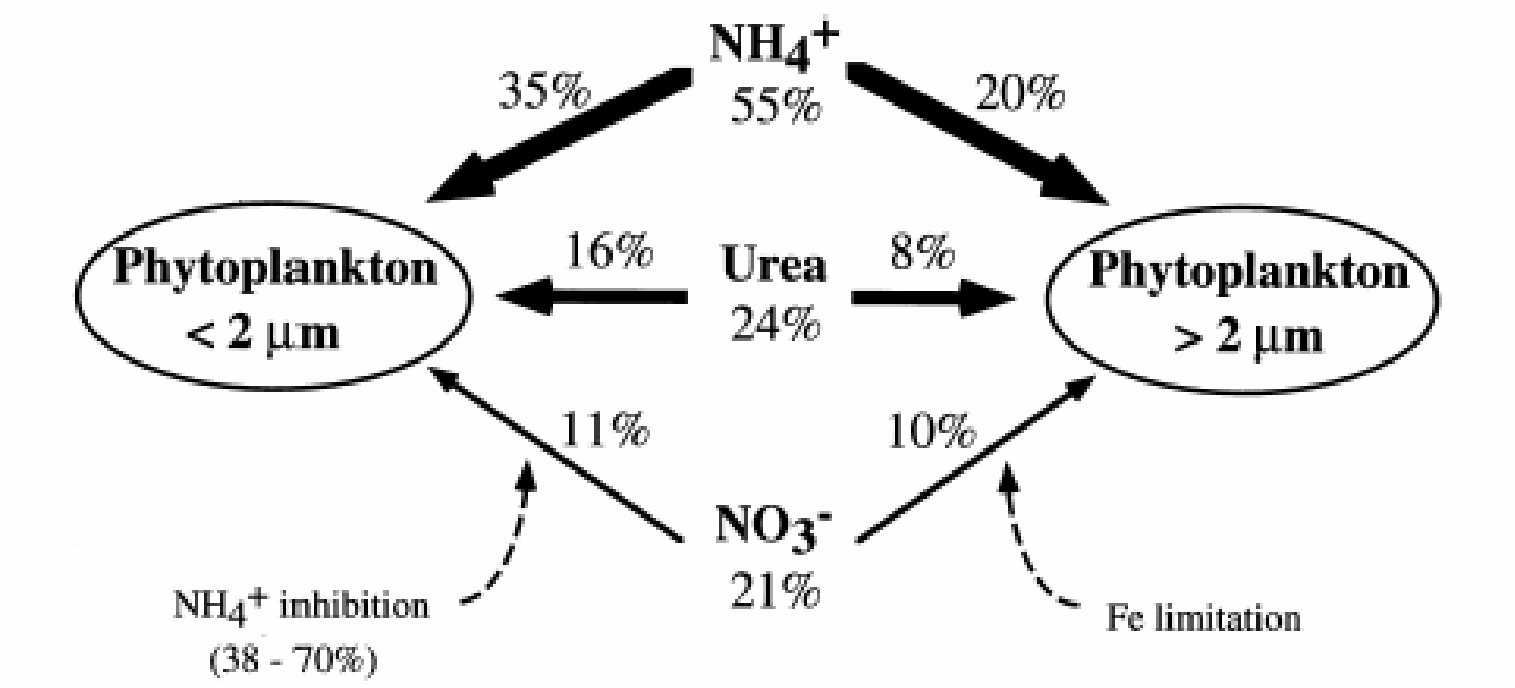
Average New Production 27%

JGOFS II: 1995-1997



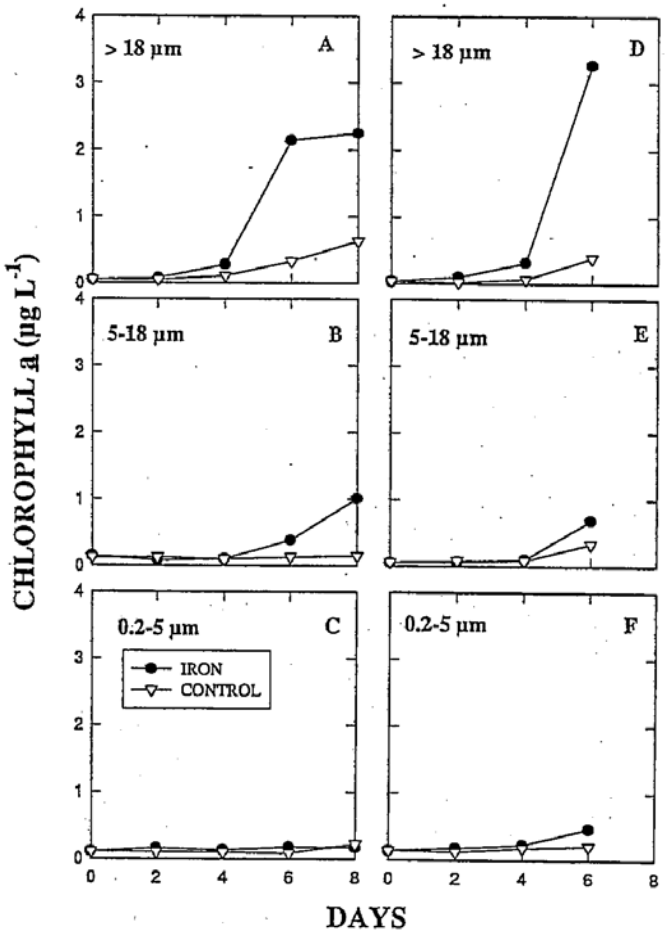
Average New Production 39%

Uptake of three nitrogen sources by two size fractions of phytoplankton

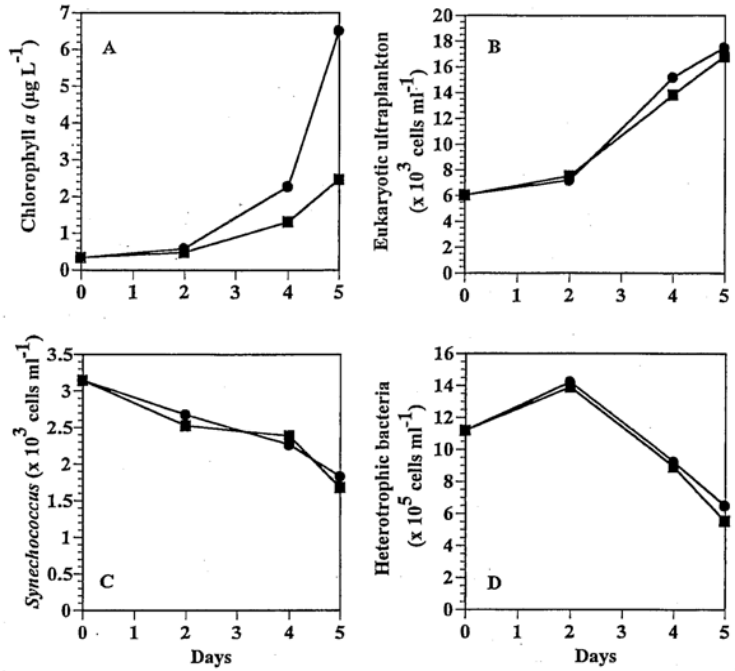


(Varela and Harrison, 1999)

In vitro iron enrichment experiment

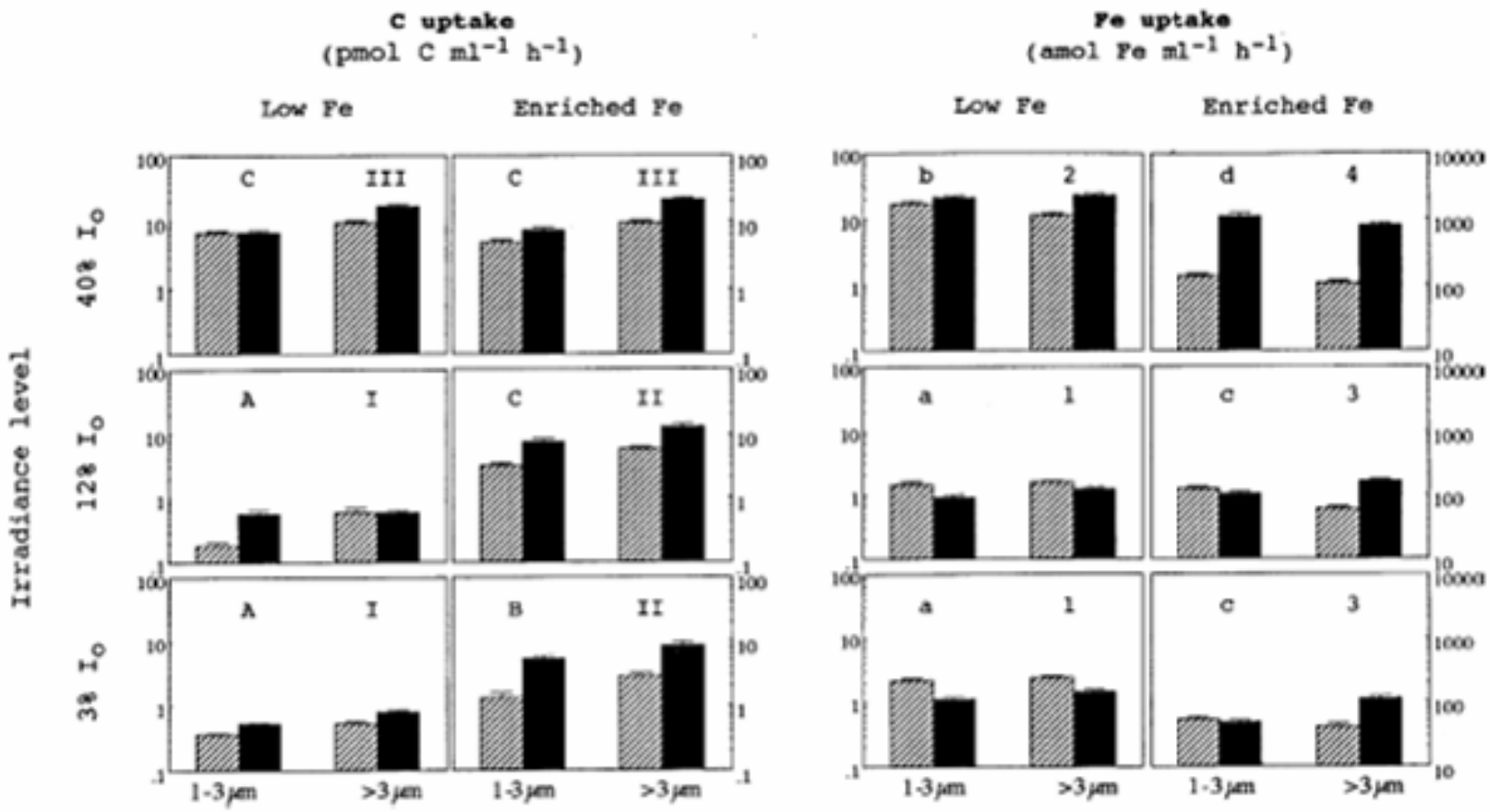


(Boyd et al., 1996)



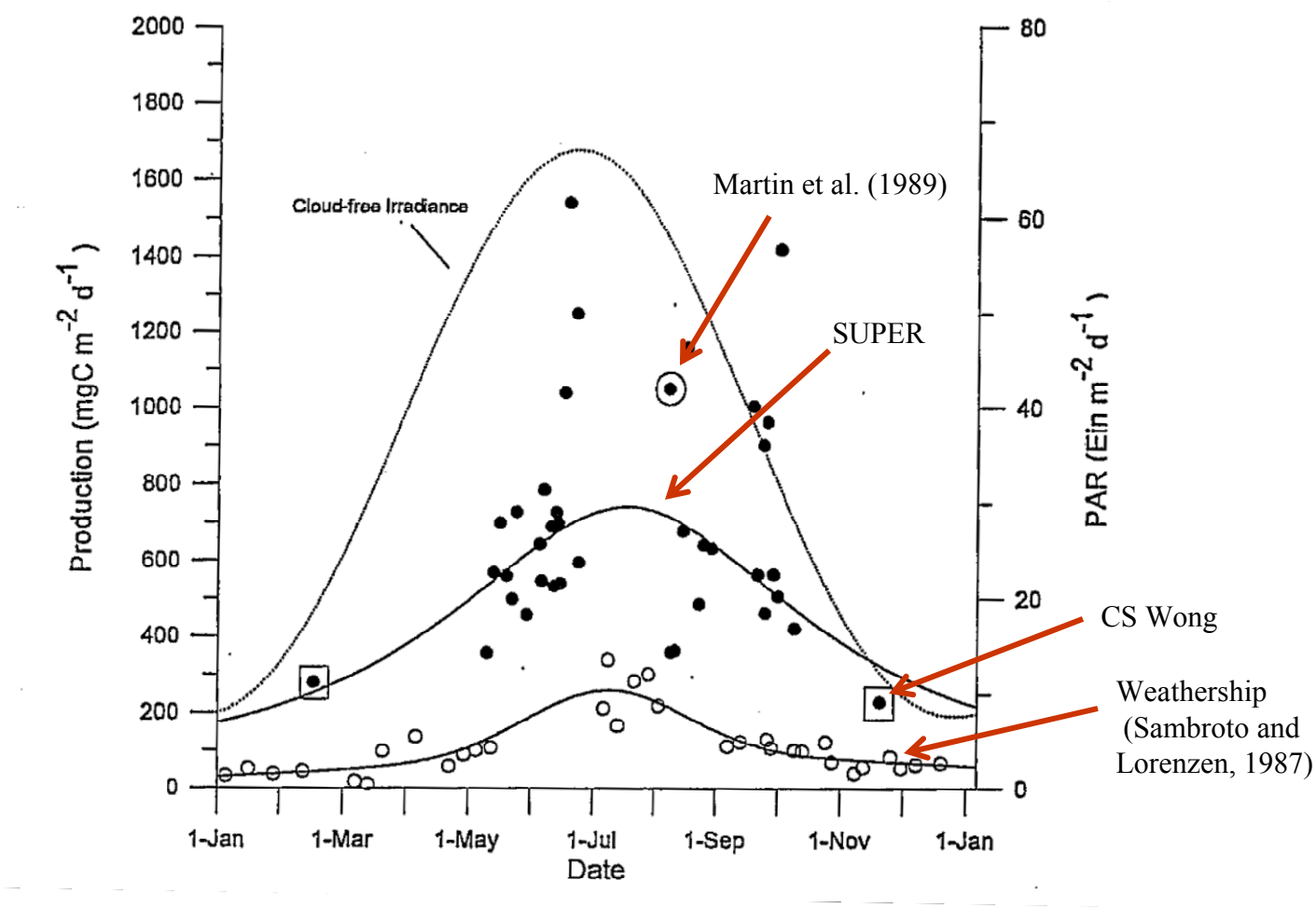
(Suzuki et al., 2002)

Co-limitation of light and iron



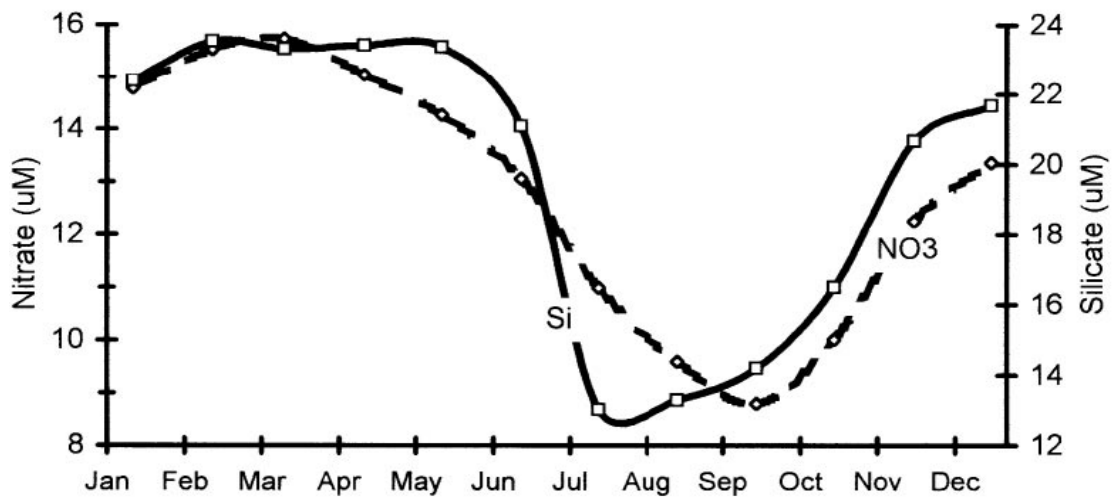
(Maldonado et al., 1999)

Phytoplankton Production at OSP



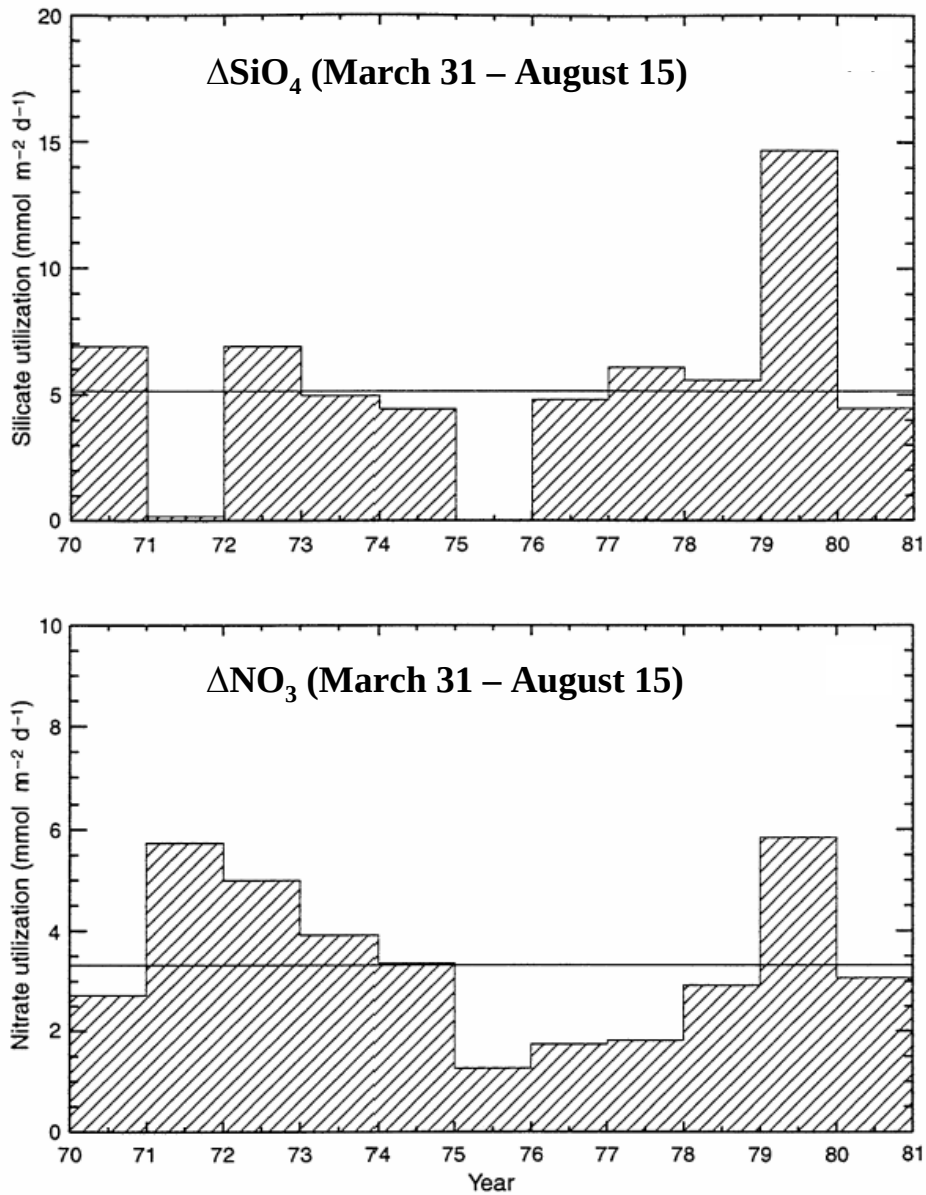
(Welschmeyer et al., 1993)

Average annual cycles of surface nitrate (monthly averages from 1969-1981) and silicate (monthly averages from 1974-1981) at OSP (Whitney and Freeland, 1990)



Whitney and Freeland, 1999

Annual silicate and nitrate utilization



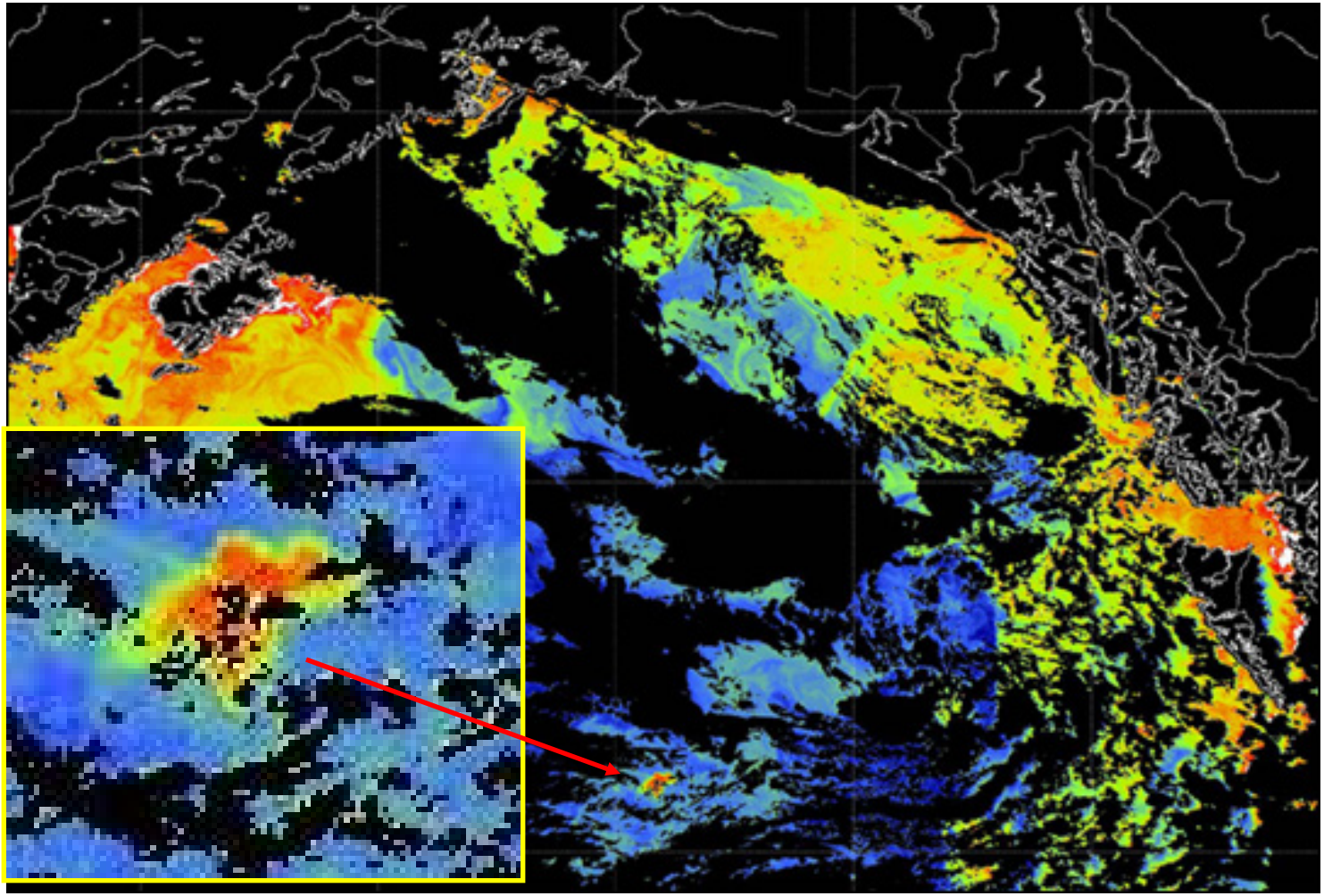
(Wong and Matear, 1999)

SERIES 2002:
Subarctic Ecosystem Response to Iron Enrichment Study
brought to life by C.S. Wong (IOS) and Paul Harrison (UBC)

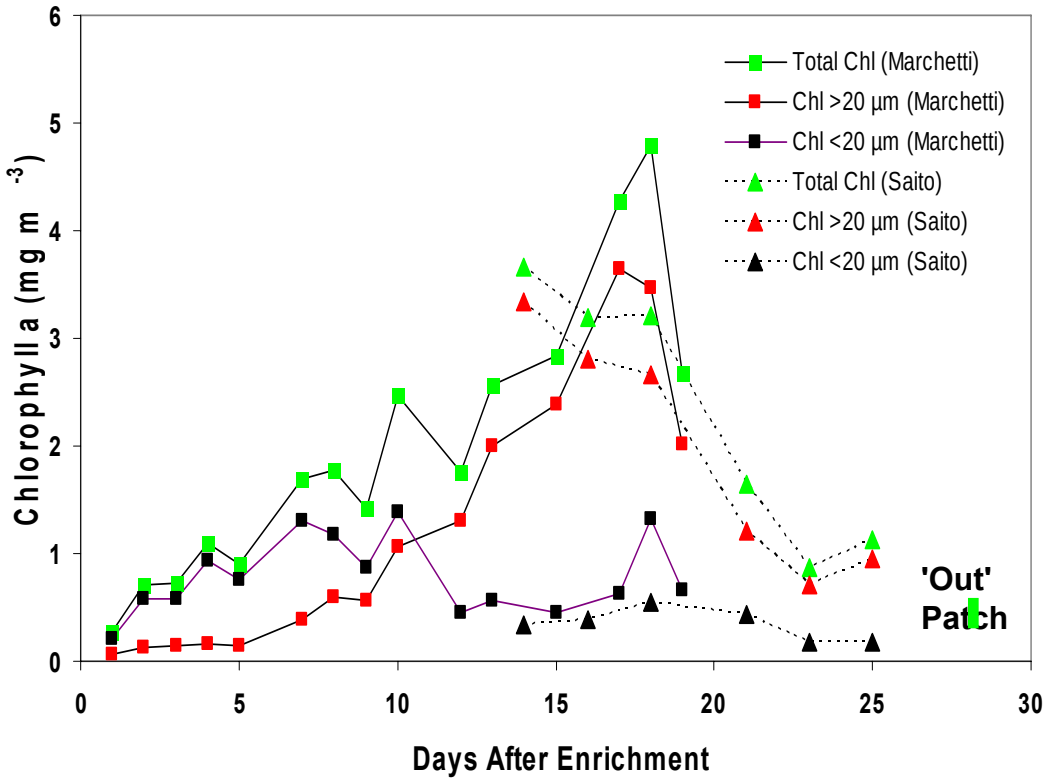
solas
surface.ocean lower.atmosphere.study

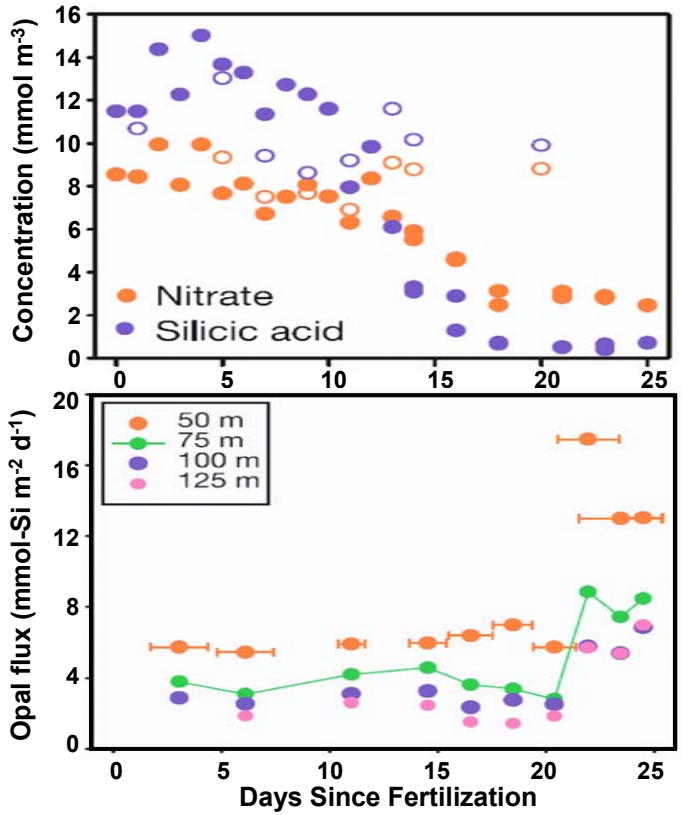
SERIES 2002:

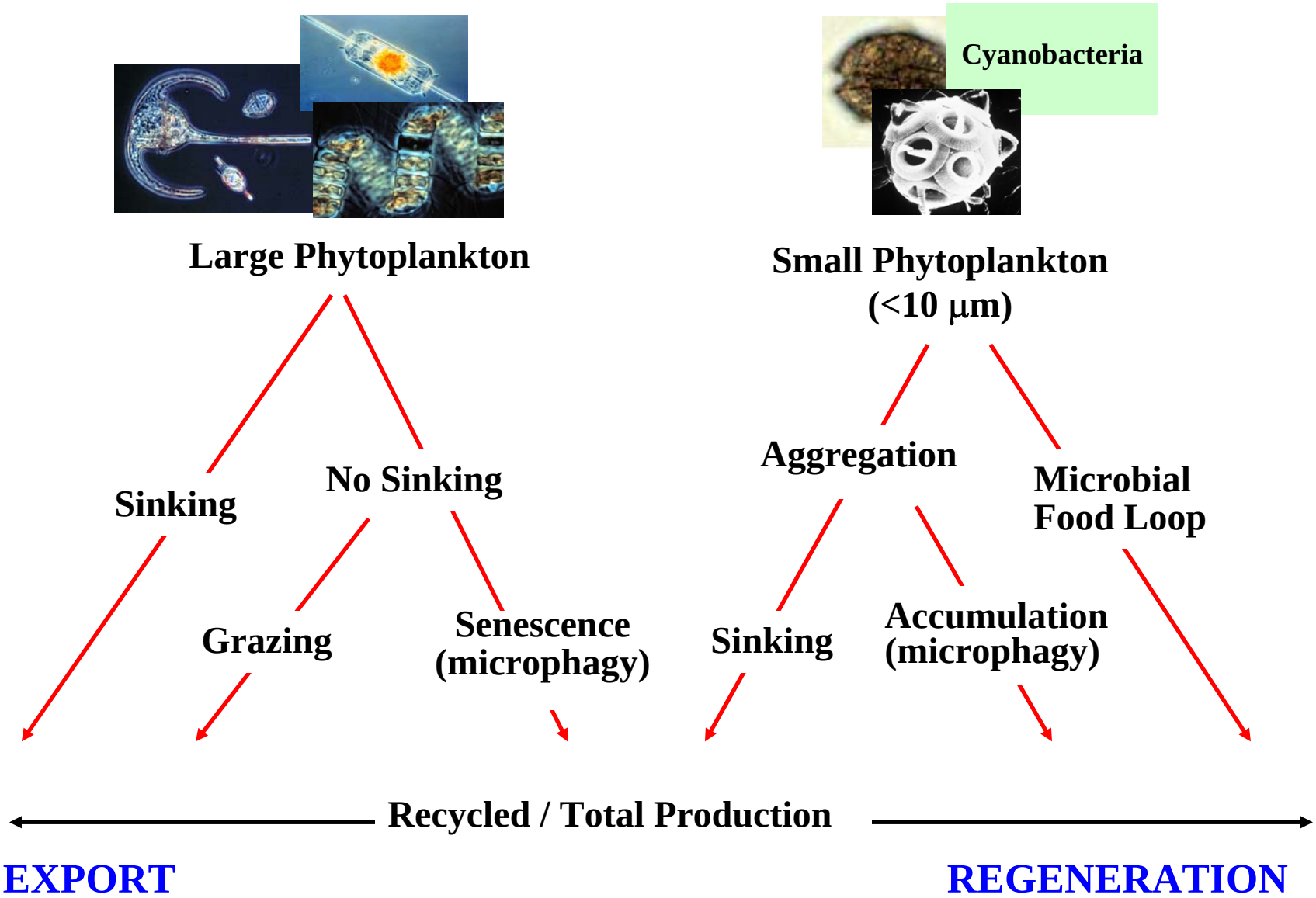
Subarctic Ecosystem Response to Iron Enrichment Study from SeaWiFS Satellite



SERIES 2002

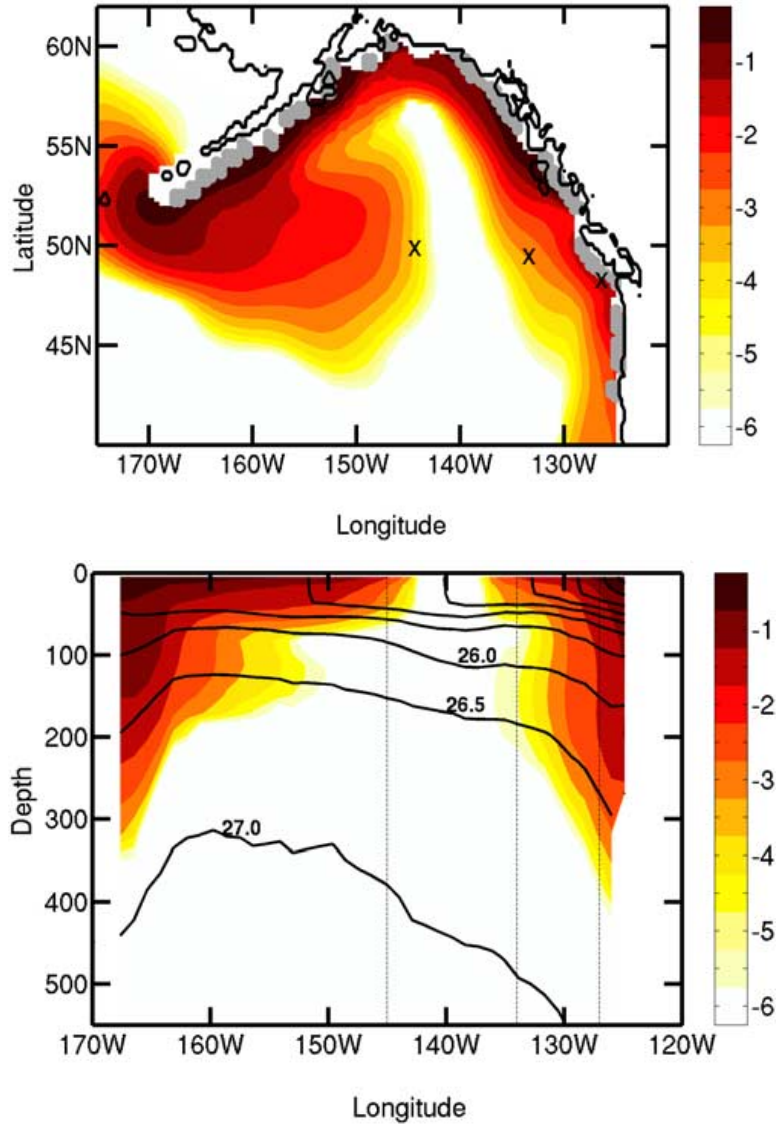

Total Chl (Marchetti)
Chl >20 µm (Marchetti)
Chl <20 µm (Marchetti)
Total Chl (Saito)
Chl >20 µm (Saito)
Chl <20 µm (Saito)
'Out' Patch
Chlorophyll a (mg m -3)
Days After Enrichment


Concentration (mmol m-3)
Nitrate
Silicic acid
Opal flux (mmol-Si m-2 d-1)
50 m
75 m
100 m
125 m
Days Since Fertilization



(Modified from Legendre and Fèvre, 1989)

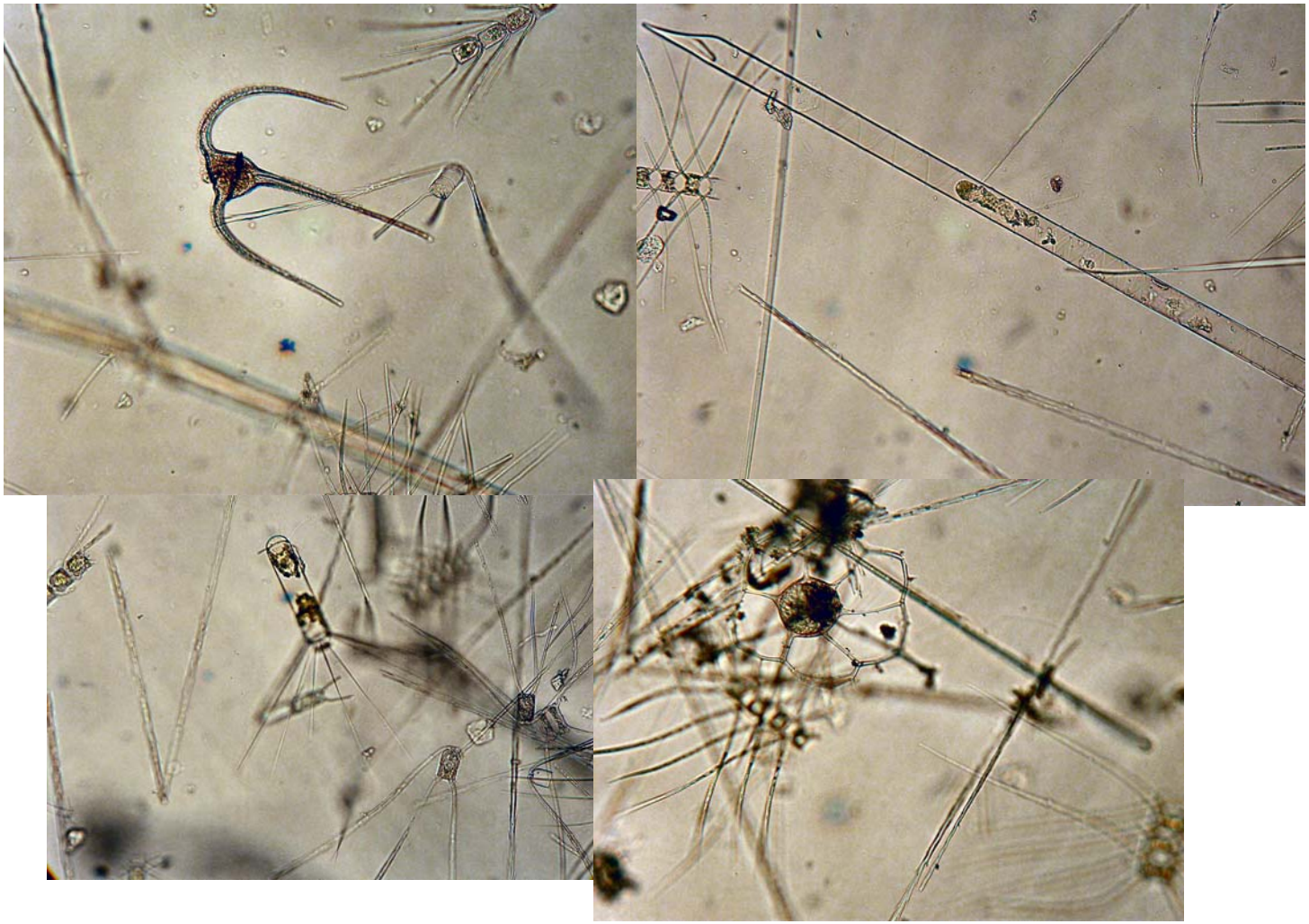
Natural Fe input



- February 1996 – hightened biological activity
- Lateral suppy of particulate iron from the continental margin off the Auletian Islands in the winter

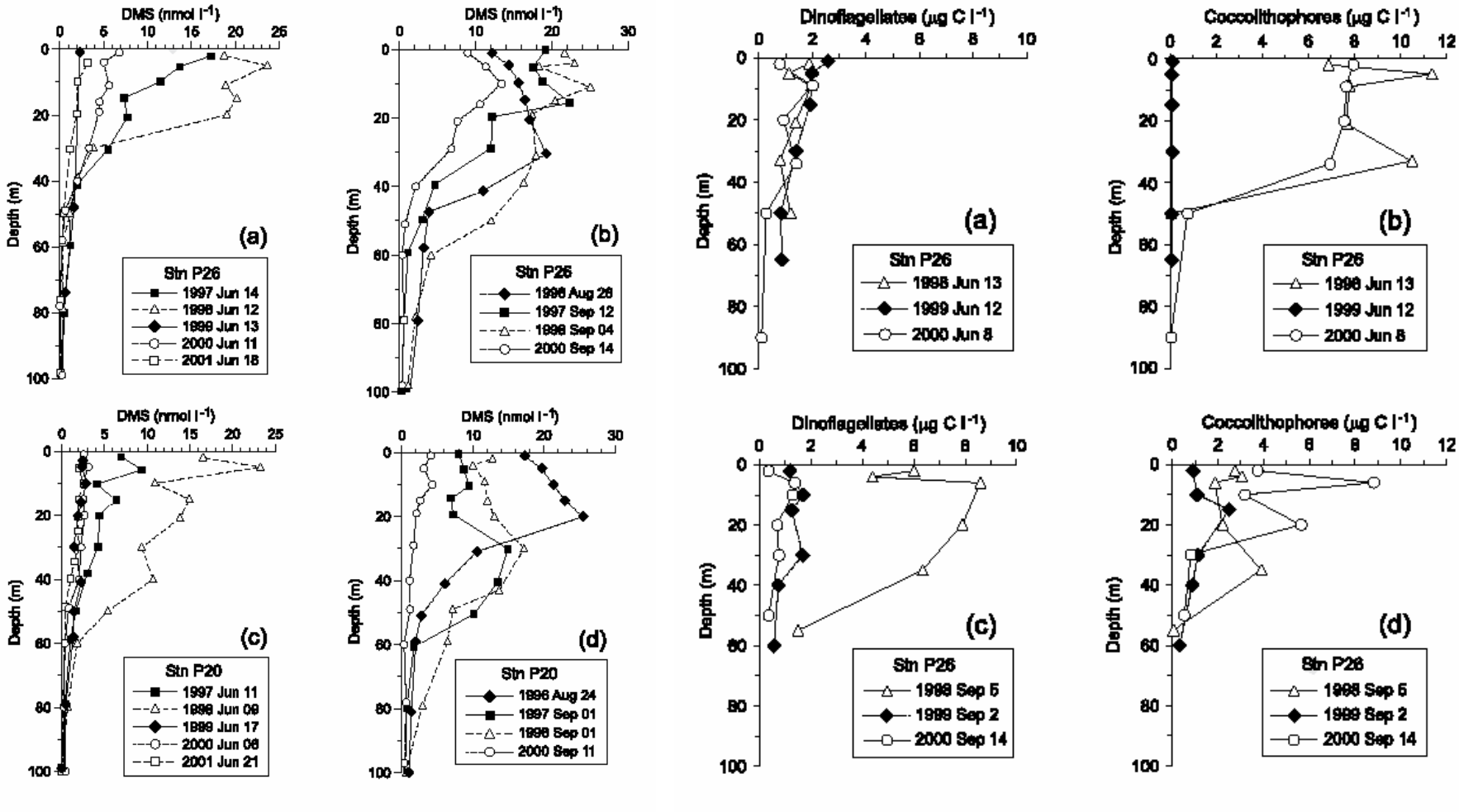
Lam et al., 2006

OSP – February 2006



Courtesy of Moira Galbrait

Phytoplankton composition – DMS production



Wong et al., in press

Summary

- Iron limits phytoplankton production in the HNLC region of the NE Pacific
- Most of the production is regenerated production
- Phytoplankton biomass and production along Line-P is dominated by small phytoplankton (<20 μm)
- Low seasonal variability along Line-P except at the most coastal station
- Most of the temporal variability in phytoplankton biomass and composition at the oceanic stations are event scale

Need more study ….

- What controls phytoplankton composition along Line-P?
- How often there are natural iron input in HNLC region and what are the effects on the ecosystem?
- Light limitation on primary production and Co-limitation of light and iron
- Importance of interannual, ENSO, and lower frequency variability on biogeochemical cycles along Line-P