Phytoplankton and Upper Ocean Biogeochemical Cycles Along Line P

Angelica Peña
Institute of Ocean Sciences, Fisheries & Oceans Canada.

Contribution: Diana Varela, Department of Biology & School of Earth and Ocean Sciences, University of Victoria
Biogeochemical Cycles

Atmosphere

Advection / Mixing

Nutrients

Biogeochemical Sinking Particles

Remineralization

C  N  P  Si  O

Biological Pump
Sampling Stations – Line P

Northeast Pacific Ocean

50° N, 145° W
4250m

48° 39' N, 126° 40' W
1300m

48° 34.5' N, 125.5° W
120m
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

Chlorophyll

Nutrients

Time

Longitude (W)
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
\[\text{NO}_3 \text{ Minimum } \sim \frac{1}{2} \text{ Winter Maximum}\]

OSP: 1966–76 (0-20 m)

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$^{-3}$

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

(via Parslow, 1981)
Annual Cycle:

\[ \text{NO}_3^- \rightarrow \text{PP} \rightarrow \text{Mesozooplankton} \]

Primary productivity (0-50m)

Mesozooplankton wet weight


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

Water collected 6 August 1987

No Fe added → little Chl a increase, little NO₃ & PO₄ drawdown

5 nmol kg⁻¹ Fe added → large Chl a increase & NO₃, PO₄ drawdown

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

(Suzuki et al., 2002)

(Boyd et al., 1996)
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

\[ \Delta \text{SiO}_4 \text{ (March 31 – August 15)} \]

\[ \Delta \text{NO}_3 \text{ (March 31 – August 15)} \]

(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)
SERIES 2002:
Subarctic Ecosystem Response to Iron Enrichment Study from SeaWiFS Satellite
SERIES 2002

![Graphs showing chlorophyll and opal flux](image-url)
Large Phytoplankton

Sinking

Grazing

Senescence (microphagy)

No Sinking

Small Phytoplankton

(<10 μm)

Aggregation

Microbial Food Loop

Sinking

Accumulation (microphagy)

Recycled / Total Production

EXPORT

REGENERATION

(Modified from Legendre and Fèvre, 1989)
Natural Fe input

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

Lam et al., 2006
Phytoplankton composition – DMS production

Wong et al., in press
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