Increase of stratification and decreased primary productivity in the subarctic North Pacific

Frontier Research System for Global Change

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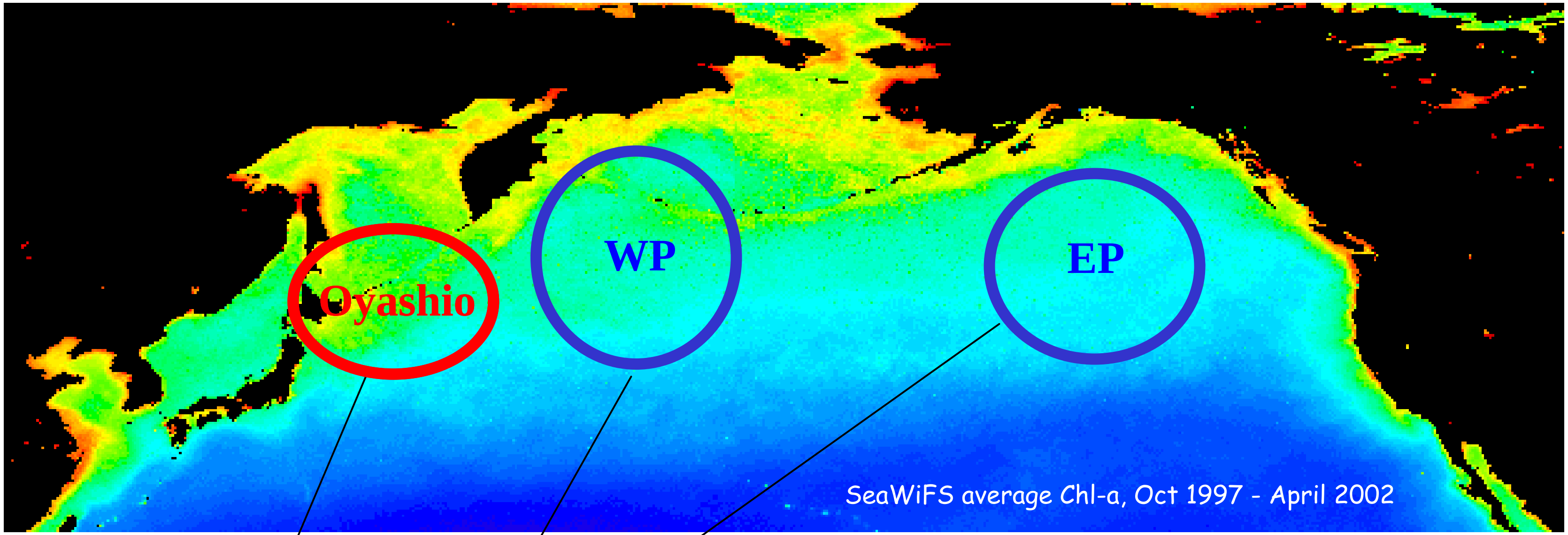
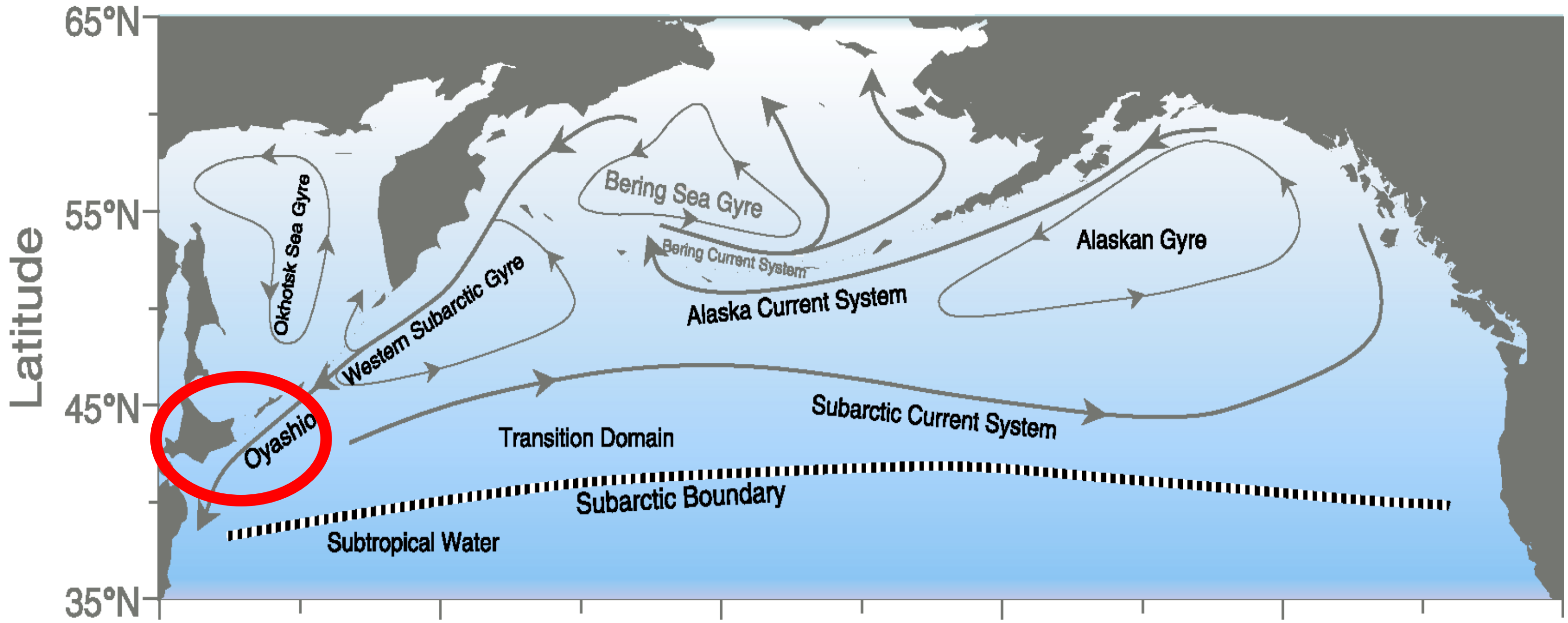


1: Oyashio

2: western and eastern subarctic

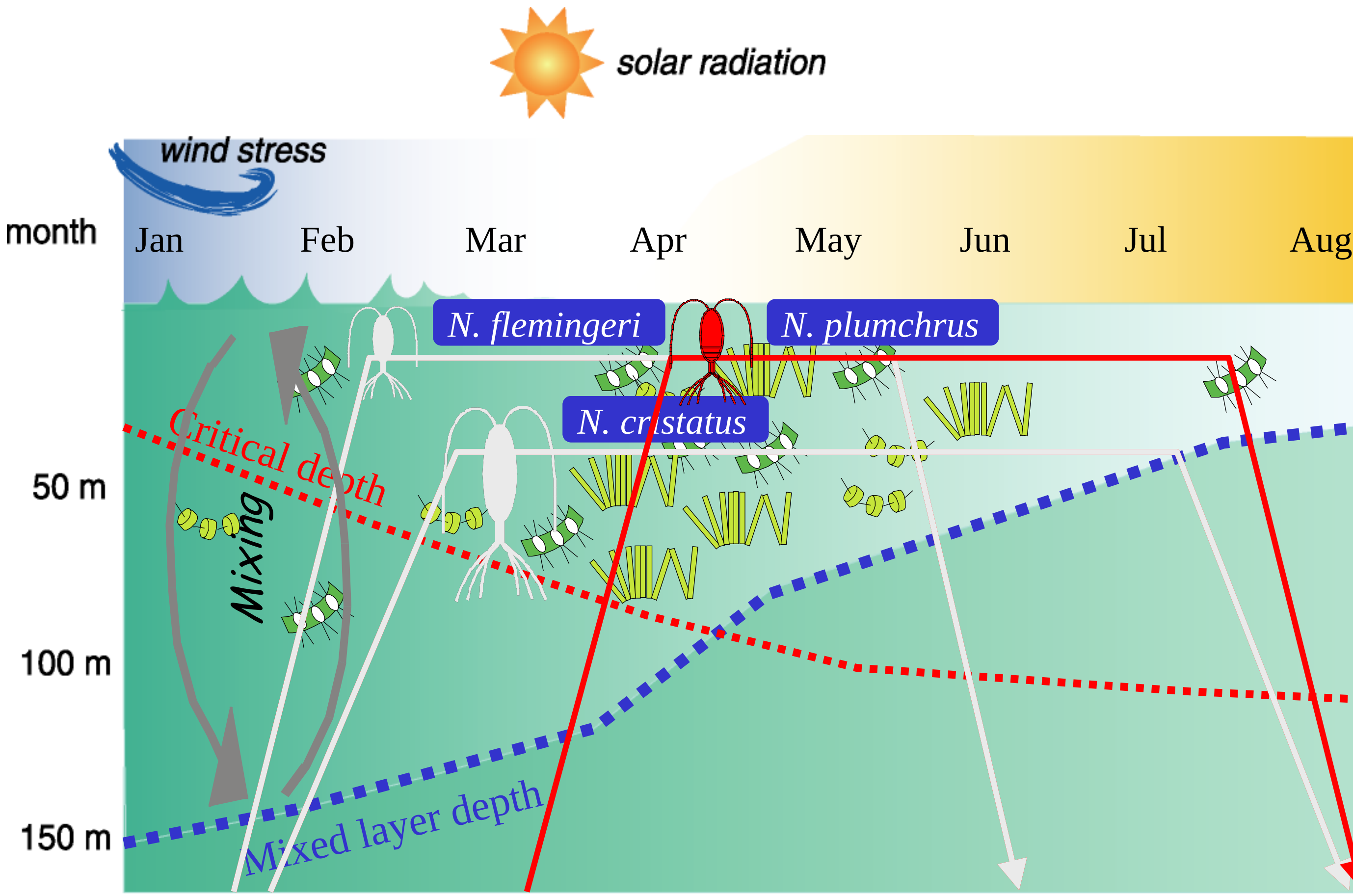
Feature of the Oyashio



Extensive spring bloom (PP>1000 mg C m^{-2} d^{-1})

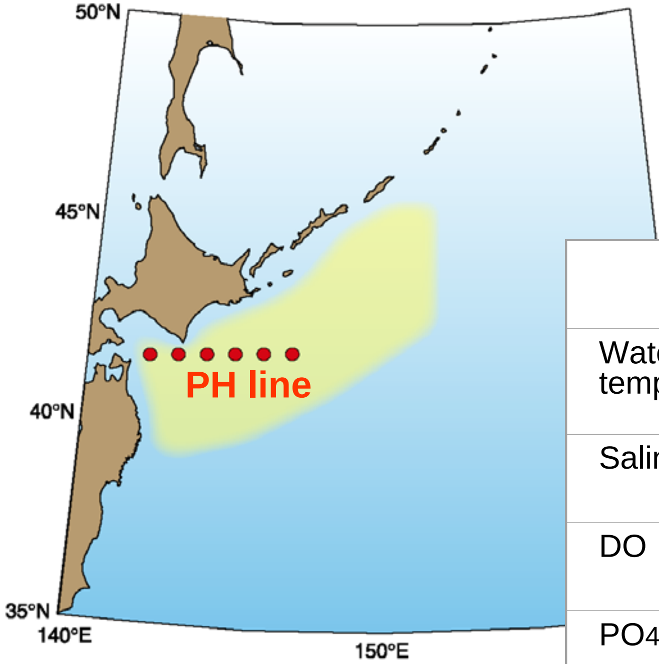
Deep mixing in winter (>150 m)

Physical/biological processes from winter to summer



Datasets

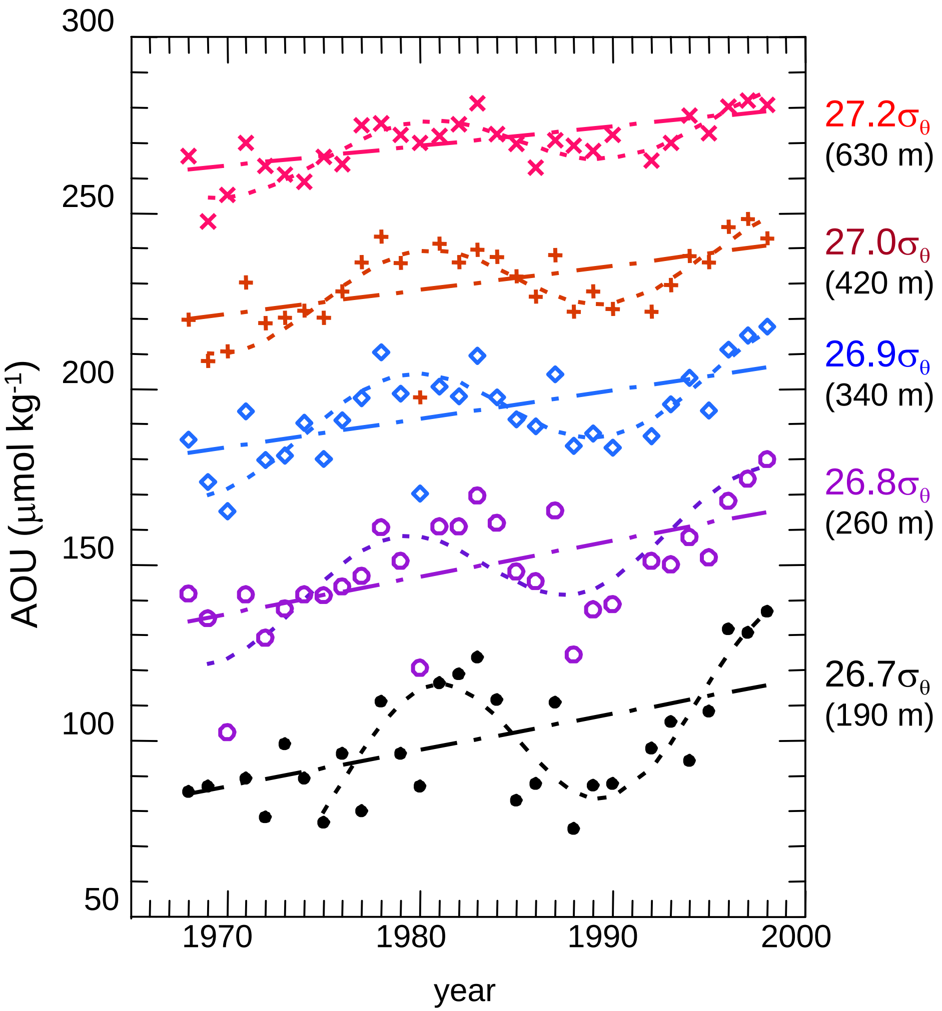
- Oyashio index: < 5℃ at 100 m
- Coastal data (<500m) were excluded.



	Period	Data source	Sampling method	analysis
Water temperature	1968-1998	Hakodate Marin Observatory (JMA), JODC	Reversing thermometer or CTD	
Salinity	1968-1998	- do.-	Nansen cast or CTD	
DO	1968-1998	- do.-	Nansen cast or Niskin bottle	Carpenter (1995)
PO_4	1968-1998	- do.-	- do.-	Murphy & Riley (1961)
Chl *a*	1972-1998	- do.-	- do.-	
Diatom composition	1972-1998	PM line dataset by Hakodate Marine Observatory (JMA).	Surface water sampling	
Zooplankton biomass	1972-1998	- do.-	0-150 m vertical haul of a NORPAC net (mesh: 330µm)	
Zooplankton composition	1981-1999	- do.-	- do.-	

Results : Physical Environments

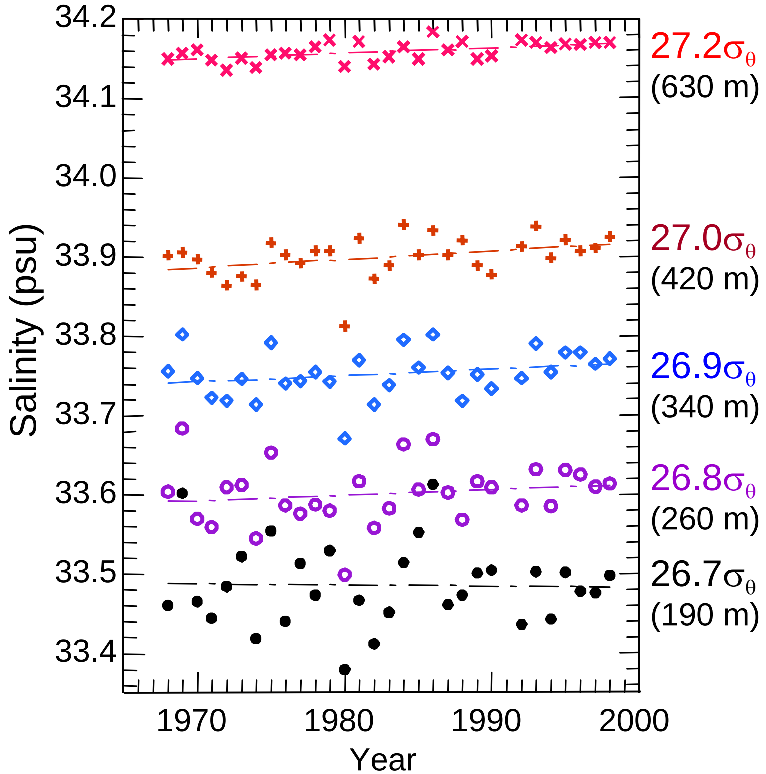
Subsurface Apparent Oxygen Utitization (AOU) in Winter



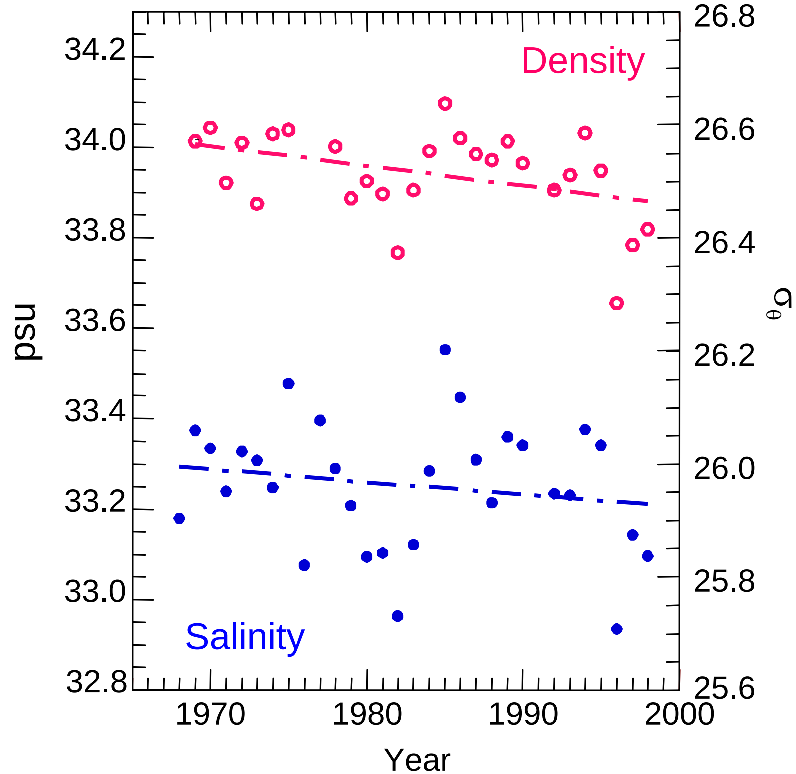
(Ono et al. 2001)

Results : Physical Environments in winter

Subsurface salinity



Surface salinity and density



Density = -0.0035 y + 33.41

Salinity = -0.0028 y + 38.73

(Ono et al. 2001)

Results: Physical Environments

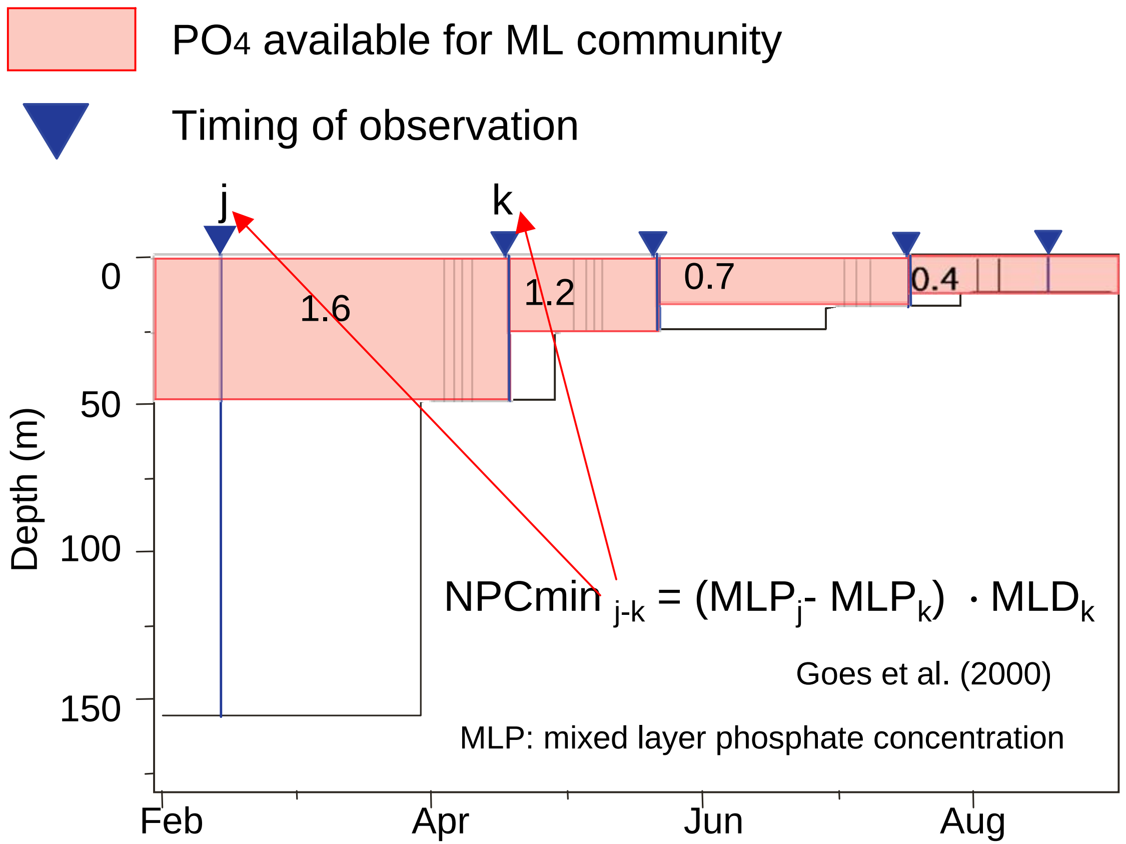
Summary: change in the water column property in winter

	Salinity	density	AOU
surface	-	-	
subsurface	+		+

These all suggest stratification increase

Results: Biological Process

Estimation of Net Community Production (NCP) from
ML Phosphate decrease (consumption) from February to August



$$NPCmin_{j\text{-}k} = (MLP_j - MLP_k) \cdot MLD_k$$

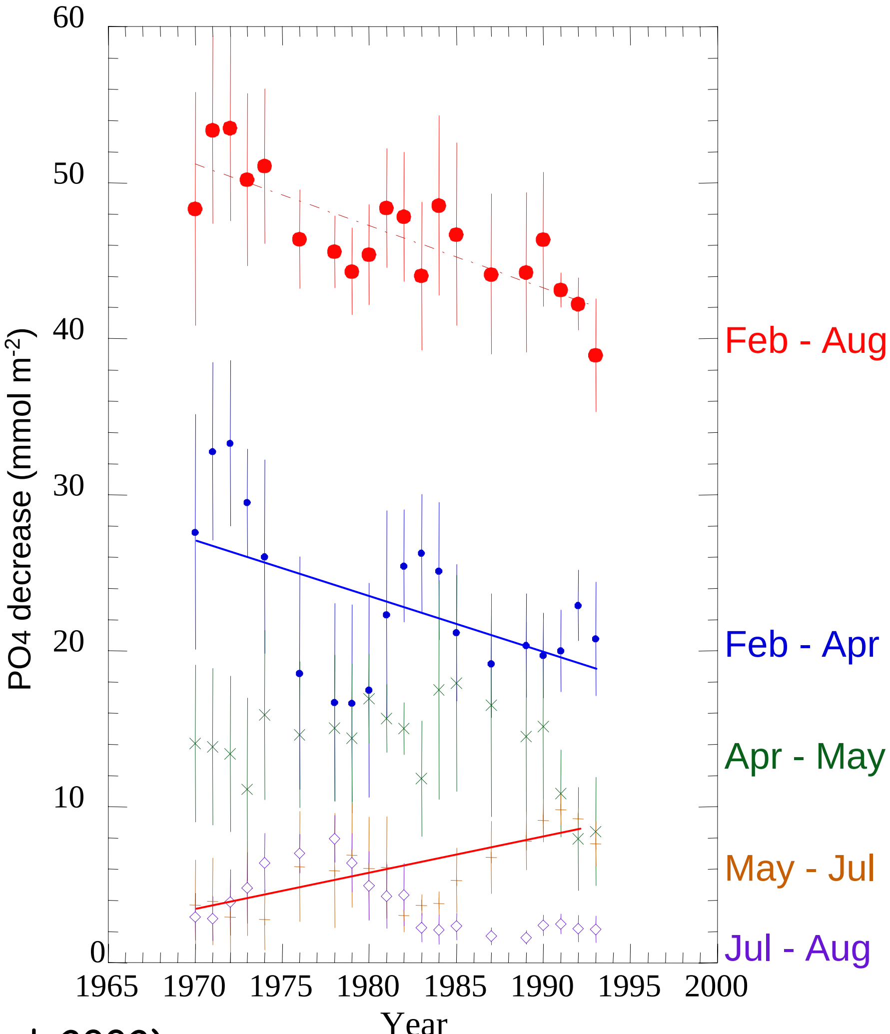
Goes et al. (2000)

MLP: mixed layer phosphate concentration

→ NCPmin

Results: Biological Process

Minimum Net Community Production (NCPmin)
= consumption of MLPO4 inventory



ΔPO_4 (Feb – Aug)
= -0.40 ± 0.07 mmol m^{-2} y^{-1}
(R^2 = 0.64)
= -0.51 ± 0.09 gC m^{-2} y^{-1}
with constant C/P ratio of 106

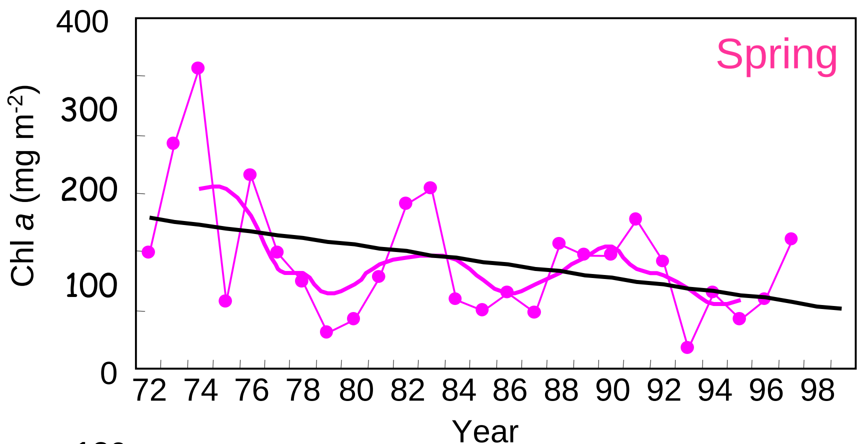
PO4: Not had depleted in April for 30 y.

Iron limitation ?

(Ono et al. 2002)

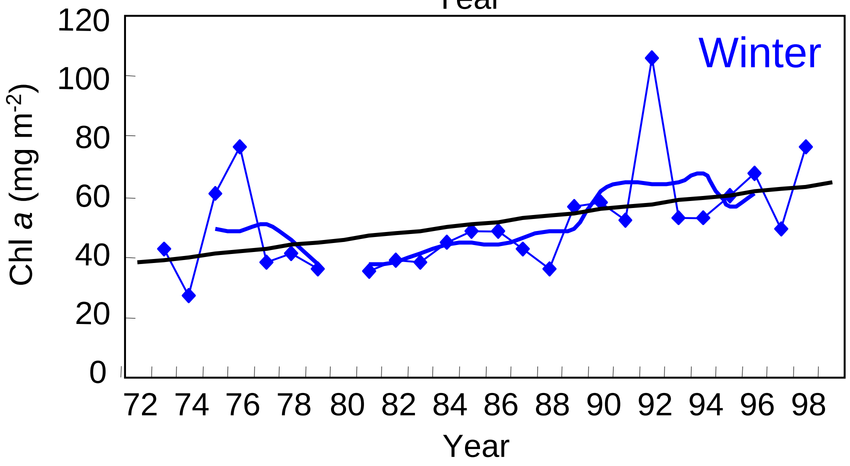
Results: Biological Process

Water column integrated Chl *a*



Chl *a* = -11.518 Y + 527.36

R^2 = 0.164   P=0.040

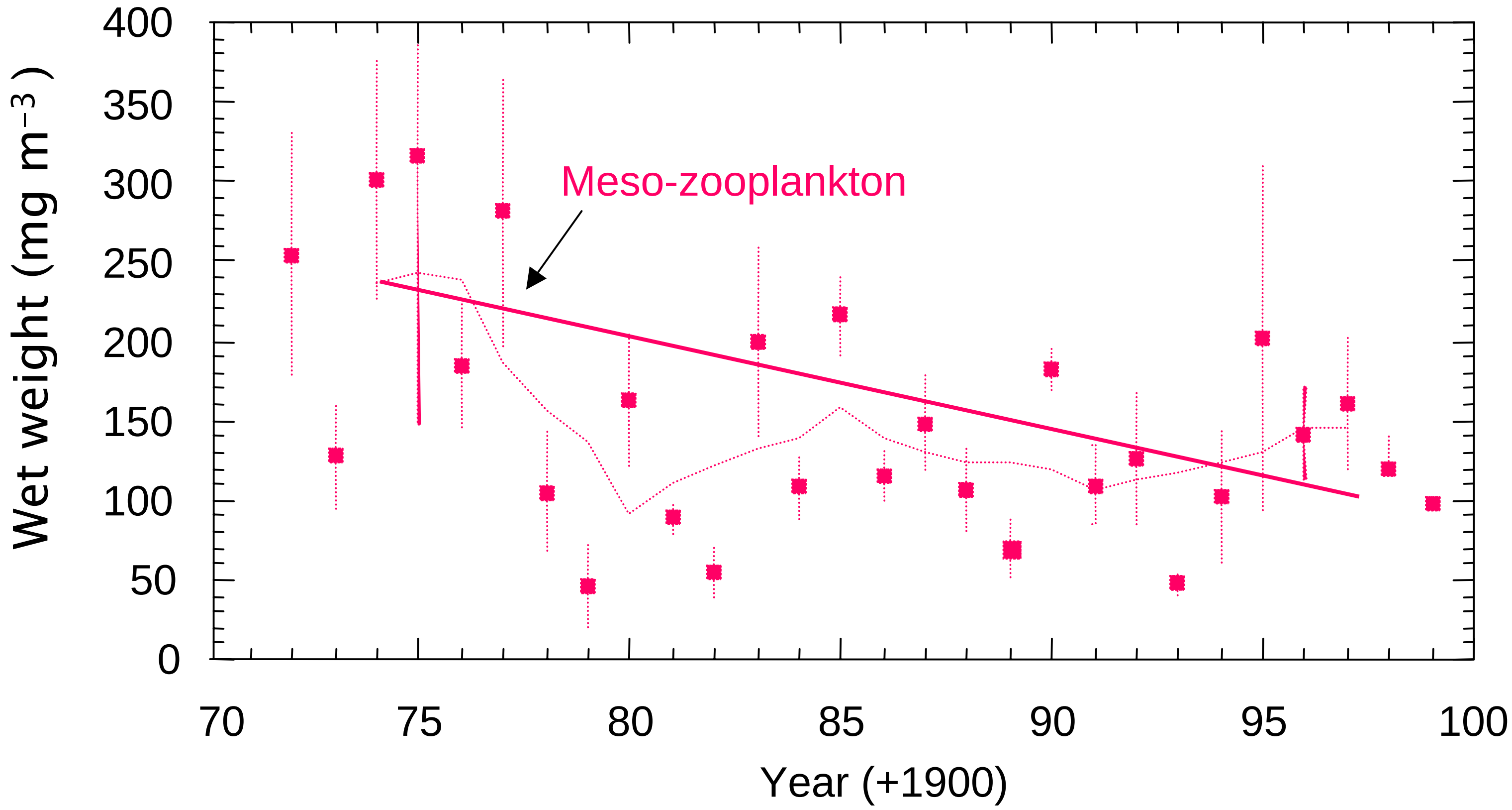


Chl *a* = 0.983 Y + 37.04

R^2 = 0.164   P=0.024

Results: Biological Process

Spring biomass of meso-zooplankton

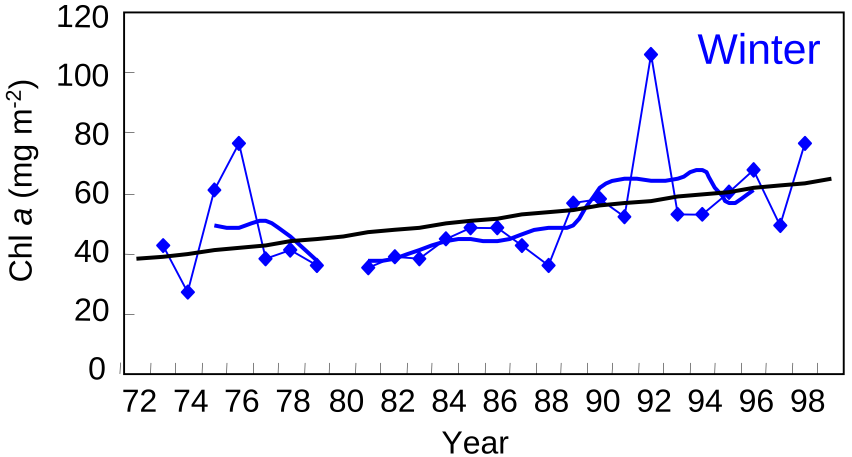


Results: Biological Process

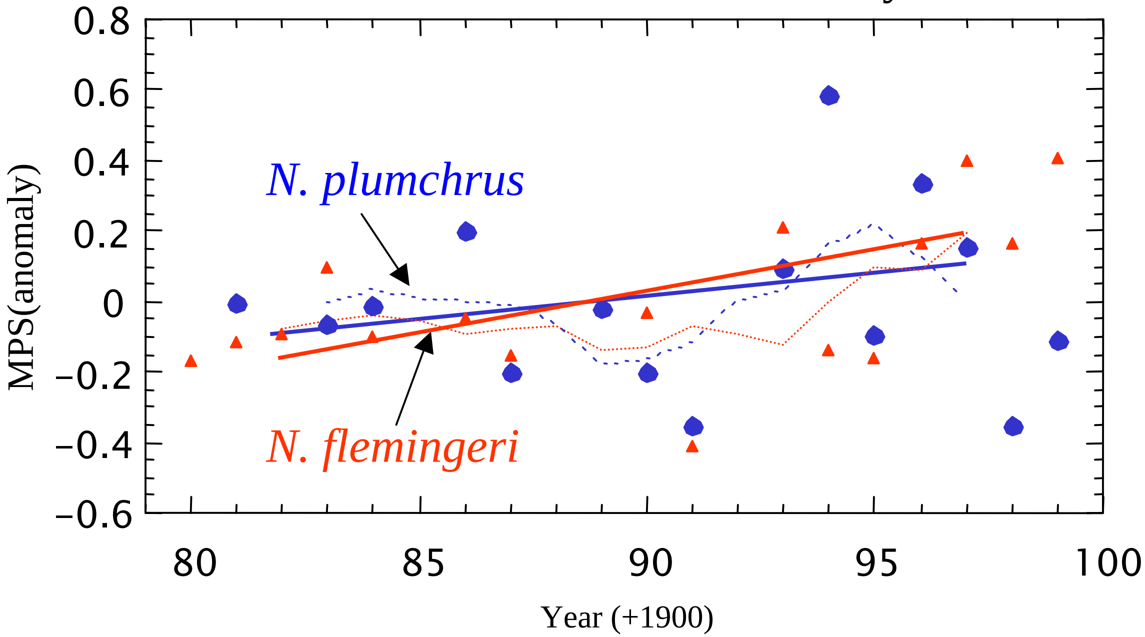
Developmental timing of *Neocalanus* copepods

MPS = mean population stage

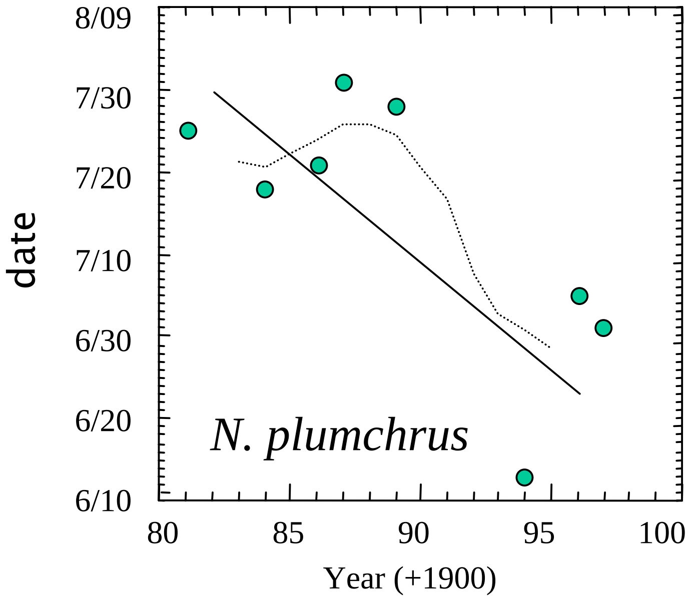
$$= \frac{(1*NCI+2*NCII+3*NCIII+4*CIVN+5*CVN)}{\text{total N}}$$



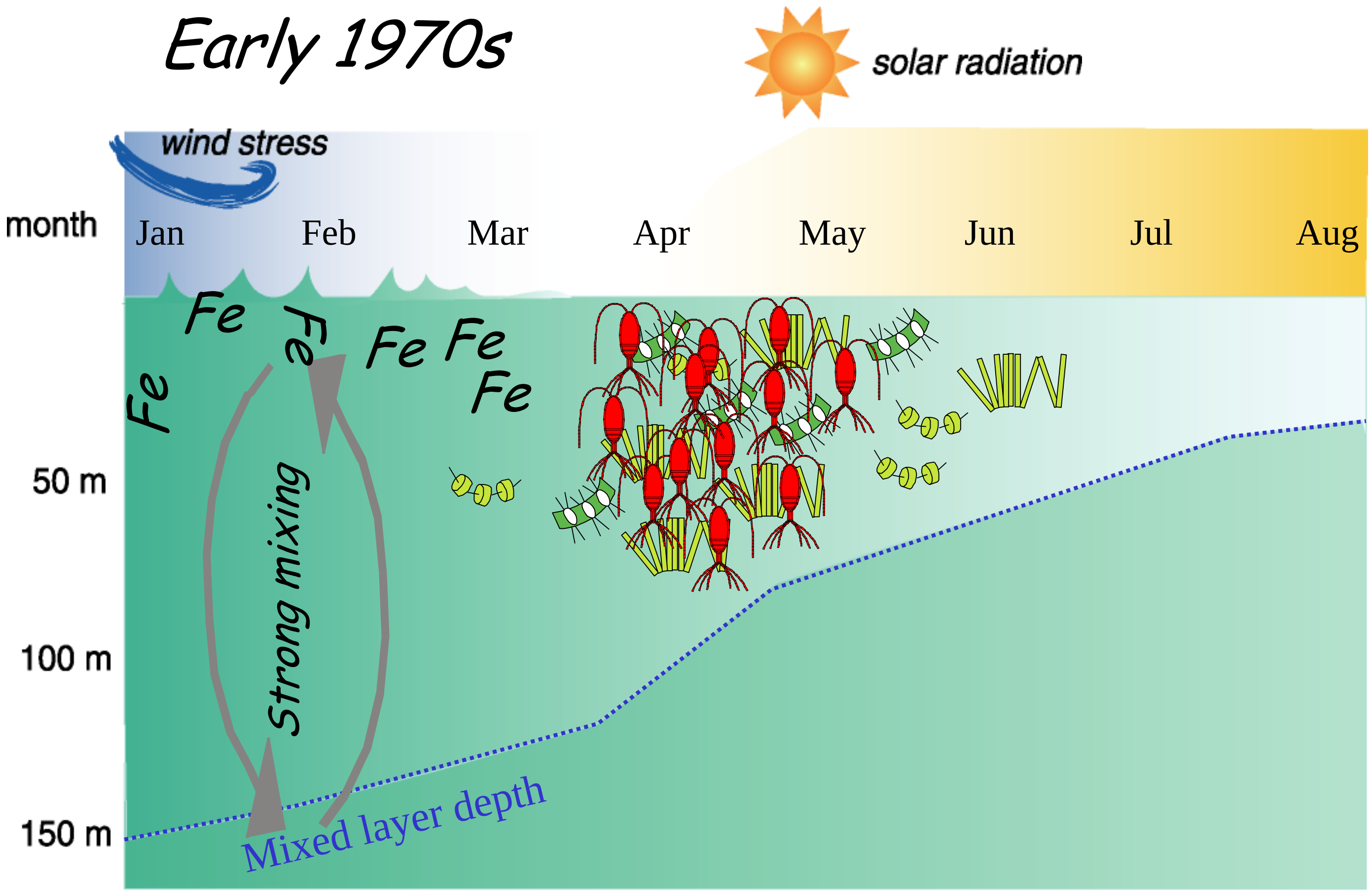
Interannual variation of MPS anomaly



Date when C5 copepdite made up 50% of copepodite population



Summary of the Oyashio



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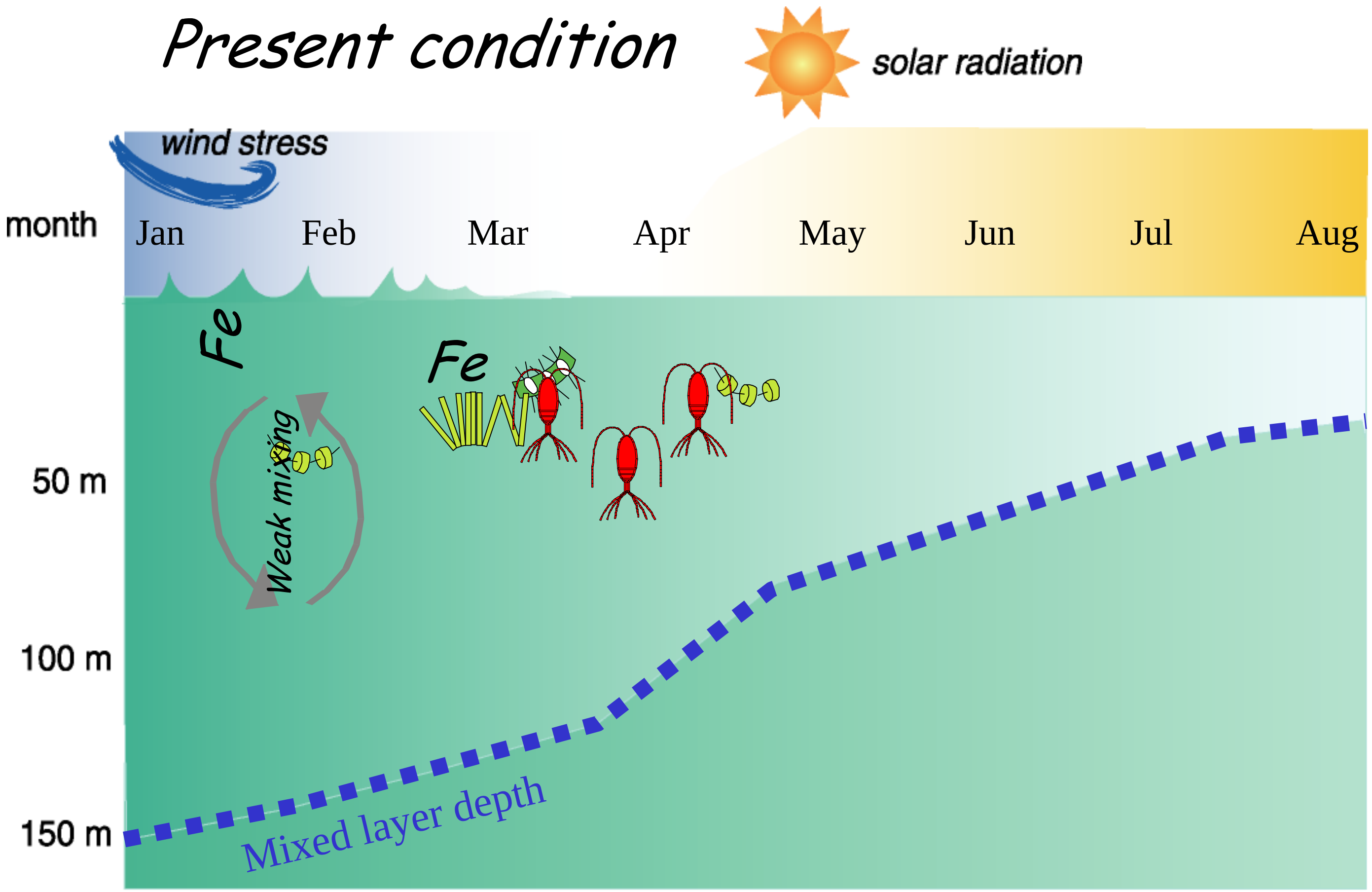
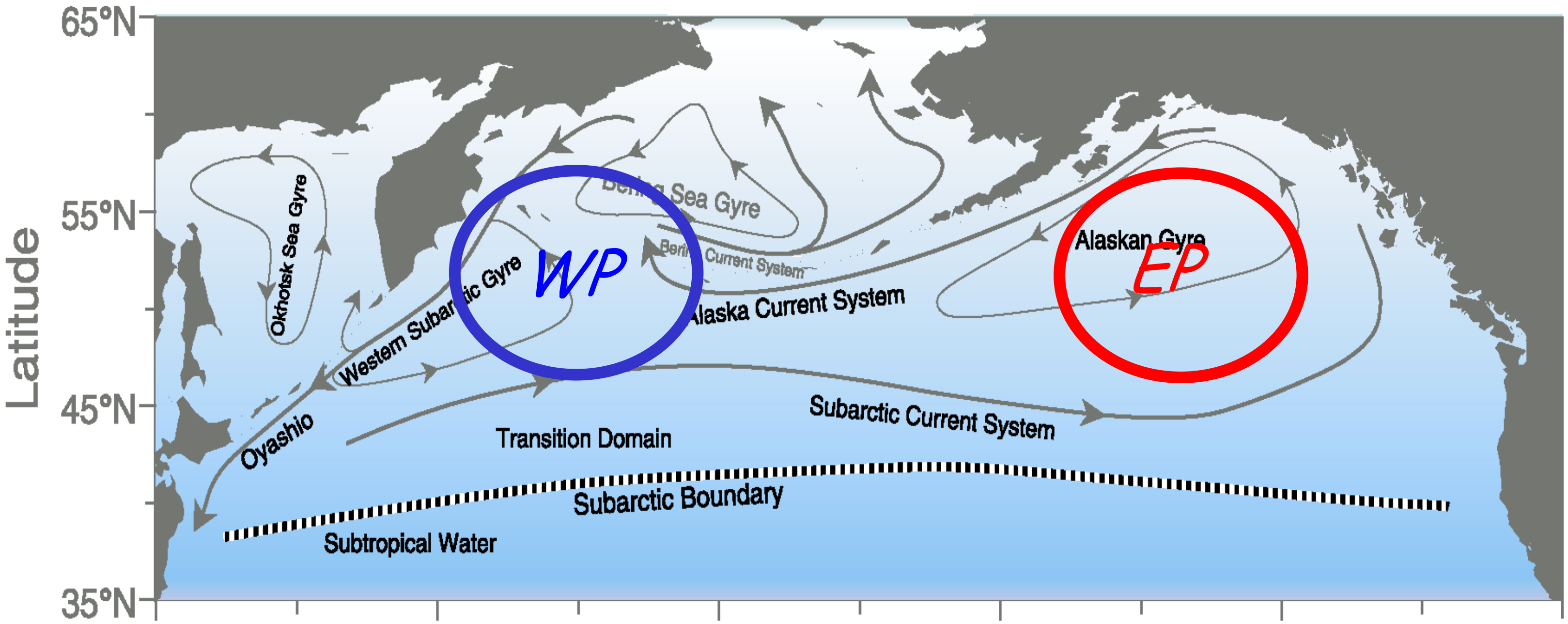
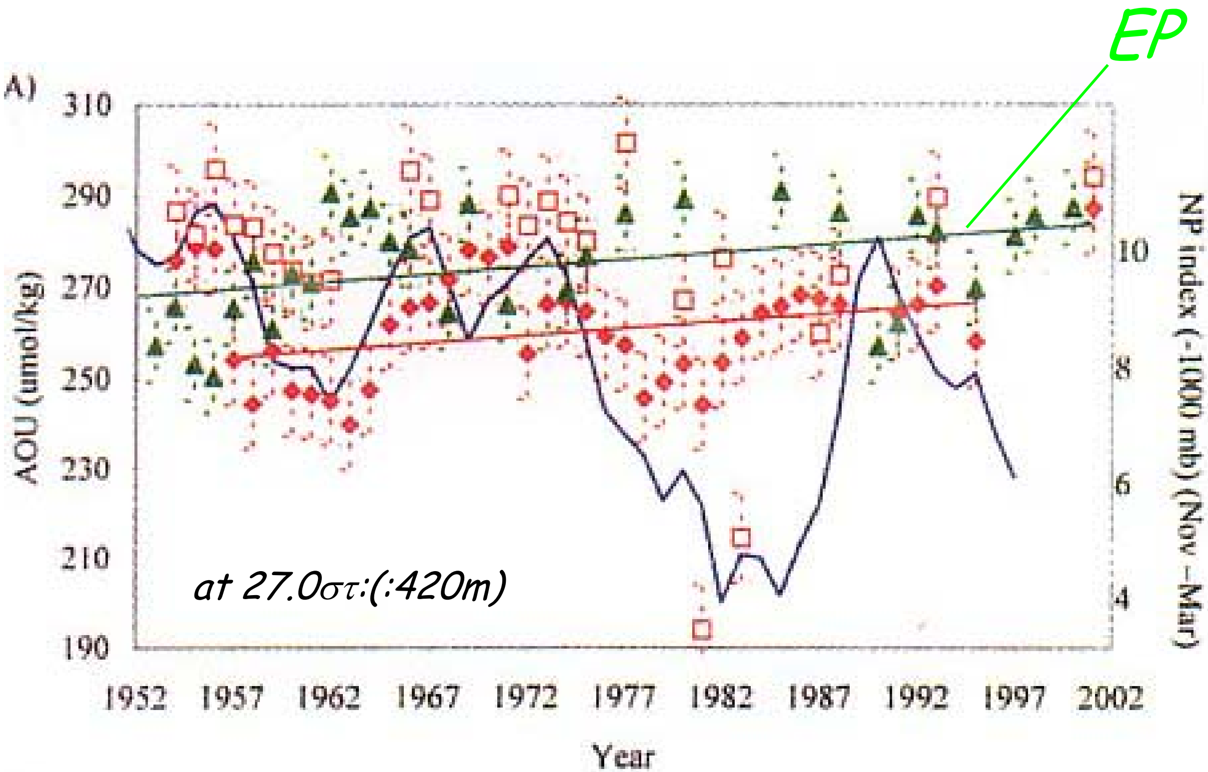


Eastern & Western subarctic



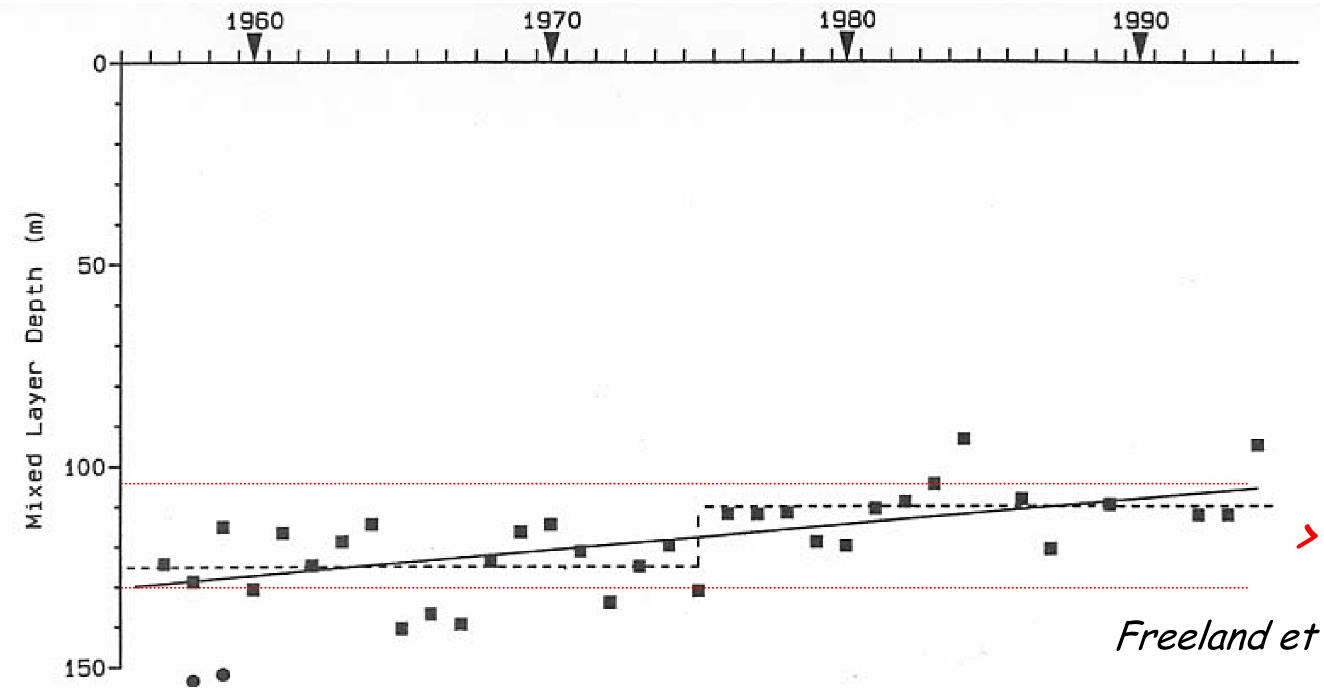
High Nutrients Low Chl-a area

EP:Subsurface AOU



Andreev & Watanabe (2002)

EP: Winter MLD



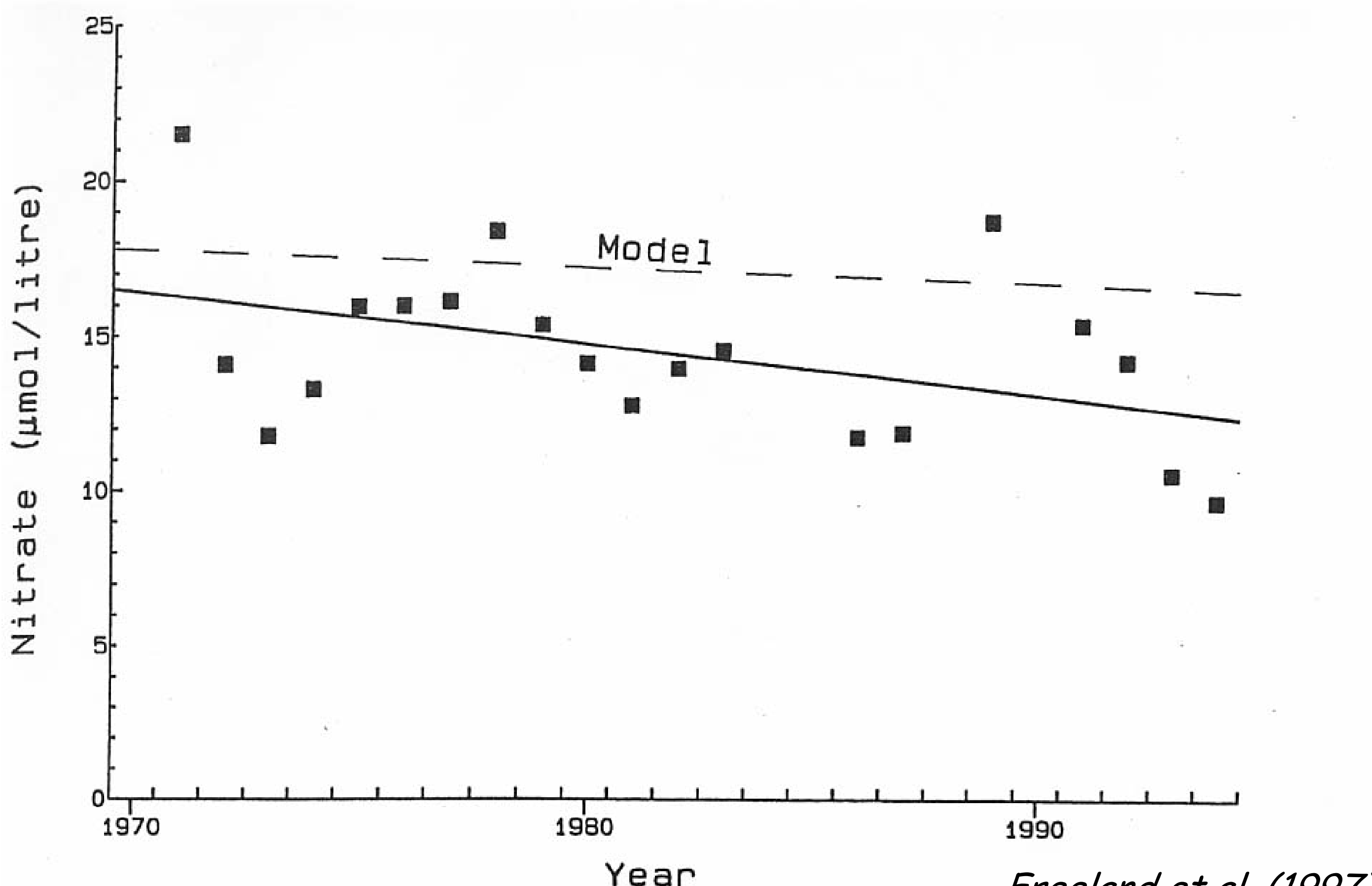
> 20m

Freeland et al. (1997)

MLD had ascended throughout 30 years

Surface layer: Temp +
Sal -

EP: Surface winter nitrate



Freeland et al. (1997)

Nitrate in ML had decreased for 30 years.

EP: NO_3 & SiO_4 consumption from winter to summer

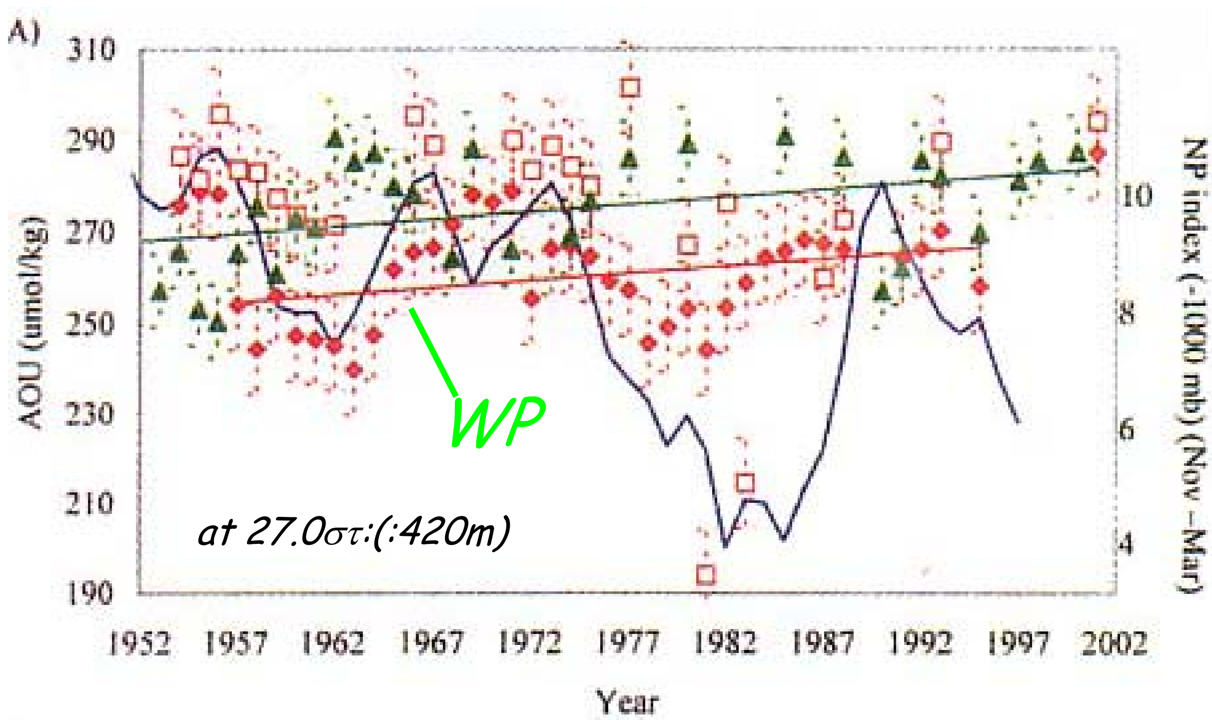
	1970s		1990s	70s-90s
NO_3	7.8μM	→	6.5μM	-1.3μM (-17%)
SiO_4	8.5μM	→	6.0μM	-2.5μM (-29%)

This imply decrease of primary production !

From Whitney et al. (1999)

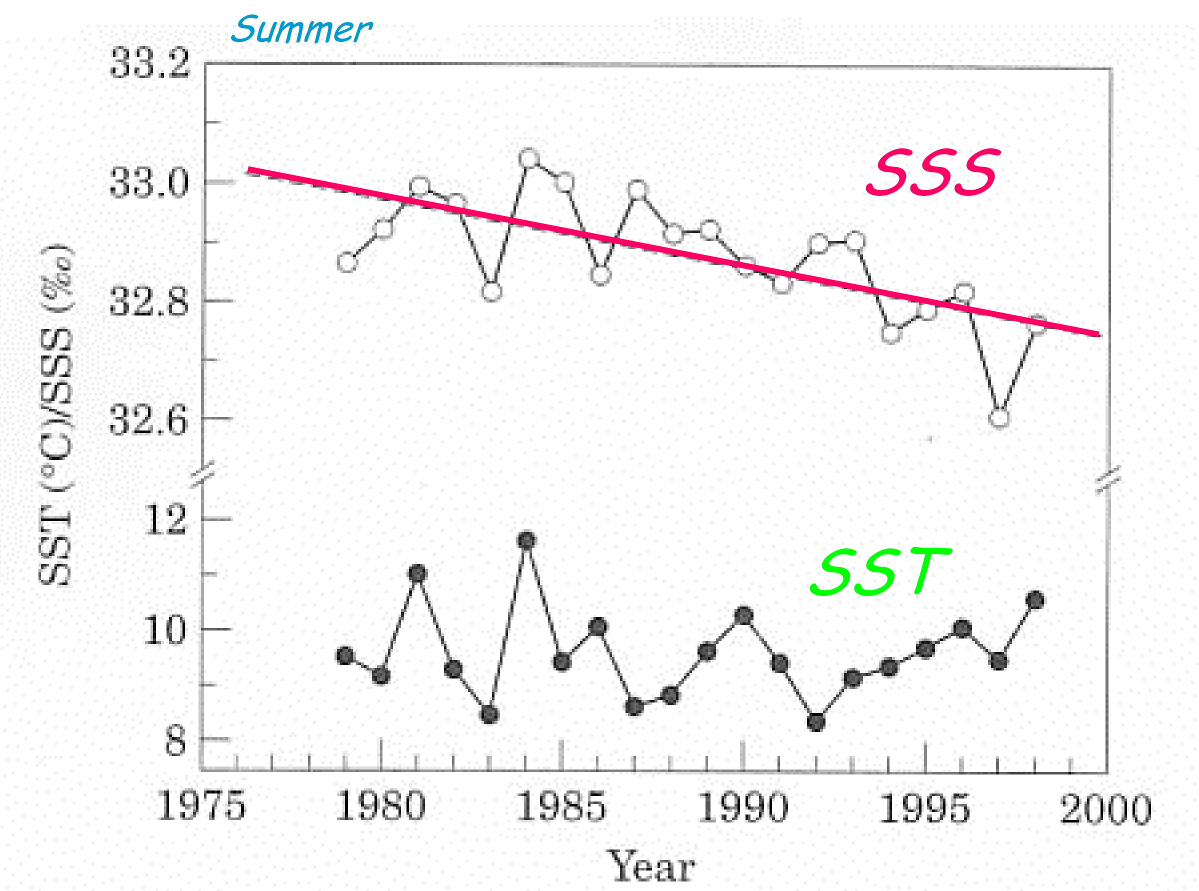
WP:Subsurface AOU

Andreev & Watanabe



Andreev & Watanabe (2002)

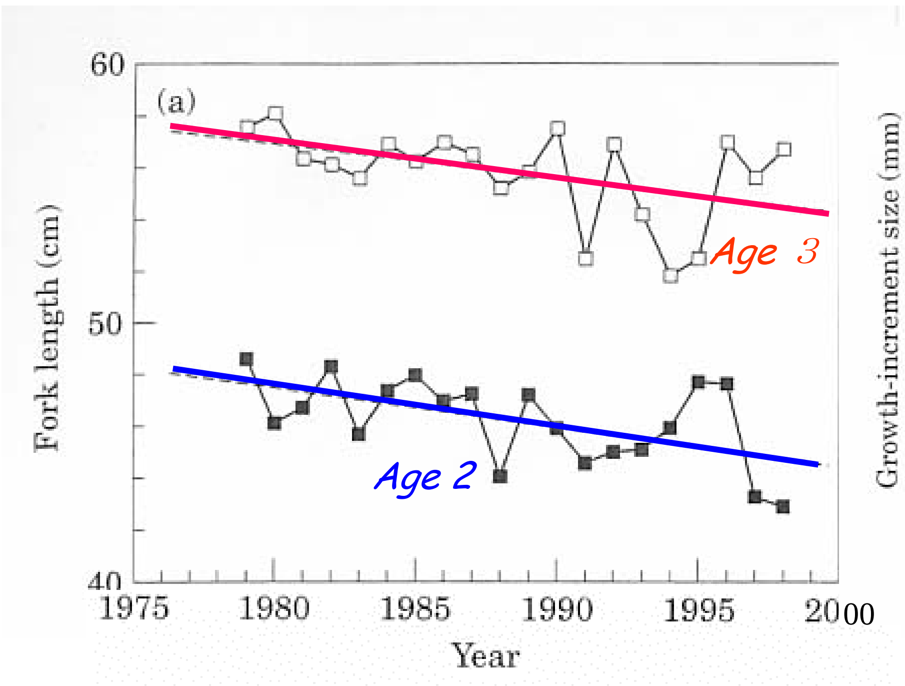
WP:surface Sal.

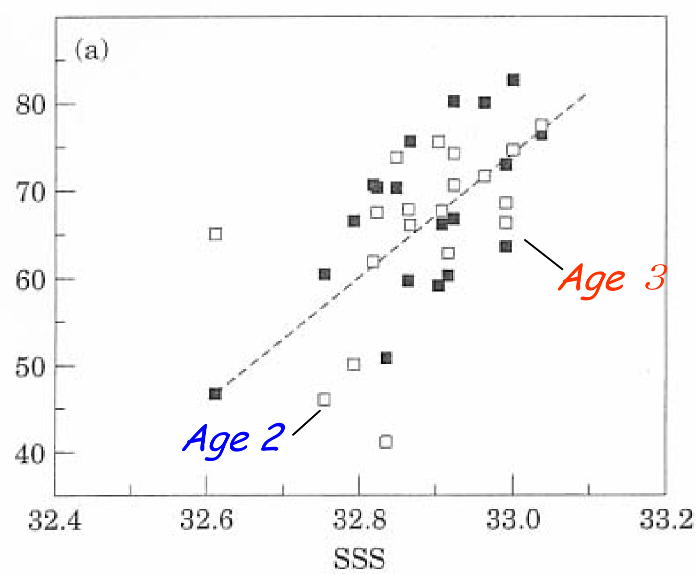


Morita et al.(2002)

SSS: decrease

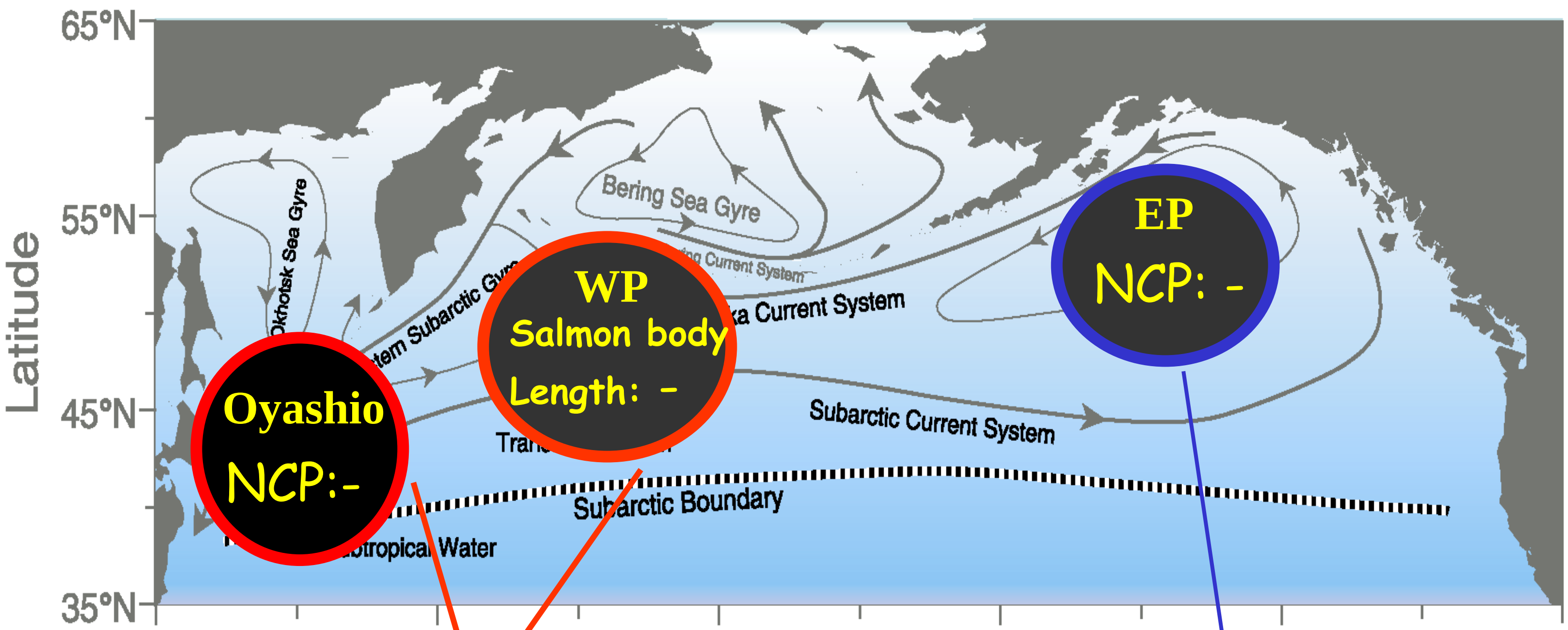
WP: body length of chum salmon





Morita et al.(2002)

Summary



Desalination

Desalination & warming

Cause of surface layer change ?

Global warming (Trend) ?

Regime shift (Oscillation) ?