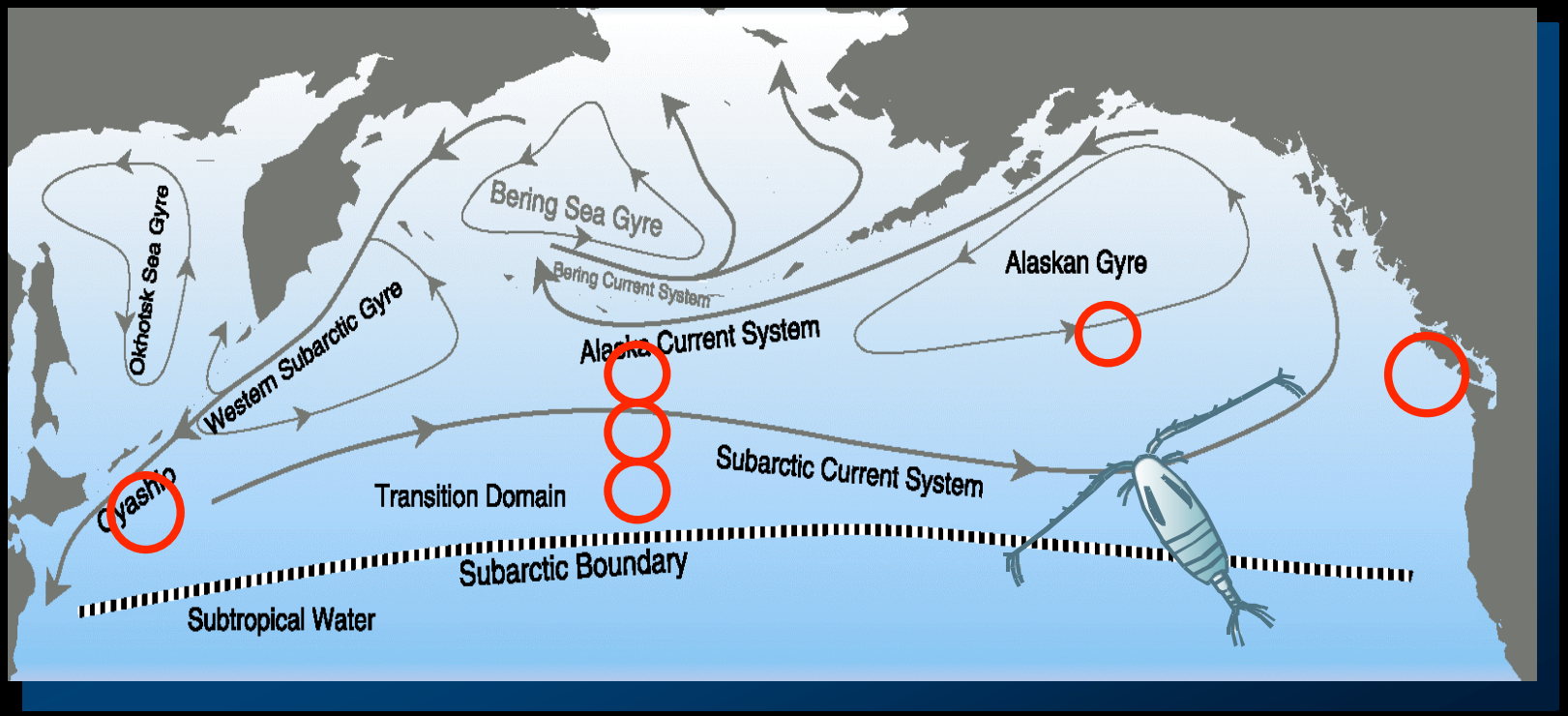
International Symposium, Effect of CC on the World Ocean, 2008 Gijon

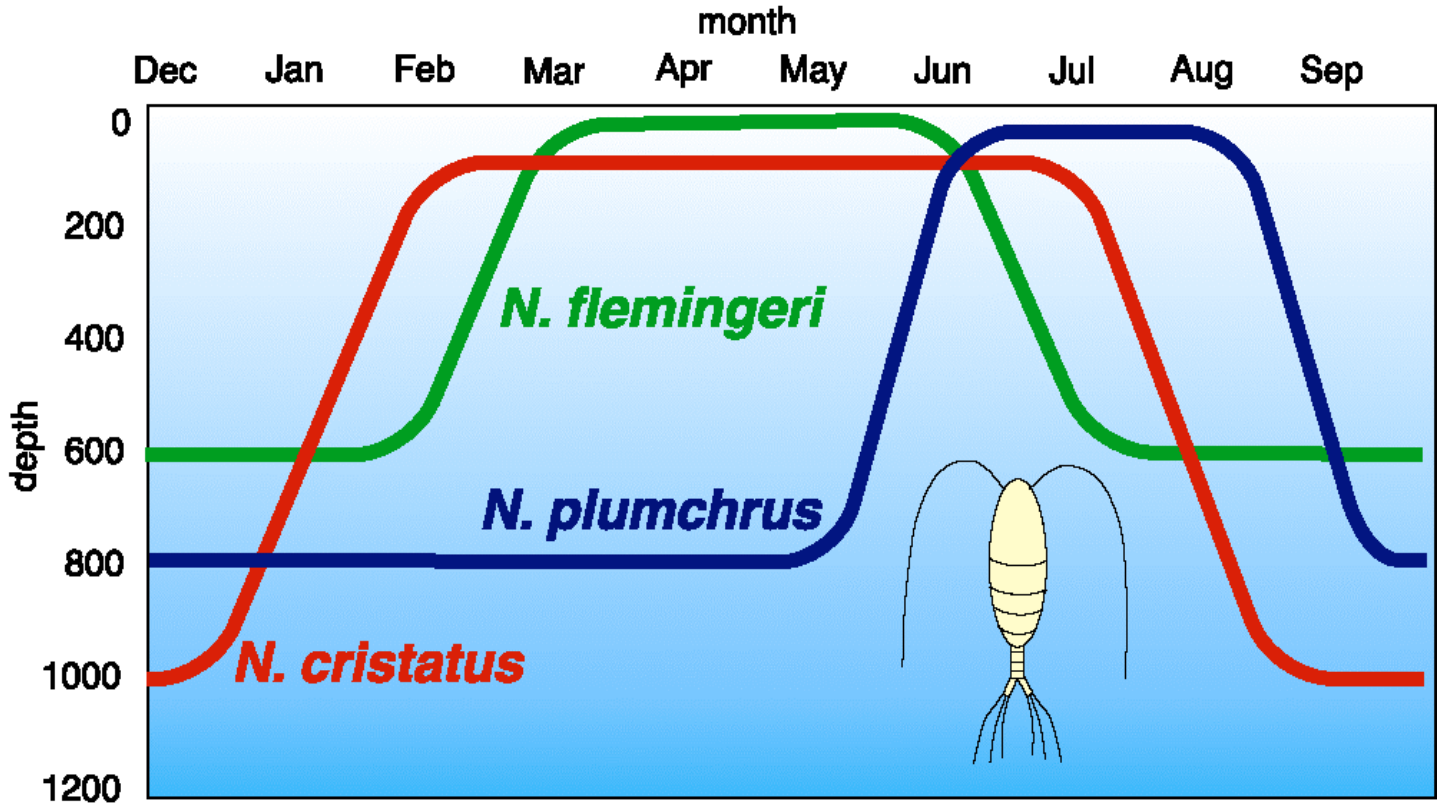
Workshop 1: Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels

Pan-North Pacific synthesis of long-term variation of *Neocalanus* spp. based on Stable Isotope analysis



Sanae Chiba, H. Sugisaki, K. Tadokoro, A. Kuwata, T. Kobari, A. Yamaguchi and D. L. Mackas

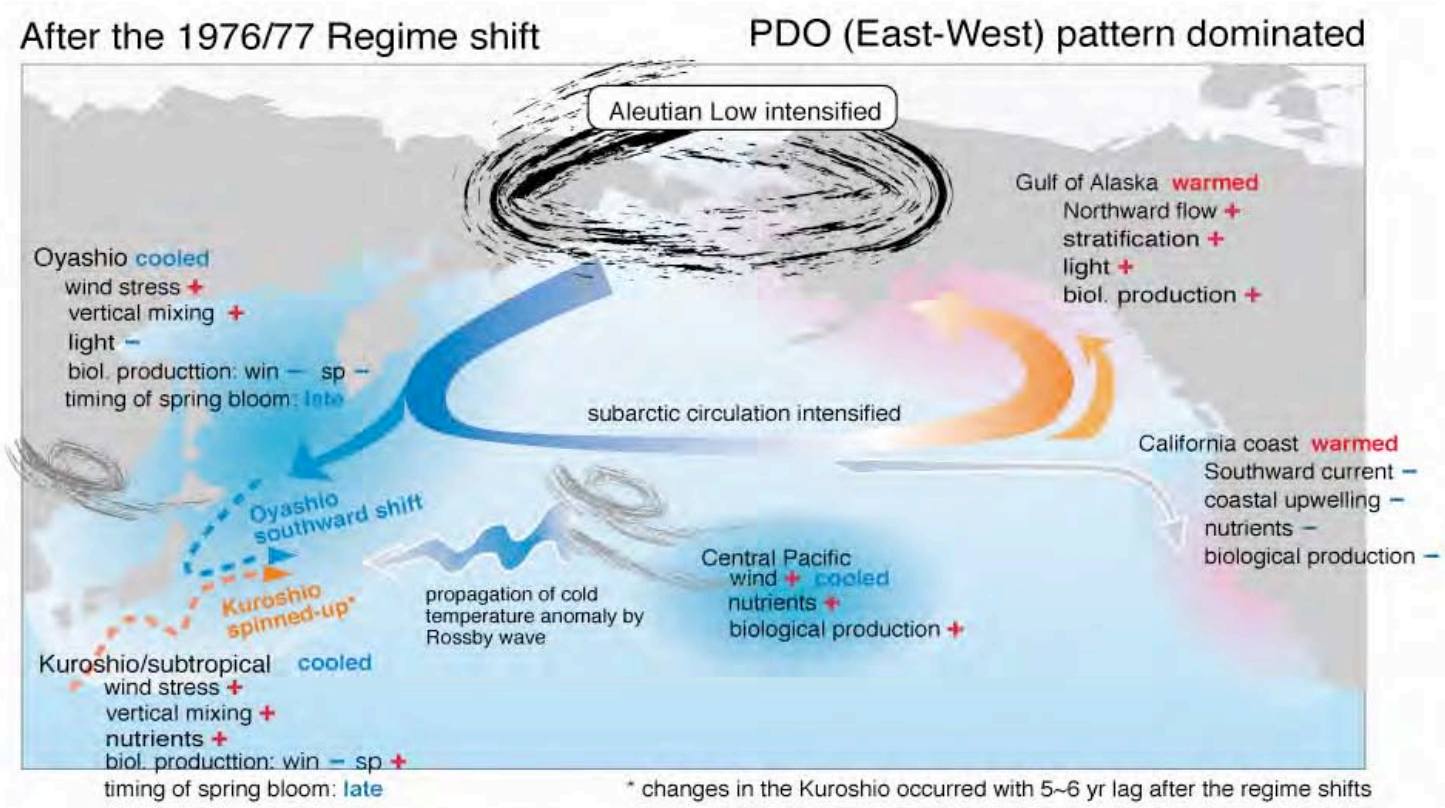
Neocalanus Copepods



Ontogenetic Migration

Goal

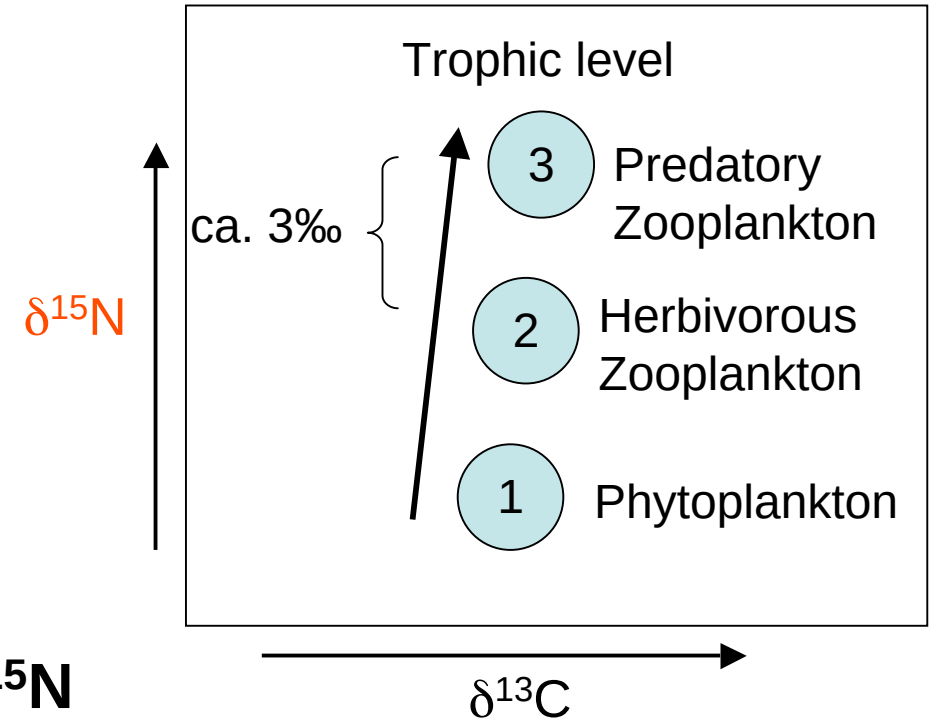
Detect regionally specific hydrograpihc & ecosystem responses to large scale climatic forcing, based on nitrogen stable isotopes of historically collected *Neocalanus* specimens



What Zooplankton Stable Isotope Tells

Fingerprint of the past environmental & ecosystem changes

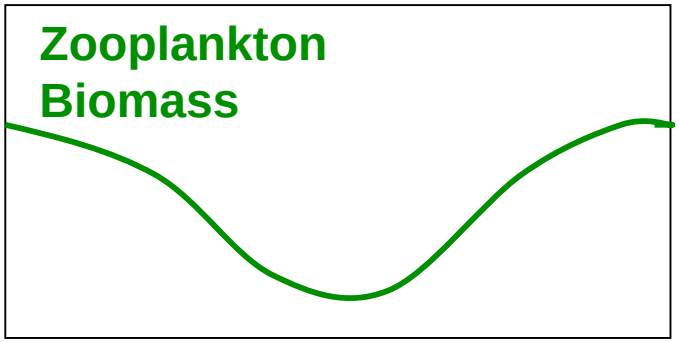
Biomass data were sometimes based on spot-observations while chemical properties of zooplankton indicate environmental condition of the past months

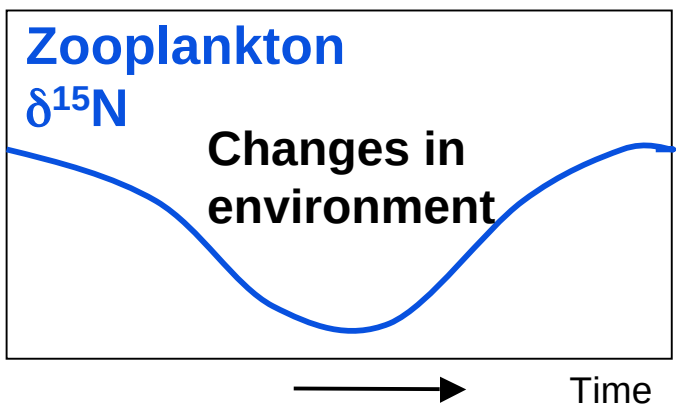


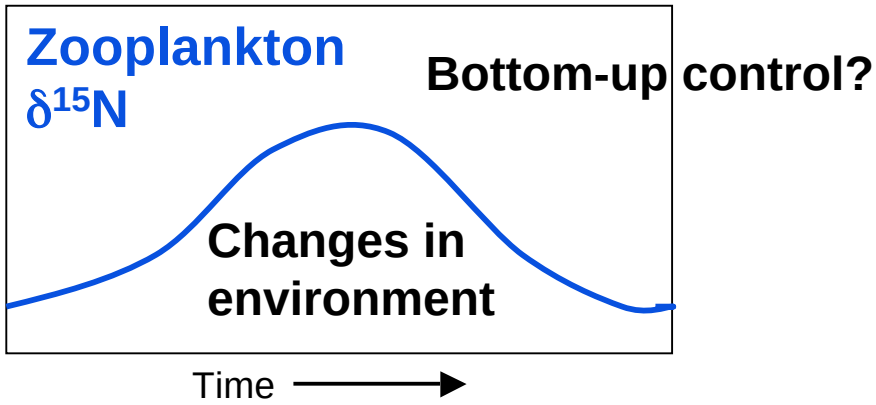
Proxy of trophic level **higher** in higher trophic levels
= switch of feeding strategy
== phytoplankton abundance
=== nitrate availability **higher** at low N availability

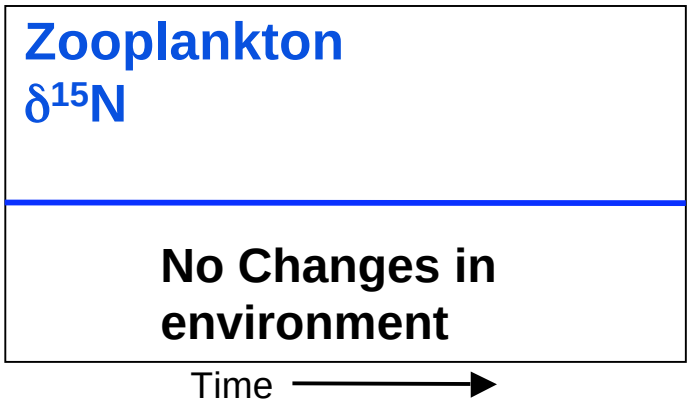
But be careful in the existence of N^2 fixation phytoplankton (decrease).

Zooplankton SI : Proxy of Environmental Changes







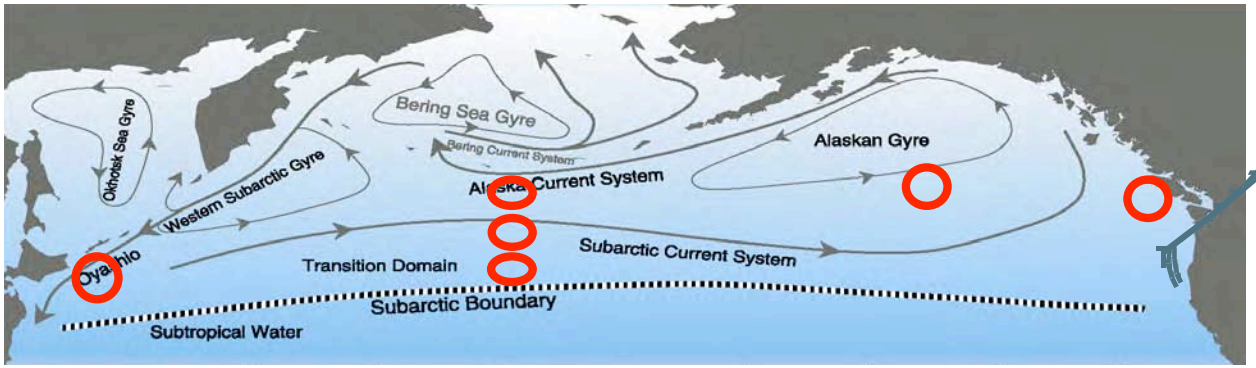


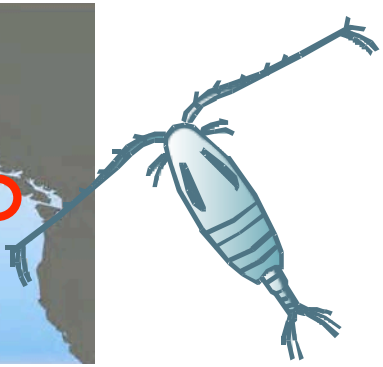
Top-down control?

Sample Information

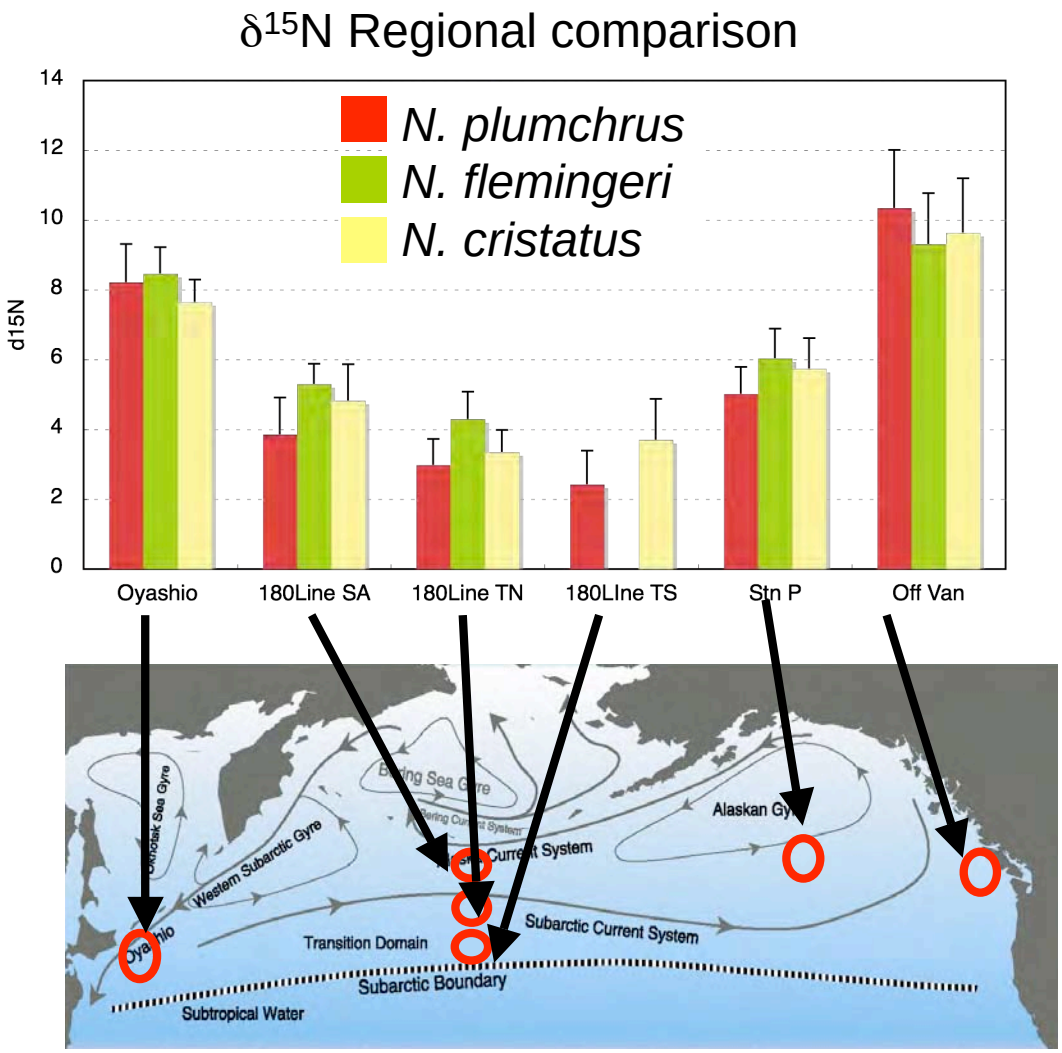
	West	Central (180° Line)			East	
	Oyashio	Subarctic (SA)	Transition North (TN)	Transition South (TS)	Off-Vancouver Island (off -Van)	St. P
Area	38°- 41° N 142° - 145°E	47°- 48°30' N	44°- 46°N	39°30' - 42°N	48°-51°N 124°30"-130°W	50°N 145°W
Year	1960-2002	1980-1997	1979-1997	1979-1997	1981-2007	1987-2007
Season	April-July		June		April-July	
Sampling Method	NORPAC 0-150m tow		NORPAC 0-150m tow		Bongo 0-250m (max)	
Preservation	5% formalin sea water					
SI measurement	Thermo Fisher Scientific, EA1112 -DELTA V ConFlo III System					

- Common procedure used for sample preparation for SI measurement **(~20 inds CV were used for each measurement)**
- Correction of sampling date bias was made when monthly averages were significantly difference within a region (only for *N. flemingeri* in Oyashio)
- Off Vancouver Island dada are composite northern, middle, southern Vancouver Island data.





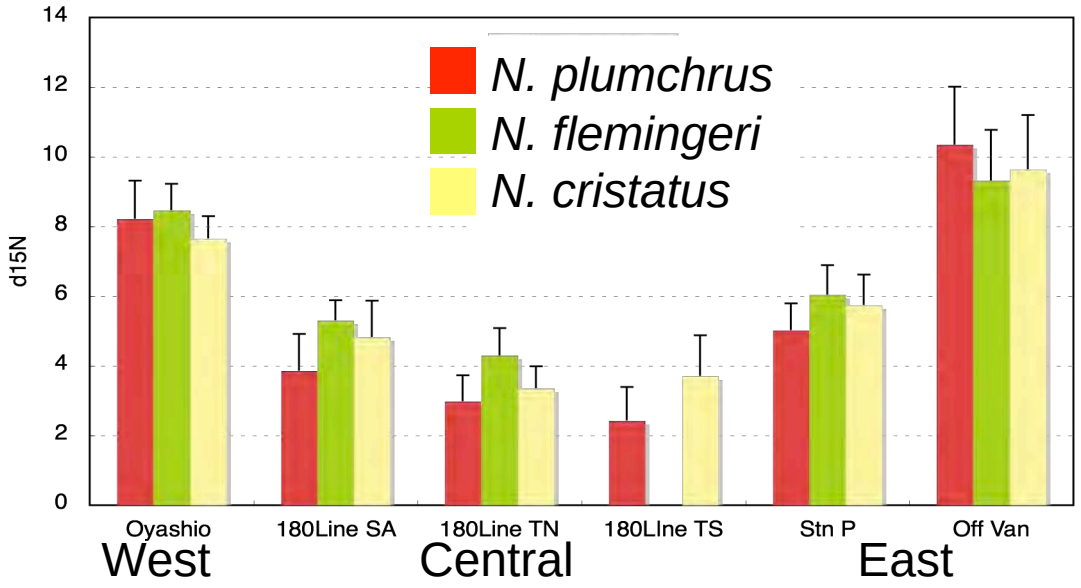
Regional Comparison of Average $\delta^{15}N$



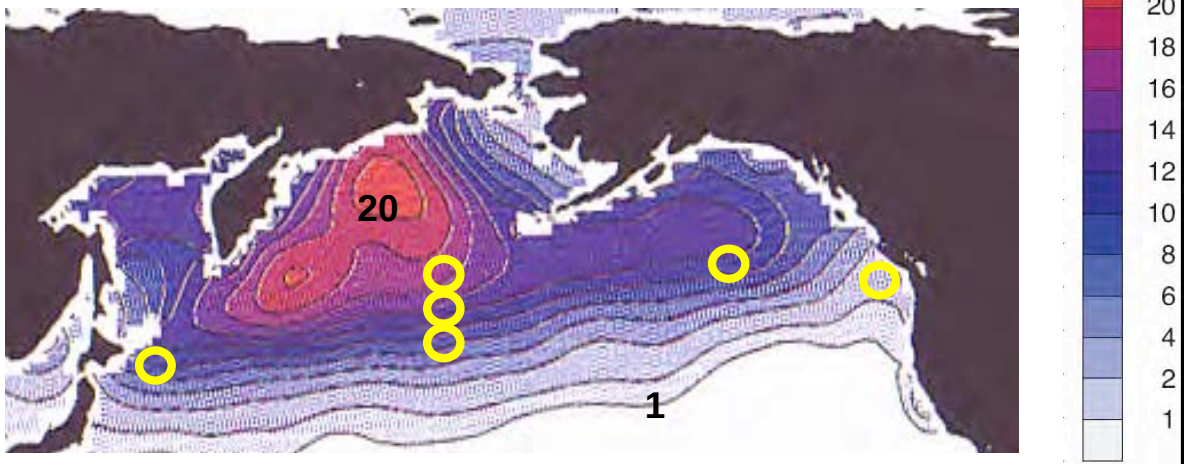
Interregional variations were larger than interspecies variations within a region

ANOVA & Post Hoc (Scheffe) Test
OY & Off Van > 180LIne and StP

Regional Comparison of Average $\delta^{15}N$



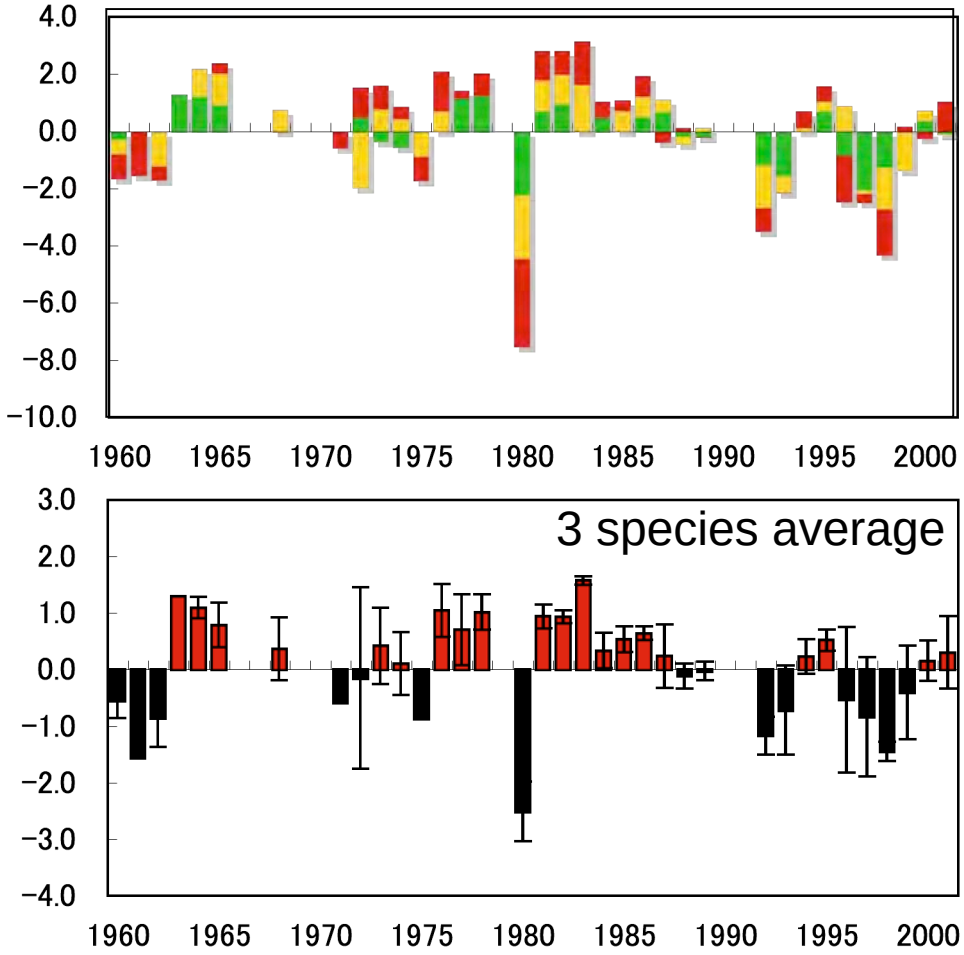
Surface Nitrate (uM) (WOA 2001)



Regional Difference in average $\delta^{15}N$ roughly corresponded to the base Nitrate concentration => unlikely to be derived from behavioral difference among regional *Neocalanus* populations.

Time series Neocalanus $\delta^{15}N$

West: Oyashio



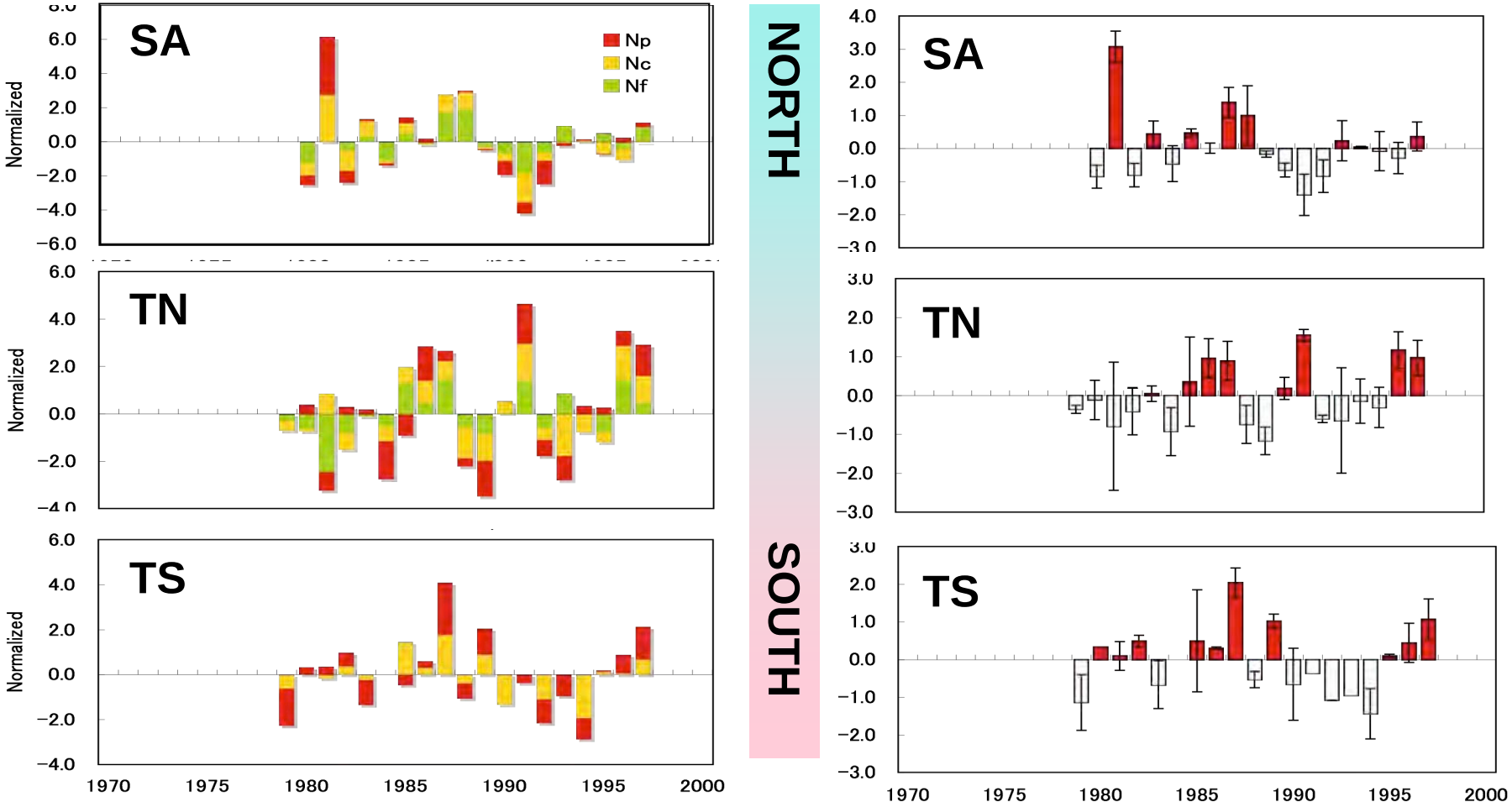
N. plumchrus
N. flemingeri
N. cristatus

Pearson R:
Nc - Nf = 0.571 (P<0.01)
Nc - Np = 0.557 (P<0.01)
Nc - Nf = 0.693 (P<0.01)

Inter-annual variation was similar among the 3 species
…indicating temporal variation of regional environment

Time series Neocalanus $\delta^{15}N$

Central: 180° Line



Pearson R:

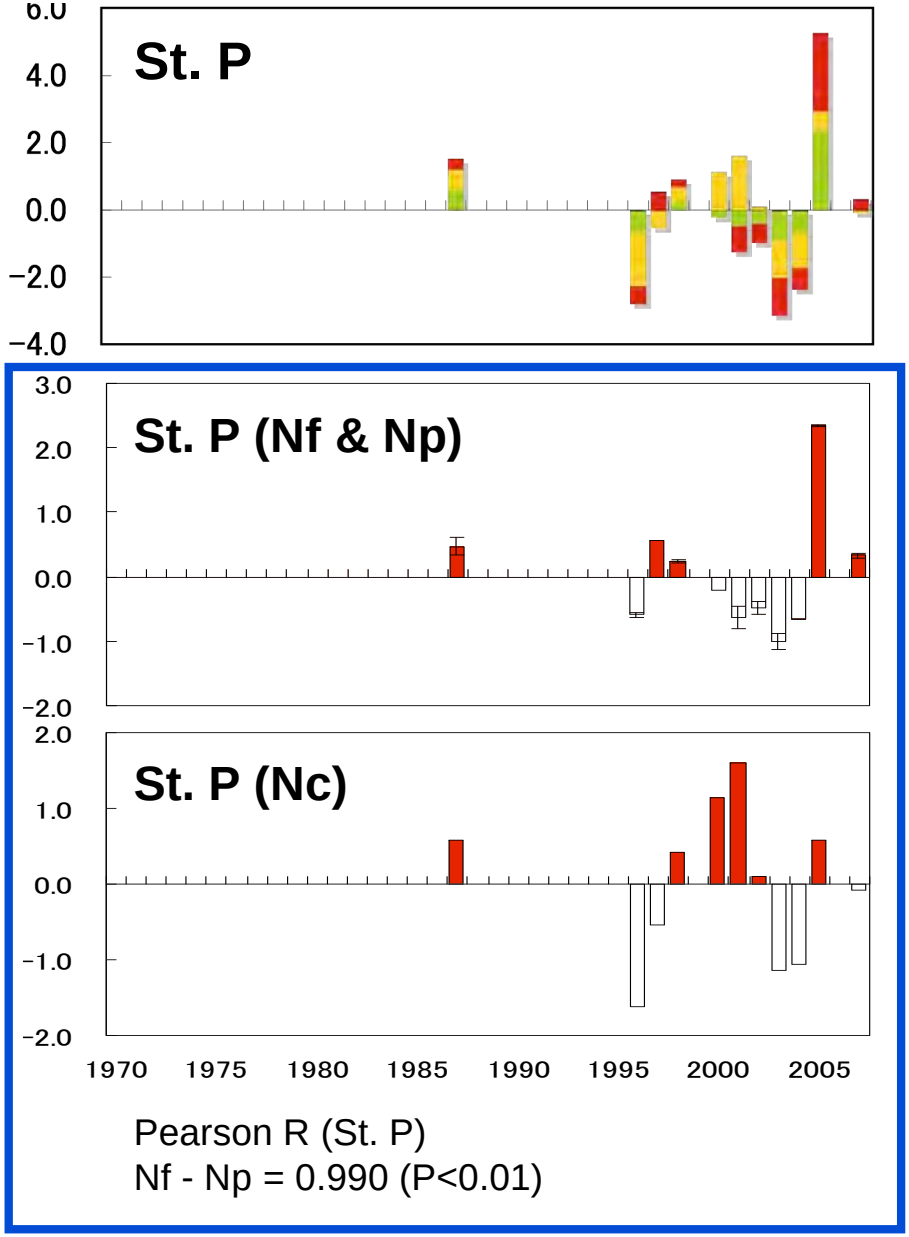
SA: Nc - Nf = 0.826, Nc - Np = 0.788 (P<0.01), Nc - Nf = 0.561 (P<0.05)

TN: Nc - Nf = 0.826, Nc - Np = 0.788 (P<0.01), Nc - Nf = 0.561 (P<0.05)

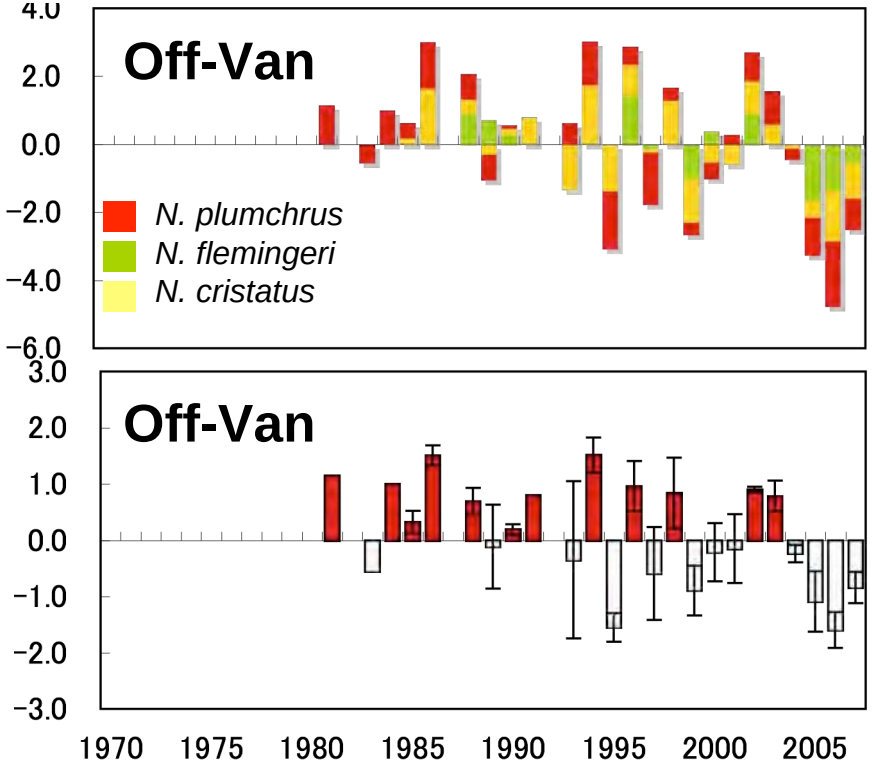
TS: Nc - Np = 0.672 (<0.01)

Time series Neocalanus $\delta^{15}N$

East

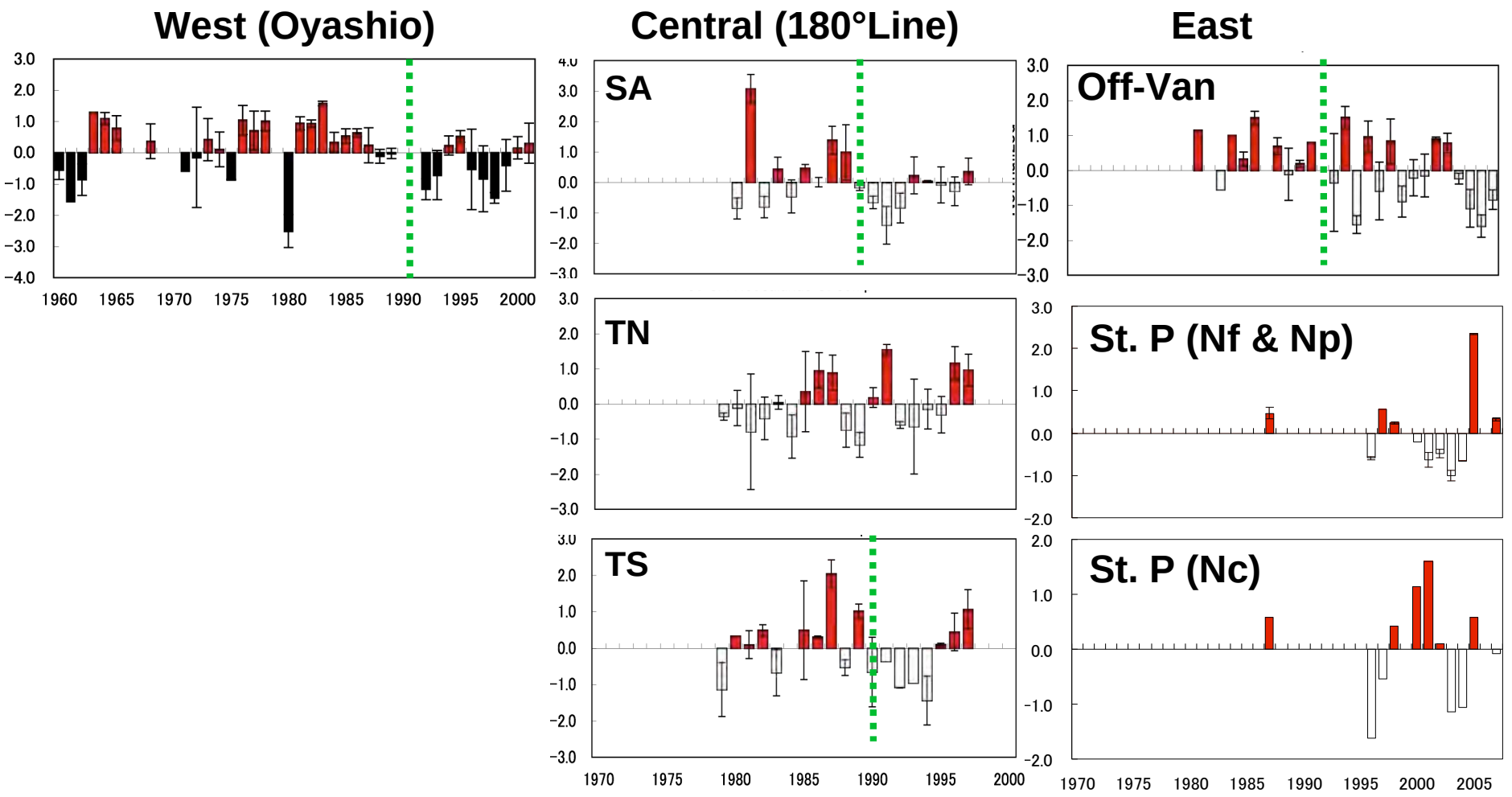


Pearson R (St. P)
Nf - Np = 0.990 (P<0.01)



Pearson R (Off-Van)
Nc - Nf = 0.823, Nc - Np = 0.740
(P<0.01), Nc - Nf = 0.755 (P<0.01)

Regional Comparison of Time-series $\delta^{15}N$



More low $\delta^{15}N$ years after 1990 in Oyashio, 180line SA, Off-Van

…but No significant correlation in Interannual variations among the regions

Atmospheric Forcing, Hydrography & $\delta^{15}N$

List of Climatic and Environmental Variables used for Correlation Analysis

	Data Source	Variable	Details
All	ICOADS	Cloud Cover	Jan-Mar, Mar-May, Mar-Jul, Annual
	ICOADS	SLP	Jan-Mar, Mar-May, Mar-Jul, Annual
	ICOADS	SST	Jan-Mar, Mar-May, Mar-Jul, Annual
	ICOADS	Zonal Wind	Jan-Mar, Mar-May, Mar-Jul, Annual
	ICOADS	Meridional Wind	Jan-Mar, Mar-May, Mar-Jul, Annual

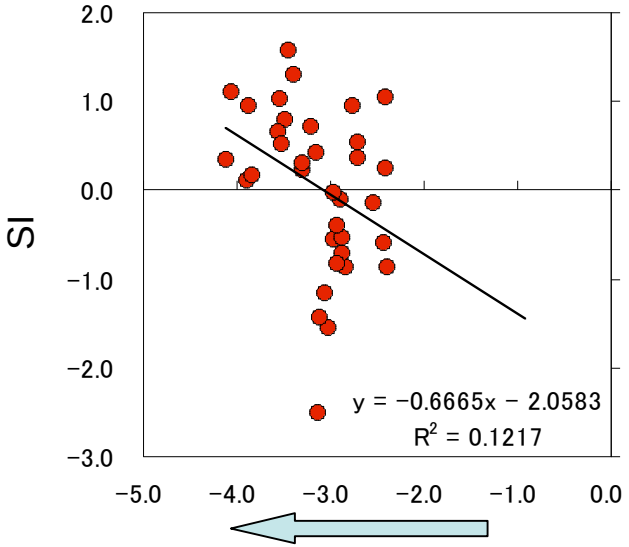
Oyashio	180°Line	Off-Van	St. P
34°-50°N 140°-156°E	40°-56°N, 174°-186°E	44°-56°N, 234°-246°W	44°-56°N, 220°-246°E

Oyashio	JODC	SSS	Feb, Apr, May
	JODC	MLD	win
	JODC	DSigma-t (0-100)	Feb, May
	JMA & JODC	Chl a	win, sp
	JMA & JODC	PO4	Feb-Nov avg
180°Line	Kobari et al, 2003, JPR	Mean Temp 0-150 m	June, per SA, TN, TS region
	Kobari et al, 2003, JPR	Chl *a*	June, per SA, TN, TS region
	Kobari et al, 2003, JPR	Delta T 0-150	June, per SA, TN, TS region
Off-Van, St. P	Crawford et al. 2007, PO	mean T 100-500m	win, sp, sm
	Crawford et al. 2007, PO	mean T 10-100m	win, sp, sm
	Crawford et al. 2007, PO	mean S 100-500m	win, sp, sm
	Crawford et al. 2007, PO	mean S 10-100m	win, sp, sm

Atmospheric Forcing, Hydrography & $\delta^{15}N$

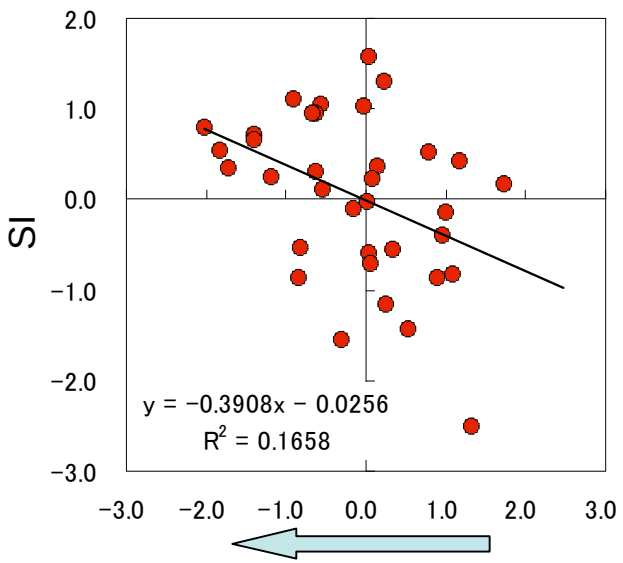
Oyashio

V-wind (Win.)



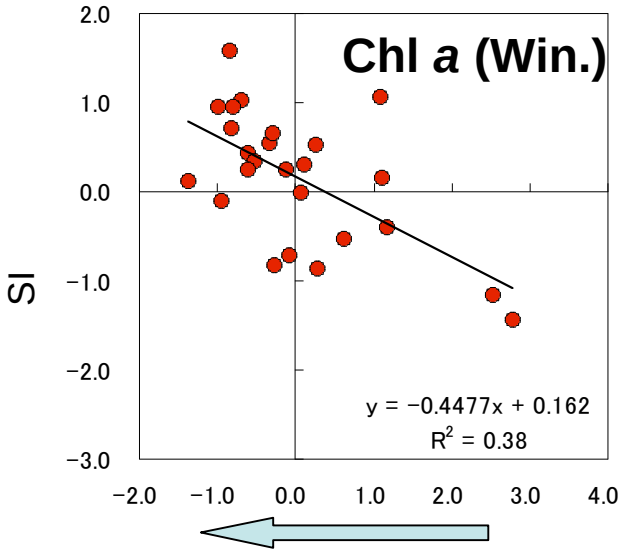
Strong North Wind

SST (Win.)



Cool

Chl *a* (Win.)



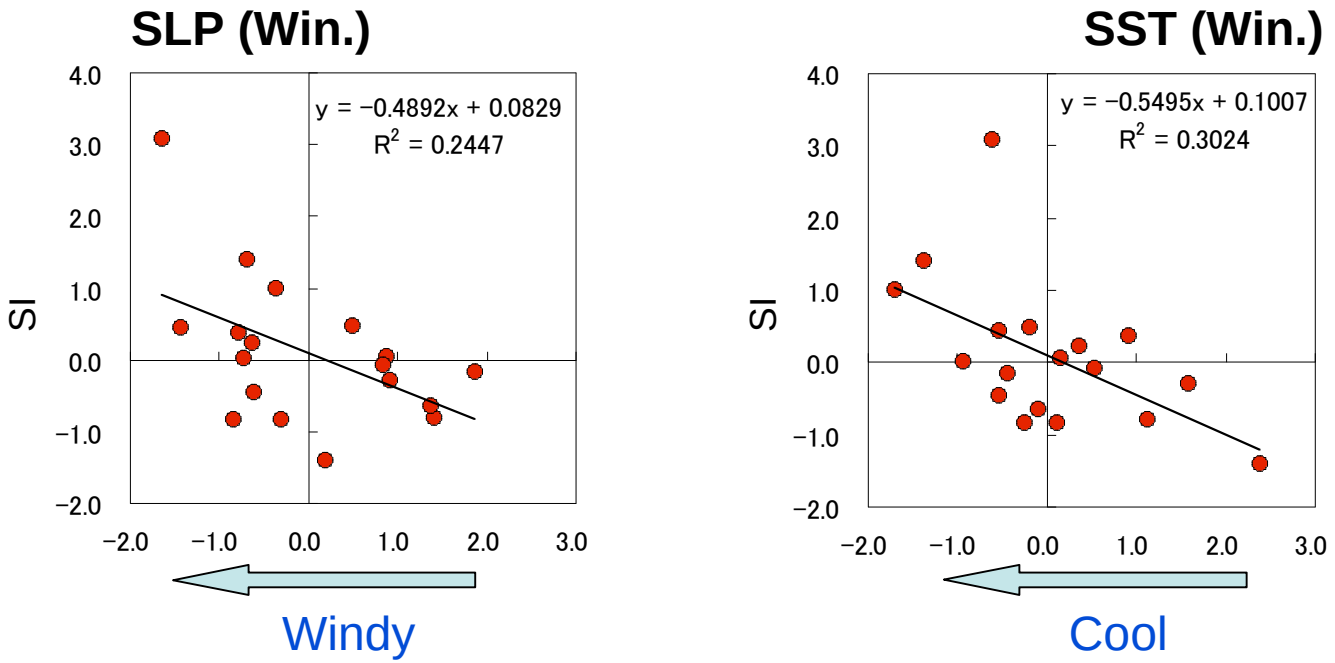
Low Chl *a*

δ^{15} N was **High**

In the years of
Cool condition with
Low winter Chl *a*
>> Neocalanus might be more omnivorous

Atmospheric Forcing, Hydrography & $\delta^{15}N$

180° Line Subarctic



No winter and spring Chl *a* data…

δ^{15} N was **High**

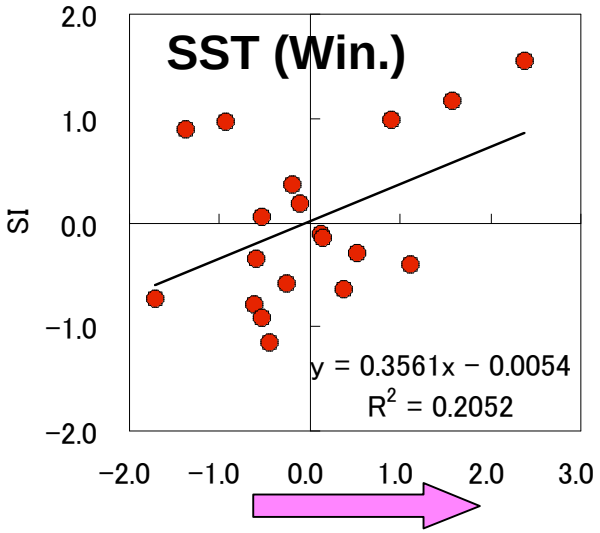
In the years of

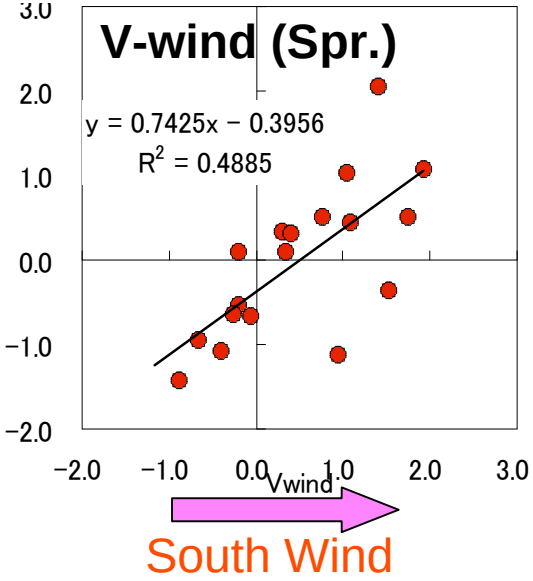
Cold Winter

…with low win Chl a?

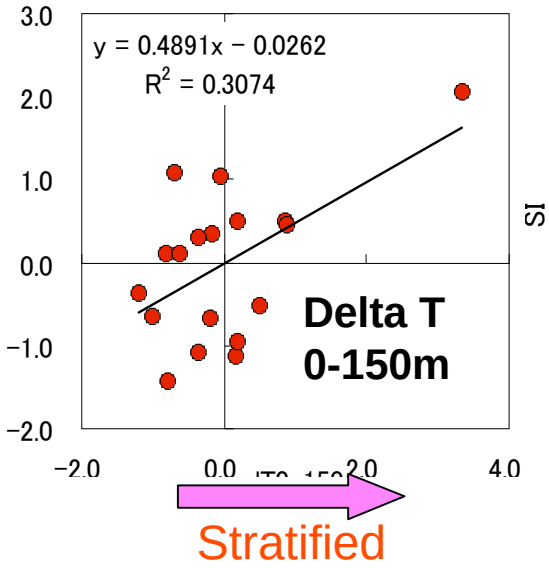
Atmospheric Forcing, Hydrography & $\delta^{15}N$

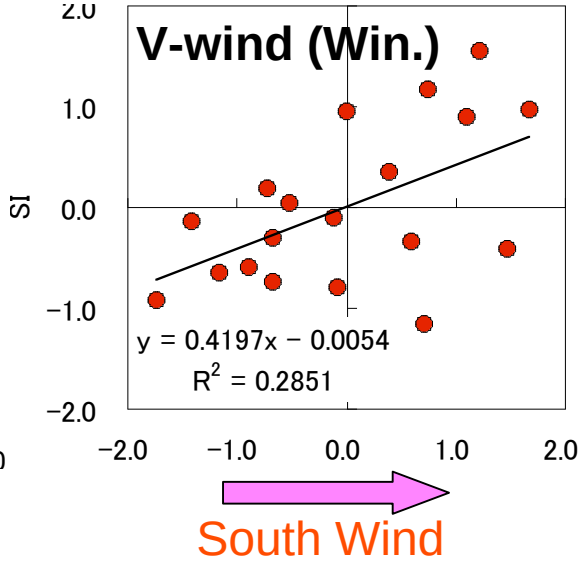
180°Line Transition North





180°Line Transition South





δ^{15} N was **High** in the Years of **Warm** conditions with Southern wind

Lower N supply
(+Higher source $\delta^{15}N$?)

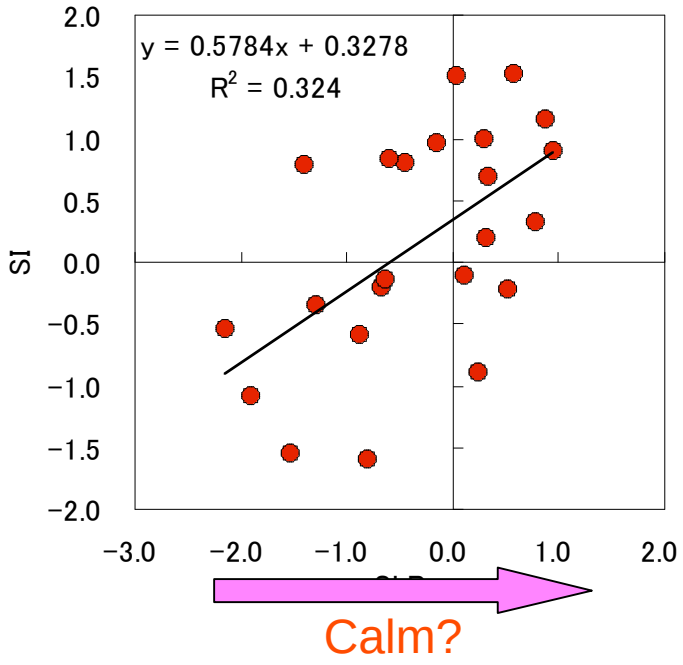
Atmospheric Forcing, Hydrography & $\delta^{15}N$

δ^{15} N was **High** in Years of **Calm** sprig-summer with strong **Westerly**

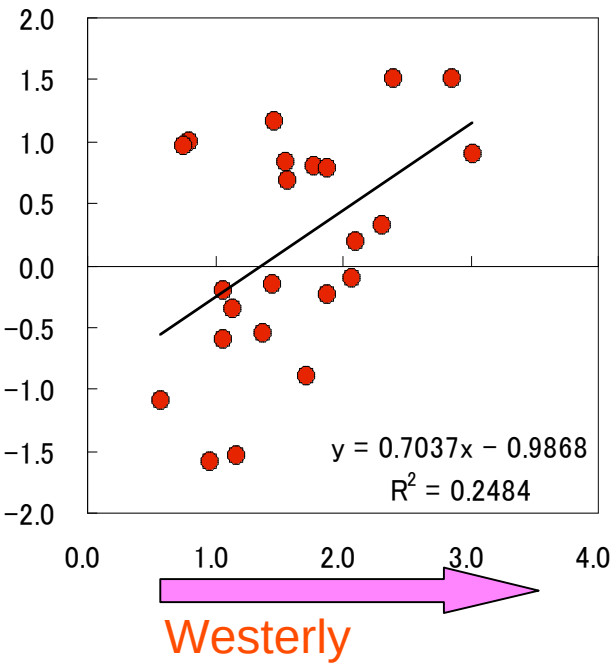
Lower N supply
(+Higher source $\delta^{15}N$?)

Off-Van

SLP (Spr. & Sum.)



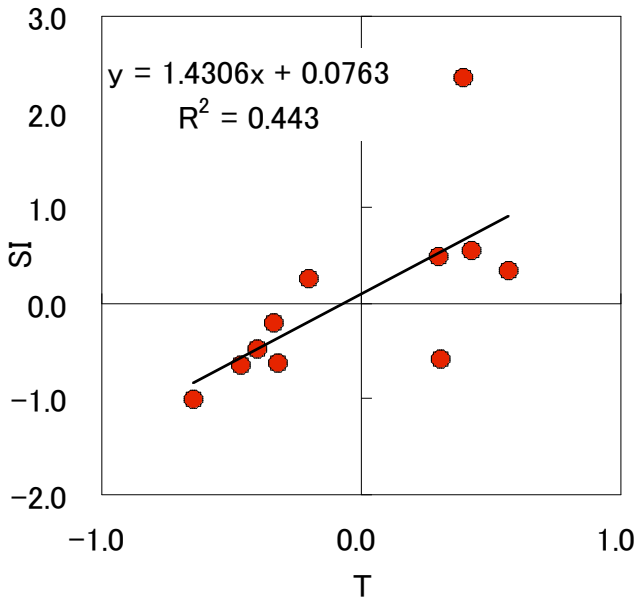
U-wind (Spr.& Sum.)



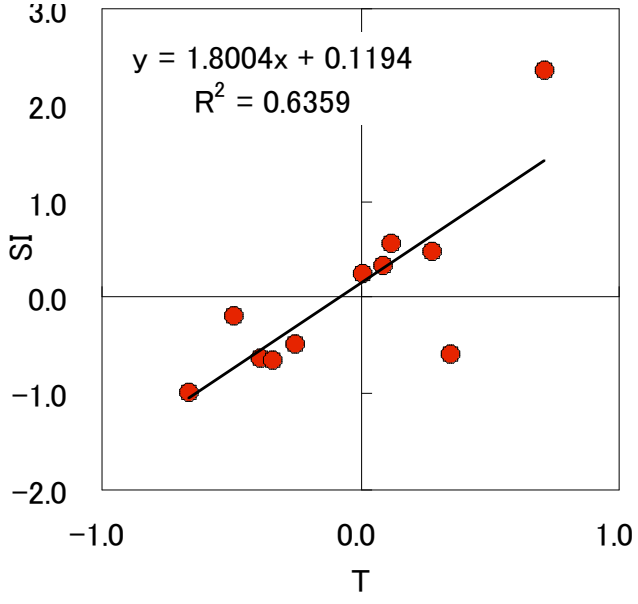
Atmospheric Forcing, Hydrography & $\delta^{15}N$

St. P

Mean T 50-100m Spr.

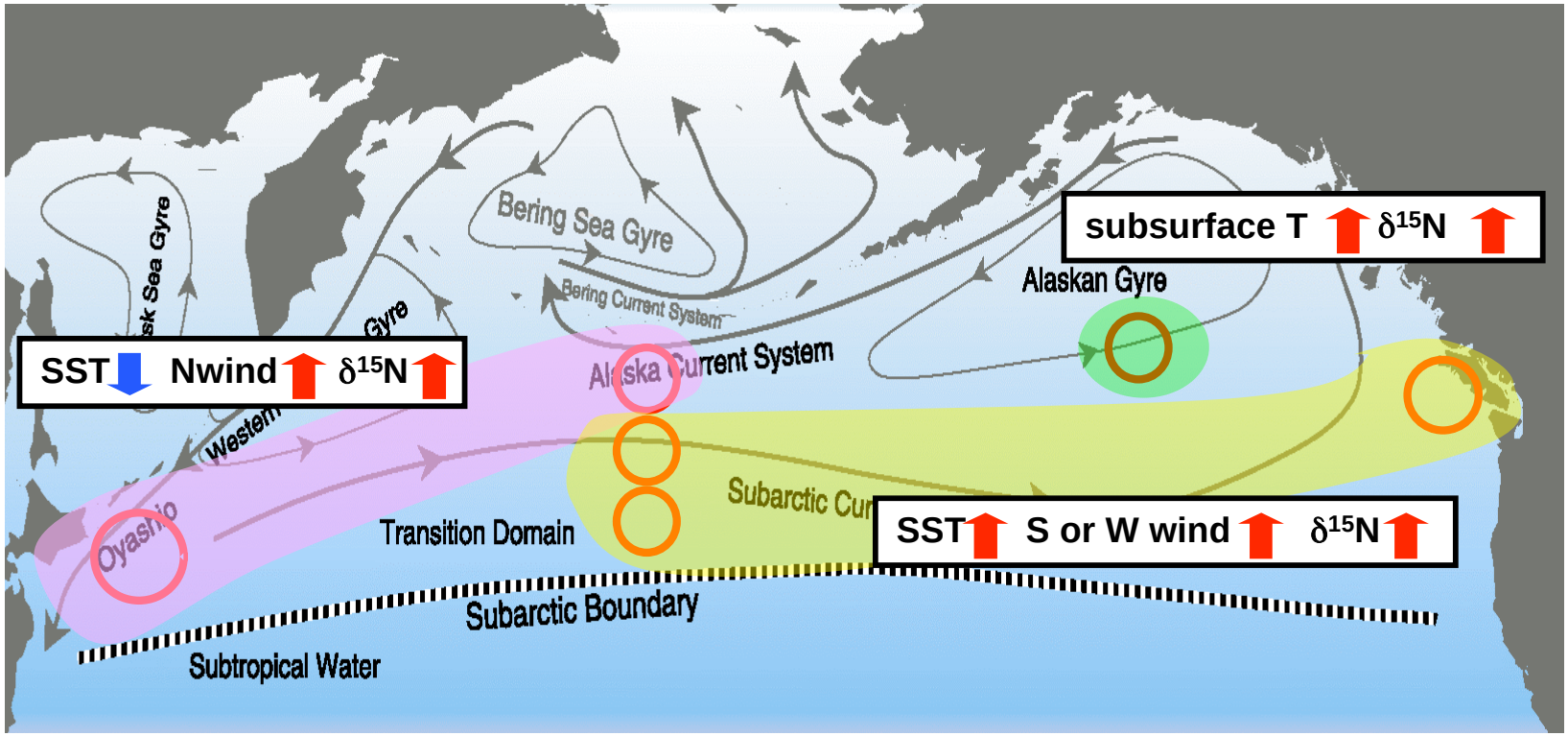


Mean T 50-100m Sum.



δ^{15} N **was High** in Years of **Warm** subsurface condition during Spring-Summer (*N. plumchrus & N. flemingeri* only)

Possible Factors Responsible for Temporal Variation of Neocalanus $\delta^{15}N$



1. OY & 180 SA

Cool winter condition, which delayed spring bloom, altered *Neocalanus* feeding strategy to more omnivorous => Behavioral Change

2. 180 TN, 180TS, Off-Van

Advection of southern water altered Nitrate availability (and source $\delta^{15}N$?) => Hydrographic Change

3. St. P

Change in properties of the subsurface water altered Nitrate availability (and source $\delta^{15}N$?)=> Hydrographic Change

Conclusion

This study suggested….

Regional difference of *Neocalanus* $\delta^{15}N$ reflects differences in hydrographic properties among the East, Central and Western subarctic North Pacific.

Regional difference of Time-series of *Neocalanus* $\delta^{15}N$ are determined by regionally specific hydrographic and ecological responses to various climatic forcing

***Neocalanus* $\delta^{15}N$ is a possible indicator of regional responses of climatic forcing**

Next Subjects

However….
There are uncertainty in the proposed mechanisms of the observed changes…

Study on mechanisms of *Neocalanus* δ^{15}N variation using newly collected specimens

Oyashio (A-line Cruise, FRA)

Monthly sampling, March to July, 2007

δ^{15}N, δ^{13}C Measurement: 3 *Neocalanus* spp., surface layer POM

Other information:

phytoplankton composition, nutrients, water column ST

Acknowledgements

Prof. Mark Ohman,
Dr. Mugi Takizawa,
Ms. Moira Galbraith
Ms. Keiko Yamamoto
And all captains, crew and researchers who worked for collection of long-tern *Neocalanus* samples