Assessment of the magnitude and interrelationship of seasonal phytoplankton bloom occurrence at the Japanese scallop (*Mizuhopecten yessoensis*) farming area of Okhotsk Sea, Hokkaido, Japan

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S3: Tipping points: defining reference points for ecological indicators of multiple stressors in coastal and marine ecosystem

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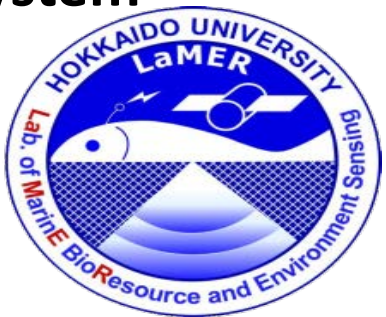


Introduction: Defining reference points

SEA ICE RESIDENCE TIME

Timing of **sea ice** retreat determines what type of ecosystem flourishes in ice-affected waters.

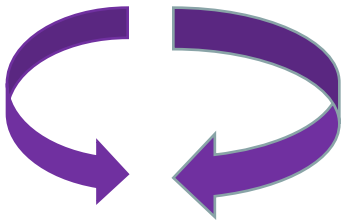
1. ICE EDGE BLOOM: BLOOM IN COLD WATER

Blooms result in a bottom-up control food web i.e. favours the **benthic** community

Since scallop bottom culture form part of **benthos** community, timing of bloom and sea ice residence time, have significant effects on growth of scallops!

Yet influence of climatic-oceanographic variability on dynamics of biological communities in Okhotsk Sea is still poorly understood (Kim, 2012).

2. EARLY ICE MELT: OPEN WATER BLOOM



(Hunt et al., 2002)

Melting: warming & stratification, light winds-no upwelling of subsurface nutrients, little export to **benthos** community.

Introduction: Gap

Mechanism of sea ice-phytoplankton bloom scanty - yet need for robust-updated trends on "definition of reference points" for management planning & scientific base for scallop farming.

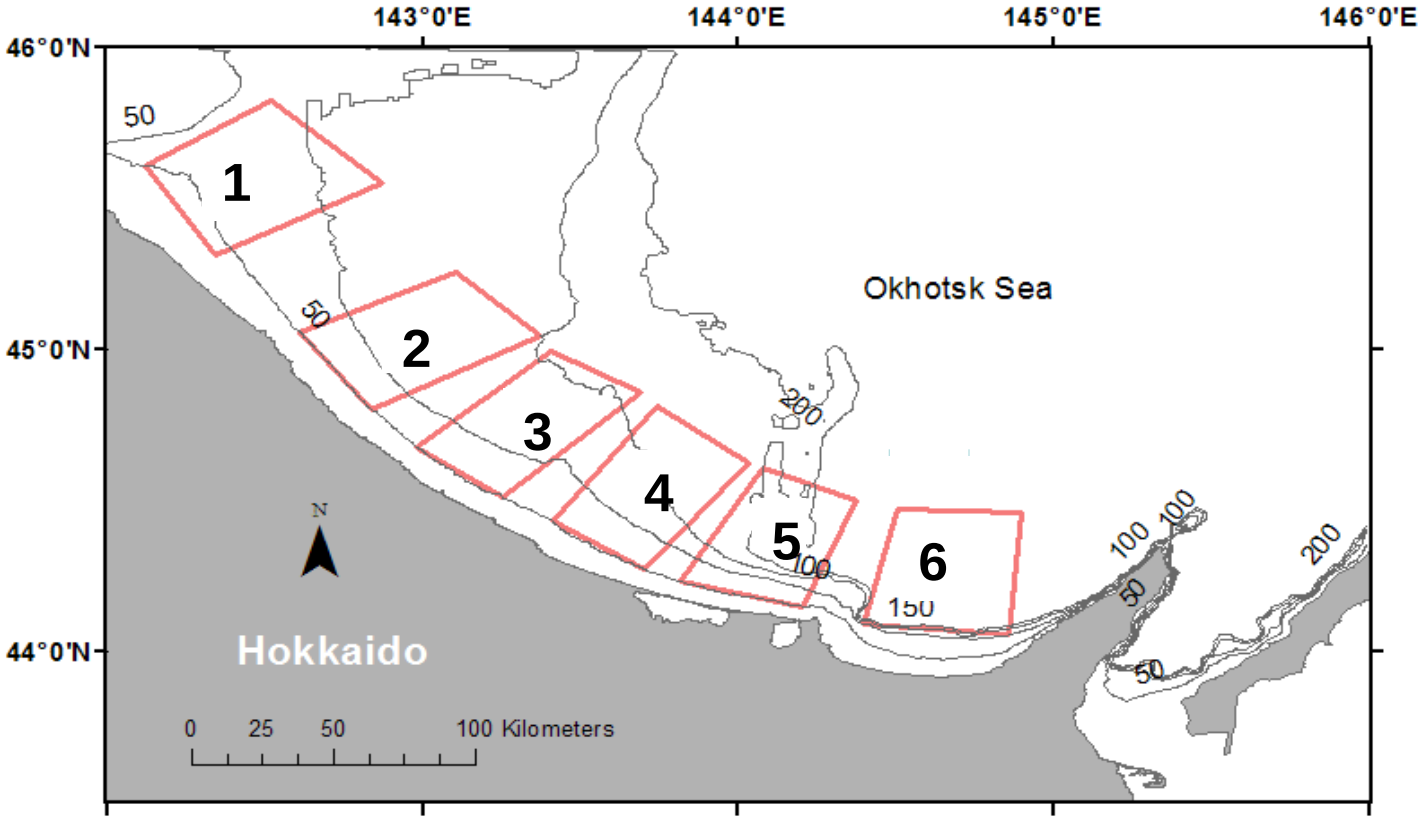
But inter-annual fluctuations in phytoplankton bloom in Okhotsk Sea in relation to warm & cool periods are not yet clear,

e.g. from 2008-2010, spring & autumn phytoplankton blooms were considered weaker than in 2005 & 2006 (http://teradata.sakhniro.ru; Kim, 2012).

What about the situation at the scallop farming area?

Objective and study area

To examine: magnitude and interrelationship of seasonal phytoplankton bloom occurrence.



The study areas **1-6** of Okhotsk Sea coastal region, Hokkaido, Japan. Depth contours are in meters with 500 m resolution. Its affected by currents: SWC = Sōya Warm current (Summer); ESC = East Sakhalin current (autumn).

Data sources and processing of indicators

Parameter	Data sources	Resolution	Time
Chlorophyll-a (Chl-a)	MODIS	1 km	2005 -2012 Daily (8-day=Weekly, Monthly)
[1]*Sea ice	DMSP F13 Special Sensor Microwave/Imager (SSM/I)	25 km	2005 -2012 Daily (8-day=Weekly, Monthly)
Surface wind stress	NOAA/OAR/ESRL NCEP/DOE AMIP-II Reanalysis		2005 -2012 Daily (8-day=Weekly)
Scallop landings	Marinenet Hokkaido website[2]*		2005 -2012 Monthly

[1]*A given pixel was defined to be ice covered whenever sea ice concentration was >15.0%.

*[2]http://www.fishexp.hro.or.jp/marinedb/internetdb/fishdb/fish_month.asp

Tipping points: definition of terms

Bloom occurrences

Chl-*a* concentrations exceeding 1.0 mg m^{-3}

Ice edge bloom

Early retreat of sea ice within 8 days in which bloom occurred within same interval.

Ice retreated late within the 8 days and bloom continued over the next 8 days

Distinguishing bloom types

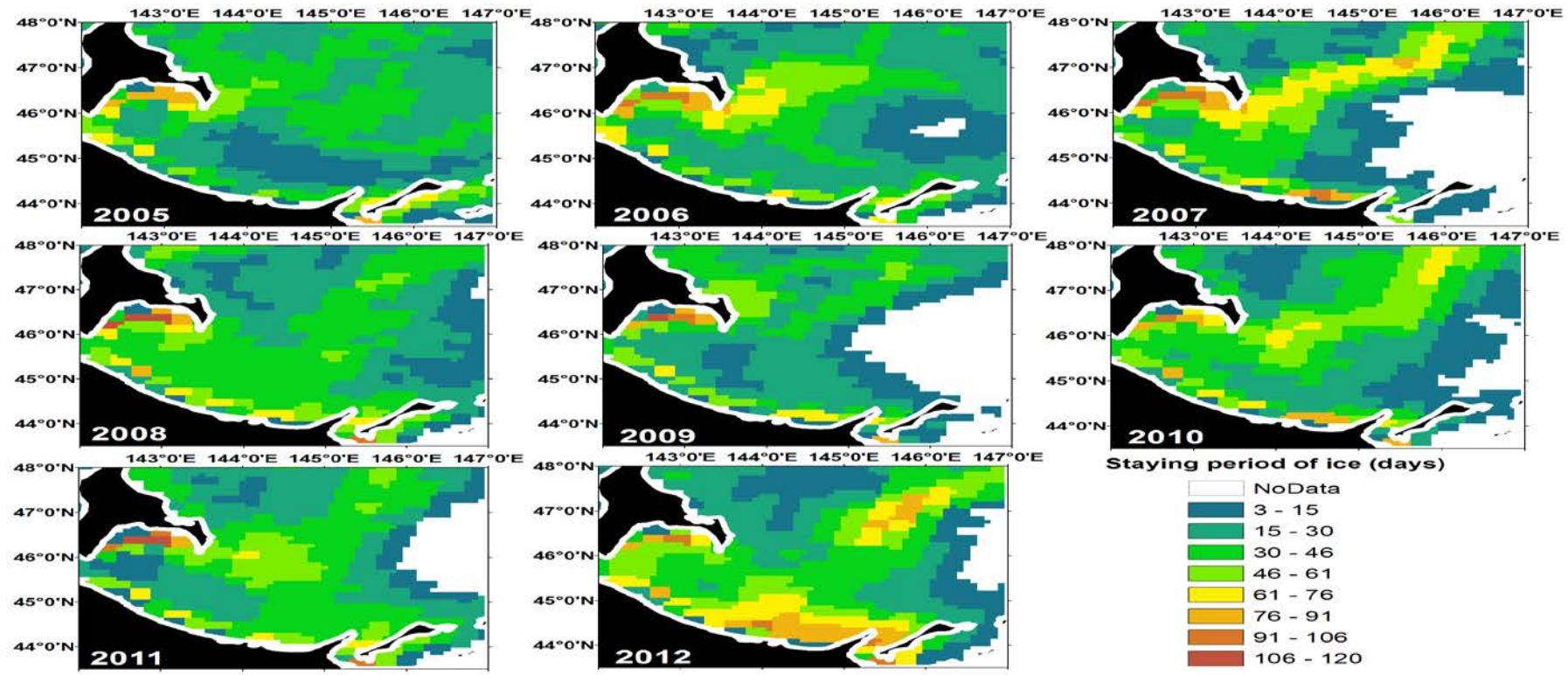
Spring bloom

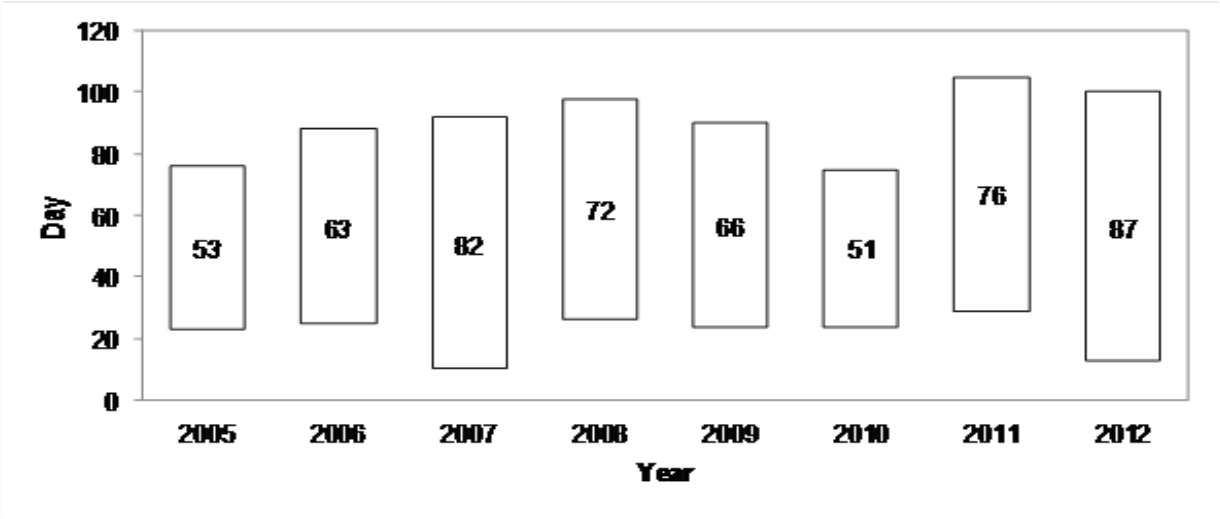
The period of the **highest** Chl-*a* concentrations

Open water bloom

Spring blooms that did not occur as either of aforementioned scenarios

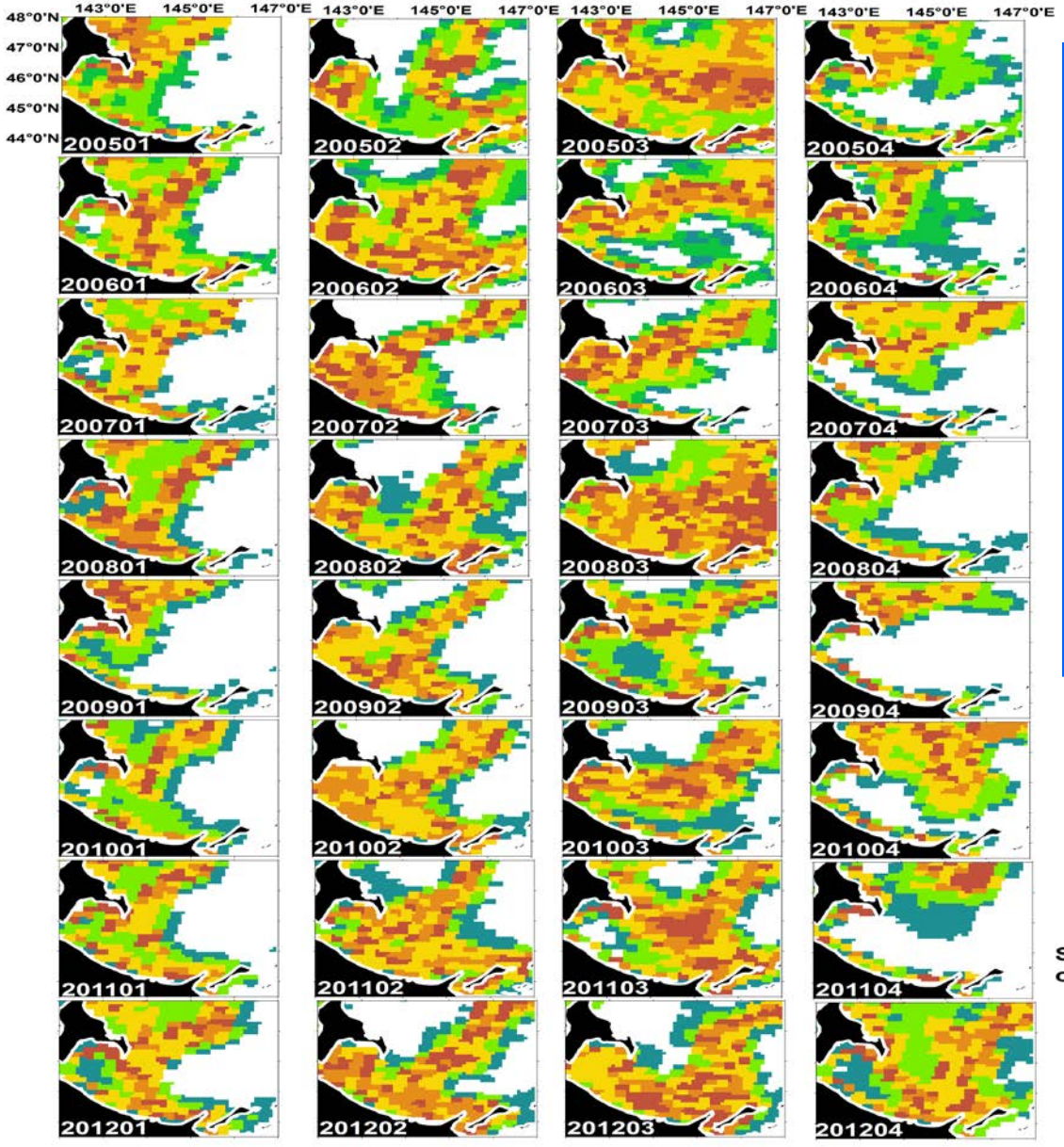
Results and Discussion: Sea ice variability 2005-2012





Spatial & inter-annual variability in sea ice residence time occurred.

Results and Discussion: Sea ice variability 2005-2012



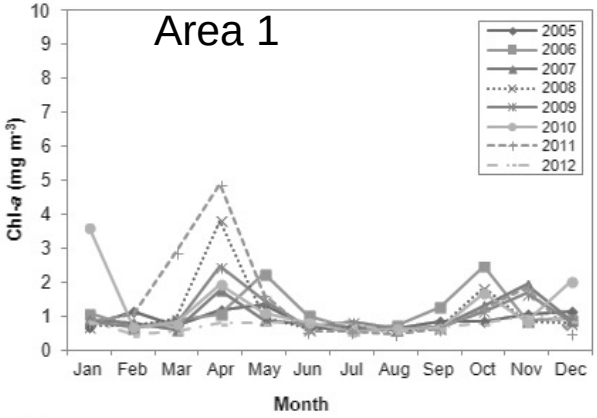
Physical forcing attributed to:

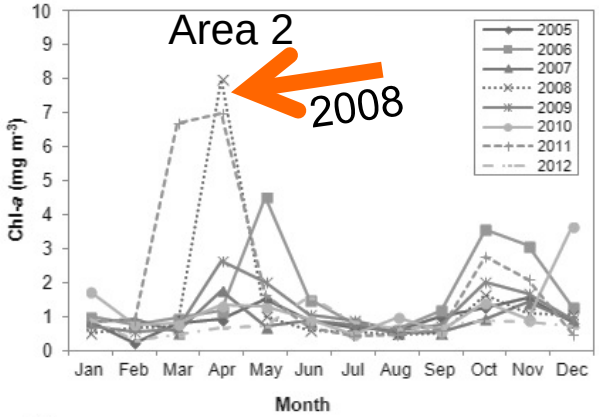
- wind stress (e.g. Okunishi et al., 2005) and solar radiation (e.g. Yoshi et al., 2003).

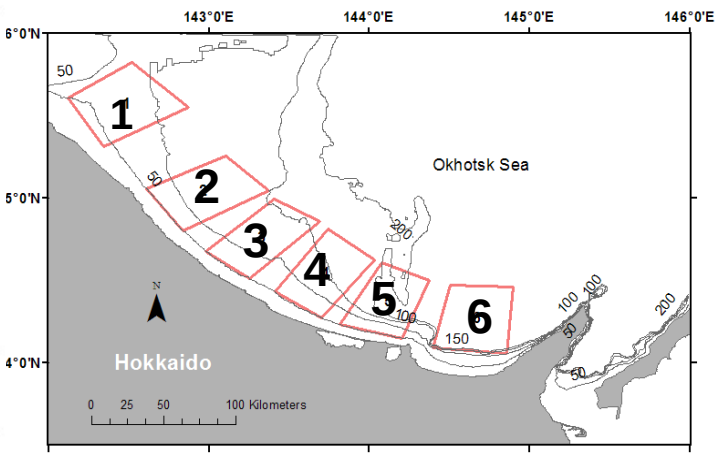
- Presence of Sōya warm current in summer & intrusion of East Sakhalin Current in autumn (Mustapha et al., 2011).

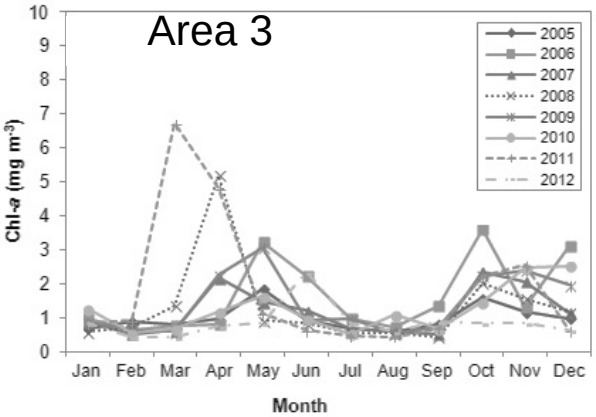
Magnitude of spring and autumn blooms

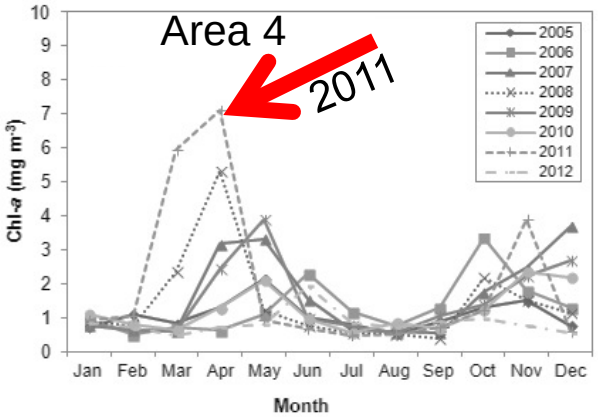
Inter-annual variability

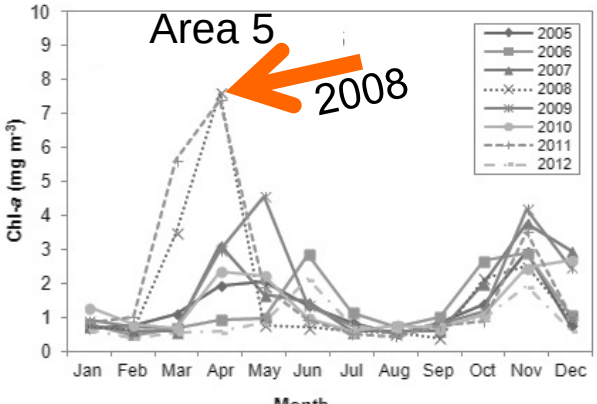


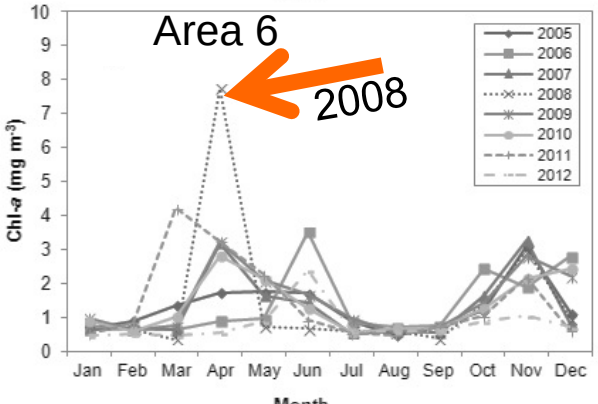








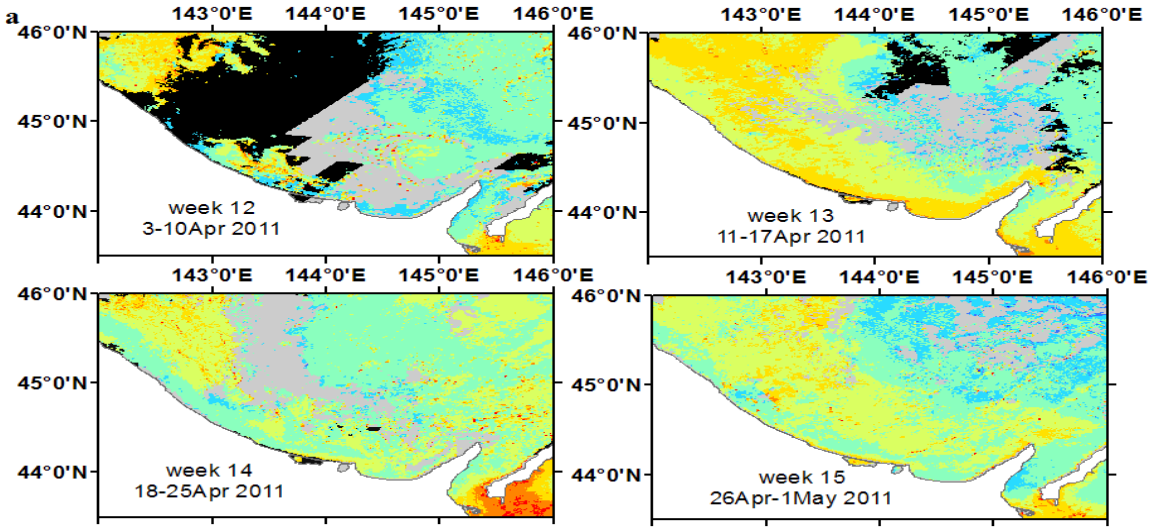




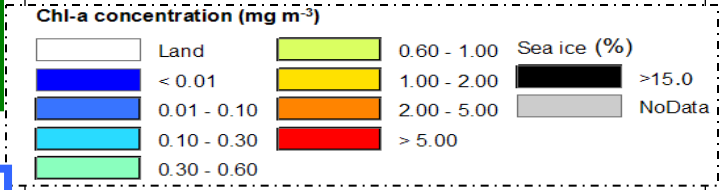
- Spring > Autumn blooms
- Both blooms were **weaker** (<8 mg m^{-3}) **than prior** findings (10 mg m^{-3}) (Mustapha and Saitoh, 2008)
- attributed to increase in surface stratification caused by warming (Ishida et al., 2009).

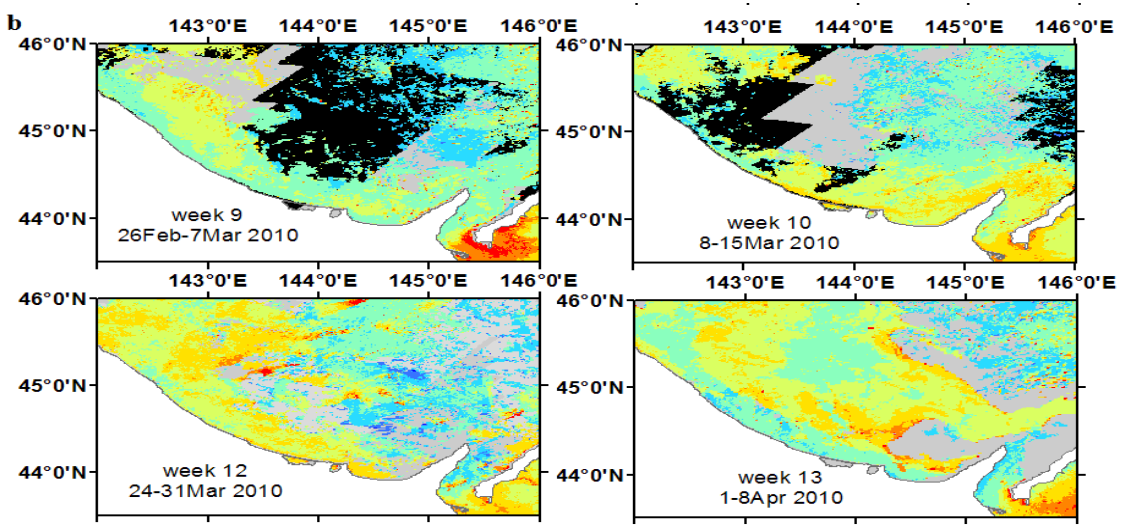
Ice edge and open water bloom variability

Representatives of weekly



Late annual phytoplankton bloom occurrence





Early annual phytoplankton bloom occurrence

Scallop farming area in the coastal Okhotsk Sea, Hokkaido, Japan.

Ice edge and open water bloom variability

Representative events (year, area) of study for timing of sea ice retreat and the peak of bloom occurrences.

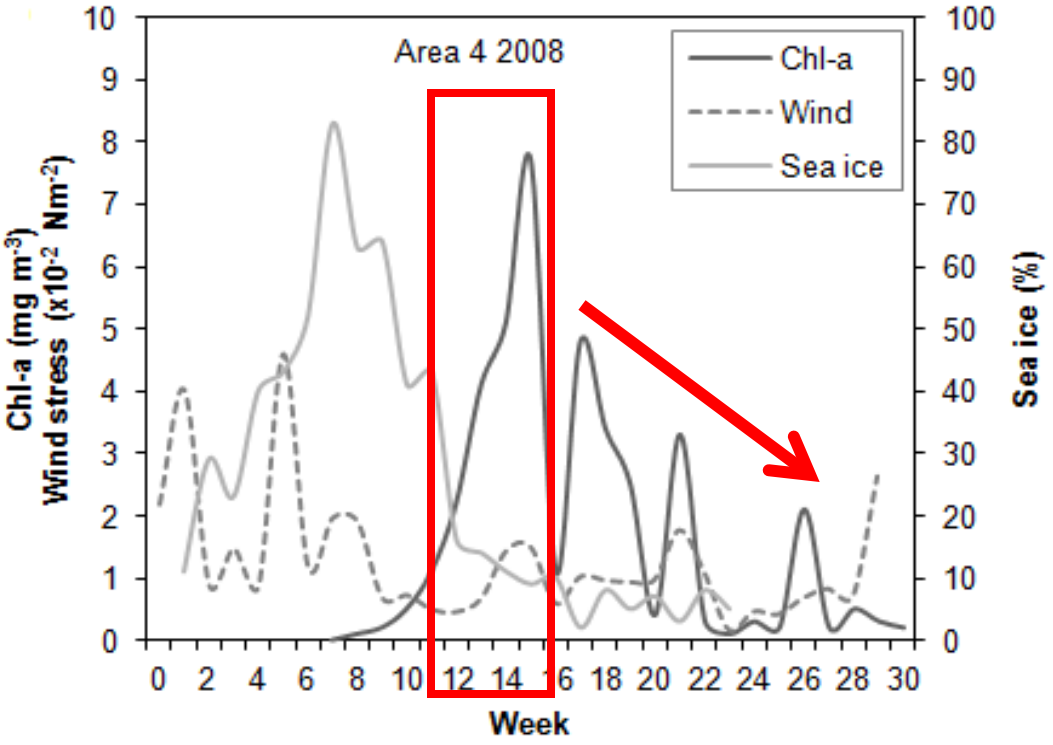
Sea ice retreat (week)	Bloom occurrences						Study representative	
	Ice edge bloom			Open water bloom				
	Week	Magnitude	Duration	Week	Magnitude	Duration	Year	Area
13	13	6.7[a]	4		_[d]		2011	4
12	15	7.7[a]	5	17	4.8	4	2008	4
10	11	1.1[b]	2	17	2.2	3	2006	1
12	15	1.9[b]	3		_[d]		2012	3
13	16	3.1[c]	7		_[d]		2007	6
10		_[d]		12	2.1	3	2010	2
13		_[d]		16	2	3	2005	5

Rows of the table presented in alphabetical order of magnitude based on: [a]Bloom in the presence of ice; [b]A 2-week lag between ice retreat and the peak of the bloom; [c]A 3-week lag between ice retreat and the peak of bloom; and [d]No bloom occurrences.

Mechanism of ice edge and open water bloom

Sea ice retreat (week)	Bloom occurences						Year	Study representative area
	Ice edge bloom			Open water bloom				
	week	magnitude	duration	week	magnitude	duration		
13	13	6.7[a]	4		-[d]		2011	4
12	15	7.7[a]	5	17	4.8	4	2008	4

[a]Bloom in the presence of ice; [d]No bloom occurrences.

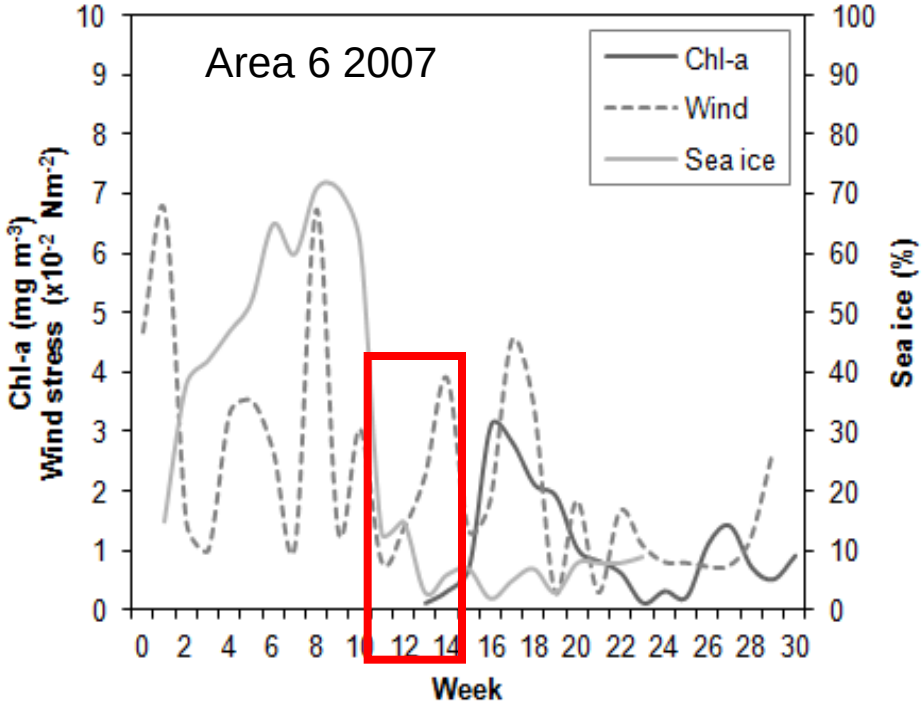


R^2=0.68

Mechanism of ice edge and open water bloom

Sea ice retreat (week)	Bloom occurences						Year	Study representative area
	Ice edge bloom			Open water bloom				
	week	magnitude	duration	week	magnitude	duration		
10	11	1.1[b]	2	17	2.2	3	2006	1
12	15	1.9[b]	3		-[d]		2012	3
13	16	3.1[c]	7		-[d]		2007	6

[b]A 2-week lag between ice retreat and peak of the bloom; [c]A 3-week lag between ice retreat and peak of bloom;. [d]No bloom occurrences

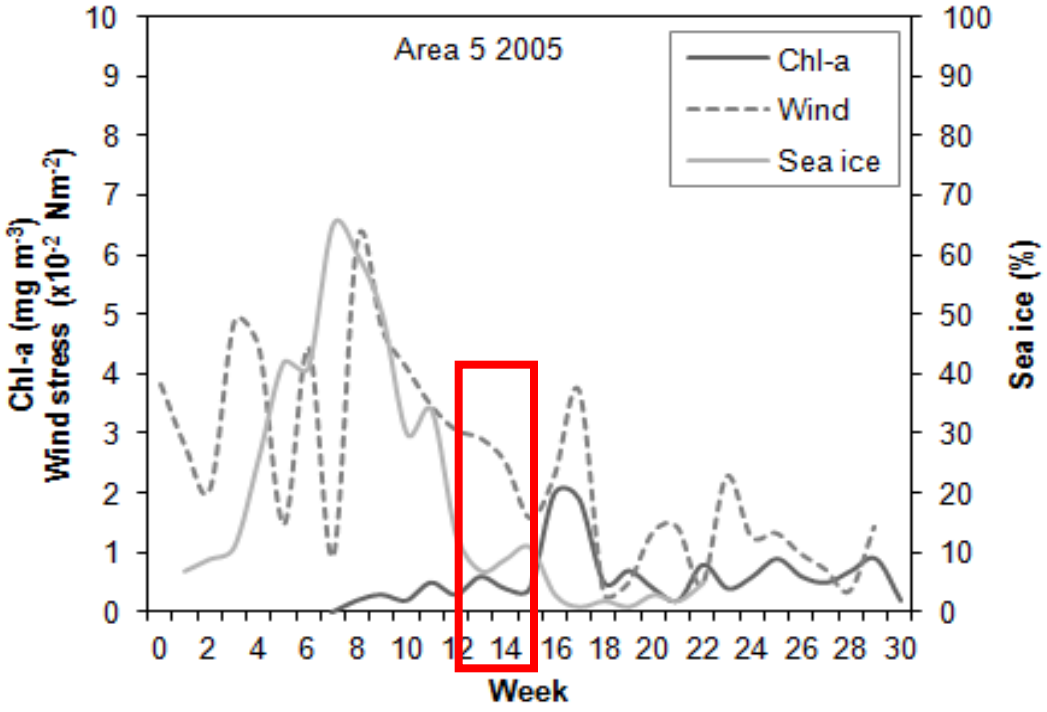


R^2=0.65

Mechanism of open water bloom variability

Sea ice retreat (week)	Bloom occurences						Year	Study representative area
	Ice edge bloom			Open water bloom				
	week	magnitude	duration	week	magnitude	duration		
10	13	_[d]	4	12	2.1	3	2010	2
13	15	_[d]	5	16	1	3	2005	5

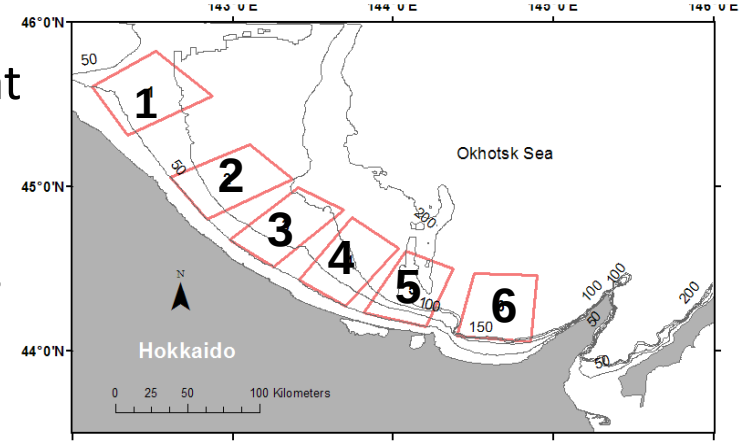
[d]No bloom occurrences

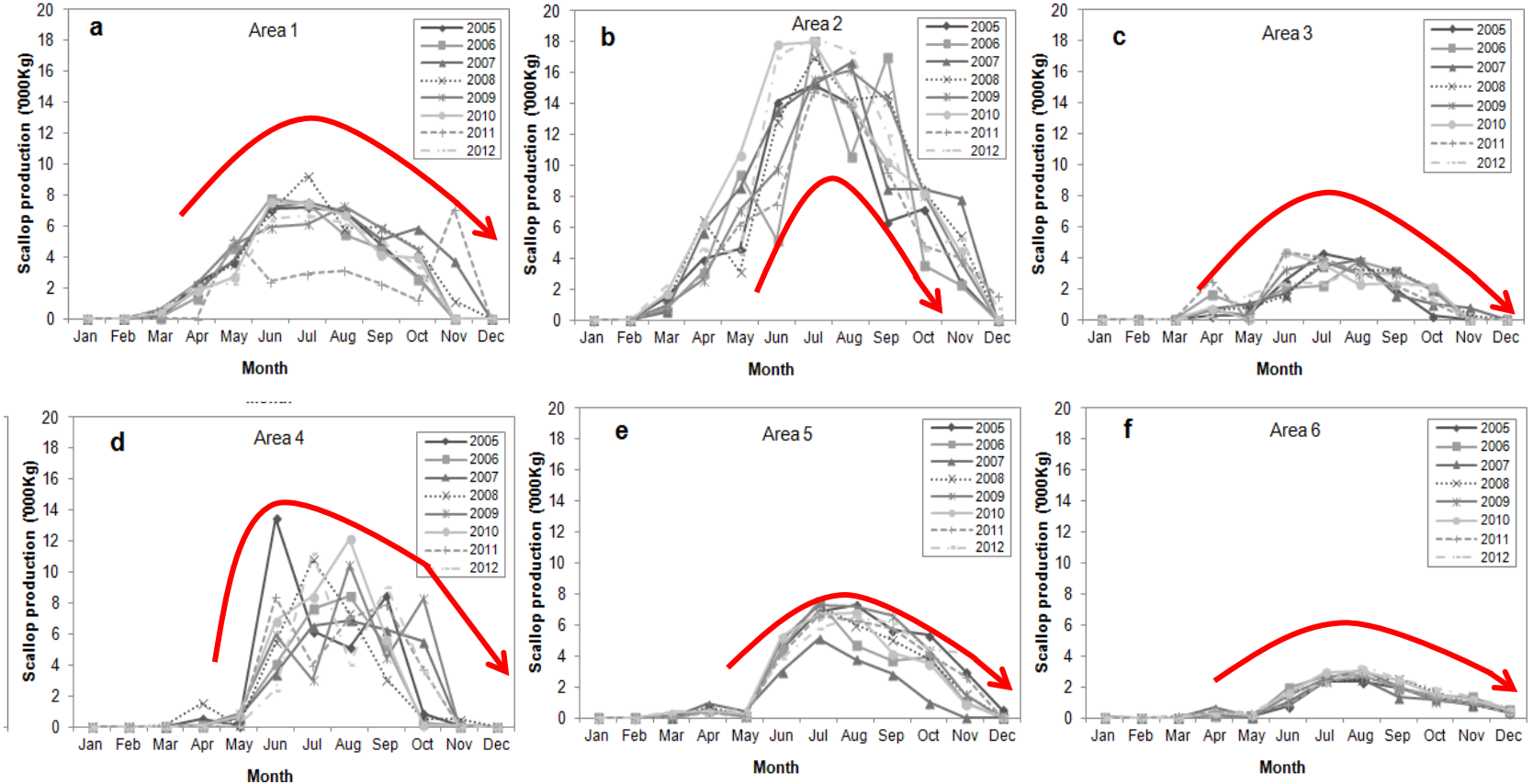


R^2=0.75

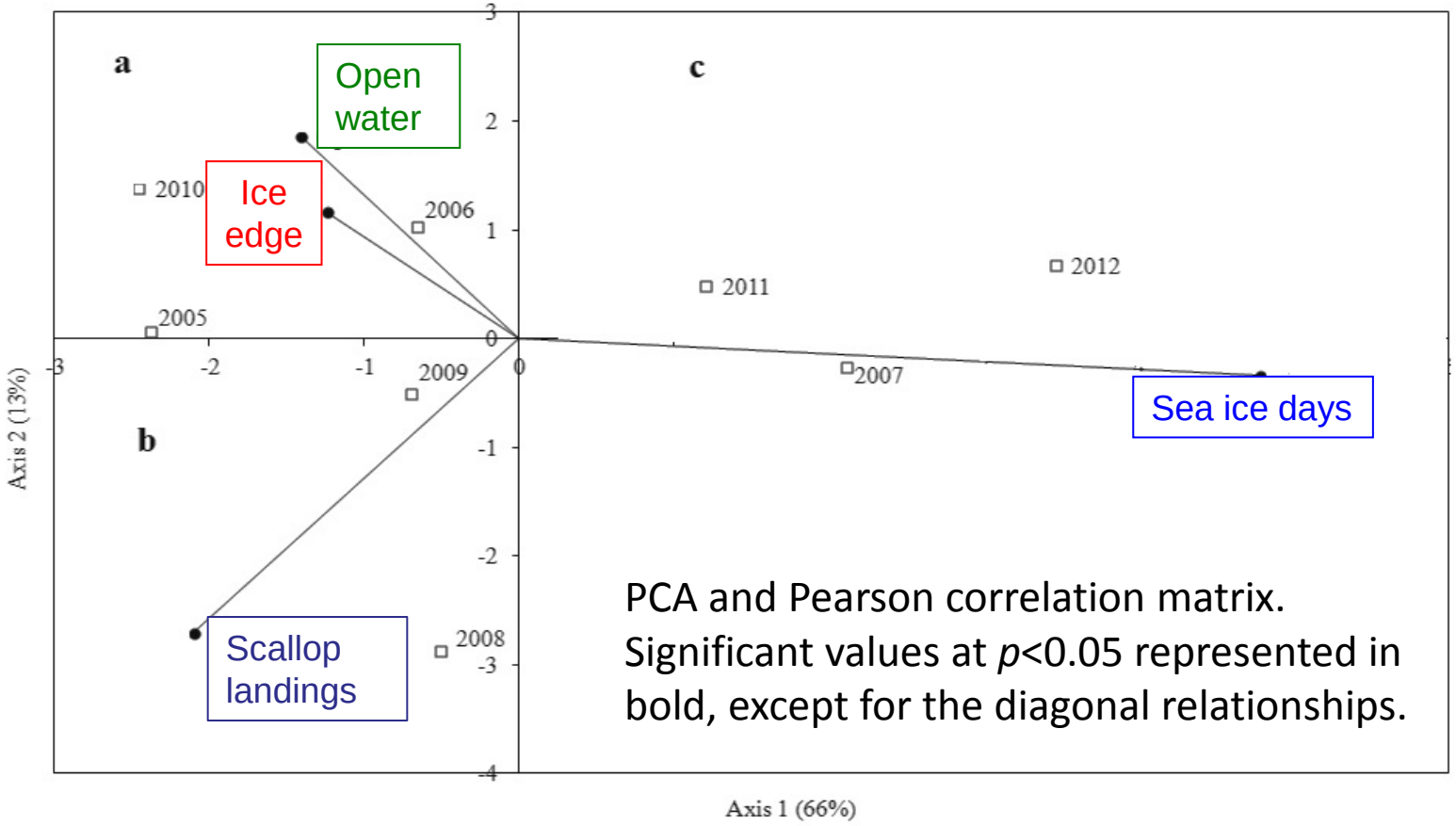
Scallop landings (2005-2012)

- Distinct increases from onset of sea ice retreat and decreases towards arrival of sea ice cover.
- Probably due to problem of accessibility to scallop sites in winter season; scallop harvesters might have been unwilling to work in winter season & blooming effect





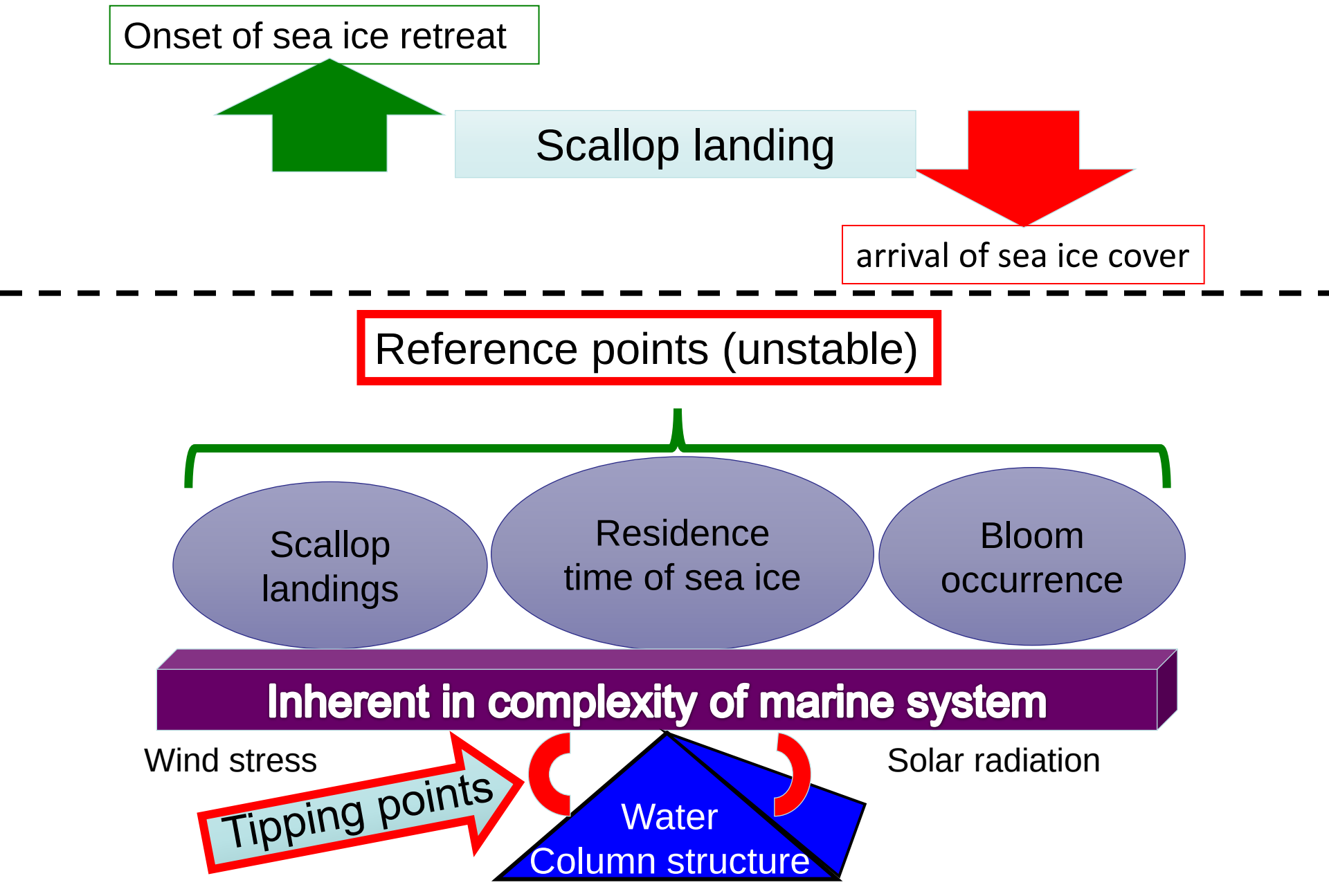
Scallop landings, sea ice cover & bloom variability



PCA and Pearson correlation matrix. Significant values at $p<0.05$ represented in bold, except for the diagonal relationships.

	Sea ice days	Landings	Ice edge bloom	Open water bloom
Sea ice days	1			
Landings	-0.38	1		
Ice edge bloom	-0.22	-0.32	1	
Open water bloom	**-0.64**	**0.54**	**0.71**	1

Conclusions



Thank you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