PICES Annual meeting 2024
Session 12
The changes in distribution of harmful algae blooms (HABs) in the North Pacific region

Observational evidences for arrival and evolutions of *Karenia* spp. in the Pacific waters off southeast Hokkaido, Japan, 2021

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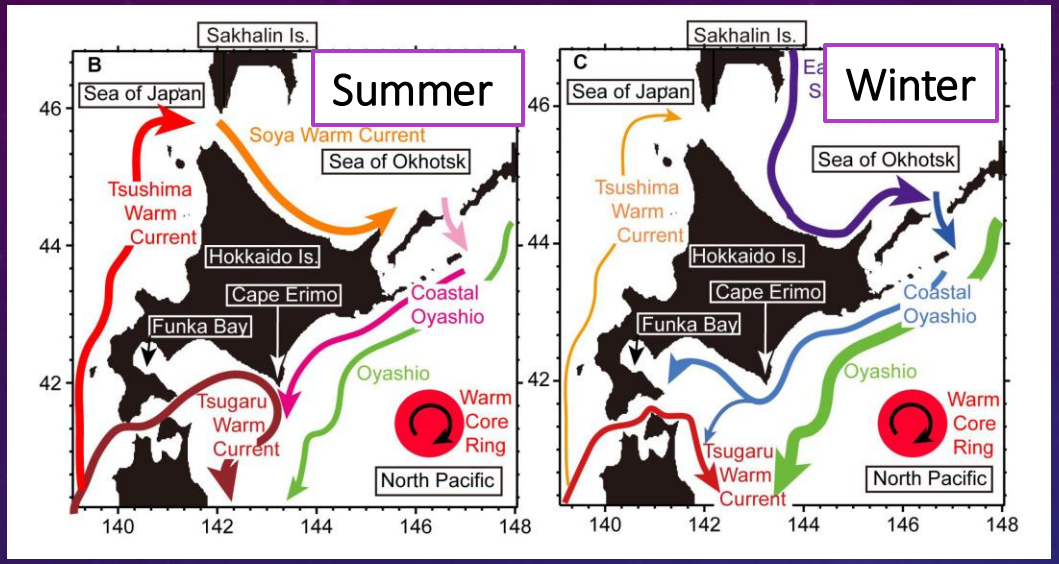
科研費
KAKENHI

マクロ沿岸海洋学
陸域から外洋におよぶ物質動態の統合的シミュレーション

FRA

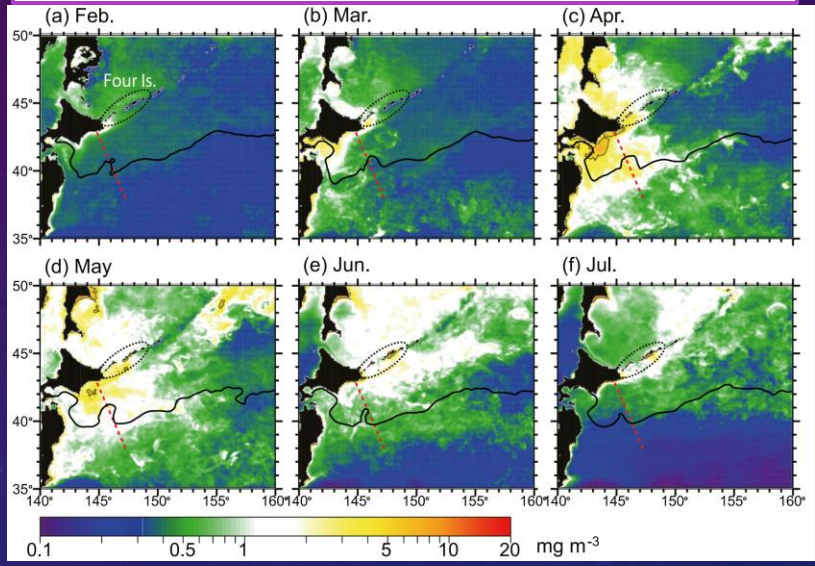
Water exchange off east coast of Hokkaido and marine ecosystem



Kuroda et al. (2020)

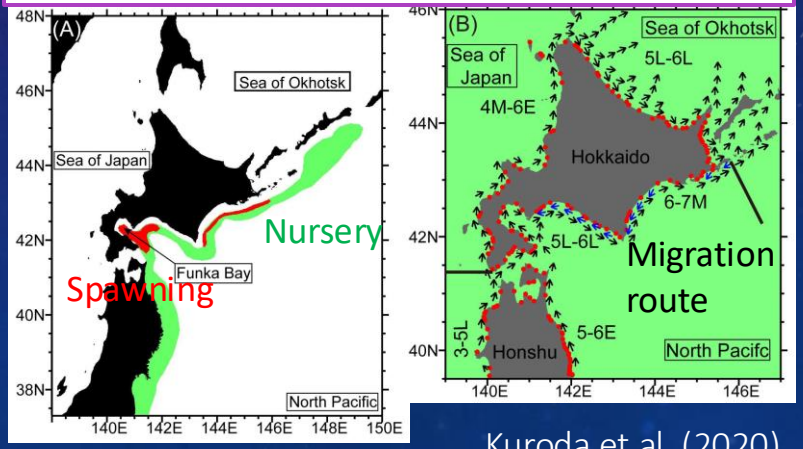
- Seasonal exchange of water mass system is prominent
  - Subarctic Oyashio water and subtropical Kuroshio water (Annual)
  - Soya warm current water (summer)
  - Coastal Oyashio water (winter)
- Primary production
  - Massive spring bloom event occurs in April off east coast of Hokkaido
- Migration, spawning, and nursery areas for commercial fishes
  - Japanese sardine, Japanese anchovy, walleye pollock, chum salmon, and Pacific saury

Spatial distribution of monthly mean satellite-derived chlorophyll-a concentration (MODIS)



Kuroda et al. (2019)

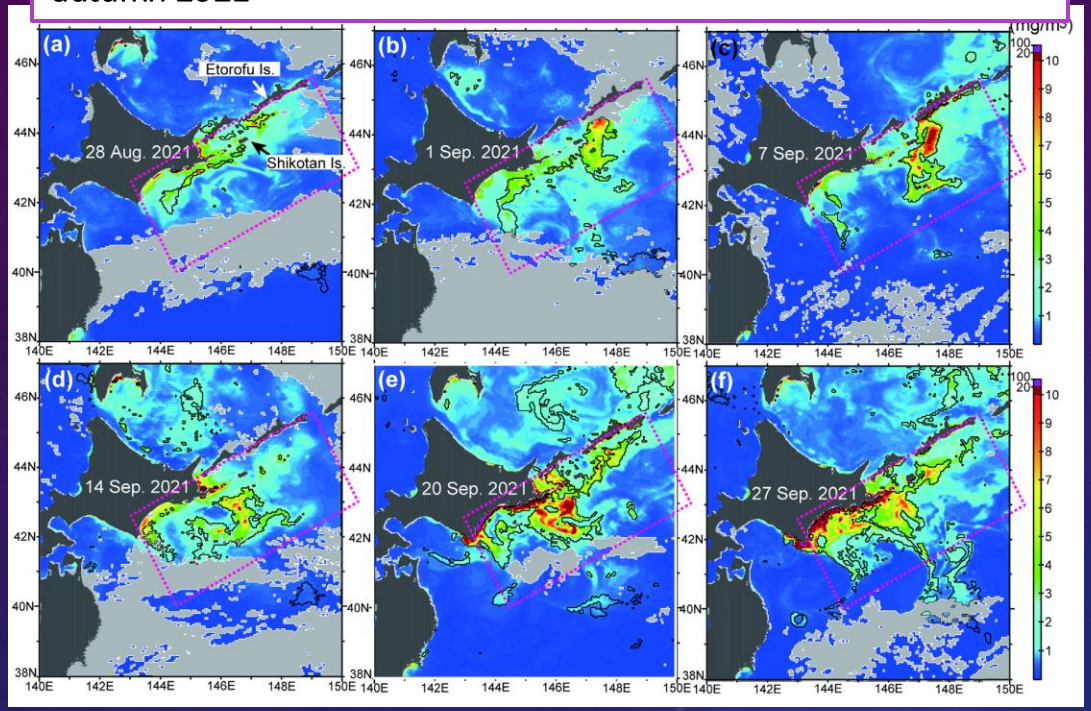
Spawning area and migration route for walleye pollack (left) and chum salmon (right)



Kuroda et al. (2020)

Harmful algal blooms in Sep. 2021 offshore of Hokkaido, Japan

Distribution of daily satellite-derived chlorophyll concentration in autumn 2021



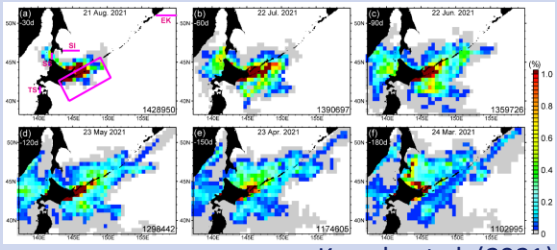
Kuroda et al. (2021)

Typical cell shapes of *Karenia* spp. in HABs 2021

Iwataki et al. (2022)

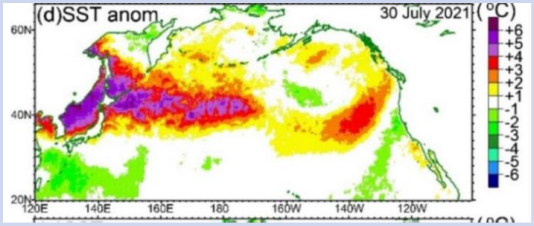
- Unprecedented harmful algae blooms (HABs) occurred in mid-September, 2021 (e.g., Kuroda et al., 2021).
  - HABs is characterized by large spatial scale (>300km) and long duration (several months) (Kuroda et al., 2022)
  - Causative spices are *Karenia* spp. (*Karenia selliformis*, *Karenia mikimotoi*, and *Karenia Longicanalis*) (Iwataki et al, 2022)
  - Serious economical damages for coastal fisheries was more than 70 million US dollars
- The drastic changes on lower-trophic level ecosystem are also indicated by numerical simulations (Takagi et al., 2022) and in-situ observations (Taniuchi et al., 2023)

When did Karenia spp. arrive and why did HABs occur off east coast of Hokkaido in mid-September, 2021?



Kuroda et al. (2021)

Particle-tracking experiments (Kuroda et al., 2021) and rDNA sequence analysis (Iwataki et al., 2022) suggest that *Karenia* spp. comes from the east coast of Kamchatka Peninsula in which HABs occurred in autumn 2020



Kuroda and Setou (2021)

The trigger of occurrences is speculated as the combinations of marine heat waves and the following vertical mixing event in summer, 2021 (Kuroda et al., 2021; Yamaguchi et al., 2022; Takagi et al., 2022)

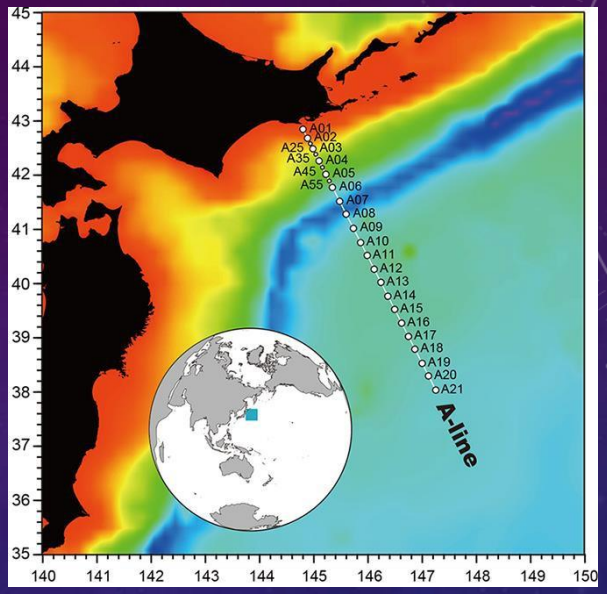
However, there is no direct observational evidence for the timing of *Karenia* spp. arrival and their evolutions

In this study, we examined arrival time and inferred the origin of *Karenia* spp. by analyzing the in-situ monitoring data

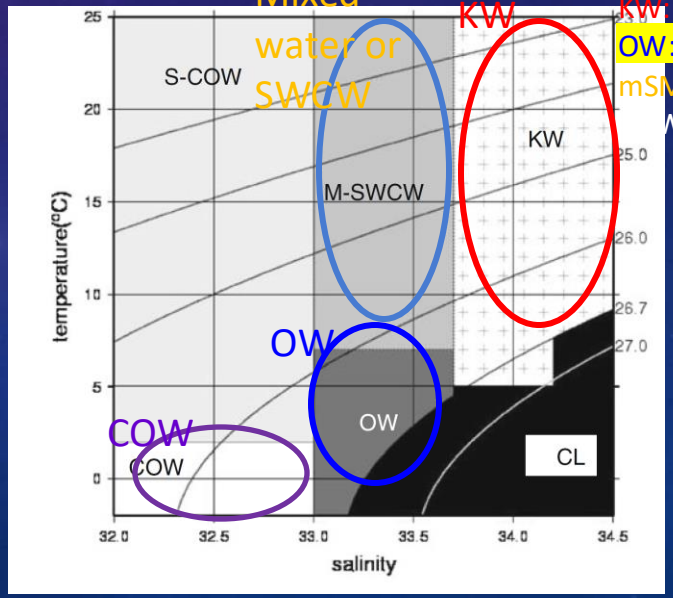
Data and method

- In-situ observations (A-line)
  - CTD data and sea water samples of Niskin bottles at A-line stations (B01, A01, A02, A03, A04, A05, A07, A09, A11, A13, A15, A17, A19, and A21)
  - Period: 2016-2022 (5 times per year)
- Phytoplankton numeration (cell density)
  - Sea water samples at 10m depth (0-150m at A04)
  - Water samples were fixed with acid Lugol's solution
  - *Karenia* spp. abundance is separately estimated by microscope analysis based on the morphological comparison (Taniuchi et al., 2023)
- Nutrient and chlorophyll concentrations
  - Phosphate, nitrate, silicate, and chlorophyll concentrations
- Water mass analysis (Kusaka et al. 2013)
  - Kuroshio water (KW), Oyashio water (OW), and their mixed water including modified Soya warm current water (mSWCW), which are dominant in warm season
  - Composite analysis is conducted in Karenia spp. detected sample

Spatial distribution of in-situ observation (A-line)



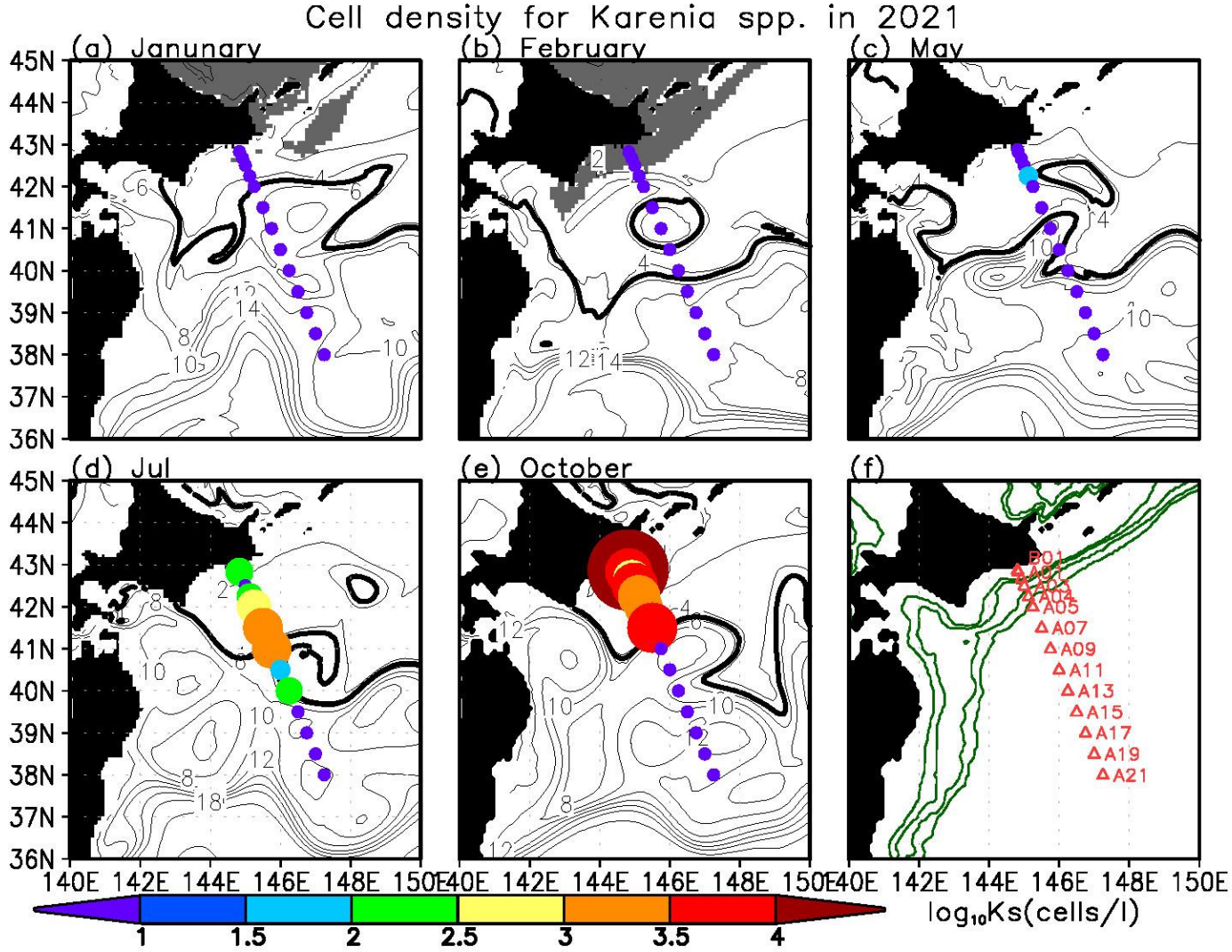
https://ocean.fra.go.jp/a-line/a-line_research.html



KW: S≥33.7, T>5
OW: T<7, 33≤S<33.7
mSWCW: T≥7, 33≤S<33.7
CW: S<33, T<2

Kusaka et al. (2013)

Spatial distribution of abundance for *Karenia* spp. at 10m depth at A-line in 2021



Karenia spp. was not detected from January to February at all

In May, small amount of phytoplankton cells for *Karenia* spp. is detected at A04

In July, substantial amount of *Karenia* spp. is identified in the offshore region in July

In October, the abundance of *Karenia* spp. is relatively large in the coastal region

Contours: ocean temperature at 100m depth (FRA-ROMS reanalysis data)
Bold: 5°C contour for the definition of Oyashio water
Purple circles indicate no detection of *Karenia* spp.

Taniuchi et al., revised

Abundance of *Karenia* spp. at A-line station from 2019–2022

2019 2020

Year	2019					2020				
Month	January	March	May	July	October	January	March	May	July	October
B01	-	-	-	-	**50**	-	-	-	-	**60**
A01	0.00	0.00	0.00	0.00	**240**	0.00	0.00	0.00	0.00	0.00
A02	0.00	0.00	0.00	0.00	**260**	0.00	0.00	0.00	0.00	**560**
A03	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
A04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A17	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Unit [N/L]

2021 2022

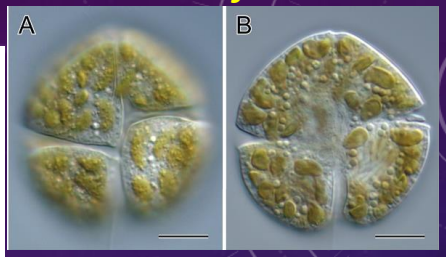
Year	2021					2022			
Month	January	March	May	July	October	January	March	May	July
B01	0.00	-	0.00	-	**20,930**	0.00	-	0.00	-
A01	0.00	0.00	0.00	**150**	**5,120**	0.00	0.00	0.00	**300**
A02	0.00	0.00	0.00	-	**920**	0.00	0.00	0.00	0.00
A03	0.00	0.00	0.00	0.00	**4,310**	0.00	0.00	0.00	0.00
A04	0.00	0.00	**0.03**	**120***	**2,240**	0.00	0.00	0.00	0.00
A05	0.00	0.00	0.00	**510**	**1,060**	0.00	0.00	0.00	0.00
A07	0.00	0.00	0.00	**1,430**	**9,300**	0.00	0.00	0.00	0.00
A09	0.00	0.00	0.00	**1,370**	0.00	0.00	0.00	0.00	0.00
A11	0.00	0.00	0.00	**40**	0.00	0.00	0.00	0.00	0.00
A13	0.00	0.00	0.00	**130**	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**400**
A17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*Note that the results for A04 in July, 2021 & May and July, 2022 are based on 0m samples

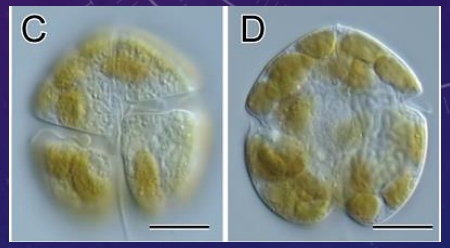
Unit [N/L]

Taniuchi et al., revised

Karenia selliformis



Karenia mikimotoi

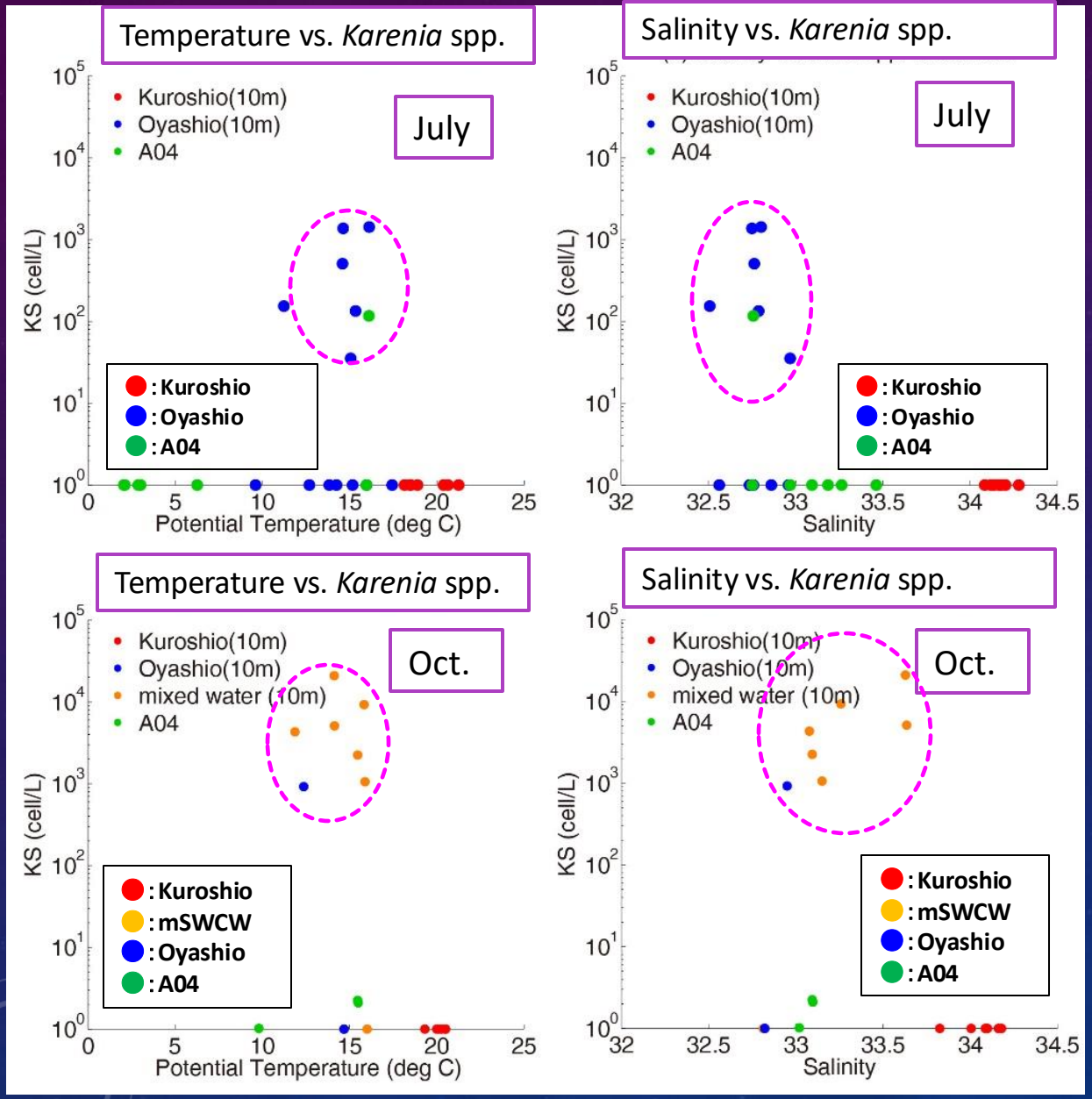


Iwataki et al. (2022)

- Before and after 2021, a small amount of *Karenia* spp. is detected, but the shape of phytoplankton cell is different from that in 2021
- *Karenia* spp. in 2019, 2020, 2022 is likely to be *K. mikimotoi*, which is different species in 2021 (*K. selliformis*)
- *Karenia* spp. is not regularly observed in this area
- The year of 2021 is quite abnormal year

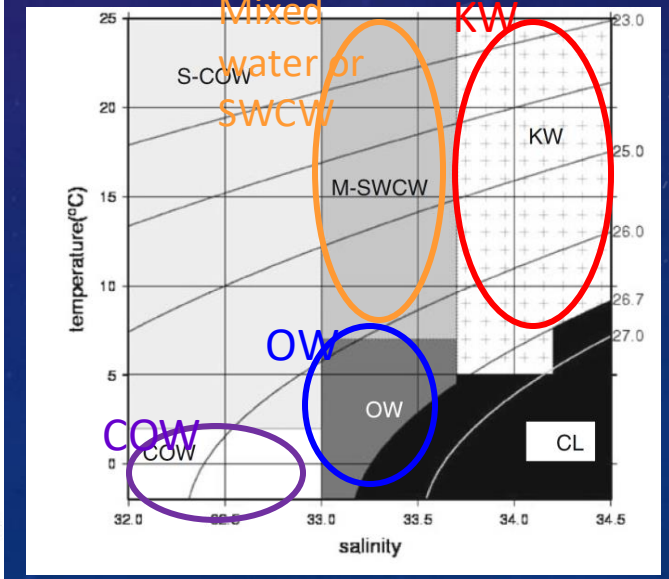
Iwataki et al. (2022)

Abundance of *Karenia* spp. and water mass properties



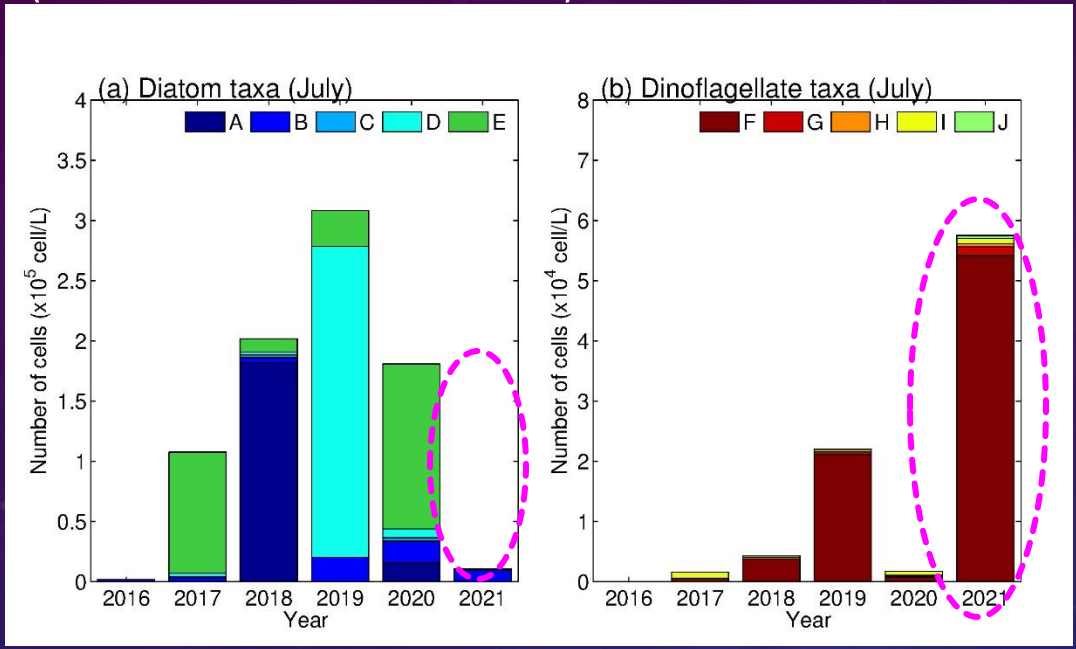
Taniuchi et al., revised

- *Karenia* spp. vs. water mass properties
  - In July, *Karenia* spp. is often detected within Oyashio water
  - In October, *Karenia* spp. is mSWCW as well as Oyashio water
- *Karenia* spp. vs. temperature
  - Relatively high around 15°C
  - Consistent with the relationship between satellite-based chlorophyll concentration and SST（Kuroda et al., 2021）
- *Karenia* spp. vs. salinity
  - In July, the high abundance is confined in the salinity less than 33
  - In October, the abundance is relatively high within 33-33.7 salinity



Kusaka et al. (2013)

Abundance of phytoplankton taxa for Oyashio water in July (2021 vs. 2016–2020)



Taniuchi et al. revision

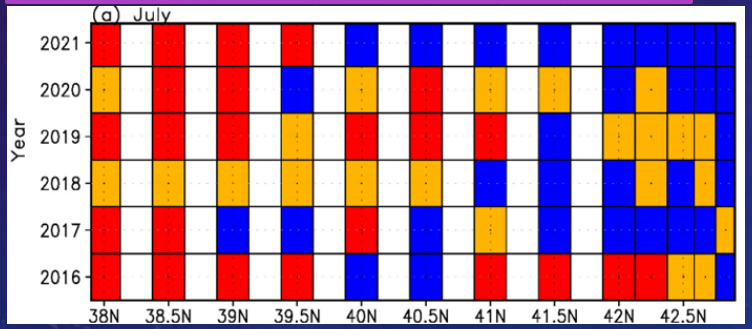
Diatom taxa

A:*Skeletonema costatum*
B:*Thalassiosira* spp.
C:*Leptocylindrus danicus*
D:*Fragilariopsis* spp.
E: *Pseudo-nitzshia seriata complex*

Dinoflagellate taxa

F: *Prorocentrum balticum*
G: *Pronoctiluca spinifera*
H: *Ceratium lineatum*
I: *Gyrodinium* sp.
J: *Karenia* spp.

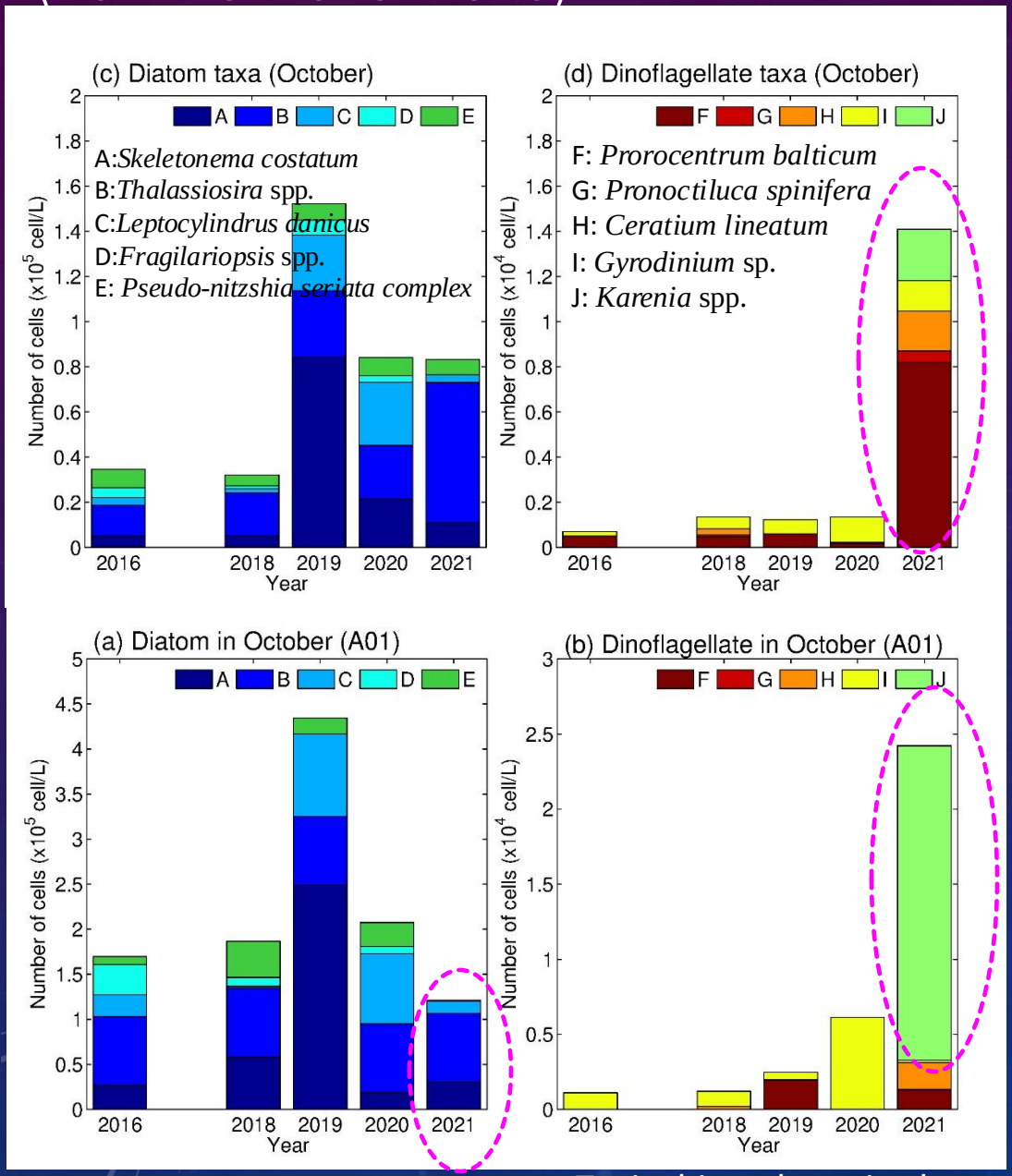
Water mass classification in July at A-line



- ~~: Kuroshio~~
- : Oyashio
- ~~: mixed water or mSWCW~~

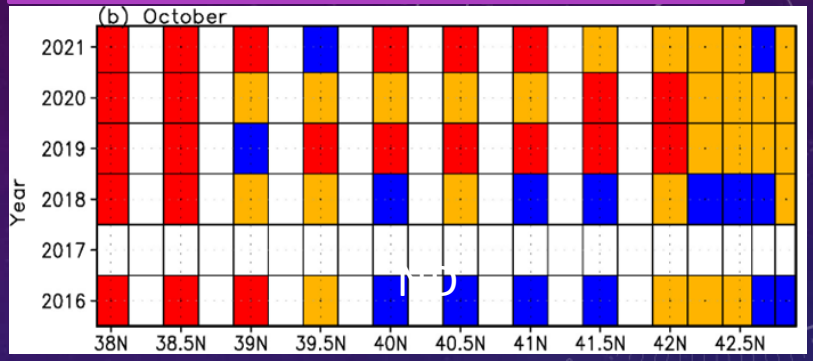
- In 2021, the abundance of major diatom taxa is 1-3 order smaller than previous 5 years
- The abundance of dinoflagellate taxa is 2-3 order higher than previous 5 years
- In July, the change in phytoplankton composition had already started in early July before the occurrence of MHW in mid July to early August

Abundance of phytoplankton taxa for Oyashio +mSWCW in October (2021 vs. 2016–2020)



Taniuchi et al., revised

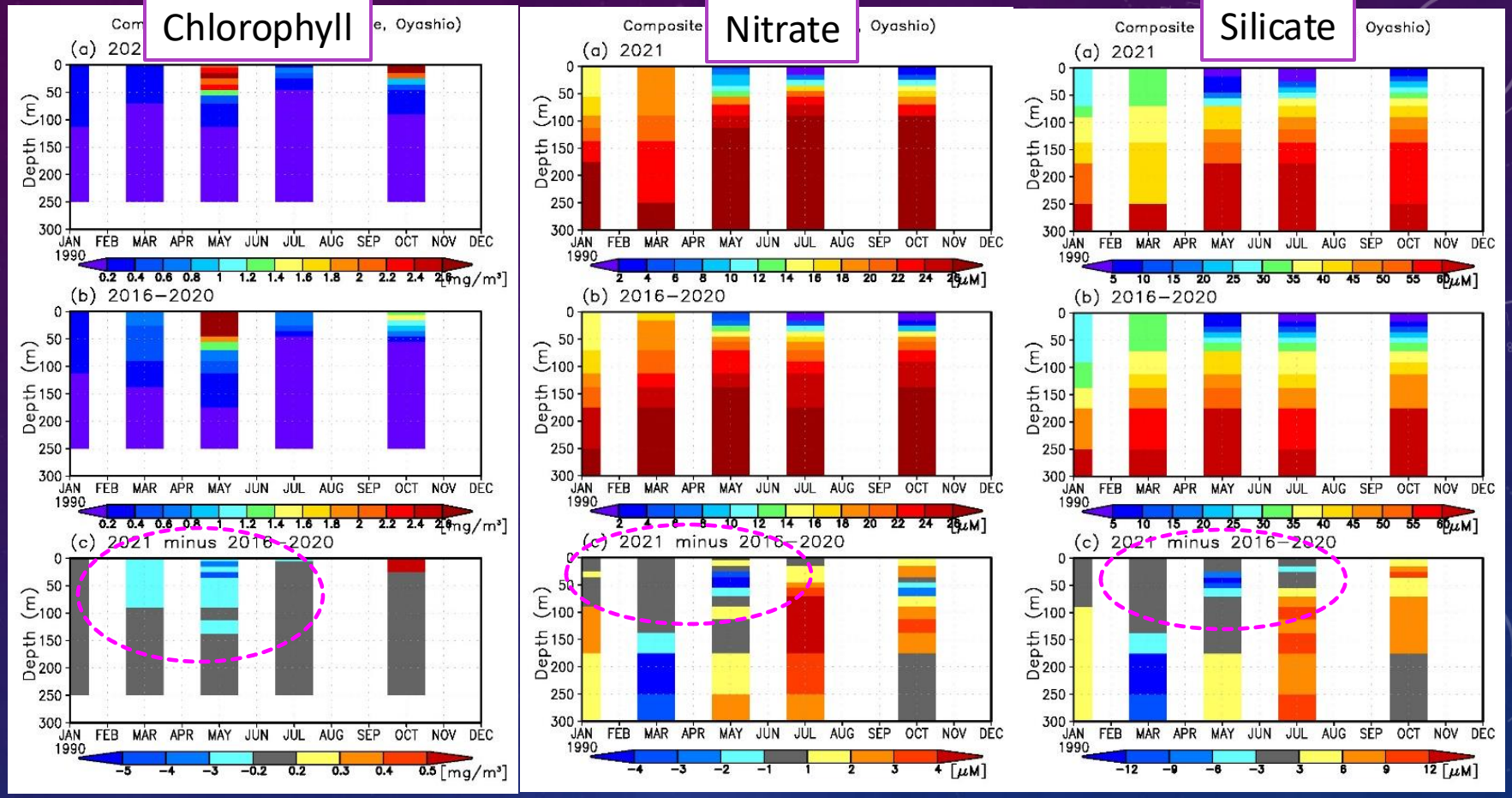
Water mass classification in October at A-line



● : Kuroshio
● : Oyashio
● : ~~mixed water or mSWCW~~

- In 2021, the abundance of diatom taxa is comparable to that in previous 5 years
  - The abundance is relatively low at station A01 (continental shelf area), which is consistent with earlier study (Taniuchi et al., 2023)
- The abundance of dinoflagellate taxa in 2021 is 1 order higher than that in previous 5 years
  - This tendency is remarkable in the most coastal station (A01)
  - *Karenia* spp. has a large fraction of total dinoflagellate taxa

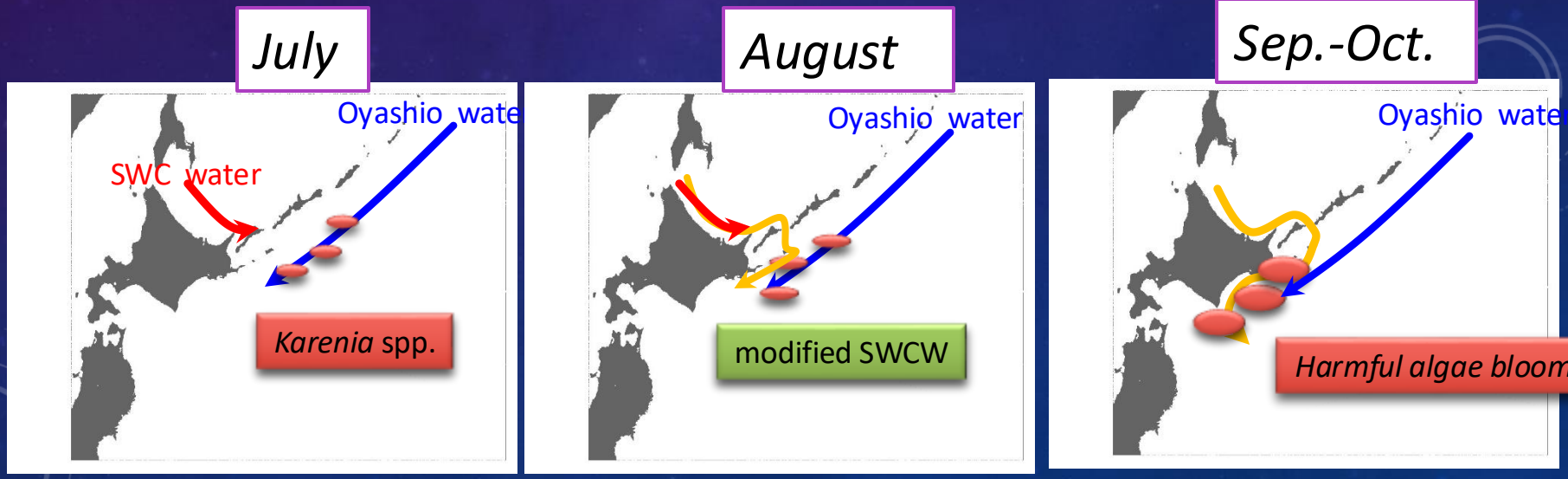
Seasonal variation of biological parameters for Oyashio water in 2021



- In 2021, surface nutrient concentration shows low level from March to July
  - Weak spring bloom in 2021 is partly related to the low abundance of diatom in July
- Other possible causes
  - High growth rate due to specific bacterial strains effects in subtropical water (Suzuki et al., 2023)
  - Toxin substance effects (Ohnishi et al., 2024)

Summary

- We examined the arrival and development of *Karenia* spp., which is the major causual species of HABs in 2021, by utilizing A-line repeated hydrographic observations
- Substantial amount of *Karenia* spp. emerges in the offshore area of Hokkaido, Japan at least in early July
- *Karenia spp*. was confined to surface Oyashio water around 15°C seawater temperature in July, but the abundance is shifted to modified Soya Warm Current water in October
- The abundance of major diatom taxa were at quite low level in *early July* 2021, which is before MHW event occurrence *from mid-July to early-August* in 2021
- *The decline of major diatom taxa cannot be explained solely by MHW*
- New mechanism for HABs occurrence
  - *Karenia* spp. is transported by Oyashio water, but moved to modified Soya Warm Current water during summer and evolved under preferable conditions (e.g., seawater temperature)




Thank you very much for your attention
Cruise observation by R/V Wakatakamaru in Aug., 2024