The following supplements accompany the article

Sea ice origin and sea ice retreat as possible drivers of variability in Arctic marine protist composition

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Supplement 1: Statistical analysis on environmental variables

METHODS:

Because different protist community structures may be expected under different environmental conditions, we examined whether the sea ice and water samples of each year differ from each other in their environmental conditions. These were for the sea ice samples: ice thickness, temperature, salinity and dissolved nutrients measured in sea ice and for the water samples: sea ice concentration, temperature, salinity and dissolved nutrients measured in the DCM. For this purpose, we computed principal component analyses (PCA) on the normalized and standardized environmental data using the package ade4 (Dray and Dufour 2007) within *R* (version 3.2.3, R development Core Team 2008). Potential groupings of the environmental profiles according to sampling region and sea ice origin for sea ice samples and sampling region and water mass for water samples were tested by using the non-parametric multivariate analysis ANOSIM (*R* package vegan, Oksanen et al. 2013) with 999 permutations and an euclidean distance measurement.

RESULTS:

Environmental conditions of sea ice samples

The sea ice sampled during the TransArc expedition in 2011 was characterized by a higher thickness (Table S1), than the sea ice sampled during the IceArc expedition in 2012. Sea ice temperatures of first-year ice (FYI) and multy-year ice (MYI) were similar in both years (Table S1).

Phosphate concentrations measured in the ice cores were in a similar range in 2011 and 2012, while nitrate concentrations were higher in 2012 than in 2011 (Table S1). In contrast, silicic acid and nitrite concentrations were on average higher in 2011 than in 2012. Sea ice drift data suggest that sea ice sampled in 2011 (Fig. 5, black lines) survived more summer periods than those sampled in 2012 (Fig. 5, blue lines) and originated from both, the Eurasian and Amerasian Basin. In contrast, sea ice cores sampled in 2012 were younger and originated from the Eurasian Basin only.

The variance between the sea ice samples collected in 2011 was mainly driven by nitrate, silicic acid and phosphate concentrations (Figure S1A). The environmental parameters showed no significant grouping according to the sampling regions (Figure S1A,

colors), even if we tested the nutrients only. However, the nutrient profile was significantly correlated to the regions of sea ice origin (ANOSIM, bottom section: R = 0.59, *P* = 0.02, entire core: R = 0.35, *P* = 0.08, Figure S1A, geometrical shapes). For example, ice cores originating from the Makarov Basin (Figure S1A, circles) were characterized by higher concentrations of silicic acid, nitrate and phosphate than those from the Amundsen Basin (Figure S1A, diamonds).

The PCA of the environmental parameters measured in 2012 explained 67% of the total variance in the environmental profile. Overall, sea ice thickness and partly nitrate were responsible for the variance of sea ice samples collected in 2012 (Figure S1B). The nutrient profiles were significantly correlated with the sampling regions (ANOSIM, R = 0.47, *P* = 0.01, Figure S2B, colors) but we observed no correlation with the regions of sea ice origin (Figure S1B, geometrical shapes). An overview of the results of statistical analysis can be found in Table 2.

Environmental conditions of water samples

The water stations were characterized by high sea ice concentrations (on average 81%, Kilias et al. 2014) during the TransArc expedition in 2011, while we observed lower sea ice concentrations (on average 54%, Table S1) during the IceArc expedition in 2012. Water temperatures measured at the chlorophyll maximum depth were in a similar range during the two expeditions (Table S1), while salinity was higher in 2012 than in 2011 (2011 average 31.2 psu, 2012 average 32.8 psu,Table S1). Dissolved nutrient concentrations, except those of nitrate, were lower in 2012 (Table S1) than in 2011.

As it was presented in Kilias et al. (2014), sea ice conditions explained the environmental distribution of water samples best (Figure S2A). In addition, water temperature was an important driver for the sample variance. A more detailed analysis of environmental variables for water samples in 2011 can be found in Kilias et al. (2014).

The PCA of environmental parameters collected for water samples in 2012 illustrates significant regional differences (ANOSIM, R = 0.54, *P* = 0.001, Figure S2B, colors). The regions differed mainly in sea ice concentration and water temperature (Table S1). Sea ice concentrations were low (0 - 53%,Table S1) on the Svalbard continental slope, the Laptev Sea and parts of the eastern Amundsen Basin. As sea ice concentration and water temperature were negatively correlated, the water temperature was higher (-1.3 - 1.4 °C,Table S1) in these parts of the Arctic Ocean compared to the other regions in this study. The Nansen Basin and the western Amundsen Basin were characterized by high sea ice concentrations (73 - 100%, Table S1) and slightly lower water temperatures ranging between -1.4 °C and -1.8 °C.

LITERATURE CITED:

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Kilias E, Kattner G, Wolf C, Frickenhaus S, Metfies K (2014) A molecular survey of protist diversity through the central Arctic Ocean. Polar Biol 37:1271–1287, doi:101007/s00300-014-1519-5

Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Wagner H (2013). vegan: Community Ecology Package. R package version 2.0-10. http://CRAN.R-project.org/package=vegan

R Development Core Team (2008) R: a language and environment for statistical computing R Foundation for Statistical ComputingVienna

Supplement 2: Figures and tables

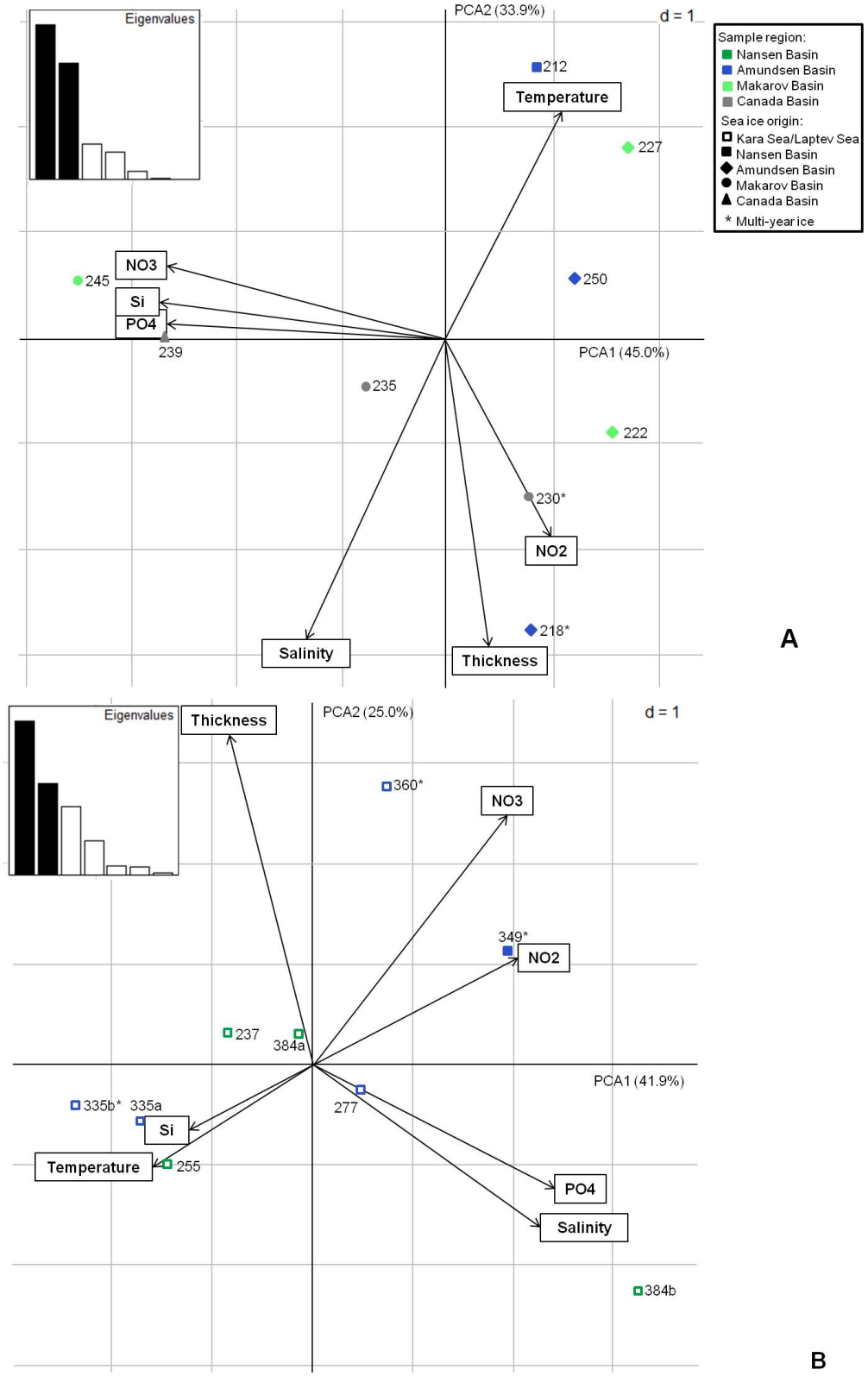

Figure S1. PCA of environmental parameters for ice cores. **A**. Sea ice samples collected in 2011. **B**. Sea ice samples collected in 2012. Color and symbol codes are given in the legend of (A).

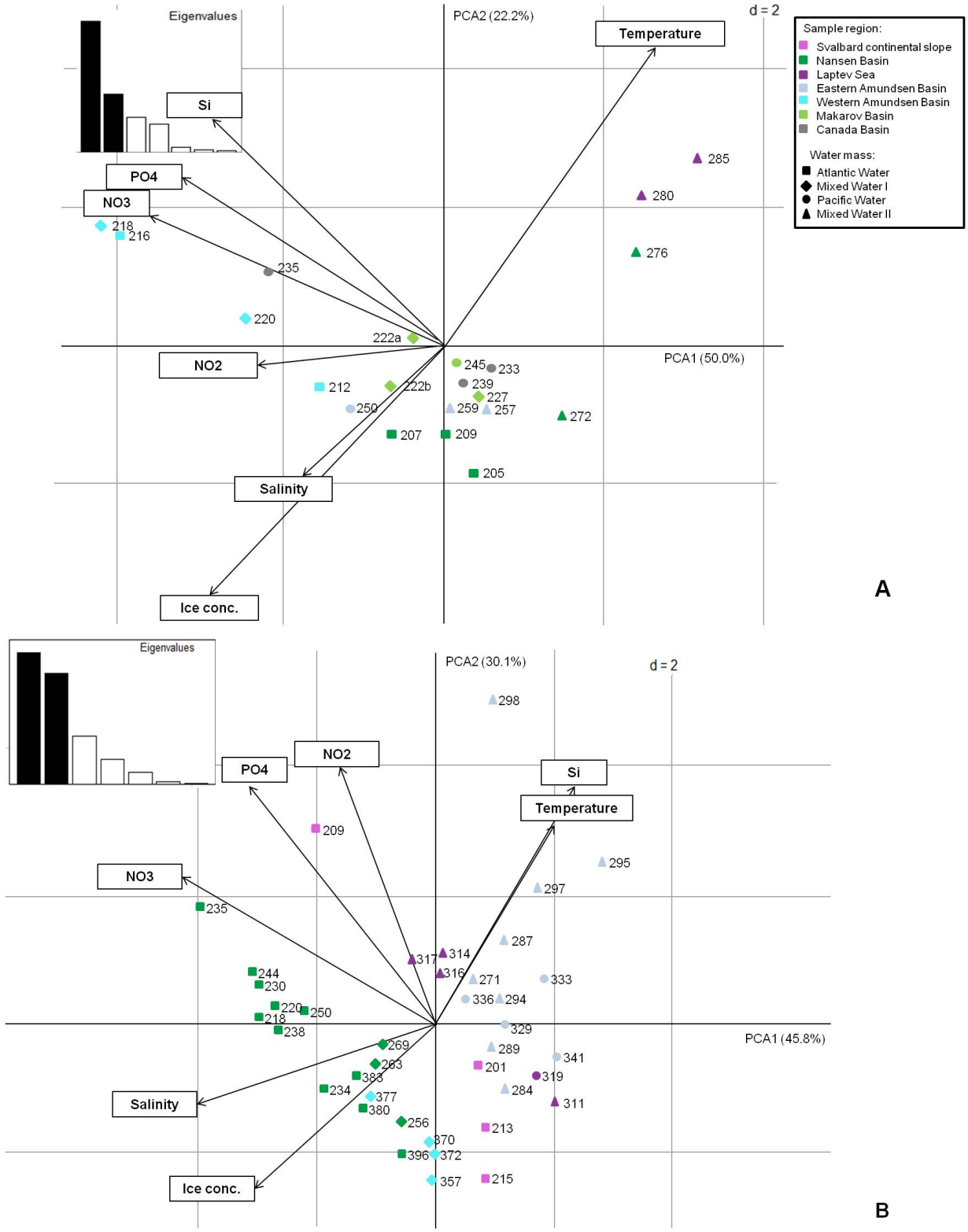

Figure S2. PCA of environmental parameters for water samples. **A**. Water samples collected in 2011. **B**. Water samples collected in 2012. Color and symbol codes are given in the legend of (A). Ice conc., ice concentration.

Table S1. Stations sampled during RV Polarstern expedition ARK XXVI/3 and ARK XXVII/3 to the Central Arctic Ocean in 2011 and 2012 in chronological order. **A.** Water samples. Table of water samples taken in 2011 can be found in Kilias et al. (2014). Water samples of 2011 analyzed with Illumina sequencing: 212, 218, 227, 235, 239, 250. **B.** Sea ice samples. Stations of 2012 that were part of the common sampling region with 2011 are marked with a star (*). Samples analyzed with Illumina sequencing are in bold. Salinity, dissolved nutrients, water temperature, sea ice concentration and water mass are given for each water station. Atlantic Water and Pacific Water formed mixed water masses with different nutrient regimes (Mix I and Mix II). Averages of salinity, temperature and dissolved organic nutrients phosphate (PO_4) silicic acid (Si), nitrite (NO_2) and nitrate (NO_3), were calculated for the sea ice bottom in 2011 and for the entire sea ice core in 2012. Ice types are given: first-year ice (FYI), multi-year ice (MYI), newly formed ice (new ice, NI). n.d. not determined.

A Water samples

Station number	Date (month/day/ year)	Latitude °N	Longitude °E	Sampling depth (m)	Ice Conc. (%)	Temp. (°C)	Salinity (psu)	NO_3 (µmol/l)	NO_2 (µmol/l)	PO_4 (µmol/l)	Si (µmol/l)	Water mass
201	08/05/2012	81.004	29.982	21	0	0.63	34.16	1.49	0.06	0.21	0.34	Atlantic Water
209	08/06/2012	81.493	30.172	32	0	-0.04	34.27	5.25	0.20	0.49	2.41	
213	08/06/2012	81.836	29.954	18	0	-1.16	33.7	0.72	0.03	0.20	1.25	
215	08/07/2012	82.495	30.003	17	52	-1.11	33.26	0.46	0.01	0.17	0.99	
218	08/07/2012	82.99	30.054	50	91	-1.75	34.25	5.57	0.08	0.45	1.90	
220	08/08/2012	83.999	30.021	50	96	-1.78	34.19	4.21	0.17	0.38	1.37	
230	08/11/2012	84.022	31.219	50	96	-1.77	34.18	4.73	0.18	0.41	1.54	
234	08/12/2012	83.99	39.474	22	94	-1.52	34.04	3.95	0.06	0.35	1.36	
235	08/13/2012	83.923	60.655	56	98	-1.68	34.18	7.57	0.15	0.54	2.97	
238	08/14/2012	83.985	78.09	30	100	-1.72	34.15	4.79	0.11	0.41	1.65	
244	08/16/2012	83.918	75.971	30	90	-1.58	34.17	6.64	0.08	0.51	2.67	
250	08/18/2012	83.588	87.452	30	73	-1.68	34.13	4.61	0.12	0.41	1.69	
256*	08/20/2012	82.674	109.59	20	93	-1.68	33.74	1.13	0.11	0.22	1.23	Mixed Water I
263*	08/22/2012	83.079	110.15	20	94	-1.67	33.09	2.21	0.14	0.28	1.68	
269*	08/23/2012	83.124	116.934	25	82	-1.62	33.19	2.49	0.11	0.32	2.39	
271*	08/24/2012	83.277	122.443	25	53	-1.39	31.43	2.27	0.09	0.34	4.54	Mixed Water II
284*	08/26/2012	82.894	129.769	10	95	-1.55	31.18	0.59	0.06	0.24	3.62	
287*	08/27/2012	82.166	126.97	20	10	-1.37	31.38	1.45	0.15	0.30	4.44	

Station number	Date (month/day/ year)	Latitude °N	Longitude °E	Sampling depth (m)	Ice Conc. (%)	Temp. (°C)	Salinity (psu)	NO_3 (µmol/l)	NO_2 (µmol/l)	PO_4 (µmol/l)	Si (µmol/l)	Water mass
289*	08/28/2012	80.004	128.484	25	0	-1.52	32.92	0.65	0.11	0.24	2.65	
294*	08/29/2012	79.05	131.78	18	0	-1.46	32.04	1.81	0.08	0.30	4.01	
295*	08/29/2012	78.745	132.326	20	0	0.11	30.21	1.10	0.11	0.32	6.53	
297*	08/29/2012	78.373	133.196	20	0	0.72	31.22	1.79	0.11	0.36	3.71	
298*	08/29/2012	78.134	133.342	25	0	1.34	31.27	3.98	0.15	0.54	7.00	
311*	09/01/2012	77.397	118.196	20	0	-0.27	32.1	0.21	0.03	0.19	1.28	
314*	09/01/2012	77.716	118.316	20	0	-0.66	33.16	1.91	0.14	0.35	2.58	
316*	09/02/2012	78.35	118.6	18	0	-1.31	33.28	2.05	0.10	0.35	3.75	
317*	09/02/2012	78.666	118.743	20	0	-1.54	32.98	2.90	0.13	0.35	3.16	
319*	09/02/2012	79.162	119.785	18	0	-1.46	31.84	0.45	0.06	0.22	2.75	Contribution of Pacific or river water
329*	09/05/2012	81.876	130.878	20	49	-1.48	31.04	0.90	0.10	0.28	3.42	
333*	09/06/2012	83.003	127.179	20	0	-1.5	31.04	1.00	0.10	0.28	4.65	
336*	09/07/2012	85.094	122.266	20	80	-1.55	31.47	1.71	0.10	0.34	4.68	
341*	09/09/2012	85.159	123.359	19	80	-1.54	29.97	0.54	0.05	0.25	4.69	
357*	09/19/2012	87.924	61.125	15	100	-1.8	33.11	1.00	0.02	0.23	1.52	Mixed Water I
370*	09/23/2012	88.771	55.927	20	100	-1.79	32.93	1.68	0.02	0.28	2.23	
372*	09/24/2012	88.408	52.33	20	100	-1.78	33.09	1.00	0.03	0.27	2.01	
377*	09/25/2012	87.211	51.843	20	100	-1.79	33.15	2.96	0.05	0.35	1.91	
380*	09/26/2012	86.318	52.192	20	100	-1.71	33.72	2.42	0.08	0.31	1.53	Atlantic Water
383	09/27/2012	84.802	52.105	20	92	-1.8	32.9	3.59	0.05	0.37	1.72	
396	09/29/2012	84.346	17.815	10	100	-1.79	32.78	2.18	0.02	0.28	1.15	

B Sea ice samples

Station number	Date (month/day/ year)	Latitude °N	Longitude °E	Ice type	Ice core length (cm)	Temp. (°C)	Salinity (psu)	NO_3 (µmol/l)	NO_2 (µmol/l)	PO_4 (µmol/l)	Si (µmol/l)	Water mass
203*	08/17/2011	85.974	59.424	FYI	104	-1.4	4	n.d.	n.d.	n.d.	n.d.	Atlantic
209*	08/17/2011	86.987	58.503	FYI	130	-0.7	2.6	n.d.	n.d.	n.d.	n.d.	
212*	08/19/2011	88.018	59.953	FYI	112	-0.2	0.1	0.54	0.03	0.06	2.68	
218*	08/22/2011	89.965	146.631	MYI	318	-1.3	4.2	0.00	0.23	0.05	0.96	MixI
222	08/26/2011	88.736	-128.249	FYI	160	-1.0	2.0	0.25	0.55	0.00	0.38	
227	08/29/2011	86.861	-155.045	FYI	130	-0.3	0.7	0.04	0.02	0.01	0.25	
230	08/31/2011	85.064	-137.235	MYI	249	-1.1	3.5	0.13	0.18	0.06	1.44	Pacific
235	09/02/2011	83.029	-130.035	FYI	209	-1.0	3.0	0.81	0.13	0.05	7.58	
239	09/05/2011	84.074	-164.202	FYI	160	-1.3	2.9	1.04	0.05	0.36	8.54	Mix II
245	09/08/2011	84.795	166.415	FYI	120	-1.2	3.2	1.37	0.06	0.31	12.91	Pacific
250*	09/11/2011	84.372	139.787	FYI	121	-1.5	0.8	0.00	0.02	0.00	0.50	Mix II
224	08/09/2012	84.051	31.114	FYI	120	-0.66	2.05	n.d.	n.d.	n.d.	n.d.	Atlantic
237	08/13/2012	83.987	78.103	FYI	140	-0.82	1.89	0.25	0.02	0.02	0.34	
255*	08/19/2012	82.671	109.590	FYI	92	-0.71	1.89	0.25	0.01	0.03	0.41	MixI
277*	08/24/2012	82.883	130.130	FYI	87	-0.67	1.66	0.74	0.02	0.06	0.19	Mix II
335a*	09/06/2012	85.102	122.245	FYI	84	-0.66	0.94	0.17	0.01	0.01	0.11	Pacific
335b*	09/06/2012	85.102	122.245	MYI	140	-0.72	1.25	0.05	0.01	0.02	0.60	
349*	09/17/2012	87.934	61.217	MYI	139	-1.94	3.19	1.55	0.02	0.09	0.10	MixI
360*	09/21/2012	88.828	58.864	MYI	194	-1.65	2.39	2.31	0.02	0.02	0.29	
384a	09/27/2012	84.375	17.454	FYI	85	-2.75	1.74	0.62	0.01	0.01	0.09	Atlantic
384b	09/27/2012	84.375	17.454	NI	2	-1.70	9.00	0.99	0.02	0.11	0.29	