

SUPPLEMENTARY MATERIALS

A decade-long study on harmful dinoflagellate blooms and biotoxin contamination in mussels from the north-western Adriatic Sea (Mediterranean Sea)

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Table S1. Geographic coordinates (WGS84) of the 10 sampling stations (i.e., S-1-10) corresponding to *M. galloprovincialis* production areas along the coast of Emilia-Romagna region (NW Adriatic Sea), ordered from northwest to southeast, and of the three ARPAE sampling stations (i.e., RA-308, FC-314, RN-319) considered for physicochemical parameters.

Station	Latitude	Longitude
S-1	44.49783	12.30583
S-2	44.49229	12.30569
S-3	44.43861	12.52100
S-4	44.33350	12.42183
S-5	44.20832	12.47957
S-6	44.19468	12.50548
S-7	44.17100	12.52383
S-8	44.07118	12.68393
S-9	44.05428	12.68393
S-10	44.00176	12.73283
308	44.48165	12.32104
314	44.22104	12.43074
319	43.98944	12.75985

Table S2. Summary statistics (maximum, minimum, average, and standard deviation) of physicochemical parameters recorded from 2012 to 2022 across the three ARPAE sampling stations along the cost of Emilia-Romagna region (i.e., RA-308, FC-314, RN-319).

RA												
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Temperature (°C)	<i>min</i>	3.71	6.95	9.19	7.18	5.63	4.86	7.09	5.73	7.04	6.78	6.53
	<i>max</i>	28.43	27.55	25.96	28.11	27.75	28.99	29.47	28.95	28.19	28.75	28.75
	<i>avrg</i>	16.54	16.52	17.35	16.22	16.09	17.25	18.36	17.12	17.73	16.37	17.82
	<i>std</i>	7.69	7.22	6.05	6.54	7.05	7.06	6.99	7.37	6.85	7.03	7.48
Salinity (psu)	<i>min</i>	22.90	10.23	8.23	22.90	20.49	28.10	17.29	15.93	13.46	22.08	28.58
	<i>max</i>	36.55	35.33	33.43	35.20	36.35	36.27	33.82	36.91	36.86	36.81	37.93
	<i>avrg</i>	31.76	30.04	26.71	29.88	30.56	32.43	30.16	30.22	29.12	31.01	34.23
	<i>std</i>	3.48	4.91	6.20	3.56	3.41	2.15	4.08	4.26	5.21	3.42	2.39
Dissolved Oxygen (mg L ⁻¹)	<i>min</i>	4.68	5.76	6.34	5.82	5.20	5.04	6.91	5.37	5.53	5.11	5.62
	<i>max</i>	14.76	14.33	15.50	14.47	11.94	10.72	14.01	13.68	15.15	12.30	12.02
	<i>avrg</i>	8.74	8.91	9.28	8.80	8.63	8.38	8.92	8.73	9.95	8.65	7.82
	<i>std</i>	2.42	2.02	2.24	1.95	1.87	1.74	1.62	1.72	2.31	1.97	1.80
NO₂⁻ + NO₃⁻ + NH₄⁺ (ug L ⁻¹)	<i>min</i>	0.2	3.1	10.2	6.2	0.0	0.0	1.2	0.0	0.0	0.0	0.0
	<i>max</i>	624.3	1161.4	1486.8	1219.0	897.8	618.7	1541.4	1076.9	1162.4	731.2	401.9
	<i>avrg</i>	206.6	370.1	419.4	301.9	290.1	198.4	271.9	261.5	295.9	248.2	128.3
	<i>std</i>	190.2	341.1	482.8	282.3	276.3	207.3	343.5	269.6	332.6	228.3	133.2
PO₄³⁻ (ug L ⁻¹)	<i>min</i>	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	<i>max</i>	12.74	10.59	27.83	25.40	17.08	7.36	20.11	4.90	25.56	11.90	18.79
	<i>avrg</i>	2.71	3.35	4.62	2.95	3.44	2.52	3.20	1.90	4.75	2.95	4.26
	<i>std</i>	3.28	3.13	6.69	5.15	4.32	2.13	4.76	1.59	5.10	2.67	4.55
Chl-a (ug L ⁻¹)	<i>min</i>	0.70	1.00	1.20	0.30	2.30	1.50	2.50	1.20	2.60	1.70	1.20
	<i>max</i>	37.10	16.80	21.70	38.80	17.70	29.30	33.40	13.30	35.90	21.20	17.70
	<i>avrg</i>	6.13	4.26	7.15	7.45	6.11	6.48	7.34	5.85	9.67	6.01	5.08
	<i>std</i>	9.16	3.81	6.52	7.90	3.74	6.04	6.33	3.02	8.32	4.16	4.53

FC												
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Temperature (°C)	<i>min</i>	3.01	7.05	9.02	7.32	5.72	4.35	5.24	5.35	6.41	6.80	7.21
	<i>max</i>	26.99	27.29	25.47	28.32	27.34	27.57	28.81	27.84	27.00	26.61	28.07
	<i>avrg</i>	15.87	15.94	16.88	16.97	16.56	15.99	18.25	16.69	17.20	15.93	17.26
	<i>std</i>	7.62	7.03	5.79	6.96	7.13	7.50	7.05	7.29	6.53	6.69	7.36
Salinity (psu)	<i>min</i>	28.56	9.49	22.05	20.31	24.11	25.00	21.69	17.96	22.33	21.35	29.22
	<i>max</i>	36.93	35.92	32.61	36.55	36.43	37.01	35.78	36.57	37.40	35.31	38.28
	<i>avrg</i>	34.48	30.76	28.33	31.65	32.84	33.88	30.74	31.69	31.32	31.90	34.83
	<i>std</i>	2.45	5.43	3.44	3.81	2.82	2.69	3.49	4.06	4.11	3.32	2.44
Dissolved Oxygen (mg L ⁻¹)	<i>min</i>	5.61	5.97	6.84	5.25	6.01	5.92	5.82	5.98	5.34	5.97	5.28
	<i>max</i>	11.15	11.94	10.99	14.56	11.17	12.71	14.06	11.37	12.00	17.17	12.06
	<i>avrg</i>	8.04	8.37	8.44	8.20	7.96	8.13	8.50	8.44	8.84	8.89	7.86
	<i>std</i>	1.53	1.42	1.06	2.01	1.46	1.88	1.90	1.72	1.87	2.65	1.73

NO₂⁻ + NO₃⁻ + NH₄⁺ (ug L⁻¹)	<i>min</i>	0.0	0.0	0.5	0.0	0.0	0.0	0.1	3.1	0.0	0.0	0.0
	<i>max</i>	1033.4	970.3	925.3	528.7	696.3	1442.4	1848.3	1222.2	839.5	850.7	374.6
	<i>avrg</i>	155.3	248.6	279.4	171.6	157.0	176.7	263.4	266.4	213.0	198.3	94.7
	<i>std</i>	236.8	244.1	264.4	138.1	192.2	296.4	404.5	322.4	256.1	226.6	118.1
PO₄³⁻ (ug L⁻¹)	<i>min</i>	0.40	0.40	0.40	0.40	0.40	0.59	0.40	0.40	0.40	0.40	0.40
	<i>max</i>	7.09	17.07	12.76	9.98	11.20	6.52	24.63	12.55	13.01	7.84	10.42
	<i>avrg</i>	1.75	2.26	3.37	1.82	2.26	2.26	3.39	2.42	2.96	2.45	2.80
	<i>std</i>	1.86	3.70	3.63	2.00	2.50	1.57	5.13	3.09	3.18	1.80	2.50
Chl-a (ug L⁻¹)	<i>min</i>	0.40	0.50	1.20	0.90	1.50	1.00	1.30	1.30	1.20	1.35	0.80
	<i>max</i>	42.50	34.60	20.80	54.40	16.80	25.90	33.50	21.90	34.50	25.00	31.80
	<i>avrg</i>	3.90	4.12	6.16	7.17	5.53	6.10	7.38	5.65	7.61	5.52	6.35
	<i>std</i>	8.43	6.79	4.92	11.07	3.61	6.83	7.89	4.40	7.54	4.98	7.63

RN												
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Temperature (°C)	<i>min</i>	2.95	7.24	9.17	7.83	6.06	4.39	6.15	5.85	7.03	6.22	7.73
	<i>max</i>	27.03	27.13	25.36	27.57	27.09	27.63	28.60	28.49	26.80	26.84	28.03
	<i>avrg</i>	16.17	16.07	17.23	17.08	16.63	16.26	18.27	16.97	17.69	16.13	17.42
	<i>std</i>	7.56	6.82	5.64	6.84	6.78	7.47	6.98	7.28	6.14	6.87	7.12
Salinity (psu)	<i>min</i>	27.47	20.72	23.19	28.02	22.47	24.14	21.39	20.59	24.75	26.67	33.04
	<i>max</i>	37.12	36.61	35.05	36.79	36.85	37.52	35.80	37.10	37.73	36.59	38.57
	<i>avrg</i>	35.18	32.55	30.93	32.94	33.01	34.67	32.10	32.91	32.92	33.50	36.13
	<i>std</i>	2.18	3.47	2.60	2.54	2.87	2.76	3.11	3.36	3.60	2.47	1.76
Dissolved Oxygen (mg L⁻¹)	<i>min</i>	5.60	5.85	6.51	5.48	3.56	5.66	5.88	6.05	6.03	5.68	5.36
	<i>max</i>	13.60	11.39	11.01	12.59	10.69	10.91	11.84	10.97	12.82	14.21	10.01
	<i>avrg</i>	8.15	8.03	8.22	8.16	7.84	8.08	8.32	8.19	8.67	8.28	7.57
	<i>std</i>	2.07	1.47	1.15	1.74	1.65	1.68	1.61	1.49	1.89	2.28	1.32
NO₂⁻ + NO₃⁻ + NH₄⁺ (ug L⁻¹)	<i>min</i>	0.0	3.4	1.6	0.0	0.0	4.4	5.0	1.4	0.0	0.0	0.3
	<i>max</i>	602.1	755.4	896.3	526.2	510.3	1292.6	828.4	839.4	502.4	689.4	267.7
	<i>avrg</i>	126.4	193.1	198.4	146.8	129.9	142.5	184.8	176.0	139.8	138.8	80.8
	<i>std</i>	170.9	186.5	207.9	137.2	134.5	261.4	193.6	194.8	156.8	163.6	98.1
PO₄³⁻ (ug L⁻¹)	<i>min</i>	0.40	0.40	0.40	0.40	0.40	0.48	0.40	0.40	0.40	0.40	0.40
	<i>max</i>	6.46	8.49	6.04	7.75	7.90	3.73	11.05	5.66	7.83	4.40	6.31
	<i>avrg</i>	1.81	2.67	2.02	1.82	2.11	1.68	2.31	2.25	2.10	1.56	2.09
	<i>std</i>	1.77	2.49	1.45	1.57	1.78	1.03	2.44	1.70	1.90	1.27	1.75
Chl-a (ug L⁻¹)	<i>min</i>	0.30	0.10	0.60	0.20	0.90	0.50	0.30	1.00	1.20	0.20	0.50
	<i>max</i>	23.80	24.00	18.50	18.80	14.60	15.30	12.70	8.00	14.50	16.40	10.60
	<i>avrg</i>	2.62	3.11	4.48	4.12	4.01	4.02	4.80	3.40	4.75	4.12	2.84
	<i>std</i>	4.88	5.06	4.23	4.76	3.14	4.11	3.56	1.86	3.12	4.25	2.27

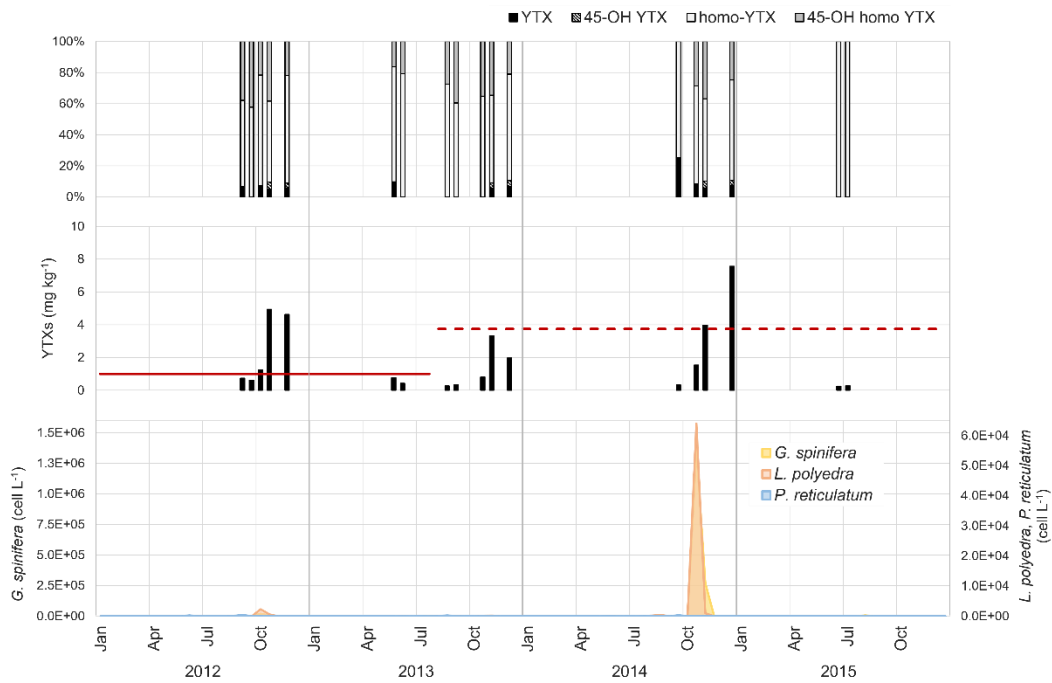


Fig. S1. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-1** in the **RA** area. The solid red line in the second graph represents the regulatory limit for YTXs of 1.00 mg kg^{-1} as defined by Reg. (EC) 853/2004, while the dashed red line represents the updated regulatory limit of 3.75 mg kg^{-1} as defined by Reg. (EC) 786/2013.

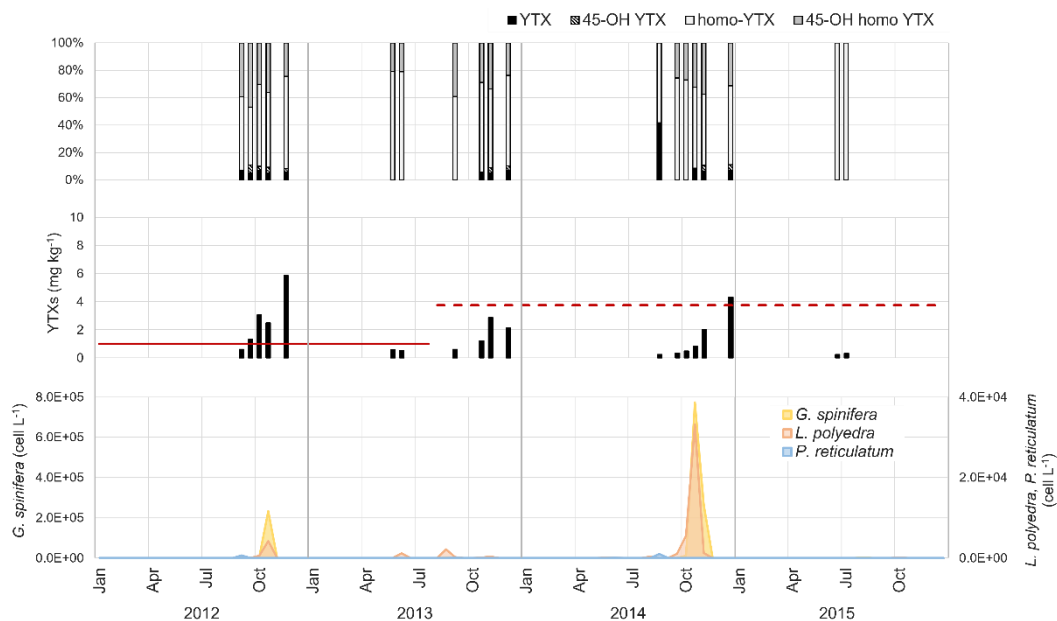


Fig. S2. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-2** in the **RA** area. Solid and dashed red lines in the second graph as in Fig. S1.

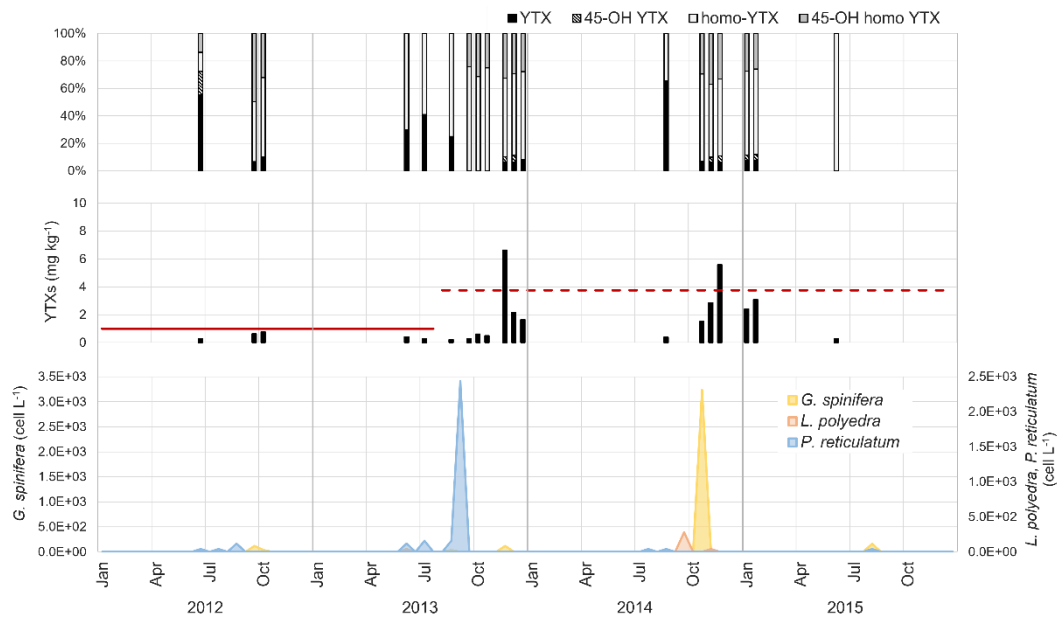


Fig. S3. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-4** in the **RA** area. Solid and dashed red lines in the second graph as in Fig. S1.

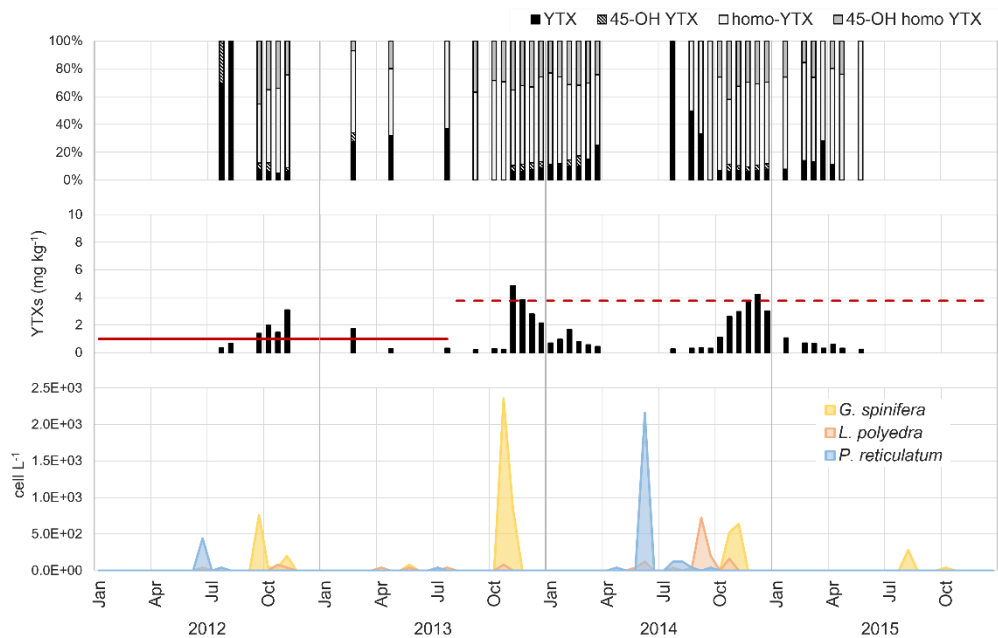


Fig. S4. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-6** in the **FC** area. Solid and dashed red lines in the second graph as in Fig. S1.

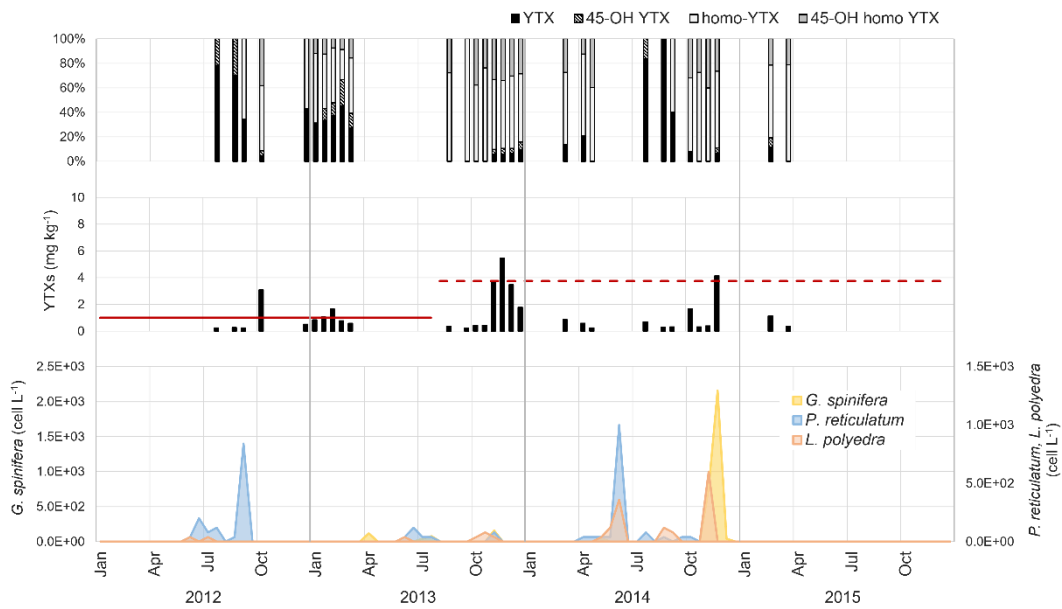


Fig. S5. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-7** in the **RN** area. Solid and dashed red lines in the second graph as in Fig. S1.

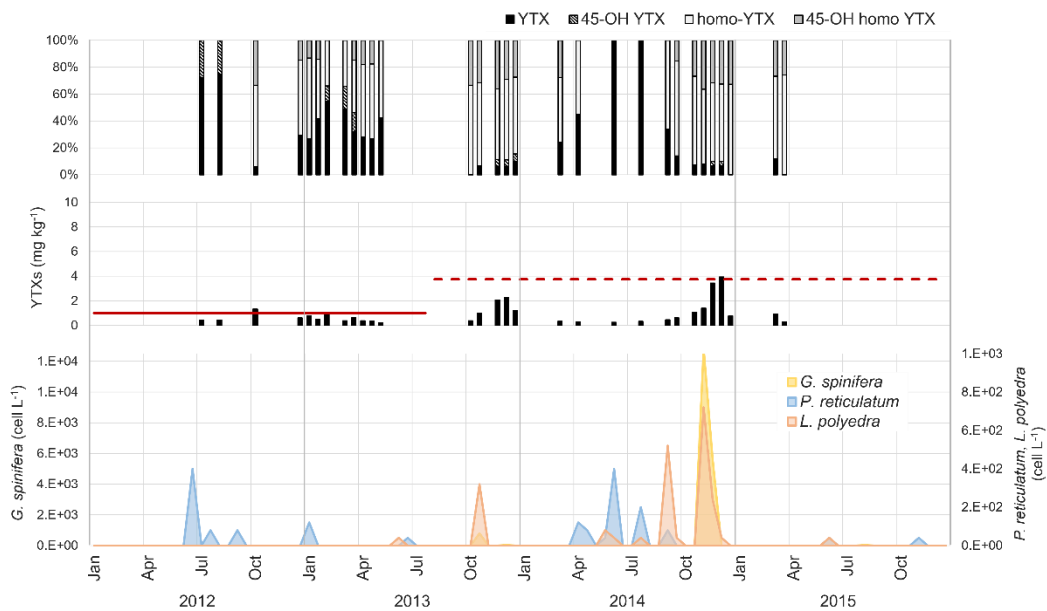


Fig. S6. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station **S-8** in the **RN** area. Solid and dashed red lines in the second graph as in Fig. S1.

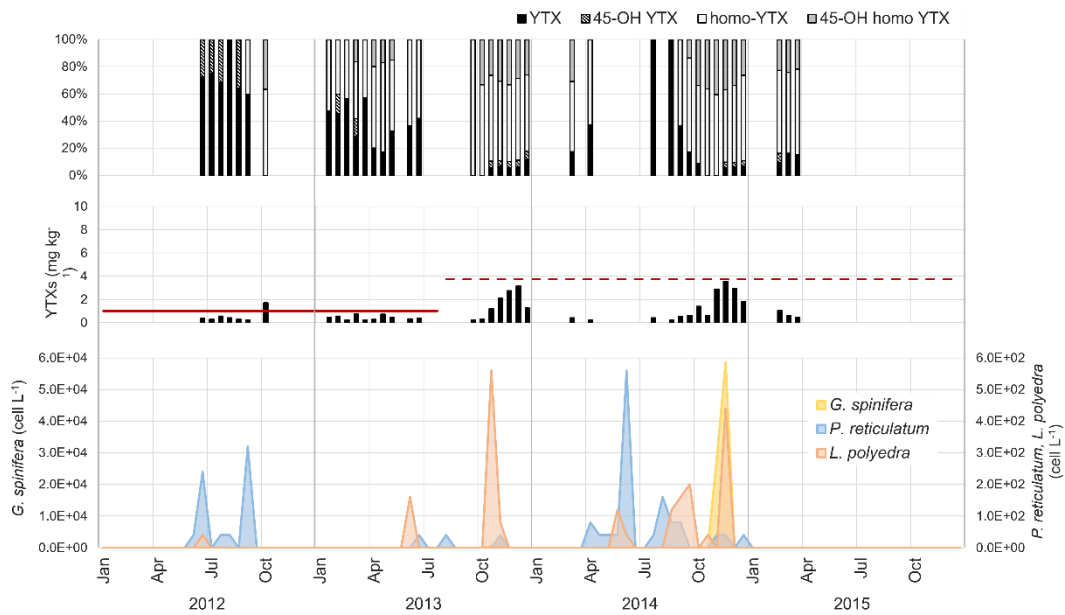


Fig. S7. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station S-9 in the RN area. Solid and dashed red lines in the second graph as in Fig. S1.

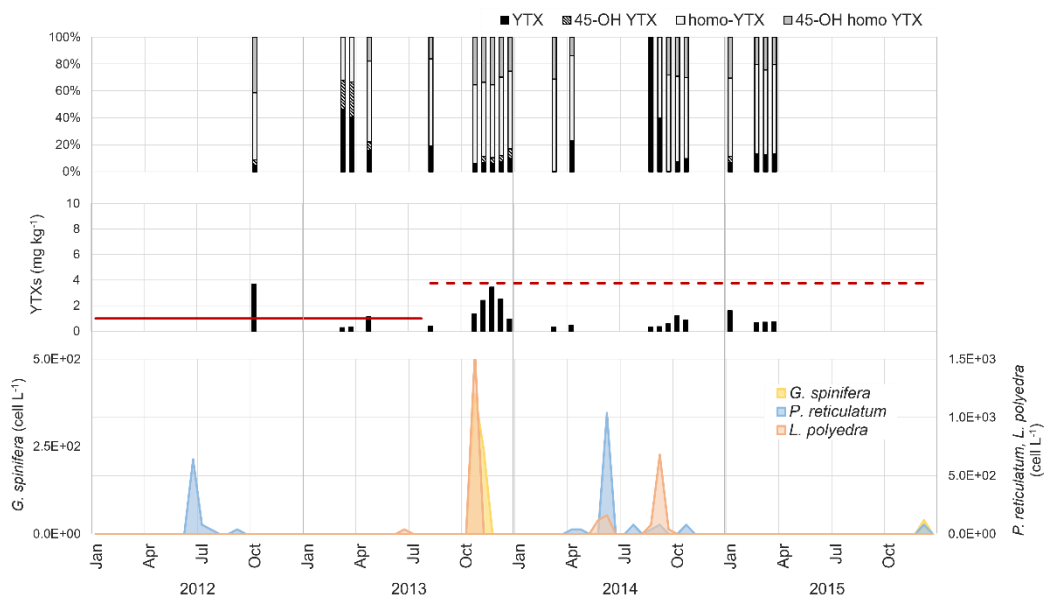


Fig. S8. Trends in YTXs concentration in mussels, relative composition of analogues, and cell counts of potentially YTXs-producing phytoplankton species in seawater at station S-10 in the RN area. Solid and dashed red lines in the second graph as in Fig. S1.

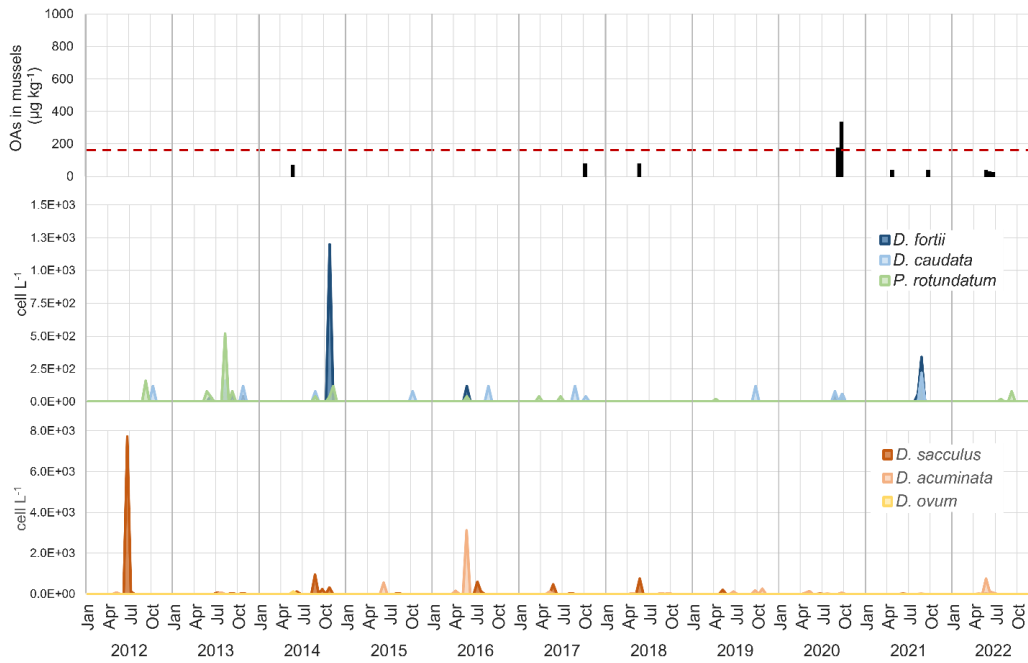


Fig. S9. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-1 in RA area. The dashed red line in the first graph represents the regulatory limit for OAs as defined by Reg. (EC) 853/2004 ($160 \mu\text{g kg}^{-1}$).

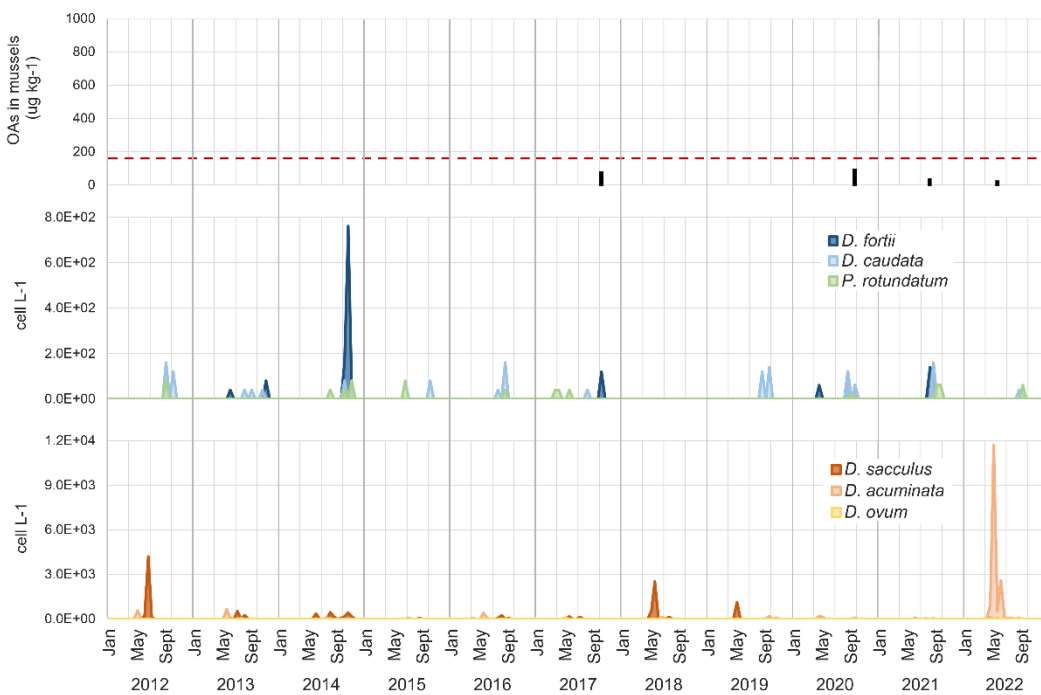


Fig. S10. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-2 in RA area. Dashed red line in the first graph as in Fig. S-9.

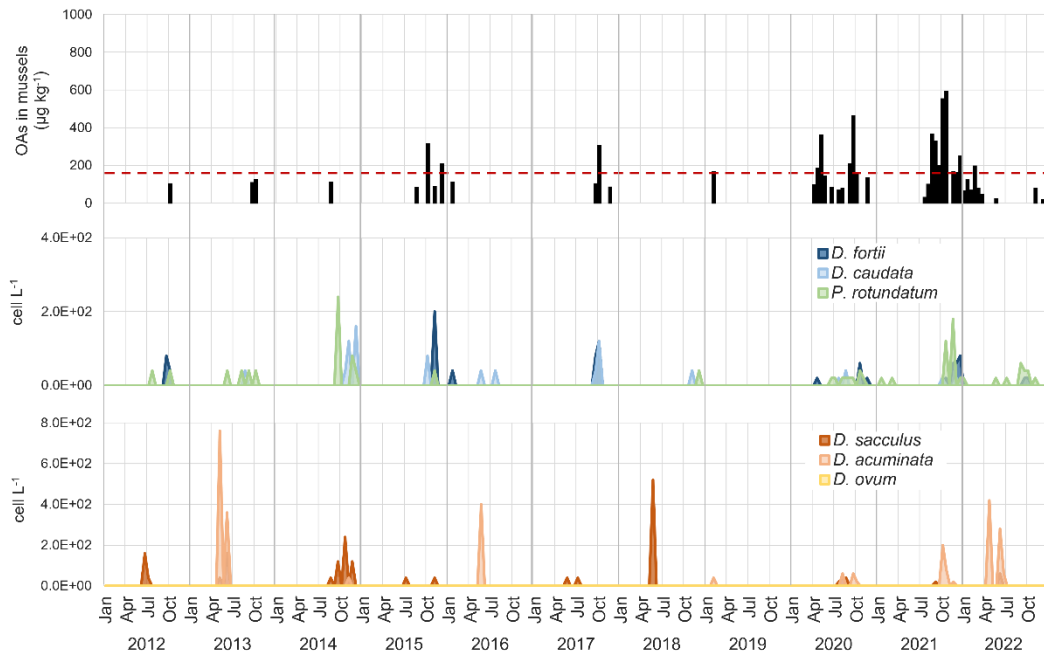


Fig. S11. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-3 in RA area. Dashed red line in the first graph as in Fig. S-9.

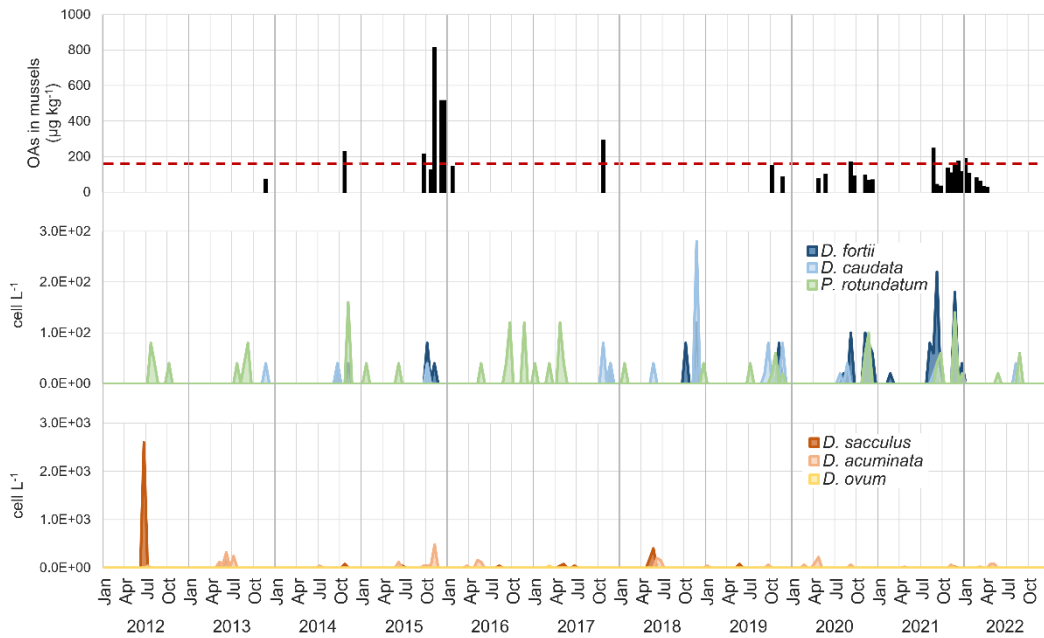


Fig. S12. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-4 in RA area. Dashed red line in the first graph as in Fig. S-9.

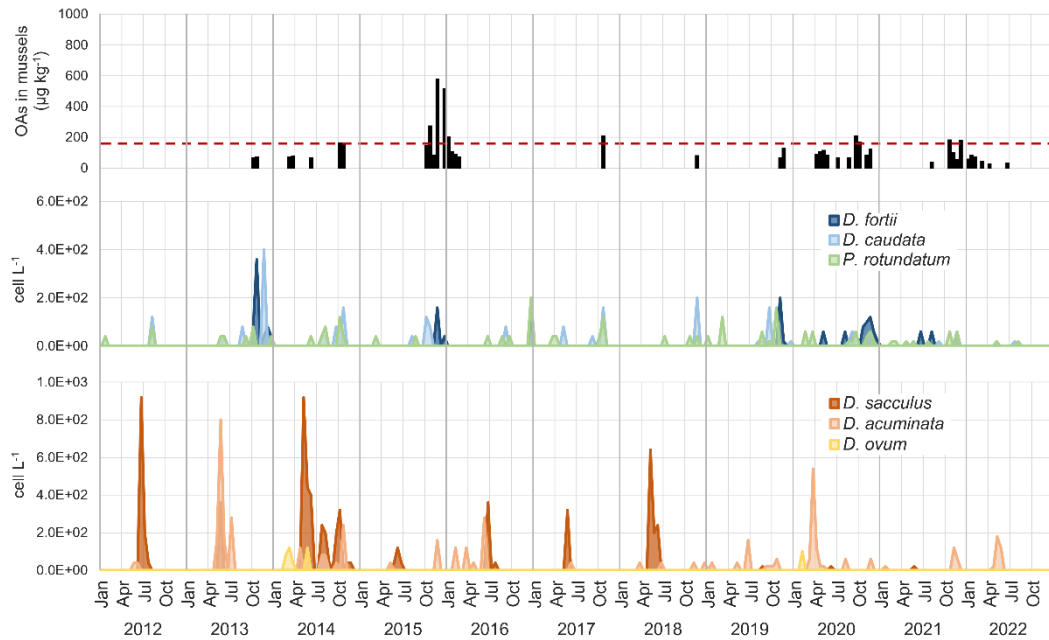


Fig. S13. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-5 in FC area. Dashed red line in the first graph as in Fig. S-9.

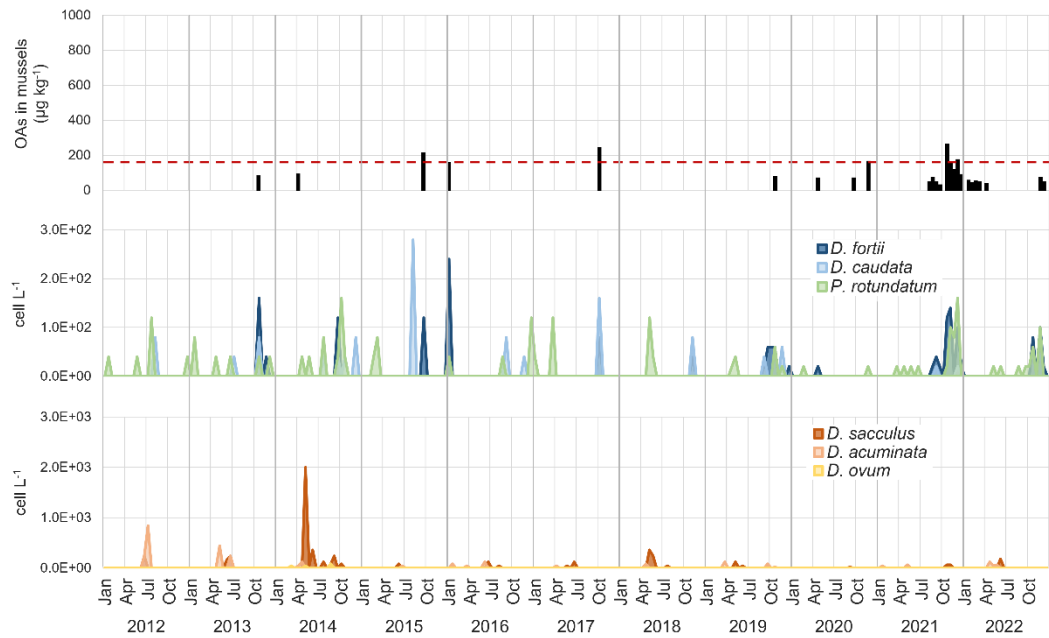


Fig. S14. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-7 in RN area. Dashed red line in the first graph as in Fig. S-9.

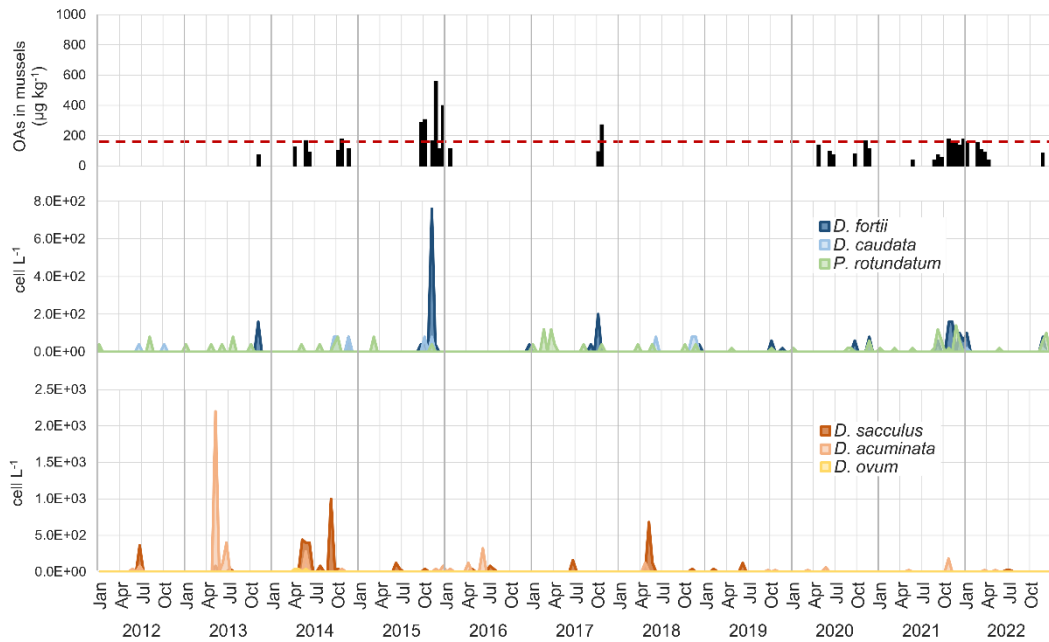


Fig. S15. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station **S-8** in **RN** area. Dashed red line in the first graph as in Fig. S-9.



Fig. S16. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station **S-9** in **RN** area. Dashed red line in the first graph as in Fig. S-9.

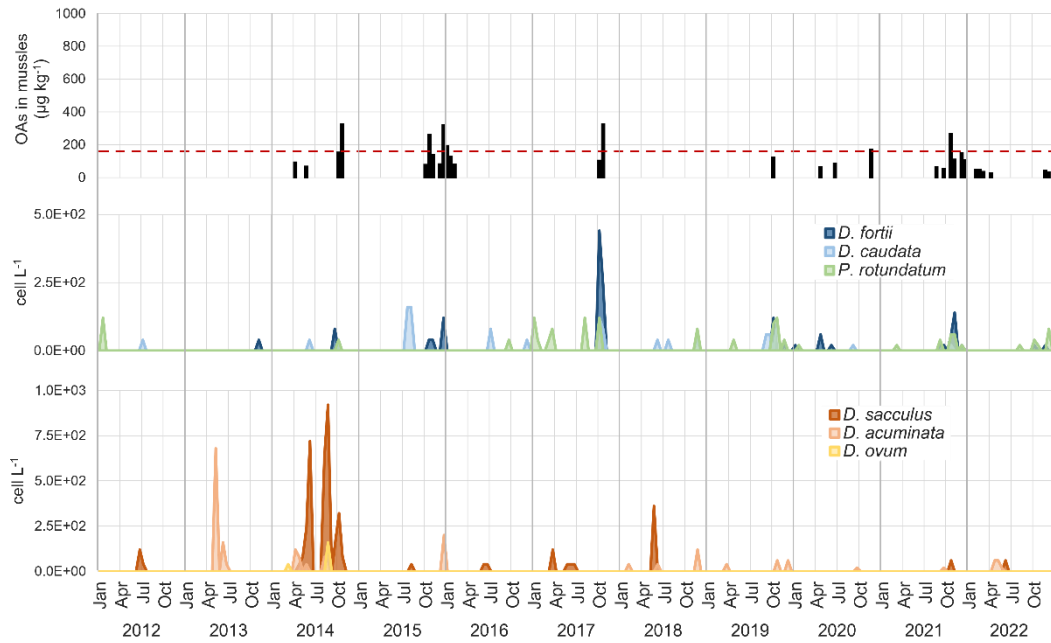


Fig. S17. Trends of OAs concentration in mussels and counts of potentially OAs-producing phytoplankton species in seawater at station S-10 in RN area. Dashed red line in the first graph as in Fig. S-9.