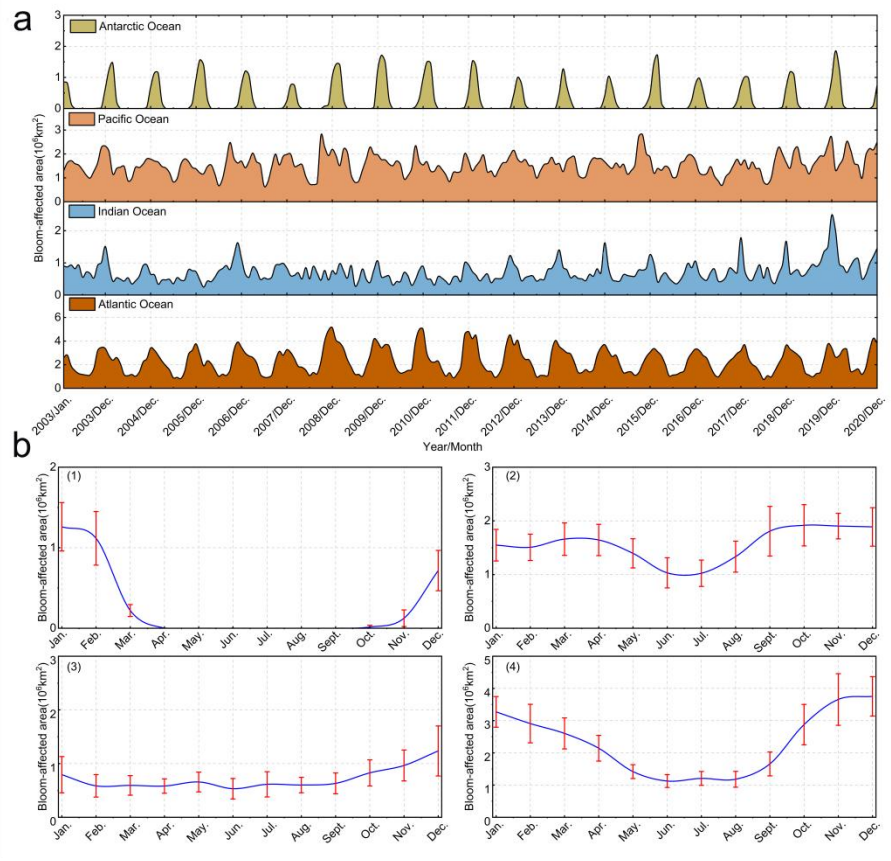
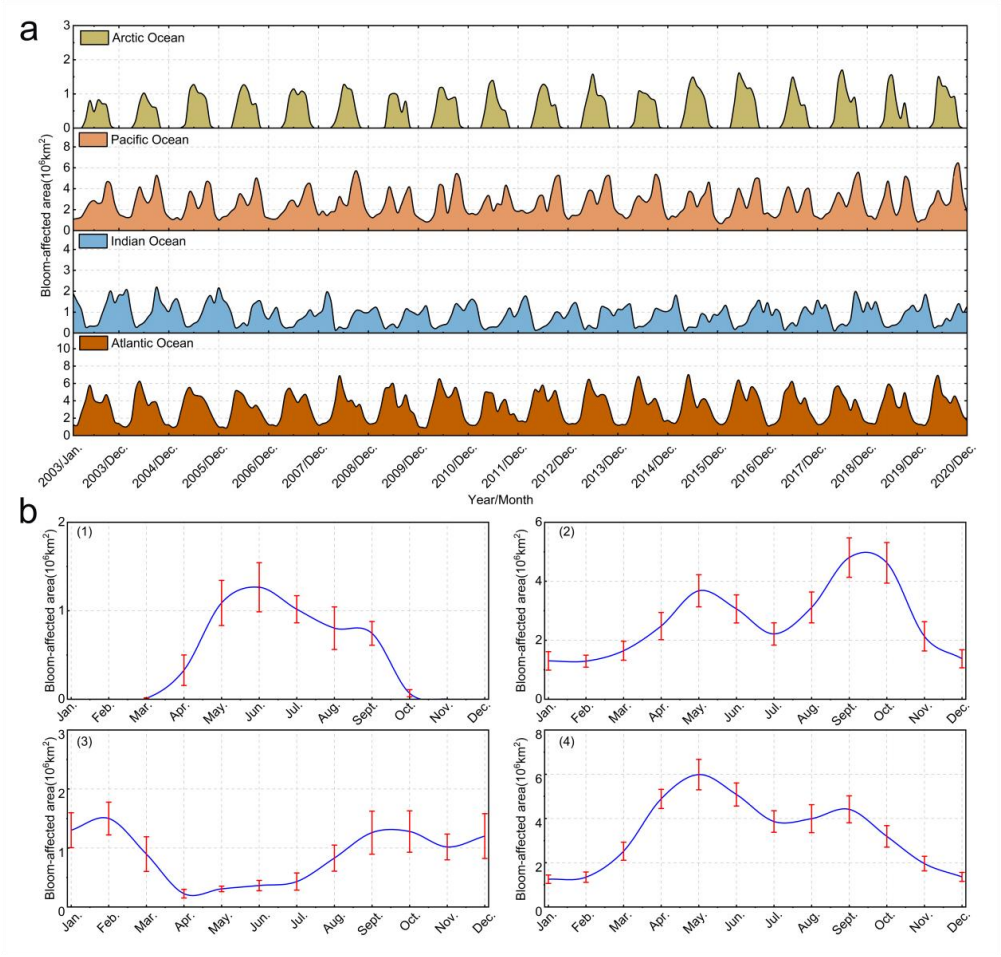
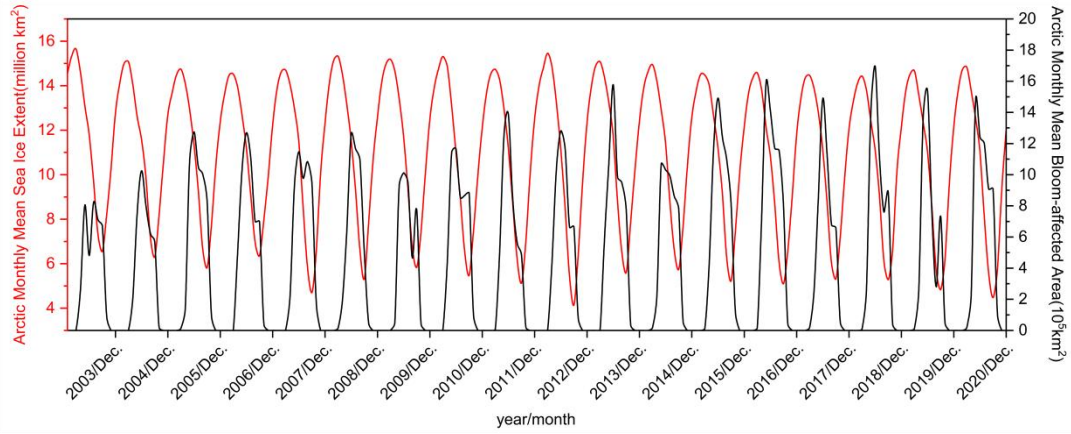
Extended Data



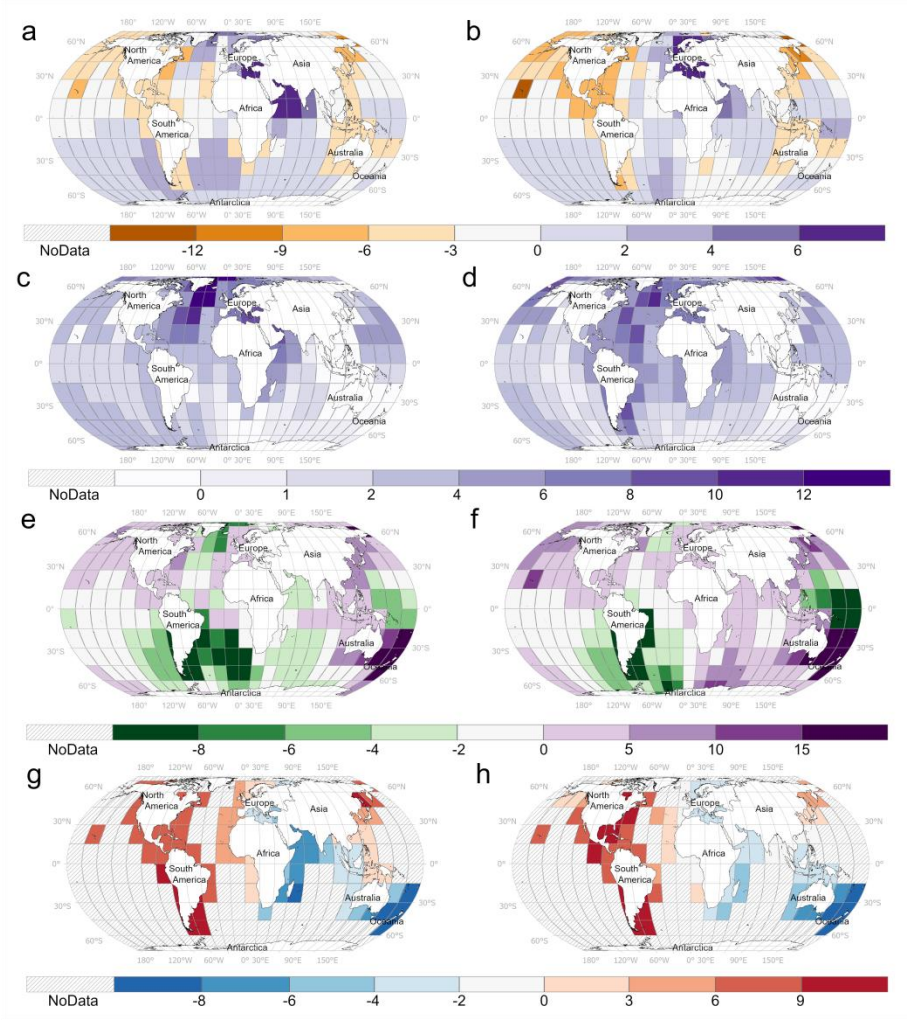
Extended Data Fig. 1 | Monthly Trends in Algal Bloom Area in the Four Major Oceans of the Southern Hemisphere. **a** presents the annual changing trend of BAA in the Southern Hemisphere's four main seas. The green section represents the Antarctic Ocean bloom, which is absent for most of the year. The orange section depicts the South Pacific bloom, displaying an annual multi-peak pattern. The blue section represents the South Indian Ocean bloom, which also exhibits an annual multi-peak pattern. The brown area shows the South Atlantic algal bloom, which varies annually and can have either a single- or multi-peak pattern. **b** illustrates the multi-year average monthly scale annual change trend of the algal bloom area in the four Southern Hemisphere oceans. **b (1),** The Antarctic Ocean trend. **b (2),** The South Pacific Ocean trend. **b (3),** The South Indian Ocean trend. **b (4),** The South Atlantic Ocean trend. The sample standard deviation in **b** is indicated by the red error bars. The map was created using Origin 2024.



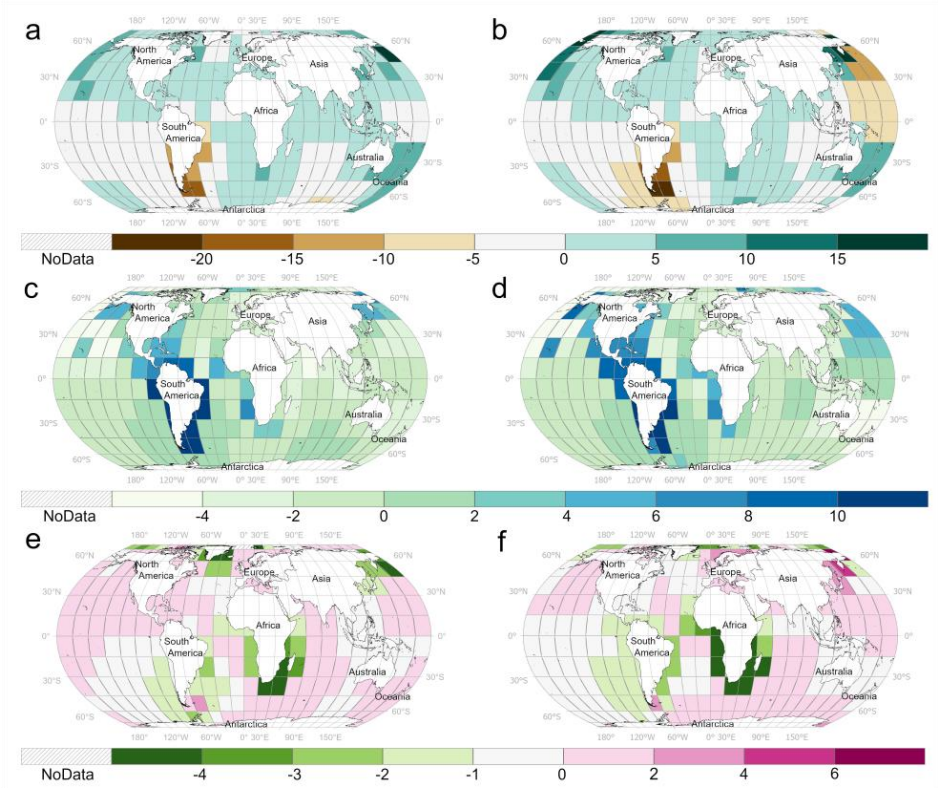
Extended Data Fig. 2 | Monthly Trends of BAA in the Four Major Oceans of the Northern Hemisphere. a, The annual changing trend in BAA across the four main seas of the Northern Hemisphere. The green area represents the Arctic Ocean bloom, which is absent during certain months. The orange area depicts the North Pacific bloom, which shows a distinct double-peak pattern annually. The blue area represents the North Indian Ocean bloom, exhibiting a multi-peak pattern each year. The brown area indicates the North Atlantic bloom, which displays a clear double-peak pattern annually. **b**, The annual trend of the multi-year average monthly scale of BAA in these oceans. **b (1),** The Arctic Ocean trend. **b (2),** The North Pacific Ocean trend. **b (3),** The North Indian Ocean trend. **b (4),** The North Atlantic Ocean trend. The red error bars in **b** indicate the sample standard deviation. The map was created using Origin 2024.



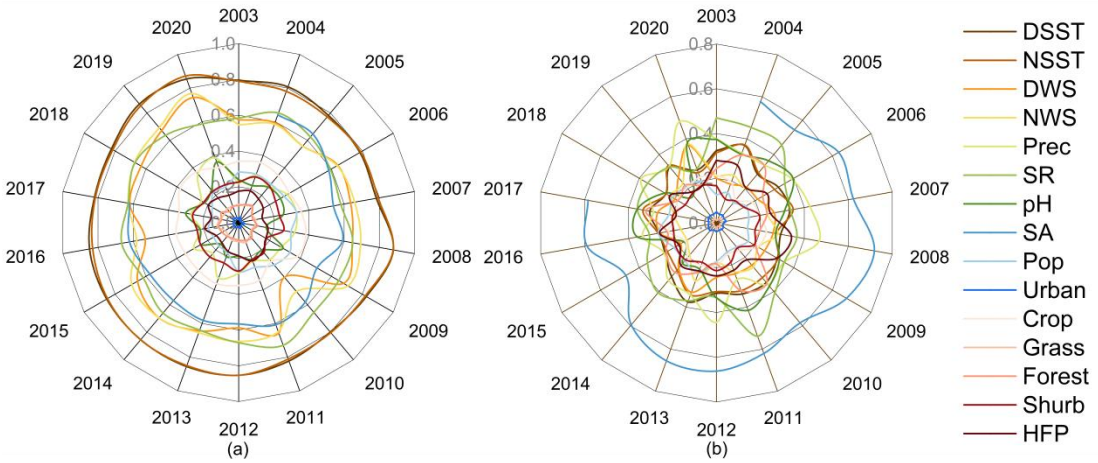
Extended Data Fig. 3 | Monthly Trend of the BAA and Sea Ice in the Arctic Ocean. The monthly variations in the sea ice extent of the Arctic Ocean are depicted by the red line. The sea ice extent reaches its maximum in March and then progressively decreases as the temperature rises, reaching its minimum in September before it begins to grow again. The BAA by Arctic Ocean is represented by a black line, illustrating monthly variations. The map was created using Origin 2024.



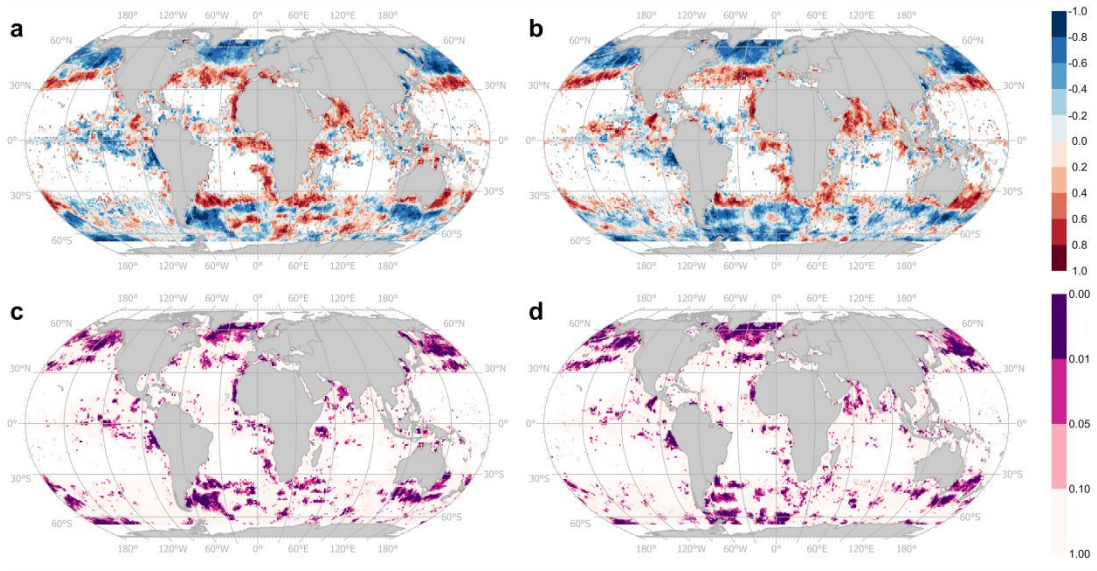
Extended Data Fig. 4 | Spatial distribution of regression coefficients for the main influencing factors on phytoplankton bloom-affected areas. **a**, Regression coefficients for daytime SST in 2003. **b**, Regression coefficients for daytime SST in 2020. **c**, Regression coefficients for nighttime wind speed in 2003. **d**, Regression coefficients for nighttime wind speed in 2020. **e**, Regression coefficients for salinity in 2003. **f**, Regression coefficients for salinity in 2020. **g**, Regression coefficients for solar radiation in 2003. **h**, Regression coefficients for solar radiation in 2020. The map was created using ArcGIS.



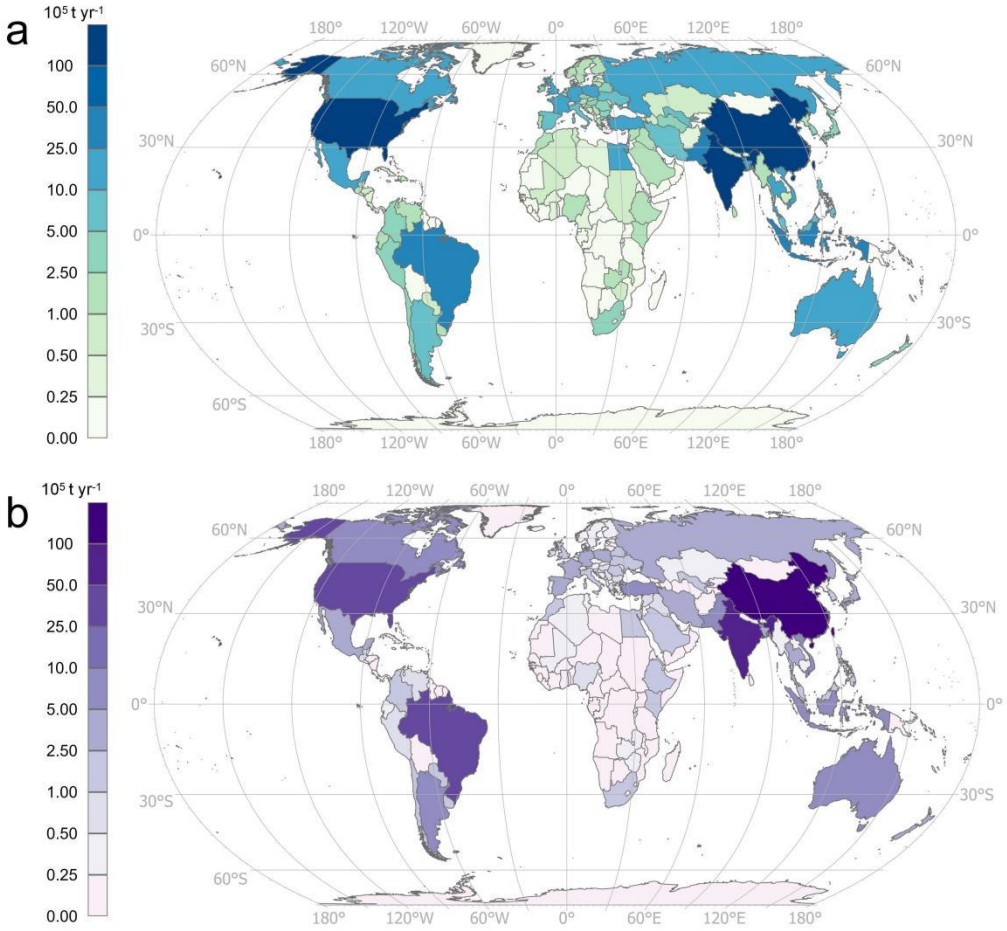
Extended Data Fig. 5 | Spatial distribution of regression coefficients for the main influencing factors on cumulative days of phytoplankton bloom. a, Regression coefficients for salinity in 2003. **b**, Regression coefficients for salinity in 2020. **c**, Regression coefficients for solar radiation in 2003. **d**, Regression coefficients for solar radiation in 2020. **e**, Regression coefficients for precipitation in 2003. **f**, Regression coefficients for precipitation in 2020. The map was created using ArcGIS.



Extended Data Fig. 6 | Contribution Degree of Each Environmental Factor to Algal Blooms. The contribution of each environmental element to algal blooms (i.e., the q value result of the factor detection function of the geographical detector) is analyzed based on units of 0.1° latitude, with n=1800. The factor detection q-value findings for each environmental factor on the BAA are displayed in **a**, and those for CBD are displayed in **b**. Salinity and sea surface temperature have the most significant effects on both the CBD and the BAA. The map was created using Origin 2024.



Extended Data Fig. 7 | Correlation and Significance between Annual Monthly Average Bloom-affected areas (BAA) and Marine Nitrogen and Phosphorus Concentrations. **a**, The correlation (ρ value) between monthly average BAA and marine nitrogen concentration. **b**, The correlation (ρ value) between monthly average BAA and marine phosphorus concentration. **c**, The significance (q value) between monthly average BAA and marine nitrogen concentration. **d,** The significance (q value) between monthly average BAA and marine phosphorus concentration. The parameters are n = 180 × 360 and t = 12 months. The map was created using ArcGIS.



Extended Data Fig. 8 | Annual Average Nitrogen and Phosphorus Fertilizer Application in Agriculture. a, The annual average application of agricultural nitrogen fertilizer. **b,** The annual average application of agricultural phosphate fertilizer. Higher amounts of fertilizer application are indicated by lighter hues. Countries with the highest fertilizer usage include Brazil, China, India, and the United States. The map was created using ArcGIS.

Extended Data Tab. 1 The top 30 algae bloom dominant species and main distribution countries in HAEDAT

Rank	Causative Species Name	Major Country	count	Secondary Country	count	Total
1	*Pyrodinium bahamense*	Philippines	665	Malaysia	23	730
2	*Dinophysis acuminata*	Spain	153	Portugal	134	418
3	*Dinophysis spp.*	France	201	Spain	56	411
4	*Pseudo-nitzschia spp.*	France	88	United States	60	239
5	*Alexandrium spp.*	Norway	76	United States	68	235
6	*Dinophysis acuta*	Norway	62	Portugal	19	103
7	*Alexandrium catenella*	United States	68	Chile	14	102
8	*Cochlodinium polykrikoides*	Korea	47	United States	24	99
9	*Gymnodinium catenatum*	Mexico	26	Portugal	21	68
10	*Heterosigma akashiwo*	Canada	38	Japan	8	66
11	*Alexandrium tamarense*	Canada	27	Norway	25	61
12	*Pseudo-nitzschia australis*	Spain	51	Ireland	5	60
13	*Karenia mikimotoi*	Japan	41	China	4	54
14	*Karenia brevis*	United States	41	Mexico	9	50
15	*Gymnodinium catenatum*	Portugal	15	Spain	13	45
16	*Pyrodinium bahamense*	Philippines	31	Mexico	12	45
17	*Nodularia spumigena*	Poland	24	Sweden	9	44
18	*Noctiluca scintillans*	China	12	Greece	7	39
19	*Skeletonema costatum*	France	18	China	17	38
20	*Alexandrium minutum*	Spain	13	Slovenia	8	35
21	*Pseudo-nitzschia seriata*	Canada	8	United States	7	26
22	*Prorocentrum minimum*	United States	18	Greece	3	25
23	*Alexandrium fundyense*	Canada	12	United States	8	23
24	*Dinophysis acuminata*	Portugal	19	Australia	2	23
25	*Dinophysis caudata*	Portugal	11	Slovenia	6	22
26	*Margalefidinium polykrikoides*	Mexico	16	United States	5	21

27	*Prorocentrum spp.*	China	19	Mexico	1	20
28	*Chaetoceros spp.*	France	14	Japan	5	19
29	*Akashiwo sanguinea*	United States	6	Japan	4	18
30	*Aureococcus anophagefferens*	United States	15	China	2	18

73 **Extended Data Tab. 2 The top 30 countries and their major and secondary causative species of**

74 **blooms in HAEDAT**

Rank	Country	Major Causative Species	Count	Secondary Causative Species	Count	Total
1	Philippines	*Pyrodinium bahamense*	665	*Skeletonema sp.*	2	670
2	United States	*Alexandrium catenella*	68	*Pseudo-nitzschia spp.*	55	504
3	France	*Dinophysis spp.*	194	*Pseudo-nitzschia spp.*	88	419
4	Spain	*Dinophysis acuminata*	153	*Dinophysis spp.*	56	402
5	Portugal	*Dinophysis acuminata*	134	*Pseudo-nitzschia spp.*	24	311
6	Norway	*Alexandrium spp.*	68	*Dinophysis acuta*	62	235
7	Mexico	*Gymnodinium catenatum*	26	*Myrionecta rubra*	19	169
8	China	*Prorocentrum sp.*	19	*Skeletonema costatum*	17	149
9	Japan	*Karenia mikimotoi*	41	*Chattonella spp.*	14	143
10	Canada	*Heterosigma akashiwo*	38	*Alexandrium tamarense*	27	142
11	United Kingdom	*Dinophysis spp.*	52	*Alexandrium spp.*	37	113
12	Korea	*Cochlodinium polykrikoides*	47	*Gonyaulax polygramma*	7	107
13	Slovenia	*Dinophysis fortii*	15	*Lingulodinium polyedra*	12	91
14	Sweden	*Dinophysis spp.*	29	*Aphanizomenon flos-aquae*	20	86
15	Poland	*Nodularia spumigena*	35	*Cylindrospermopsis raciborskii*	6	67
16	Ireland	*Dinophysis acuminata*	12	*Dinophysis acuta*	12	62
17	Turkey	*Heterosigma akashiwo*	5	*Emiliania huxleyi*	4	58
18	Uruguay	*Dinophysis acuminata*	8	*Dinophysis spp.*	5	43
19	Brazil	*Pseudo-nitzschia pseudodelicatissima*	1	*Alexandrium spp.*	1	40
20	Malaysia	*Pyrodinium bahamense*	23	*Cochlodinium polykrikoides*	5	39
21	Australia	*Gambierdiscus spp.*	5	*Pseudo-nitzschia pseudodelicatissima*	4	36
22	Argentina	*Alexandrium catenella*	9	*Gymnodinium catenatum*	3	31
23	New Zealand	*Alexandrium minutum*	2	*Alexandrium catenella*	2	28
24	Chile	*Alexandrium catenella*	14	*Chattonella verruculosa*	3	28

25	Greece	*Noctiluca scintillans*	7	*Prorocentrum minimum*	3	25
26	Denmark	*Dinophysis acuminata*	6	*Chattonella spp.*	5	23
27	India	*Noctiluca scintillans*	7	*Trichodesmium erythraeum*	5	23
28	South Africa	*Alexandrium catenella*	2	*Gonyaulax polygramma*	2	23
29	Russian Federation	*Heterosigma akashiwo*	3	*Noctiluca scintillans*	3	22
30	Peru	*Akashiwo sanguinea*	7	*Alexandrium ostenfeldii*	3	19

75