## Supplementary Materials: Blooms of the toxic cyanobacterium *Nodularia spumigena* in Norwegian fjords during Holocene warm periods

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**Figure S1.** MRM chromatogram of nodularin (NOD) extracted from 30–32 cm layer of the long core (LC) collected in Oslofjorden.



Figure S2. Enhanced product ion mass spectra (EPI) of nodularin (NOD) extracted from the long sediment core collected in Balsfjorden.



**Figure S3.** Age-depth models for two studied long sediment cores (Oslofjorden and Balsfjorden). The sedimentation rate ranges are given in brackets. The model shows that the sedimentation rates for Trondheimsfjorden were higher (0.53–0.59 mm/yr), but their variations are lower, compared to Oslofjorden (0.20–0.43 mm/yr). In Oslofjorden sedimentation rate in older times was lower (0.20 mm/yr) than in recent times (0.32–0.43 mm/yr).



0.020

**Figure S4.** Neighbour-joining phylogenetic tree based on the 16S rDNA sequences (504 bp) obtained from DNA isolated from Oslofjorden (marked in blue) and reference sequences (retrieved from NCBI). Phylogenetic relationships were bootstrapped 1000 times.

Com la conformi	NOD	AP 883a
Core layer [cm]	[ng/g dw]	peak area
Sho		
0-8*	-	-
8–10	1.15	597.49
10-40*	-	-
Lon	g core (LC)	
0–2	1.21	-
2–4	0.32	traces
4-6	0.47	1530.13
6-8	0.85	1135.28
8-10	0.90	1727.59
10–12	1.09	691.04
12–14	1.64	-
14–16	1.26	-
16-18	1.56	traces
18-20	0.98	traces
20–22	1.54	1382.06
22–24	1.49	-
24-26	1.16	789.76
26-28	1.25	1283.33
28-30	1.33	1135.24
30-32	1.80	937.83
32-34	3.84	1283.36
34-36	1 27	-
36_38	1.27	2023 72
38_40	1.15	2023.72
30-40 40 42	1.70	-
40-42	1.17	-
42-45	0.52	1085.92
16-18	0.69	-
48-50	0.62	_
<del>1</del> 0-50 50-52	0.74	2369.23
52-54	0.84	740.40
54-56	0.95	740.40
54-50	0.93	1678 23
50-50	1 21	1070.25
50-00 60 6 <b>2</b>	1.01	-
62 64	1.04	-
64 66	1.09	tracos
04-00	0.09	traces
68 70	0.99	-
00-70 70 72	1.14	-
70-72	1.22	-
74-74	1.02	-
/ <del>1</del> -/0	1.00	-
/0-/0	1.02	traces
/0-0U	1.11	-
ðU-ð2	1.08	937.81
02-04 04 06	1.11	-
04-00	1.68	-
86-88	1.53	-
88-9U	1.21	-
90-92	1.21	-
92–94	0.67	-

**Table S1.** Changes in nodularin contents (NOD) [ng/g dw] and changes in relative amounts of anabaenopeptin AP883a (expressed as a ratio of AP peak area/g dw) in the short core (SC) and long core (LC) from Oslofjorden (\* results for individual 2 cm layers).

94–96	0.43	-
96–98	0.84	-
98-100	1.57	-
100-102	0.80	-
102–104	0.37	-
104-106	0.33	-
106-108	0.27	-
108-110	0.52	_
110-112	0.65	_
112_114	0.61	_
112 111	0.82	_
114-110	0.29	_
110-110	0.22	-
110-120	0.62	-
120-122	0.63	-
122-124	0.50	-
124–126	0.35	-
126–128	0.39	-
128–130	0.33	-
130–132	0.31	-
132–134	0.52	-
134–136	0.50	-
136-138	0.45	-
138-140	0.58	-
140–142	0.28	-
142–144	0.32	-
144–146	0.31	_
111 110	0.01	_
146_148	0.28	
146–148 148, 150	0.28	
146–148 148–150	0.28 0.21	-
146-148 148-150 Core layer [cm]	0.28 0.21 NOD	- AP 883a
146-148 148-150 Core layer [cm]	0.28 0.21 NOD [ng/g dw]	- AP 883a peak area
146-148 148-150 Core layer [cm] Lon	0.28 0.21 NOD [ng/g dw] g core (LC)	- AP 883a peak area
146-148 148-150 Core layer [cm] Lon 152-154	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23	- AP 883a peak area
146-148 148-150 Core layer [cm] Lon 152-154 154-156	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32	- AP 883a peak area -
146-148 148-150 Core layer [cm] <u>Lon</u> 152-154 154-156 156-158	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32 0.29	- AP 883a peak area - - -
146-148 148-150 Core layer [cm] 152-154 154-156 156-158 158-160	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32 0.29 0.30	- AP 883a peak area - - - -
146-148 148-150 Core layer [cm] 152-154 154-156 156-158 158-160 160-162	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32 0.29 0.30 0.29	- AP 883a peak area - - - - - -
146-148 148-150 Core layer [cm] Lon 152-154 154-156 156-158 158-160 160-162 162-164	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32 0.29 0.30 0.29 0.30 0.29 0.35	- AP 883a peak area - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24	- AP 883a peak area - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.32 0.29 0.30 0.29 0.35 0.24 0.23	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.26	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.26 0.21	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.35 0.24 0.23 0.24 0.23 0.35 0.24 0.23 0.23 0.35 0.24 0.23 0.23 0.35 0.24 0.23 0.35 0.24 0.23 0.35 0.23 0.35 0.24 0.23 0.35 0.24 0.23 0.35 0.24 0.23 0.23 0.35 0.24 0.23 0.23 0.35 0.24 0.23 0.23 0.23 0.35 0.24 0.23 0.23 0.23 0.35 0.24 0.23 0.23 0.23 0.35 0.24 0.23 0.26 0.23 0.23 0.35 0.24 0.23 0.26 0.23 0.35 0.24 0.23 0.26 0.23 0.23 0.35 0.24 0.23 0.26 0.23 0.23 0.23 0.35 0.24 0.23 0.26 0.21 0.23 0.23 0.23 0.23 0.23 0.24 0.23 0.26 0.21 0.23 0.26 0.27 0.23 0.26 0.27 0.23 0.24 0.23 0.26 0.21 0.26 0.21 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.26 0.21 0.37 0.24 0.37 0.37 0.37 0.37 0.27 0	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.29 0.35 0.24 0.23 0.24 0.23 0.29 0.35 0.24 0.23 0.24 0.23 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.35 0.24 0.23 0.23 0.24 0.23 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.23 0.24 0.37 0.37 0.37 0.37 0.31 0.37 0.31 0.32 0.31 0.32 0.32 0.24 0.37 0.31 0.31 0.32 0.31 0.32 0.32 0.32 0.24 0.37 0.31 0.31 0.31 0.31 0.32 0.32 0.32 0.32 0.24 0.37 0.31 0	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.26 0.21 0.37 0.31 0.20	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.23 0.24 0.23 0.26 0.21 0.24 0.23 0.26 0.21 0.23 0.26 0.21 0.23 0.24 0.23 0.26 0.21 0.37 0.37 0.37 0.37 0.37 0.37 0.37 0.37 0.37 0.32 0.29 0.37 0.37 0.31 0.29 0.32 0.29 0.37 0.31 0.29 0.32 0.29 0.35 0.24 0.37 0.29 0.31 0.29 0.32 0.29 0.31 0.29 0.32 0.29 0.31 0.29 0.32 0.29 0.31 0.29 0.32 0.29 0.31 0.29 0.32 0.29 0.31 0.29 0.32 0.24 0.37 0.31 0.29 0.44 0.23 0.24 0.29 0.34 0.29 0.34 0.29 0.44 0.29 0.44 0.29 0.44 0.29 0.44 0.29 0.44 0.29 0.44 0.29 0.44 0.29 0.44 0.25 0	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.24 0.23 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.36	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.36 0.48	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194 194–196	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.36 0.48 0.14	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194 194–196	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.34 0.36 0.45	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194 194–196 196–198 198–200	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.36 0.48 0.14 0.45 0.66	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194 194–196 196–198 198–200 200–202	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.34 0.36 0.48 0.14 0.45 0.66 0.45	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 186–188 188–190 190–192 192–194 194–196 196–198 198–200 200–202 202–204	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.34 0.36 0.48 0.14 0.45 0.66 0.45 0.40	- AP 883a peak area - - - - - - - - - - - - - - - - - - -
146–148 148–150 Core layer [cm] Lon 152–154 154–156 156–158 158–160 160–162 162–164 164–166 166–168 168–170 170–172 172–174 174–176 176–178 178–180 180–182 182–184 184–186 188–190 190–192 192–194 194–196 196–198 198–200 200–202 202–204 202–204	0.28 0.21 NOD [ng/g dw] g core (LC) 0.23 0.29 0.30 0.29 0.35 0.24 0.23 0.26 0.21 0.37 0.31 0.29 0.44 0.33 0.30 0.46 0.31 0.34 0.36 0.48 0.14 0.45 0.66 0.45 0.49 0.42	- AP 883a peak area - - - - - - - - - - - - - - - - - - -

006 000	0.40	
206-208	0.48	-
208-210	0.53	-
210-212	0.48	-
212–214	0.07	-
214–216	0.07	-
216-218	-	-
218-220	0.08	-
220–222	-	-
222–224	0.07	-
224–226	0.07	-
226-228	-	-
228-230	-	-
230-232	-	-
232-234	-	-
234-236	-	-
236-238	0.03	-
238-240	0.14	-
240-242	0.19	_
242-244	0.23	-
244-246	0.23	-
246-248	0.29	_
248-250	0.18	_
250-252	0.10	
250-252	0.21	-
252-254	0.21	-
254-250	0.34	-
256-258	0.20	-
258-260	0.26	-
260-262	0.22	-
262-264	0.08	-
264-266	0.15	-
266–268	0.13	-
268–270	0.07	-
270–272	0.10	-
272–274	0.06	-
274–276	-	-
276–278	0.19	-
278-280	0.10	-
280-282	0.08	-
282-284	-	-
284-286	0.30	-
286-288	-	-
288-290	-	-
290–292	-	-
292–294	0.53	-
294–296	0.08	-
296–298	-	-
298-300	0.11	-
300-302	_	-
302-304	0.06	-
304-334*	-	-

Sampling station Layer [cm]	Calibrated age [yr BP]
Balsfjorden 152–154	3540-3830
Balsfjorden 220–222	4820-5140
Balsfjorden 230–232	4990-5310
Oslofjorden 32–34	2330-2660
Oslofjorden 84–86	4360-4690
Oslofjorden 104–106	4070-4380
Oslofjorden 200–202	7100-7370
Oslofjorden 278–280	11000-11300
Trondheimsfjorden 92–94	4200-4520

Table S2. Calibrated age of sediment samples from the Norwegian fjords.

**Table S3.** Changes in nodularin contents (NOD) [ng/g dw] and changes in relative amounts of anabaenopeptin AP883a (expressed as a ratio of AP peak area/g dw) in the long core (LC) from Trondheimsfjorden (\*results for individual 2 cm layers; # results for integrated 10 cm sections).

Core layer	NOD	AP	Calibrated age[yr BP]
[cm]	[ng/g dw]		
Long core (LC)	(integrated 10-	cm sections)	
0-60#	-	-	
60–70	0.05	-	
70-80	0.02	-	
80-90	0.11	-	
90-100	0.63	AP 883a	
100-110	0.04	-	
110-120	0.08	-	
120-130	0.03	-	
130-136	0.07	-	
Long co	re (LC) (2-cm la	yers)	
0-90*	-	-	
90-92	0.09	AP 883a	
92–94	0.27	AP 883a	4200-4520
94–136*	-	-	

Core layer	NOD	AP	Calibrated age
[cm]	[ng/g dw]		[yr BP]
Long core (LC)	(integrated 10	cm sections)	
0-140#	-	-	
140-150	0.14	-	
150-160	0.22	AP 827	
160-220#	-	-	
220-230	0.80	AP 883a	
230-240	1.19	-	
240-260#	-	-	
260-270	0.18	-	
270-440#	-	-	
Long co	re (LC) (2-cm la	ayers)	
0-152*	-	-	
152-154	traces	-	3540-3830
154-204*	-	-	
204-206	0.10	-	
206-220*	-	-	
220-222	0.58	AP 883a	4820-5140
222-224	0.08	-	
224-226	0.05	-	
226-228*	-	-	
228-230	0.02	-	
230-232	0.41	-	4990-5310
232-234	-	-	
234–236	0.40	-	
236-238	0.19	-	
238-240	0.10	-	
262-272*	-	-	

**Table S4.** Changes in nodularin contents (NOD) [ng/g dw] and changes in relative amounts of anabaenopeptins (APs) (expressed as a ratio of AP peak area/g dw) in the long core (LC) from Balsfjorden (\*results for individual 2 cm layers; # results for integrated 10 cm sections).