

康志成, 高春蕾, 郭嘉宁, 孟范平, 王宗灵 (2026) 渤海与北黄海春季有害甲藻包囊: 多样性、分布及环境相关性. 生物多样性, 34, 25426. <https://www.biodiversity-science.net/CN/10.17520/biods.2025426>

附录1 基于高通量测序的渤海和北黄海海域有害甲藻包囊物种名录。*: 渤海海域已有报道; #: 北黄海海域已有报道; PSTs: 麻痹性贝毒; YTXs: 虾夷扇贝毒素; HAB: 有害藻华。

Appendix 1 The inventory of harmful dinoflagellate cyst species in the Bohai Sea and the North Yellow Sea based on high-throughput sequencing data. *, Reported in the Bohai Sea; #, Reported in the North Yellow Sea; PSTs, Paralytic shellfish toxins; YTXs, Yessotoxins; HAB, Harmful algal blooms.

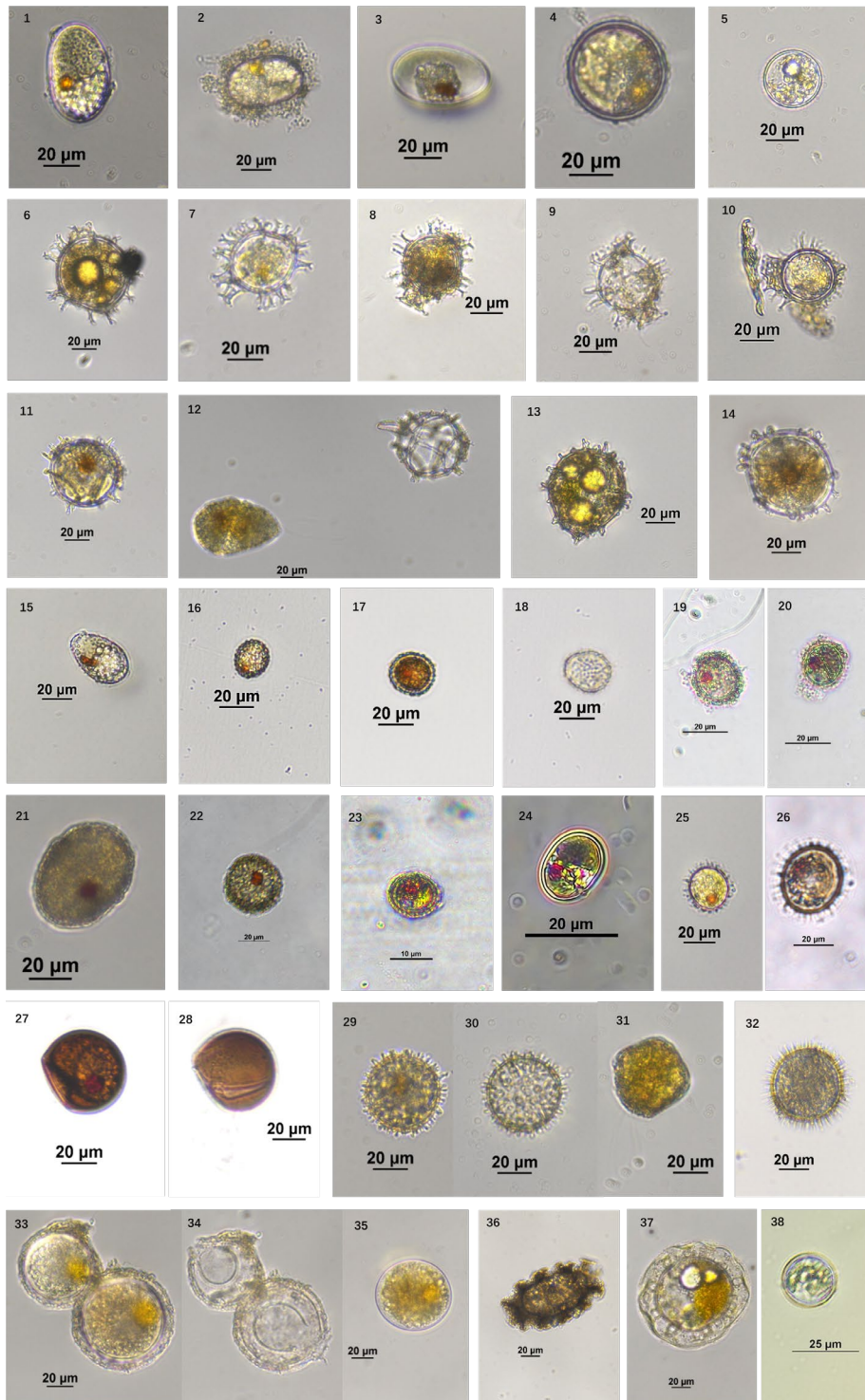
属 Genus	物种 Species	是否产包囊 Produce cyst or not	危害类型 Types of hazards	参考文献 Reference
亚历山大藻属 <i>Alexandrium</i>	相似亚历山大藻 <i>A. affine</i> [#]	是 Yes	PSTs; HAB	宋伦等, 2018; 陈楠生等, 2023
	安德森亚历山大藻 <i>A. andersonii</i> [#]	是 Yes	PSTs; HAB	宋伦等, 2018; 陈楠生等, 2023
	链状亚历山大藻 <i>A. catenella</i> [#]	是 Yes	PSTs; HAB	宋伦等, 2018; 陈楠生等, 2023
	<i>A. fragae</i>	未知 Unknown	PSTs	Branco et al., 2020
	傅勒特亚历山大藻 <i>A. fraterculus</i> [#]	是 Yes	HAB	MacKenzie et al., 2004; 陈楠生等, 2023
	李氏亚历山大藻 <i>A. leei</i> [#]	是 Yes	PSTs; HAB	宋伦等, 2018
	微小亚历山大藻 <i>A. minutum</i> [#]	是 Yes	PSTs; HAB	Anderson et al., 2012; 陈楠生等, 2023
	奥氏亚历山大藻 <i>A. ostenfeldii</i> [#]	是 Yes	PSTs; HAB	Anderson et al., 2012; 陈楠生等, 2023
	太平洋亚历山大藻 <i>A. pacificum</i> [#]	是 Yes	PSTs; HAB	Andeson et al., 2012; 陈楠生等, 2023
	拟膝沟亚历山大藻 <i>A. pseudogonyaulax</i> [#]	是 Yes	Goniodomin; HAB	Amandine & Zouher, 2018; 陈楠生等, 2023
<i>Ansanelia</i>	<i>A. granifera</i> [#]	是 Yes	HAB	Vega, 2021
环胶藻属 <i>Azadinium</i>	腹孔环胶藻 <i>A. poporum</i> [#]	是 Yes	AZAs; HAB	Luo et al., 2016
	具刺环胶藻 <i>A. spinosum</i>	未知 Unknown	AZAs; HAB	Tillmann et al., 2009; 陈楠生等, 2023
<i>Barrufeta</i>	<i>B. bravensis</i>	是 Yes	HAB	王朝晖等, 2022
别什藻属 <i>Biecheleria</i>	短沟别什藻 <i>B. brevisulcata</i> [#]	是 Yes	HAB	王欢等, 2017
裸甲藻属 <i>Gymnodinium</i>	链状裸甲藻 <i>G. catenatum</i> [#]	是 Yes	PSTs; HAB	宋伦等, 2018; 陈楠生等, 2023
	伊姆裸甲藻 <i>G. impudicum</i> [#]	是 Yes	HAB	宋伦等, 2018
	<i>G. microreticulatum</i> [*]	是 Yes	PSTs	宋伦等, 2018
	<i>G. nolleri</i>	是 Yes	HAB	Balkis et al., 2016
膝沟藻属 <i>Gonyaulax</i>	具刺膝沟藻 <i>G. spinifera</i> [#]	是 Yes	YTX; HAB	宋伦等, 2018; 陈楠生等, 2023
环沟藻属 <i>Gyrodinium</i>	纺锤环沟藻 <i>G. fusiforme</i>	未知 Unknown	HAB	顾海峰等, 2014; 刘奎艳等, 2023
	螺旋环沟藻 <i>G. Spirale</i>	未知 Unknown	HAB	陈楠生等, 2023
异冒藻属 <i>Heterocapsa</i>	斯氏异冒藻 <i>H. steinii</i> [*]	是 Yes	HAB	Millette et al., 2023
	<i>H. rotundata</i> [*]	是 Yes	HAB	Millette et al., 2023
鳞甲藻属 <i>Lepidodinium</i>	<i>L. chlorophorum</i>	未知 Unknown	HAB	Roux et al., 2022
莱万藻属 <i>Levanderina</i>	垂裂莱万藻 <i>L. fissa</i> [*]	是 Yes	HAB	王朝晖等, 2022
舌甲藻属 <i>Lingulodinium</i>	多边舌甲藻 <i>L. polyedrum</i> [#]	是 Yes	YTXs; HAB	Paz et al., 2004; Arévalo et al., 2006
原三甲藻属 <i>Protoperdinium</i>	偏心原三甲藻 <i>P. excentricum</i> [#]	是 Yes	HAB	Shamsudin et al., 1996
扁甲藻属 <i>Pyrophacus</i>	斯氏扁甲藻 <i>P. steinii</i> [#]	是 Yes	HAB	陈楠生等, 2023
	<i>Paragymnodinium</i>	<i>P. shiwhaense</i>	是 Yes	HAB
五隔藻属 <i>Pentapharsodinium</i>	戴尔五隔藻 <i>P. dalei</i> [#]	是 Yes	HAB	Ellegaard et al., 2017
多沟藻属 <i>Polykrikos</i>	宝石多沟藻 <i>P. geminatus</i> [#]	是 Yes	HAB	陈楠生等, 2023
	科夫多沟藻 <i>P. kofoidii</i> [#]	是 Yes	HAB	陈楠生等, 2023
	<i>P. schwartzii</i> [#]	是 Yes	HAB	陈楠生等, 2023
	哈曼多沟藻 <i>P. hartmanni</i> [#]	是 Yes	鱼毒素; HAB	陈楠生等, 2023
原角藻属 <i>Protoceratium</i>	网状原角藻 <i>P. reticulatum</i> [#]	是 Yes	YTXs; HAB	宋伦等, 2018; 陈楠生等, 2023
斯氏藻属 <i>Scrippsiella</i>	锥状斯氏藻 <i>S. acuminata</i> [#]	是 Yes	HAB	陈楠生等, 2023
<i>Stoeckeria</i>	<i>S. algicida</i> [#]	是 Yes	Hemolysin; HAB	Jeong et al., 2005; 宋伦等, 2018

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附录2 渤海及北黄海沉积物中部分有害甲藻包裹及萌发后的细胞。(1)链状亚历山大藻; (2-3)亚历山大藻未定种; (4)奥氏亚历山大藻; (5)安德森亚历山大藻; (6)具指膝沟藻; (7) *Gonyaulax carbonell-mooreae*; (8-9)具刺膝沟藻; (10) *Gonyaulax kunsanensis*; (11-12)膝沟藻未定种1包裹、空包裹和游动合子; (13)膝沟藻属未定种2; (14)膝沟藻未定种3; (15)拉科斯氏藻; (16-18)锥状斯氏藻活体包裹和空包裹; (19-20)锥状斯氏藻相似种; (21)斯氏藻未定种; (22) *Scripsiella cf. rotunda*; (23) *Scripsiella cf. erinaceus*; (24)环胺藻未定种; (25-26) 戴尔五隔藻; (27-28)链状裸甲藻活体包裹和空包裹; (29-31)多边舌甲藻活体包裹、空包裹和游动合子; (32)网状原角藻; (33-35)墨西哥易碎藻活体包裹、空包裹和暂时性包裹; (36)斯氏多沟藻; (37)斯氏扁甲藻; (38)短沟别什莱藻: 通过单包裹PCR鉴定获得。

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Appendix 2 Some harmful dinoflagellate cysts and germinated cells in sediments from the Bohai Sea and North Yellow Sea. (1) *Alexandrium catenella*; (2–3) *Alexandrium* sp.; (4) *Alexandrium ostenfeldii*; (5) *Alexandrium andersonii*; (6) *Gonyaulax digitale*; (7) *Gonyaulax carbonell-mooreae*; (8–9) *Gonyaulax spinifera*; (10) *Gonyaulax kunsanensis*; (11–12) *Gonyaulax* sp. 1 cyst, empty cyst and motile planozygotes; (13) *Gonyaulax* sp. 2; (14) *Gonyaulax* sp. 3; (15) *Scrippsiella lachrymose*; (16–18) *Scrippsiella acuminata*, living cysts and empty cyst; (19–20) *Scrippsiella cf. acuminata*; (21) *Scrippsiella* sp.; (22) *Scrippsiella cf. rotunda*; (23) *Scrippsiella cf. erinaceus*; (24) *Azadinium* sp.; (25–26) *Pentapharsodinium dalei*; (27–28) Living and empty cysts of *Gymnodinium catenatum*; (29–31) Living cyst, empty cyst, and motile planozygotes of *Lingulodinium polyedra*; (32) *Protoceratium reticulatum*; (33–35) Living cyst, empty cyst, and temporary cyst of *Fragilidium mexicanum*; (36) *Polykrikos schwartzii*; (37) *Pyrophacus steinii*; (38) *Biecheleria brevisulcata*, indicates species identified by single-cyst PCR.

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附录3 渤海及北黄海各站位 α 多样性指数

Appendix 3 Alpha-diversity indices at each station in the Bohai Sea and the North Yellow Sea

海区 Sea area	站位 Station	Chao1 指数 Chao1 index	Shannon 多样性指数 Shannon diversity index	Pielou 均匀度指数 Pielou evenness index
渤海 Bohai Sea	BH0	18	0.449	0.155
	BH3	23	2.063	0.658
	BH4	22	2.512	0.813
	NS12	18	1.088	0.376
	NS13	22	2.069	0.669
	NS18	19	1.832	0.622
	NS19	21	2.365	0.777
	NS20	21	1.984	0.652
	NS21	20	1.532	0.511
	NS22	25	2.431	0.755
	NS23	23	1.736	0.554
	NS24	23	0.694	0.221
	NS25	13	1.613	0.629
	NS26	19	2.433	0.826
	NS27	22	2.192	0.709
渤海海峡 Bohai Strait	NS28	19	2.299	0.781
	NS29	22	2.269	0.734
	NS30	14	1.332	0.505
北黄海 North Yellow Sea	NS31	21	2.157	0.709
	BH2	25	2.100	0.652
	NS35	13	0.811	0.316
	BH5	12	2.139	0.861
	BH6	21	1.354	0.445
	NS10	14	1.475	0.559
	NS36	13	0.284	0.111
	NS37	9	0.522	0.238
	NS38	10	0.810	0.352
	NS39	12	0.397	0.160
NS40	21	2.112	0.694	
NS41	16	2.235	0.806	
NS42	5	1.180	0.733	
NS7	19	1.692	0.575	
NS8	15	0.646	0.239	
NS9	13	0.772	0.301	
NSA4	15	0.900	0.332	
NSA5	12	0.694	0.279	
NSA6	11	0.525	0.219	
NSA7	22	1.627	0.526	

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附录4 8种渤海与北黄海海区新鉴定甲藻包囊的扩增子序列变体(ASVs)比对结果

Appendix 4 Amplicon sequence variants (ASVs) alignment results of 8 newly identified dinoflagellate cysts in the Bohai Sea and the North Yellow Sea

ASV 编号 ASV no.	扩增区间 regions	Amplification	GenBank 序列号 GenBank accession	物种 Species	序列一致性百分比 Percent Identity (PID, %)
ASV_237	18S V4		KX097019	<i>Alexandrium fragae</i>	99.729
ASV_53	18S V4		LS974165	具刺环胺藻 <i>Azadinium spinosum</i>	99.374
			LS974159	具刺环胺藻 <i>Azadinium spinosum</i>	99.374
			MT644697	环胺藻未定种 <i>Azadinium</i> sp.	99.374
ASV_180	18S V4		MH732694	<i>Barrufeta bravensis</i>	100
ASV_195	ITS1		FN645813	<i>Barrufeta bravensis</i>	99.308
ASV_154	18S V4		AB265963	<i>Gymnodinium nolleri</i>	100
ASV_90	ITS1		AM998535	<i>Gymnodinium nolleri</i>	100
ASV_586	18S V4		KJ758203	纺锤环沟藻 <i>Gyrodinium fusiforme</i>	100
ASV_155	18S V4		KJ757122	螺旋环沟藻 <i>Gyrodinium spirale</i>	99.729
ASV_267	18S V4		AB686254	<i>Lepidodinium chlorophorum</i>	99.649
			AB686253	<i>Lepidodinium chlorophorum</i>	99.649
			AY664967	鳞甲藻未定种 <i>Lepidodinium</i> sp.	99.649
ASV_324	18S V4		AM408889	<i>Paragymnodinium shiwhaense</i>	99.187