Dinoflagellates from Hainan Island: Potential threat for transporting harmful algae from Hainan to Japan

Yin Anqi
Course in Ecosystem Conservation

1. Introduction

Coastal areas in Hainan Island, China, are important for commercial fisheries, but few studies on harmful algal bloom (HAB) have been performed to date. In south part of Japan, large quantities of the seedlings for greater amberjack farming are imported from Hainan Island every year since 1988. In this study, the dinoflagellate species were identified and described from the plankton samples around Hainan Island to make a list of the species occurred including HAB species for providing against potential threat of HAB events. Additionally, phytoplankton communities between Hainan Island and the two bays in south part of Japan were determined from the plankton and the sediment samples using both microscopic and molecular analyses, to evaluate a possibility for artificial transportation of tropical HAB species to Japan.

2. Occurrence of dinoflagellates in the coastal areas around Hainan Island

A total of 37 dinoflagellate species in 11 genera from nine families were identified from 11 coastal stations around Hainan Island (Table 1). Eight toxic and four red tide-forming species (Fig. 1) were found at most stations, except for Station (St.) 4. These species included the five genera of *Ceratium, Dinophysis, Lingulodinium, Prorocentrum*, and *Protoperidium. Ceratium furca*, a red tide-forming species, and *Prorocentrum rhathymum*, a ciguatera fish poisoning species, were occurred in large numbers at St. 7 and 8, respectively, both of which are near fish farms or fishing villages. *Prorocentrum lima* and *Dinophysis acuminata* are diarrhetic shellfish poisoning species and *Lingulodinium polyedrum* is a yessotoxin species, which appeared only at St. 5, near the location of a fish farm and seafood markets. These results suggest potential threats of harmful algal blooms around Hainan Island that could cause fish, shellfish, and human poisoning.

3. Occurrence of dinoflagellates in the Kagoshima Bay and Uranouchi Bay, south Japan

A total of 27 dinoflagellate species in eight genera from seven families were identified from the plankton samples in Kagoshima Bay and Uranouchi Bay, south Japan (Table 2). Species from the Kareniaceae were found only in south Japan, while species from the Gonyaulacaceae, Peridiniaceae, and Heterocapsaceae in Hainan Island. Similarity analysis in six families that appeared in both south Japan and Hainan Island between the two areas showed high similarity level (over 50%) except Prorocentraceae and Dinophysiaceae (Fig. 2a), and the similarity of the harmful species between the two areas was higher, 60%, than those of the total, 40.63% (Fig. 2b).

4. Phytoplankton community from the bottom sediments in Hainan Island and Kagoshima Bay based on metagenomic analysis

Phytoplankton from the sediment samples in Hainan Island consists of 81 species from seven phyla (Fig. 3a). Whereas in Kagoshima Bay, it consists of 61 species from six phyla (Fig. 3b). Species from the Bacillariophyta were found most frequently in both Hainan Island and Kagoshima Bay. Species from the Cryptophyta and Phaeophyta were found only in Hainan Island, while species from the Haptophyta in Kagoshima Bay. Similarity indices in 17 orders that appeared in both areas between Hainan Island and Kagoshima Bay calculated using the non-quantitative analysis showed a high similarity level (>50%) except for Naviculales (Fig. 4a), which appeared 24 species of *Pinnularia* in Hainan Island while only three in Kagoshima Bay. Similarity index for the harmful species between the two areas was 40 %, being lower than those of total, 49% (Fig. 4b).

Table 1 List of dinoflagellate species observed in the coastal areas around Hainan Island

No.	Species name	Station no.										
		1	2	3	4	5	6	7	8	9	10	11
	Family Prorocentraceae											
1	*Prorocentrum emarginatum*					+						
2	*P. hoffmannianum* [T]								+			
3	*P. lima* [T]					+						
4	*P. micans* [R]	+				+	+		+	+	+	+
5	*P. rhathymum* [T]	+	+	+		+	+		+		+	+
6	*P. shikokuense*	+		+								
7	*P. sigmoides* [R]					+			+			
	Family Dinophysiaceae											
8	*Dinophysis acuminata* [T]					+						
9	*D. caudata* [T]									+		
10	*D. rudgei*						+					
	Family Gonyaulacaceae											
11	*Gonyaulax polygramma*						+					
12	*Lingulodinium polyedrum* [T]					+						
	Family Pyrophacaceae											
13	*Pyrophacus horologium*									+		
	Family Ceratiaceae											
14	*Ceratium furca* [R]	+					+	+		+	+	
15	*C. fusus* [R]	+					+	+	+			
16	*C. kofoidii*							+		+		
17	*C. tripos*							+		+		
	Family Peridiniaceae											
18	*Durinskia capensis*					+			+			
19	*Peridinium quinquecorne*	+				+	+	+	+	+	+	
	Family Protoperidiniaceae											
20	*Protoperidinium avellanum*					+						
21	*P. bipes*						+			+		
22	*P. claudicans*					+	+					
23	*P. divaricatum*					+						
24	*P. excentricum*	+				+	+			+		
25	*P. latispinum*						+		+	+		
26	*P. marukawai*									+		
27	*P. minutum*								+			
28	*P. obtusum*								+			
29	*P. oceanicum* [T]	+				+						
30	*P. pellucidum* [T]			+		+			+	+	+	
31	*P. punctulatum*					+	+			+		
32	*P. pyriforme*									+		
	Family Calciodinellaceae											
33	*Scrippsiella trochoidea*										+	
	Family Heterocapsaceae											
34	*Heterocapsa* sp. 1						+					
35	*Heterocapsa* sp. 2						+					
36	*Heterocapsa* sp. 3						+					
37	*Heterocapsa* sp. 4						+					

+ Occurrence

[T] Toxic species

[R] Red tide-forming species

Table 2 List of dinoflagellate species observed in Kagoshima and Uranouchi Bays, south Japan

No.	Species name	Station no.				
		A	B	C	D	E
	Family Prorocentraceae					
1	*Prorocentrum compressum*	+	+	+		
2	*P. gracile*		+	+		
3	*P. rhathymum* [T]*		+	+		
4	*P. sigmoides* [R]*		+	+		+
5	*P. triestinum*	+		+		
	Family Dinophysiaceae					
6	*Dinophysis caudata* [T]*		+	+	+	
7	*D. parvula*		+	+		
8	*D. rotundata* [T]		+	+		
9	*Ornithocercus magnificus*				+	
	Family Kareniaceae					
10	*Karenia digitata*					+
11	*K. mikimotoi* [R]					+
	Family Pyrophacaceae					
12	*Pyrophacus horologium* *		+			
	Family Ceratiaceae					
13	*Ceratium boehmii*		+	+	+	
14	*C. candelabrum*	+		+	+	
15	*C. concilians*	+	+	+	+	
16	*C. furca* [R]*	+	+	+		+
17	*C. fusus* [R]*	+	+	+	+	
18	*C. trichoceros*		+	+	+	
19	*C. tripos* *	+	+	+	+	
	Family Protoperidiniaceae					
20	*Protoperidinium conicum*			+		
21	*P. excentricum* *			+		
22	*P. latispinum* *	+		+	+	
23	*P. obtusum* *			+		
24	*P. pellucidum* [T]*	+	+	+		
25	*P. punctulatum* *	+		+	+	
	Family Calciodinellaceae					
26	*Scrippsiella spinifera*					+
27	*S. trochoidea* *					+

+ Occurrence

[T] Toxic species

[R] Red tide-forming species

* Species appeared in both south Japan and Hainan Island

5. Potential threat for the invasion of species from Hainan Island by natural and artificial factors

Potential threat for the invasion of species from Hainan Island by natural and artificial factors

Thirteen dinoflagellate species including six harmful species were found in both Hainan Island and south Japan from the plankton samples (Table 2), and most species were recorded from Japan recently, while 35 phytoplankton species including one harmful species were found in both Hainan Island and Kagoshima Bay from the sediment

Table 3 Phytoplankton species appeared in both Hainan Island and Kagoshima Bay (based on the homology of more than 95% of the Blast Hit identity values)

No.	GenBank accession	Species name	Phylum	Class	Order	Sequences number	
						Hainan Island	Kagoshima Bay
1	DQ473679.1	*Synechococcus* sp.1	Cyanobacteria	Cyanophyceae	Chroococcales	3	40
2	AY995306.1	*Synechococcus* sp.4	Cyanobacteria	Cyanophyceae	Chroococcales	2	23
3	DQ473684.1	*Synechococcus* sp.5	Cyanobacteria	Cyanophyceae	Chroococcales	2	11
4	EU851956.1	*Micromonas pusilla*	Chlorophyta	Mamiellophyceae	Mamiellales	22	21
5	EU851970.1	*Ostreococcus* sp.1	Chlorophyta	Mamiellophyceae	Mamiellales	1	165
6	AY857618.1	*Tetraselmis marina*	Chlorophyta	Prasinophyceae	Chlorodendrales	48	7
7	AB561048.1	*Pseudoscourfieldia marina*	Chlorophyta	Prasinophyceae	Pseudoscourfieldiales	33	266
8	AY119764.1	*Peridinium foliaceum*	Dinoflagellate	Dinophyceae	Peridiniales	298	146
9	AB430737.1	*Psammodictyon constrictum*	Bacillariophyta	Bacillariophyceae	Bacillariales	2597	25
10	AB430735.1	*Navicula* sp.	Bacillariophyta	Bacillariophyceae	Naviculales	4550	108
11	JN418733.1	*Pinnularia subanglica*	Bacillariophyta	Bacillariophyceae	Naviculales	3563	1
12	JN418709.1	*Pinnularia viridiformis*	Bacillariophyta	Bacillariophyceae	Naviculales	4873	52
13	JN418719.1	*Pinnularia subcommutata*	Bacillariophyta	Bacillariophyceae	Naviculales	35	8
14	JN418734.1	*Sellaphora blackfordensis*	Bacillariophyta	Bacillariophyceae	Naviculales	465	6
15	AB430733.1	*Campylodiscus thuretii*	Bacillariophyta	Bacillariophyceae	Surirellales	23	6
16	JQ217358.1	*Chaetoceros socialis*	Bacillariophyta	Coscinodiscophyceae	Chaetocerotales	97	586
17	AB430706.1	*Chaetoceros radicans*	Bacillariophyta	Coscinodiscophyceae	Chaetocerotales	1	4
18	AB430701.1	*Melosira dubia*	Bacillariophyta	Coscinodiscophyceae	Melosirales	134	15
19	AB430703.1	*Stephanopyxis turris*	Bacillariophyta	Coscinodiscophyceae	Melosirales	1297	243
20	AB430702.1	*Rhizosolenia setigera*	Bacillariophyta	Coscinodiscophyceae	Rhizosoleniales	48795	3796
21	AY119761.1	*Skeletonema costatum*	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	313	1690
22	AB430705.1	*Cyclotella meneghiniana*	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	10804	2900
23	JQ217360.1	*Discostella* sp.	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	12	1
24	JQ217365.1	*Stephanodiscus hantzschii*	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	24	9
25	HQ710698.1	*Thalassiosira conferta*	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	307	867
26	JQ217368.1	*Thalassiosira punctigera*	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	3	140
27	AB430699.1	*Aulacoseira granulata*	Bacillariophyta	Coscinodiscophyceae	Aulacoseirales	28	18
28	AB430712.1	*Asteroplanus karianus*	Bacillariophyta	Fragilariophyceae	Fragilariales	13714	13
29	AB430724.1	*Plagiostriata goreensis*	Bacillariophyta	Fragilariophyceae	Fragilariales	17236	20
30	AB430728.1	*Pseudostaurosira brevistriata*	Bacillariophyta	Fragilariophyceae	Fragilariales	13852	75
31	HQ710696.1	*Asterionella glacialis*	Bacillariophyta	Fragilariophyceae	Fragilariales	35	4
32	AB430723.1	*Opephora* sp.	Bacillariophyta	Fragilariophyceae	Fragilariales	2	12
33	AB430708.1	*Eunotogramma laevis*	Bacillariophyta	Mediophyceae	Anaulales	984	520
34	AB430707.1	*Cymatosira cf. belgica*	Bacillariophyta	Mediophyceae	Cymatosirales	170	348
35	U18090.1	*Heterosigma carterae*	Heterokonphyta	Raphidophyceae	Chattonellales	1	135

samples (Table 3), being more than 50% of species which occurred in Kagoshima Bay, and red tide-forming species *Heterosigma carterae* recorded from Japan since 1994, after the importation of fish fry, indicated the invasion of tropical species, including harmful ones, from Hainan Island to Japan by the global warming through the current systems and/or by artificial transportation of fish fry may be plausible.

6. Conclusions

This study suggest that, Hainan Island potentially faces the danger of HABs, and the invasion of the tropical harmful species to Japan may be plausible.

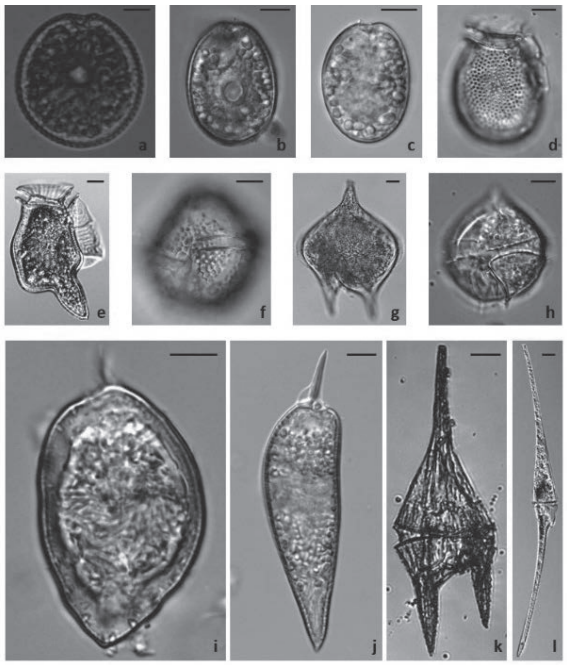

Fig. 1 Harmful species occurred in Hainan Island. a - h: toxic species, *Prorocentrum hoffmannianum, P. lima, P. rhathymum, Dinophysis acuminata, D. caudata, Lingulodinium polyedrum, Protoperidinium oceanicum, P. pellucidum.* i - l: red tide-forming species, *Prorocentrum micans, P. sigmoides, Ceratium furca, C. fusus.*

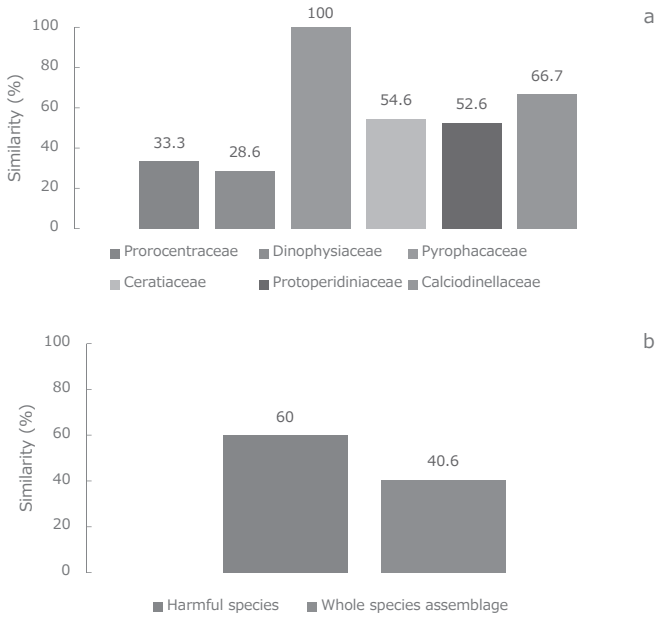

Fig. 2 Similarity between south Japan and Hainan Island on family level (a) and harmful species (b) (based on species occurrence, nonquantitatively).

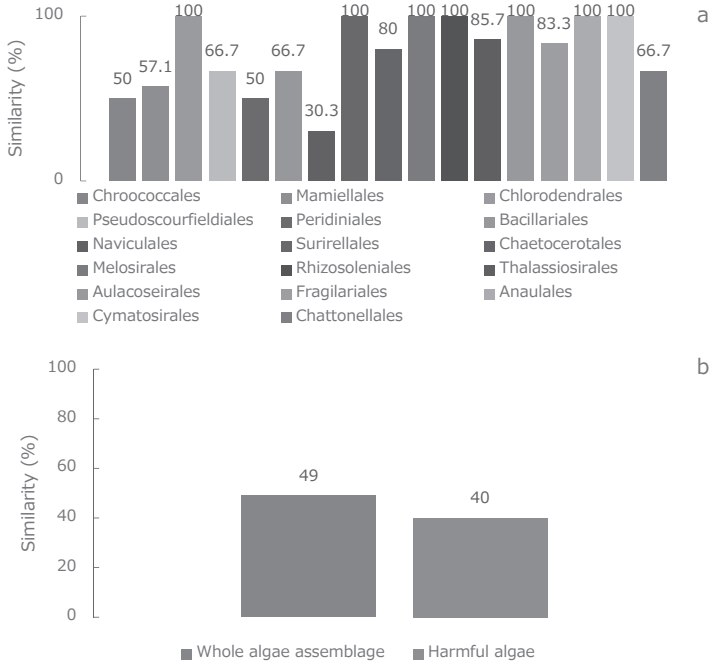

Fig. 4 Similarity between Hainan Island and Kagoshima Bay on order level (a) and Harmful algae (b) (based on species occurrence by metagenomic analysis in sediments, nonquantitatively).

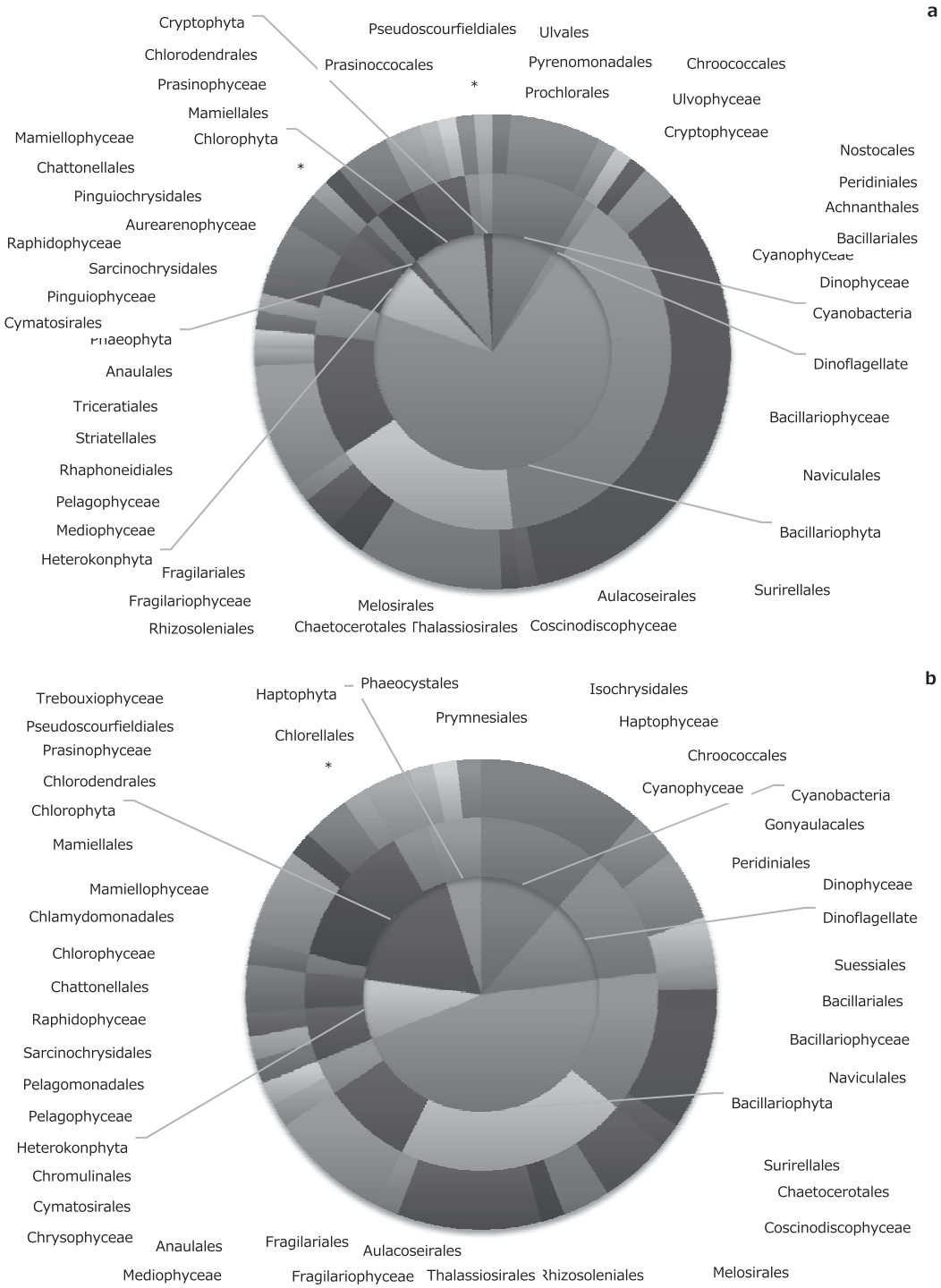

Fig. 3 Diversity richness of phytoplankton and phylogenetic distribution on phylum (inner circle), class (middle circle), and order level (outer circle) (based on over 95% homology) of Hainan Island (a) and Kagoshima Bay (b). '*' represents unclassified groups. No relationship among the same colors.