

<Original article>

New Records of Dinoflagellates in Five Genera of Peridinales (Dinophyceae) from Korean Waters

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Abstract - A study searching for unrecorded and taxonomically undescribed indigenous species has been conducted since 2006. Samples were collected from many sites in coastal waters and offshore in Korea as well as around Jeju Island. Since 2008 we have found 13 unrecorded species belonging to family Diplopsaliaceae, Heterocapsaceae, Kolkwitzellaceae, Proto-peridiniaceae and Thoracosphaeraceae. The species are as follows, *Preperidinium meunieri* (2014), *Heterocapsa ovata* (2015), *H. pseudotriquetra* (2015), *Diplopsalis lenticula* (2008), *Proto-peridinium abei* (2009), *P. diabolus* var. *longipes* (2010), *P. depressum* (synonym: *P. parallelum* (2008)), *P. latispinum* (2016), *P. punctulatum* (2010), *P. solidicorne* (synonym: *P. spinosum* (2010)), *P. subpyriforme* (2010), *P. pacificum* (2013), *Scrippsiella hexapraecingula* (2009) (note; The numbers in parenthesis refer to the year that the species was reported as unrecorded indigenous species by National Institute of Biological Resources, NIBR hereafter). Among these, 5 species were described as newly recorded species in Korean waters, and 8 were re-described in this study.

Key words : *Diplopsalis*, *Heterocapsa*, *Preperidinium*, *Peridinales*, *Proto-peridinium*, *Scrippsiella*

INTRODUCTION

Dinoflagellates are one of major group in phytoplankton community. Although many studies have been conducted in terms of ecological approach, many dinoflagellate taxa are still unrecorded in Korean waters. A study searching for these unrecorded indigenous species, that has not been described taxonomically in Korea, has been conducted as part of projects by NIBR from 2006. Since *Proto-peridinium* genus was created by Bergh (1881) for the new species *P. pellucidum*, many species of genus *Peridinium* described first by Ehrenberg (1830) have been moved to genus *Proto-peridinium* according to the number of girdle plate by Balech (1974). He included all the Peridinea with three girdle plates to Bergh's genus *Proto-peridinium* and left the remaining with 5 or 6 girdle plates in the genus *Peridinium*.

In general, genus *Proto-peridinium* as marine species differed from genus *Peridinium* as freshwater species. General characteristics of this genus are; armored, small to large cell of varied shape, girdle usually with or without left- or right-handed displacement, surface ornamentation varied, most species heterotrophic without chloroplast, some species producing cysts. According to the Kofoid's plate formula, the thecal plate of this genus is 4', 3a, 7'', 3c, 5''', 2'''. Although there is no evidence that *Proto-peridinium* is a causative taxon of Korean HABs, this genus occurs massively in Korean waters in terms of the number of species and abundance and cysts found most abundantly in the seed population of dinoflagellates from the surface sediments (Lee and Matsuoka 1996; Lee *et al.* 1998).

To date, a total of 120 species in Peridinales were reported from Korean waters (Table 1), only if taxonomical research papers were considered (Shim *et al.* 1981; Han and Yoo 1983; Shim 1994; Kim *et al.* 2013; Shah *et al.* 2013;

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Table 1. Continued

Species name	Shim <i>et al.</i> (1981)	Han and Yoo (1983)	Shim (1994)	Kim <i>et al.</i> (2013)	Shah <i>et al.</i> (2013)	Lee and Kim (2015)	Shin (2016)	Present study
<i>Protoperidinium divergens</i>	•	•	•			•	•	
<i>Protoperidinium dolichoporum</i> ⁿ			•			•	•	
<i>Protoperidinium elegans</i>			•			•	•	
<i>Protoperidinium elongatum</i> ⁿ			•			•	•	
<i>Protoperidinium excentricum</i>			•			•	•	
<i>Protoperidinium fastum</i> ⁿ						•	•	
<i>Protoperidinium fatiipes</i> ^f						•	•	
<i>Protoperidinium globifer</i> ⁿ						•	•	
<i>Protoperidinium globulus</i> ⁿ						•	•	
<i>Protoperidinium grande</i> ^f						•	•	
<i>Protoperidinium granii</i>	•					•	•	
<i>Protoperidinium hemisphaericum</i> ^f	•					•	•	
<i>Protoperidinium hirobis</i>	•					•	•	
<i>Protoperidinium hyalinum</i>			•			•	•	
<i>Protoperidinium inclinatum</i>			•			•	•	
<i>Protoperidinium incognitum</i> ⁿ			•			•	•	
<i>Protoperidinium inflatum</i>			•			•	•	
<i>Protoperidinium islandicum</i>			•			•	•	
<i>Protoperidinium joergensenii</i> var. <i>luculentum</i> ⁿ						•	•	
<i>Protoperidinium latidorsale</i> ⁿ						•	•	•
[#] <i>Protoperidinium latissimum</i>						•	•	
<i>Protoperidinium latissimum</i>	•					•	•	
<i>Protoperidinium leonis</i>			•			•	•	
<i>Protoperidinium lipopodium</i> ⁿ			•			•	•	
<i>Protoperidinium longipes</i>			•			•	•	
<i>Protoperidinium majus</i> ⁿ						•	•	
<i>Protoperidinium mariebourbiae</i>		•				•	•	
<i>Protoperidinium matzenaueri</i> ⁿ			•			•	•	
<i>Protoperidinium metananum</i> ⁿ						•	•	
<i>Protoperidinium mite</i>						•	•	
<i>Protoperidinium monospinum</i>						•	•	
<i>Protoperidinium munobis</i> ⁿ						•	•	
<i>Protoperidinium nudum</i> ⁿ						•	•	
<i>Protoperidinium nux</i>	•		•			•	•	
<i>Protoperidinium oblongum</i>	•		•	•		•	•	
<i>Protoperidinium obtusum</i>	•		•	•		•	•	
<i>Protoperidinium oceanicum</i> = syn. <i>Protoperidinium murrayi</i>						•	•	
<i>Protoperidinium orbicular</i> ^f						•	•	
<i>Protoperidinium ovatum</i>	•		•			•	•	
<i>Protoperidinium oviforme</i>						•	•	
<i>Protoperidinium ovum</i>						•	•	
[*] <i>Protoperidinium pacificum</i>						•	•	
<i>Protoperidinium pallidum</i>	•		•			•	•	
<i>Protoperidinium parvum</i> ⁿ	•	•	•			•	•	

Table 1. Continued

Species name	Shim <i>et al.</i> (1981)	Han and Yoo (1983)	Shim (1994)	Kim <i>et al.</i> (2013)	Shah <i>et al.</i> (2013)	Lee and Kim (2015)	Shin (2016)	Present study
<i>Protoperidinium paulseni</i> ^f								
<i>Protoperidinium pedunculatum</i>								
<i>Protoperidinium pellucidum</i>			•			•	•	
<i>Protoperidinium pentagonum</i>			•			•	•	
<i>Protoperidinium perplexum</i> ⁿ	•					•	•	
<i>Protoperidinium perradiatum</i> ⁿ						•	•	
<i>Protoperidinium porosum</i> ⁿ						•	•	
[#] <i>Protoperidinium punctulatum</i>			•			•	•	•
<i>Protoperidinium pyriforme</i>						•	•	
<i>Protoperidinium quarnrense</i> ^f						•	•	
<i>Protoperidinium rectum</i> ^f						•	•	
<i>Protoperidinium roseum</i>			•			•	•	
<i>Protoperidinium saltans</i> = syn. <i>Protoperidinium valgus</i> ⁿ						•	•	
<i>Protoperidinium simulum</i> ⁿ						•	•	
<i>Protoperidinium sinuosum</i> ⁿ						•	•	
[#] <i>Protoperidinium solidicorne</i> = syn. <i>Protoperidinium spinosum</i>	•					•	•	•
<i>Protoperidinium somma</i>	•					•	•	
<i>Protoperidinium sphaericum</i> ^f			•			•	•	
<i>Protoperidinium sphaeroides</i> ⁿ						•	•	
<i>Protoperidinium steidingerae</i> ⁿ						•	•	
<i>Protoperidinium steinii</i>						•	•	
<i>Protoperidinium subinerve</i>		•	•	•		•	•	
[#] <i>Protoperidinium subpyriforme</i>						•	•	•
<i>Protoperidinium thorianum</i>				•		•	•	
<i>Protoperidinium thulesense</i>						•	•	
<i>Protoperidinium tumidum</i> ^f						•	•	
<i>Protoperidinium ventricum</i> ⁿ						•	•	
<i>Protoperidinium venustum</i> ⁿ						•	•	
<i>Protoperidinium verrucosum</i> ⁿ						•	•	
<i>Scrippsiella acuminata</i> = syn. <i>Scrippsiella trochoidea</i>	•	•	•			•	•	•
[*] <i>Scrippsiella hexapraecingula</i>						•	•	
<i>Scrippsiella spinifera</i> ^f						•	•	
<i>Scrippsiella sweeneyae</i> ⁿ						•	•	
No. of species	18	12	35	6	1	75	75	13

Lee and Kim 2015; Shin 2016). Shim (1994) described 35 species in a monograph, and recently Shin (2016) listed and described 75 species in the other monograph. We identified approximately 20 species around Jeju Island and in the Korean Straits since 2006, and some *Proto-peridinium* species were described by Kim *et al.* (2013). This study clarifies 13 additional species belonging to 5 genera in order Peridinales with respect to classification and easy taxonomical key based on Light Microscope (LM) criteria.

MATERIALS AND METHODS

Samples were collected at coastal stations around Jeju Island of the Republic of Korea and the East China Sea, as the station's information is mentioned in Lee *et al.* (2014) June 2006–December 2016. Plankton samples were obtained by using a 20 µm mesh size plankton net and fixed with formaldehyde (final concentration of about 1%) or glutaraldehyde (final concentration of about 1%). Planktonic dinoflagellates were identified by using LM (Axioplan, Carl Zeiss, Oberkochen, Germany). To make slide specimens for one species, dinoflagellate samples were washed with distilled water and the method described in Kim *et al.* (2013) was followed.

For species identification, several monographs reported relative to different oceans such as Japan's adjacent sea (Yamaji 1984), the British Ocean and Atlantic Ocean (Dodge 1982), the Kuroshio Current (Fujioka 1990), Korean waters (Shim 1994) and the Western Pacific (Omura *et al.* 2012) were used. Dinoflagellate classification for new combinations of the family Diplopsaliaceae, Heterocapsaceae, Kolkwitiellaceae, Proto-peridiniaceae and Thoracosphaeraceae was cited from AlgaeBase (<http://www.algaebase.org>) (Guiry and Guiry 2017).

RESULTS AND DISCUSSION

A total of 13 species of 5 genera (*Preperidinium*, *Heterocapsa*, *Diplopsalis*, *Proto-peridinium*, *Scrippsiella*) belonging to the family Diplopsaliaceae, Heterocapsaceae, Kolkwitiellaceae, Proto-peridiniaceae and Thoracosphaeraceae from Korean waters were identified and classified

as below. Among them, 5 species were described as newly recorded species in Korean waters and 8 were re-described, respectively, in this study. The newly recorded and the re-described species are marked with asterisks (*) and sharps (#), respectively. 'C' indicates a currently accepted name, 'S' a synonym, 'P' a preliminary AlgaeBase entry, 'U' an uncertain taxonomic status based on the species database of AlgaeBase (Guiry and Guiry 2017), respectively.

Systematics of dinoflagellates in the order Peridinales occurred in Korean waters

Class Dinophyceae West et Fritsch

Order Peridinales Haeckel

Family Diplopsaliaceae Matsuoka

Genus *Preperidinium* Mangin

#*Preperidinium meunieri* (Pavillard) Elbrächter C

Family Heterocapsaceae Fensome, Taylor, Noris, Sargeant, Wharton et Williams

Genus *Heterocapsa* Stein

**Heterocapsa ovata* Iwataki et Fukuyo C

Heterocapsa psammophila Tamura, Iwataki et Horiguchi C

**Heterocapsa pseudotriquetra* Iwataki, Hansen et Fukuyo C

Heterocapsa rotundata (Lohmann) Hansen C

Heterocapsa triquetra (Ehrenberg) Stein C

Family Kolkwitiellaceae Lidemann

Genus *Diplopsalis* Bergh

#*Diplopsalis lenticula* Bergh C

Diplopsalis pilula Ostenfeld C

Genus *Qia* Liu, Mertens et Gu

Qia lebouriae Liu, Mertens et Gu C

= *Diplopsalis lebouriae* (Nie) Balech S

Family Amphidiniopsidaceae Dodge

Genus *Archaeperidinium* Jørgensen

Archaeperidinium minutum (Kofoid) Jørgensen C

= *Proto-peridinium minutum* (Kofoid) Loeblich III S

Family Proto-peridiniaceae Balech

Genus *Peridinium* Ehrenberg

Peridinium quadridentatum (Stein) Hansen C

= *Proto-peridinium quinquecorne* (Abé) Balech S

Genus *Protopteridinium* Bergh[#]*Protopteridinium abei* Paulsen C*Protopteridinium abei* var. *rotundatum* (Abé) Taylor C= *Protopteridinium rotundatum* Abé S*Protopteridinium acutum* (karsten) Balech C*Protopteridinium americanum* (Gran et Braarud) Balech C*Protopteridinium angustum* (Dangeard) Balech C*Protopteridinium avellana* (Meunier) Balech C*Protopteridinium biconicum* (Dangeard) Balech C*Protopteridinium bidentatum* (Abé) Balech P*Protopteridinium bipes* (Paulsen) Balech C*Protopteridinium bispinum* (Schiller) Balech C*Protopteridinium breve* Paulsen C*Protopteridinium brevipes* (Paulsen) Balech C*Protopteridinium brochii* (Kofoid et Swezy) Balech C*Protopteridinium bulla* (Meunier) Balech C*Protopteridinium cerasus* (Paulsen) Balech C*Protopteridinium claudicans* (Paulsen) Balech C*Protopteridinium complanatum* Meunier C*Protopteridinium compressum* (Abé) Balech C*Protopteridinium conicoides* (Paulsen) Balech C*Protopteridinium conicum* (Gran) Balech C*Protopteridinium corniculum* (Kofoid et Michener) Taylor et Balech P*Protopteridinium crassipes* (Kofoid) Balech C*Protopteridinium cruciferum* (Balech) Balech C= *Protopteridinium parvum* Abé S*Protopteridinium curvipes* (Ostenfeld) Balech C*Protopteridinium cuspidatum* Balech C*Protopteridinium decipiens* (Jørgensen) Parke et Dodge C*Protopteridinium denticulatum* (Gran et Braarud) Balech C[#]*Protopteridinium depressum* (Bailey) Balech C= *Protopteridinium parallelum* Paulsen S*Protopteridinium diabolus* (Cleve) Balech C^{*}*Protopteridinium diabolus* var. *longipes* (Karsten) U*Protopteridinium divaricatum* (Meunier) Parke et Dodge C*Protopteridinium divergens* (Ehrenberg) Balech C*Protopteridinium dolichoporum* Borgese C*Protopteridinium elegans* (Cleve) Balech C*Protopteridinium elongatum* (Meunier) Balech C*Protopteridinium excentricum* (Paulsen) Balech C*Protopteridinium fastum* Balech C*Protopteridinium fatulipes* (Kofoid) Balech C*Protopteridinium globifera* Abé C*Protopteridinium globulus* (Stein) Balech C*Protopteridinium grande* (Kofoid) Balech C*Protopteridinium granii* (Ostenfeld) Balech C*Protopteridinium hemisphaericum* (Abé) Balech P*Protopteridinium hirobis* (Abé) Balech P*Protopteridinium hyalinum* (Meunier) Balech P*Protopteridinium inclinatum* (Balech) Balech P*Protopteridinium incognitum* (Balech) Balech C*Protopteridinium inflatum* (Okamura) Balech P*Protopteridinium islandicum* (Paulsen) Balech C*Protopteridinium joergensenii* var. *luculentum* Balech C*Protopteridinium latidorsale* (Dangeard) Balech C[#]*Protopteridinium latispinum* (Mangin) Balech C*Protopteridinium latissimum* (Kofoid) Balech C*Protopteridinium leonis* (Pavillard) Balech C*Protopteridinium lipopodium* (Balech) Balech C*Protopteridinium longipes* Balech C*Protopteridinium majus* (Dangeard) Balech C*Protopteridinium mariebouriaae* (Paulsen) Balech C*Protopteridinium matzenaueri* (Böhm) Balech C*Protopteridinium metanatum* (Balech) Balech C*Protopteridinium mite* (Pavillard) Balech C*Protopteridinium monospinum* (Paulsen) Zonneveld et Dale C*Protopteridinium munobis* (Abé) Balech C*Protopteridinium nudum* (Meunier) Balech C*Protopteridinium nux* (Schiller) Balech P*Protopteridinium oblongum* (Aurivillius) Parke et Dodge C*Protopteridinium obtusum* (Karsten) Parke et Dodge C*Protopteridinium oceanicum* (Vanhöffen) Balech C= *Protopteridinium murrayi* (Kofoid) Hernández-Becerril S*Protopteridinium orbiculare* Paulsen C*Protopteridinium ovatum* Pouchet C*Protopteridinium oviforme* (Dangeard) Balech C*Protopteridinium ovum* (Schiller) Balech C

**Protoperidinium pacificum* (Kofoid et Michener) Taylor et Balech ex Balech P
Protoperidinium pallidum (Ostenfeld) Balech C
Protoperidinium parcum (Balech) Balech C
Protoperidinium paulsenii (Pavillard) Balech C
Protoperidinium pedunculatum (Schütt) Balech C
Protoperidinium pellucidum Bergh C
Protoperidinium pentagonum (Gran) Balech C
Protoperidinium perplexum (Balech) Balech C
Protoperidinium perradiatum Balech C
Protoperidinium porosum Balech C
[#]*Protoperidinium punctulatum* (Paulsen) Balech C
Protoperidinium pyriforme (Paulsen) Balech C
Protoperidinium pyrum (Balech) Balech C
Protoperidinium quarnerense (Schröder) Balech C
Protoperidinium rectum (Kofoid) Balech P
Protoperidinium roseum (Paulsen) Balech C
Protoperidinium saltans (Meunier) Balech C
= *Protoperidinium valgus* Abé S
Protoperidinium simulum (Paulsen) Balech C
Protoperidinium sinuosum Lemmermann C
[#]*Protoperidinium solidicorne* (Mangin) Balech C
= *Protoperidinium spinosum* Schiller S
Protoperidinium somma (Matzenauer) Balech C
Protoperidinium sphaericum (Murray et Whitting) Balech P
Protoperidinium sphaeroides (Dangeard) Balech P
Protoperidinium steidingerae Balech C
Protoperidinium steinii (Jørgensen) Balech C
Protoperidinium subinermis (Paulsen) Loeblich III C
[#]*Protoperidinium subpyriforme* (Dangeard) Balech C
Protoperidinium thorianum (Paulsen) Balech C
Protoperidinium thulesense (Balech) Balech C
Protoperidinium tumidum (Okamura) Balech C
Protoperidinium ventricum (Abé) Balech P
Protoperidinium venustum (Matzenauer) Balech C
Protoperidinium verrucosum (Meunier) Balech C

Family Thoracosphaeraceae Schiller

Genus *Scrippsiella* Balech ex Loeblich III

Scrippsiella acuminata (Ehrenberg) Kretschman, Elbrächter, Zinssmeister, Soehner, Kirsch, Kusber et Gottschlig C
= *Scrippsiella trochoidea* (Stein) Loeblich III S

**Scrippsiella hexapraecingula* Horiguchi et Chihara C
Scrippsiella spinifera Honsell et Cabrini C
Scrippsiella sweeneyae Balech ex Loeblich III C

Taxonomic description of unrecorded dinoflagellates

Genus *Preperidinium* Mangin 1913

Lectotype species: *Preperidinium paulseni* (Mangin) Mangin.

Description: Medium-sized (50–90 µm) dinoflagellate of subspherical to lenticular shape, characterized by a short apical horn and a large left sulcal list. Thecal plates are smooth, sometimes with broad intercalary bands. Sulcus is characterized by a large flagellar pore. Cingulum is circular, dividing the cell into 2 parts of equal size. Most specimens reddish colored, no chloroplasts. Nucleus ovoid spherical (Guiry and Guiry 2017).

Numbers of names and species: There are 8 species (and infraspecific) names in the database at present, of which 4 have been flagged as currently accepted taxonomically (Guiry and Guiry 2017).

***Preperidinium meunieri* (Pavillard) Elbrächter 1993 (Fig. 1a)**

Basionym: *Peridinium meunieri* Pavillard

Synonym: *Peridinium meunieri* Pavillard, *Diplosalis lenticula* f. *minor* Paulsen, *Peridinium lenticulum* Mangin, *Peridinium paulsenii* Mangin, *Peridinium lenticulatum* Mangin, *Diplopeltopsis minor* Pavillard, *Preperidinium paulseni* (Mangin) Mangin, *Diplopsalis minor* (Paulsen) Lindemann, *Glenodinium lenticula* f. *minor* Schiller, *Zyga-bikodinium lenticulatum* Loeblich Jr. et Loeblich III.

References: Tomas 1997, p. 530, pl. 48; Jardim and Cardoso 2013, p. 633, fig. 1E–G.

Specimen examined: Serial No. LJB2014006.

Description: Cell shape is like *Diplosalis lenticula*. Thecal plate is relatively hard, small or medium sized. It is a slightly spherical shape like a lens with prominent left sulcal list and APC. Cingulum is medium and circular with prominent rib-supported lists. The surface is scratch on the groove. Chloroplasts are absent.

Size: 30–40 µm long, 45–60 µm wide in the apical view.

Sampling: Sep. 2014. Ieo-do coast (32°7'12.35"N, 125°8'

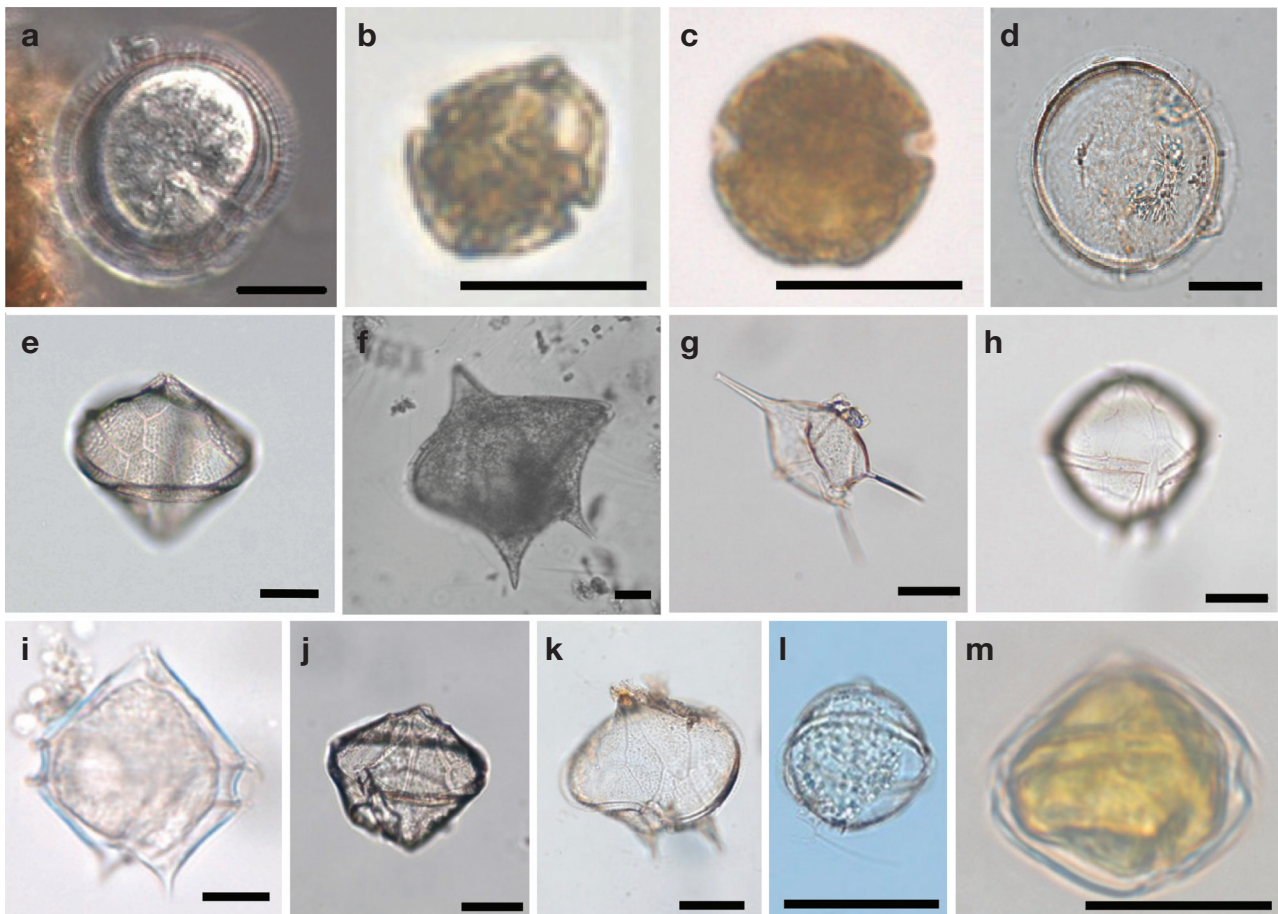


Fig. 1. Light micrographs of genera *Preperidinium*, *Heterocapsa*, *Diplopsalis*, *Protoperidinium* and *Scrippsiella*. (a) *Preperidinium meunieri*, apical view, (b) *Heterocapsa ovata*, ventral view, (c) *Heterocapsa psuedotriquetra*, ventral view, (d) *Diplosalis lenticula*, apical view, (e) *Protoperidinium abei*, left lateral view, (f) *Protoperidinium depressum*, right lateral view, (g) *Protoperidinium diabolus* var. *longipes*, ventral view, (h) *Protoperidinium latispinum*, ventral view, (i) *Protoperidinium pacificum*, dorsal view, (j) *Protoperidinium punctulatum*, lateral view, (k) *Protoperidinium solidicorne*, apical view, (l) *Protoperidinium subpyriforme*, right lateral view, (m) *Scrippsiella hexapraeicingula*, right lateral view (Scale bars, 20 μ m).

40.51"E).

Habitat: Marine species. This species was found in the surface layer with a water temperature of 24.2–26.2°C and salinity of 33.5–34.4 psu.

Distribution: Europe: Black Sea (Gómez and Boicenco 2004), Helgoland (Hoppenrath 2004), Mediterranean (Gómez 2003); North America: Florida (Gribble and Anderson 2006); South America: Brazil (Jardim and Cardoso 2013).

Note: This species name may be regarded as a taxonomic synonym of *Zygabikodinium lenticulatum* Loeblich Jr. et Loeblich III (Guiry and Guiry 2017). This species was reported as a new record for Korea by Shim (1994) as *Zygabikodinium lenticulatum* Loeblich Jr. et Loeblich III (Table 1), and reported as a re-described species in coastal waters

of Korea in this study.

Genus *Heterocapsa* Stein 1883

Holotype species: *Heterocapsa triquetra* (Ehrenberg) Stein

Description: Medium-sized (20–40 μ m) biflagellated thecate dinoflagellates irregularly spindle shaped or ovoid with a medium and circular cingulum, sulcus restricted to the hypocone. The plate pattern is difficult to establish and has been disputed. Numerous chloroplasts and an ovoid nucleus. Marine plankton, worldwide distribution mainly in coastal waters (Guiry and Guiry 2017).

Numbers of names and species: There are 24 species (and infraspecific) names in the database at present, of which 19 have been flagged as currently accepted taxonomically

(Guiry and Guiry 2017).

***Heterocapsa ovata* Iwataki et Fukuyo 2003 (Fig. 1b)**

Synonym: No synonym.

References: Iwataki *et al.* 2003, p. 630, figs. 1–16, 29–33; Omura *et al.* 2012, p. 130.

Specimen examined: Serial No. LJB2015015 / NIBR No. NIBRDN00000009.

Description: Cells are ovoid. The epitheca is smaller or equal to lower than the hypotheca. The upper part of the hypotheca is the widest in the cell. Cingulum exists in the central part. Sulcus is narrow and spreads towards the antapex. Chloroplasts present.

Size: 24–33 µm long, 18–28 µm wide in lateral view.

Sampling: Mar. 2015. Sehwa-ri coast in Jeju Island (33°16' 4.2"N, 125°49'1.8"E).

Habitat: Marine species. This species was found in the surface layer with a water temperature 14.1°C and salinity of 34.8 psu.

Distribution: Japan (Iwataki *et al.* 2003, 2004).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2015 and reported as a newly recorded species in coastal waters of Korea in this study.

***Heterocapsa pseudotriquetra* Iwataki, Hansen et Fukuyo 2004 (Fig. 1c)**

Synonym: No synonym.

References: Iwataki *et al.* 2004, p. 395, figs. 1–18; Omura *et al.* 2012, p. 130.

Specimen examined: Serial No. LJB2015016 / NIBR No. NIBRDN00000010.

Description: Cells are spherical or ovoid. The epitheca is larger than the hypotheca or of equal. The epitheca is hemispheric type. The cingulum is slightly below the middle or middle part. The sulcus is wide and spreads towards the antapex. Chloroplasts present.

Size: 18–27 µm long, 14–22 µm wide in lateral view.

Sampling: Mar. 2015. Sehwa-ri coast in Jeju Island (33°16' 4.2"N, 125°49'1.8"E).

Habitat: Marine species. This species was found in the surface layer with a water temperature 14.1°C and salinity of 34.8 psu.

Distribution: North America: Massachusetts (Iwataki *et al.* 2004); Asia: Japan (Iwataki *et al.* 2004).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2015 and reported as a newly recorded species in coastal waters of Korea in this study.

Genus *Diplopsalis* Bergh 1881

Holotype species: *Diplopsalis lenticula* Bergh.

Description: Medium-sized (30–60 µm) thecate dinoflagellates of lenticular to spherical shape. Cingulum circular, dividing the theca into 2 more or less equal sized parts; sulcus characterized by a large flagellar pore and restricted to the hypocone, at the left side with a large wing. Epitheca with an apical pore. Thecal plates smooth, sometimes with large intercalary bands (Guiry and Guiry 2017).

Numbers of names and species: There are 36 species (and infraspecific) names in the database at present, of which 11 have been flagged as currently accepted taxonomically (Guiry and Guiry 2017).

***Diplopsalis lenticula* Bergh 1881 (Fig. 1d)**

Synonym: *Dissodium leniculum* (Bergh) Loeblich III, *Peridiniopsis lenticula* (Bergh) Starmach, *Glenodinium lenticula* Pouchet.

References: Dodge 1982, p. 154, pl. III b, c, fig. 18I–K; Omura *et al.* 2012, p. 126.

Specimen examined: Serial No. LJB2008008.

Description: Cell is a lens shaped and generally spherical. The epitheca and the hypotheca are almost equal. The cingulum is in the middle part. Around the cell, there is the cingulum of strap shaped lists. The sulcus is wide and reaches the center of the hypotheca.

Size: 23–48 µm long, 32–68 µm wide in the apical view.

Sampling: Sep. 2008. Yellow Sea (35°30'5.97"N, 124°58' 16.09"E).

Habitat: Marine species.

Distribution: Europe: Black Sea (Goméz and Boicenco 2004), Britain (Parke and Dixon 1976), Helgoland (Hoppenrath 2004), Mediterranean (Goméz 2003); North America: Florida (Gribble and Anderson 2006); Asia: China (Liu 2008).

Note: This species was recorded as floristic lists by Yoo (1990) and Lee and Kim (2015), and described by Shin (2016) (Table 1). It was reported as an unrecorded indigenous species by NIBR in 2008 and reported as a re-described species in coastal waters of Korea in this study.

Genus *Protopteridinium* Bergh 1881

Lectotype species: *Protopteridinium pellucidum* Bergh.

Description: The cell is medium sized to large size. The cell body has various shapes. The cell is distinguished epitheca and hypotheca by a cingulum. The sulcus may slightly influence on the epitheca. Chromatophores and chloroplasts are absent (Dodge 1982).

Numbers of names and species: There are 381 species (and infraspecific) names in the database at present, of which 259 have been flagged as currently accepted taxonomically (Guiry and Guiry 2017).

Protopteridinium abei (Paulsen) Balech 1974 (Fig. 1e)

Basionym: *Peridinium abei* Paulsen

Synonym: *Peridinium abei* Paulsen, *Peridinium biconicum* Abé.

References: Yuri 2008, p. 105, pl. 1, figs. 9–12; Omura *et al.* 2012, p. 113.

Specimen examined: Serial No. LJB2009024 / NIBR No. NIBRFL0000125586.

Description: The cells are medium sized. The epitheca and hypotheca are shown in the cone form, and horn is pointed. The thecal plates are seen with a lot of small holes, and cingulum is clearly observed with a slight thickness. The sulcus is slanted towards the left side of the hypotheca.

Size: 57–77 µm long, 37–48 µm wide in the lateral view.

Sampling: Aug. 2009. Seongsan-ri coast in Jeju Island (33° 25'08"N, 126°56'38"E).

Habitat: Marine species.

Distribution: Europe: Black Sea (Goméz and Boicenco 2004), Mediterranean (Goméz 2003); North America: Mexico (Merino-Virgilio *et al.* 2013); Asia: China (Liu 2008).

Note: This species was described as a new record for Korea by Shin (2016) (Table 1), and reported as an unrecorded indigenous species by NIBR in 2009 and reported as a re-described species in coastal waters of Korea in this study.

Protopteridinium depressum (Bailey) Balech 1974

(Fig. 1f)

Basionym: *Peridinium depressum* Bailey

Synonym: *Peridinium depressum* Bailey, *Protopteridinium parallelum* Paulsen.

References: Yamaji 1984, p. 130, pl. 42, fig. 9.

Specimen examined: Serial No. LJB2008011.

Description: Overall form is like *Protopteridinium claudicans* but the epitheca is represented angle instead of the round shape. The two horns at the hypotheca is extend to the bottom, and the cingulum of the central cell tends to protrude.

Size: 140–190 µm long, 90–145 µm wide in the ventral view.

Sampling: Sep. 2008. Seongsan-ri coast in Jeju Island (33° 25'08"N, 126°56'38"E).

Habitat: Marine species.

Distribution: Europe: Black Sea (Goméz and Boicenco 2004), Britain (Parke and Dixon 1976), Mediterranean (Goméz 2003), Helgoland (Hoppenrath 2004); North America: Mexico (Okolodkov 2005), Asia: China (Liu 2008), Japan (Yamaji 1984), Korea (Shim *et al.* 1981).

Note: This species name may be regarded as a taxonomic synonym of *Protopteridinium parallelum* Paulsen 1907 (Guiry and Guiry 2017). This species was reported as a new record for Korea by Shim *et al.* (1981). However, the *Protopteridinium parallelum* was reported as an unrecorded indigenous species by NIBR in 2008 and reported as a re-described species in coastal waters of Korea in this study.

Protopteridinium diabolus var. *longipes* (Karsten)

(Fig. 1g)

Synonym: No synonym.

References: Fujioka 1990, p. 66–67.

Specimen examined: Serial No. LJB2010027 / NIBR No. NIBRFL0000125623.

Description: Cells look slightly oval, and are generally slender. Similar to *Protopteridinium diabolus*. The apical horn is thinner and pointy, and tail spur is characterized by spine.

Size: 50–75 µm long, 42–60 µm wide in the lateral view.

Sampling: Sep. 2010. East China Sea (33°35'128"N, 125° 40'247"E).

Habitat: Marine species. This species was found in the surface layer with a water temperature of 24.8°C and salinity of 30.4 psu.

Distribution: Japan (Fujioka 1990).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2010 and reported as a newly recorded species in coastal waters of Korea in this study.

***Protoperidinium latispinum* (Mangin) Balech 1974**

(Fig. 1h)

Basionym: *Peridinium latispinum* Mangin**Synonym:** *Peridinium latispinum* Mangin, *Peridinium africanoides* Dangeard, *Protoperidinium africanoides* (Dangeard) Balech.**References:** Okolodkov 2005, p. 290, figs. 11, 27; Omura 2012, p. 117.**Specimen examined:** Serial No. LJB2016005 (winter) / NIBR No. NIBRDN0000000618.**Description:** The whole form has a round shaped pattern, with a hexagonal 1' plate. The cells have an apical horn. Cingulum is located slightly lower than the left side and slightly tilted. As the sulcus goes down, it becomes wider and has two spines in the hypotheca.**Size:** 80–115 µm long, 55–80 µm wide in the ventral view.**Sampling:** Jan. 2017. Seogwipo coast in Jeju Island (33°12'39.026"N, 126°35'1.750"E).**Habitat:** Marine species.**Distribution:** Europe: Mediterranean (Goméz 2003); North America: Mexico (Okolodkov 2005), Asia: China (Liu 2008).**Note:** This species was reported as an unrecorded indigenous species by NIBR in 2016 and described as a new record for Korea by Shin (2016) (Table 1). It is reported as a re-described species in the Korea waters in this study.***Protoperidinium pacificum* (Kofoid et Michener)****Taylor et Balech ex Balech 1974 (Fig. 1i)****Synonym:** No synonym.**References:** Okolodkov 2008, p. 138, pl. 13, figs. 9–12; Jardim and Cardoso 2013, p. 635, fig. 2G.**Specimen examined:** Serial No. LJB2013012.**Description:** Cells are thin and slightly rounded, with a very short apex and a full cell shape of Meta-quadrata. The hypothecal pore is absent. Cingulum offset 1.4 times width. Plate 1' is slightly asymmetrical, with the right distal side longest. Plate 2a is trapezoidal and slightly longer than plate 4". The two horns are relatively close and the two post-shaped lists are slightly more pronounced in the left lists.**Size:** 50–65 µm long, 55–60 µm wide.**Sampling:** Jul. 2010. Chagwi-do coast in Jeju Island (33°18'776"N, 126°08'246"E).**Habitat:** Tropical and temperate species.**Distribution:** South America: Brazil (Jardim and Cardoso 2013), North America: Mexico (Okolodkov 2008).**Note:** This species was reported as an unrecorded indigenous species by NIBR in 2013 and reported as a newly recorded species in coastal waters of Korea in this study.***Protoperidinium punctulatum* (Paulsen) Balech 1974**

(Fig. 1j)

Basionym: *Peridinium punctulatum* Paulsen**Synonym:** *Peridinium punctulatum* Paulsen, *Peridinium subinermis* var. *punctulatum* (Paulsen) Schiller.**References:** Dodge 1982, p. 183, fig. 20L, M.**Specimen examined:** Serial No. LJB2010028 / NIBR No. NIBRFL0000125624.**Description:** The cells are almost a diamond shape. The epitheca is in a triangular shape and sulcus is narrow. The cingulum is equatorial, and has lists supported by spines. The hypotheca has concave.**Size:** 40–72 µm long, 45–50 µm in the ventral view.**Sampling:** Jan. 2011. Seongsan-ri coast in Jeju Island (33°25'08"N, 126°56'38"E).**Habitat:** Marine species. This species was found in the surface layer with a water temperature of 13.5°C and salinity of 34.2 psu.**Distribution:** Europe: Black Sea (Goméz and Boicenco 2004), Mediterranean (Goméz 2003), Helgoland (Hoppenrath 2004); North America: Mexico (Okolodkov 2005); Asia: China (Liu 2008).**Note:** This species recorded as floristic lists by Chang *et al.* (1995), Lee and Kim (2015) and described as a new record for Korea by Shin (2016) (Table 1). This species was reported as an unrecorded indigenous species by NIBR in 2010 and reported as a re-described species in the Korea waters in this study.***Protoperidinium solidicorne* (Mangin) Balech 1974**

(Fig. 1k)

Basionym: *Peridinium solidicorne* Mangin.**Synonym:** *Peridinium solidicorne* Mangin, *Protoperidinium spinosum* Schiller, *Peridinium spiniferum* Schiller, *Protoperidinium spiniferum* (Schiller) Balech.**References:** Fujioka 1990, p. 68–69.**Specimen examined:** Serial No. LJB2010029 / NIBR No. NIBRFL0000125625.

Description: Cells are flattened out of the dorsal-ventral sides. The apical horn protrudes upwards and cells have two pointy antapical horns. Sides of the plate are recessed towards the end and antapical end, and convex around the cingulum.

Size: 90–100 µm long, 65–70 µm wide.

Sampling: Jan. 2011. Seongsan-ri coast in Jeju Island (33° 25'08"N, 126°56'38"E).

Habitat: Marine species. This species was isolated from pelagic layer in the eastern coast of Jeju Island with water temperature 13.5°C, salinity 34.2 psu.

Distribution: Europe: Black Sea (Goméz and Boicenco 2004), Mediterranean (Goméz 2003), Asia: China (Liu 2008), Japan (Fujioka 1990).

Note: This species name may be regarded as a taxonomic synonym of *Protoperidinium spinosum* Schiller 1937 (Guiry and Guiry 2017). This species was reported as a new record for Korea by Shim *et al.* (1981) (Table 1). However, *Protoperidinium spinosum* (as *Protoperidinium spinulosum*) was reported as an unrecorded indigenous species by NIBR in 2010 and reported as a re-described species in Korean waters in this study.

***Protoperidinium subpyriforme* (Dangeard) Balech 1974 (Fig. 11)**

Basionym: *Peridinium subpyriforme* Dangeard.

Synonym: *Peridinium subpyriforme* Dangeard.

References: Yamaji 1984, p. 126–127.

Specimen examined: Serial No. LJB2010030 / NIBR No. NIBRFL0000125626.

Description: Cell is a spherical and small. There is a small protuberance on the top of the epitheca. Cingulum is in the center of the cell and has two spines on the hypotheca.

Size: 40–80 µm long, 30–50 µm wide in the lateral view.

Sampling: Aug. 2009. Seongsan-ri coast in Jeju Island (33° 25'08"N, 126°56'38"E).

Habitat: Marine species.

Distribution: This species is commonly seen in oceanic region.

Note: This species was listed as a recorded species in Korea by Lee and Kim (2015) and described by Shin (2016) (Table 1). It was reported as an unrecorded indigenous species by NIBR in 2010 and reported as a re-described species in Korean waters in this study.

Genus *Scrippsiella* Balech ex Loeblich III 1965

Holotype species: *Scrippsiella sweeneyae* Balech ex Loeblich III.

Description: Small-sized subspherical dinoflagellate with a conical epitheca and rounded hypotheca, characterized by a short apical horn. Thecal plates are relatively thin and unsculptured. Cingulum is separated by hypotheca. Chloroplasts present. Nucleus spherical to ovoid, centrally placed (Dodge 1982).

Numbers of names and species: There are 42 species (and infraspecific) names in the database at present, of which 34 have been flagged as currently accepted taxonomically (Guiry and Guiry 2017).

***Scrippsiella hexapraecingula* Horiguchi et Chihara 1983 (Fig. 1m)**

Synonym: No synonym.

References: Horiguchi and Chihara 1983, p. 352, figs. 1–3; Fukuyo *et al.* 1990, p. 158; Hoppenrath *et al.* 2014, p. 163, figs. 75, 76.

Specimen examined: Serial No. LJB2009009 / NIBR No. NIBRFL0000125571.

Description: Cell is small-sized and slightly flattened cell with conical epitheca and rounded hypotheca. Thecal plates are smooth with scattered pores. Cingulum is slightly tilted. Sulcus is wide and slightly extends into epitheca and reaches the end of hypotheca.

Size: 25–30 µm long, 20–25 µm wide in ventral view.

Sampling: Aug. 2009. Samyang coast in Jeju Island (33° 32'136"N, 126°35'996"E).

Habitat: Benthic species.

Distribution: North America: California (Horiguchi and Pienaar 1988); Asia: Japan (Fukuyo *et al.* 1990; Hoppenrath 2014).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2009 and reported as a newly recorded species in coastal waters of Korea in this study.

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