

⟨Original article⟩

New Records of Benthic Dinoflagellates of Four Genera (*Bispidodinium*, *Cabra*, *Prorocentrum*, *Sinophysis*) from the Coastal Beach of Korea

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Abstract - A research probing for the unrecorded and taxonomically undescribed indigenous species has been initiated since 2006. Samples were collected from an intertidal zone along the coasts of Korea as well as around the Jeju Island. We have found five unrecorded species of four genera belonging to the order Dinophysiales, Gymnodiniales, Peridiniales, and Prorocentrales. The species are as follows, *Sinophysis canaliculata* (2017) *Bispidodinium angelaceum* (2015), *Cabra armorica* (2016), *Prorocentrum bimaculatum* (2017), and *P. tsawwassenense* (2017) (note; The numbers in parenthesis refer to the year in which the species was reported as unrecorded indigenous species by National Institute of Biological Resources, NIBR hereafter).

Keywords: *Bispidodinium*, *Cabra*, *Prorocentrum*, *Sinophysis*, benthic dinoflagellates

INTRODUCTION

Marine benthic dinoflagellates have been paid attention in terms of microalgal monitoring due to potentially harmful benthic species which lead to the economic loss by killing fish/shellfish through toxic blooms and subsequently human health especially in subtropical to tropical coastal areas (Hallegraeff 1993; Gilbert *et al.* 2005). Benthic dinoflagellates are known to be present in tropical and subtropical regions of the Pacific Ocean, Indian Ocean, and the Caribbean where they are found to be associated with seagrasses, macroalgae and sediments (Fukuyo 1981; Morton and Faust 1997; Aligizaki *et al.* 2008; Almazán-Becerril *et al.* 2015). Recently some species are also found in temperate regions (Pistocchi *et al.* 2011; Selina and Levchenko 2011; Shah *et al.* 2013). Several benthic dinoflagellates species of the genera *Ostreopsis*, *Coolia*, *Prorocentrum*, and *Amphidinium* are

known to be potentially toxic (Fukuyo 1981; Besada *et al.* 1982; Faust 1995; Mohammad-Noor *et al.* 2007).

Previously, the toxic dinoflagellates recorded from Korean temperate waters were planktonic, but potentially toxic benthic sand dwelling and epiphytic dinoflagellates have not been well documented. To date, no toxic event caused by a marine benthic dinoflagellate has been reported from Jeju Island. Since Kim *et al.* (2011), Jeong *et al.* (2012a, b), Kang *et al.* (2013) and Lim *et al.* (2013) described 6 benthic epiphytic dinoflagellates in the coast of Jeju Island, Shah *et al.* (2013) added 37 benthic dinoflagellates from the Jeju coastal beach through two years of intensive survey. A research searching for unrecorded indigenous species, which has not been described taxonomically in Korea, has been done as part of projects by NIBR from 2006. This study clarify additionally 5 species belonging to 4 genera with the respects of classification and easy taxonomical key based on Light Microscope (LM) criteria.

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MATERIALS AND METHODS

Samplings were done at intertidal zone of sandy beach in Korea as well as Jeju Island from January 2015 to April 2017. Samples of sand sediment were collected on sandy beaches using a spatula. The samples were transferred to plastic bottles with seawater. The samples were incubated and then isolated by picking method and fixed with formaldehyde (final concentration of 1%) or glutaraldehyde (final concentration of about 1%). Benthic dinoflagellates were identified by using LM (Axioplan, Carl Zeiss, Oberkochen, Germany). To make slide specimens for one species, the dinoflagellate samples were washed with distilled water and then the method described in Kim *et al.* (2013) was followed.

For identification, a monograph of Hoppenrath *et al.* (2014) reported from different areas were mainly used. Classification for the new combinations of the family Dinophysiales familia incertae sedis, Gymnodiniaceae, Peridinales incertae sedis and Prorocentraceae was cited from AlgaeBase (<http://www.algaebase.org>) (Guiry and Guiry 2018).

RESULTS AND DISCUSSION

A total of 36 species of 4 genera (*Sinophysis*, *Bispinodinium*, *Cabra* and *Prorocentrum*) belonging to the family Dinophysiales familia incertae sedis, Gymnodiniaceae, Peridinales incertae sedis and Prorocentraceae from Korean coastal beach were identified and classified in the checklist based on valid name as below. Five species were described as newly recorded species in Korean waters. The newly recorded are marked with asterisks (*), 'C' indicates a currently accepted name, 'S' a synonym based on the species database of AlgaeBase (Guiry and Guiry 2018), respectively.

Checklist of the genus *Sinophysis*, *Bispinodinium*, *Cabra* and *Prorocentrum* occurred in Korea Waters

Class Dinophyceae West et Fritsch

Order Dinophysiales Kofoid

Family Dinophysiales familia incertae sedis

Genus *Sinophysis* Nie et Wang

**Sinophysis canaliculata* Quod, Ten-Hage, Turquet, Mascarell et Couté C

Order Gymnodiniales Apstein

Family Gymnodiniaceae Lankester

Genus *Bispinodinium* Yamada et Horiguchi

**Bispinodinium angelaceum* Yamada et Horiguchi C

Order Peridinales Haeckel

Family Peridinales incertae sedis

Genus *Cabra* Murray et Patterson

**Cabra armorica* Chomérat, Couté et Nézan C

Cabra matta Murray et Patterson C

Order Prorocentrales Lemmermann

Family Prorocentraceae Stein

Genus *Prorocentrum* Ehrenberg

Prorocentrum aporum (Schiller) Dodge C

Prorocentrum arcuatum Issel C

Prorocentrum balticum (Lohmann) Loeblich III C

**Prorocentrum bimaculatum* Chomérat et Saburova C

Prorocentrum clipeus Hoppenrath C

Prorocentrum compressum (Bailey) Abé ex Dodge S

= *Tryblionella compressa* (Bailey) Poulin C

Prorocentrum concavum Fukuyo C

Prorocentrum cordatum (Ostenfeld) Dodge C

= *Prorocentrum minimum* (Pavillard) Schiller S

Prorocentrum cornutum Schiller C

Prorocentrum dactylus (Stein) Dodge C

Prorocentrum dentatum Stein C

Prorocentrum emarginatum Fukuyo C

Prorocentrum fukuyoi Murray et Nagahama C

Prorocentrum gracile Schütt C

= *Prorocentrum sigmoides* Böhm S

Prorocentrum hoffmannianum Faust C

= *Prorocentrum belizeanum* Fasut S

Prorocentrum koreanum Han, Cho et Wang C

Prorocentrum leve Faust, Kibler, Vandersea, Tester et Litaker C

Prorocentrum lima (Ehrenberg) Stein C

Prorocentrum maculosum Faust C

Prorocentrum mexicanum Osorio-Tafall C

Prorocentrum micans Ehrenberg C

Prorocentrum nanum Schiller C

Prorocentrum oblongum (Schiller) Taylor C

Prorocentrum rhathymum Loeblich III, Sherley et Schmidt C

Prorocentrum rostratum Stein C

Prorocentrum ruetzlerianum Faust C
Prorocentrum scutellum Schröder C
Prorocentrum sipadanensis Mohammad-Noor,
 Daugbjerg et Moestrup C
Prorocentrum triestinum Schiller C
Prorocentrum tropicale Faust C
 **Prorocentrum tsawwassenense* Hoppenrath et Lean-
 der C

Taxonomic description of unrecorded dinoflagellates

Genus *Sinophysis* Nie et Wang 1944

Holotype species: *Sinophysis microcephala* Nie et Wang.

Description: Medium-sized (35–45 µm) laterally compressed dinoflagellate, circular to subcircular in lateral view. Thecal plates are covered by many areolae. It has a very small epicone, separated by a well-developed cingulum from the large hypocone with a well-developed sulcus which does not reach the antapex. It has 2 pairs of channeled and parallel projections, possesses a large apical pore. No chloroplasts (Guiry and Guiry 2018).

Numbers of names and species: There are 9 species names in the database at present, of which 9 have been flagged as accepted taxonomically (Guiry and Guiry 2018).

Sinophysis canaliculata Quod, Ten-Hage, Turquet, Mascarell et Couté 1999 (Fig. 1a and b)

Synonym: No synonym.

References: Hoppenrath *et al.* 2014. p. 165. figs. 77A, 78A–C, 79A and B.

Specimen examined: Serial No. LJB2017001.

Description: Cells are almost spherical and compressed. The relatively large, dome shape epitheca has two parallel anterior projection. The hypotheca is slightly elongated and posteriorly rounded. Cingulum is relatively deep and wide. Sulcus is present on the right side and covers about two-thirds of the cell length.

Size: 45–57 µm long, 37–51 µm wide in the apical view.

Sampling: Jan. 2015. Sa-gye beach in Jeju Island (33°13' 53.12" N, 126°18'38.22" E).

Habitat: Marine species.

Distribution: Atlantic Islands: Canary Islands (García-Portela *et al.* 2017); North America: Mexico (Caribbean) (Almazán-Becerril *et al.* 2015); South America: Brazil (Di-

niz *et al.* 2017); Asia: Japan (García-Portela *et al.* 2017).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2017 and reported as a newly recorded species in the coastal waters of Korea in the present study.

Genus *Bispinodinium* Yamada et Horiguchi 2013

Holotype species: *Bispinodinium angelaceum* Yamada et Horiguchi.

Description: *Amphidinium*-like athecate photosynthetic dinoflagellate. Cells composed of a short epicone and a large hypocone. The cingulum completely encircling the cell. (Hoppenrath 2014).

Numbers of names and species: There is only one species or infraspecific name in the database at present, which has been flagged as accepted taxonomically (Guiry and Guiry 2018).

Bispinodinium angelaceum Yamada et Horiguchi 2013 (Fig. 1c)

Synonym: No synonym.

References: Hoppenrath *et al.* 2014. p. 62, fig. 23.

Specimen examined: Serial No. LJB2015003.

Description: Cells are almost oval and athecate dinoflagellates. The epicone is triangle and the hypocone is oval. The ventral and dorsal side is flattened. The cingulum is located at about one-third of the total cell length. The sulcus is straight, narrow and extends antapex. The nucleus is spherical and is located in the middle of the hypocone. Chloroplasts exist.

Size: 30–42 µm long, 25–33 µm wide in the lateral view.

Sampling: Jul. 2015. Hamduk beach in Jeju Island (33° 32'36.11" N, 126°40'4.98" E).

Habitat: Marine species.

Distribution: Japan (Yamada *et al.* 2013).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2017 and reported as a newly recorded species in the coastal waters of Korea in the present study.

Genus *Cabra* Murray et Patterson 2004

Holotype species: *Cabra matta* Murray et Patterson.

Description: Medium sized (30–55 µm) sand-dwelling dinoflagellates. Cells are strongly compressed and asym-

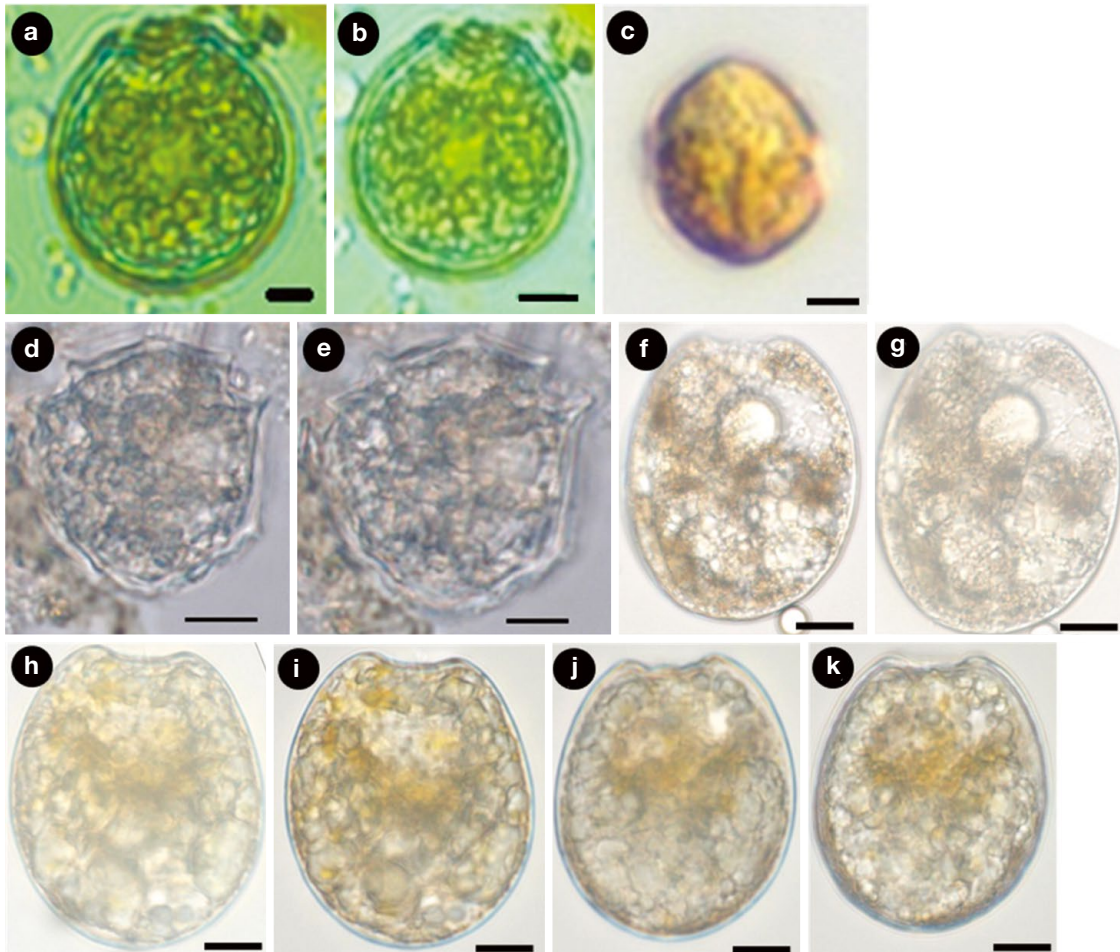


Fig. 1. Light micrographs of the genus *Sinophysis*, *Bispinodinium*, *Cabra* and *Prorocentrum*. (a), (b) *S. canaliculata*, lateral view, (c) *B. angelaceum*, ventral view, (d), (e) *C. armorica*, lateral view, (f), (g) *P. bimaculatum*, right lateral view, (h), (i) *P. tsawwassenense*, right lateral view, and (j), (k) *P. tsawwassenense*, left lateral view (Scale bars: 10 μ m).

metric, appearing different from the left as compared to the right side. Heterotrophic thecal plates are more or less pentagonal and irregular in lateral view. The cingulum is markedly ascending (Hoppenrath *et al.* 2014).

Numbers of names and species: There are 4 species names in the database at present, of which 4 have been flagged as accepted taxonomically (Guiry and Guiry 2018).

***Cabra armorica* Chomérat, Couté et Nézan 2010 (Fig. 1d and e)**

Synonym: No synonym.

References: Hoppenrath *et al.* 2014. p. 74, figs. 29A–C, 30A–F.

Specimen examined: Serial No. LJB2016011.

Description: Cells are polygonal. Thecal plates are areolate

shallowly depressions. The hypotheca is larger than the epitheca. The plate of hypotheca 2^{'''} and 4^{'''} makes up 4 multi-discipline shaped cells, separated by ridges. The apical pore is hook shape but extends to the dorsal left side of cells.

Size: 37–40 μ m long, 31–38 μ m wide in the lateral view.

Sampling: Jul. 2016. Sinyang beach in Jeju Island (33° 26'6.63" N, 126°55'30.07" E).

Habitat: Marine species.

Distribution: France (Chomérat *et al.* 2010).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2017 and reported as a newly recorded species in the coastal waters of Korea in the present study.

Genus *Prorocentrum* Ehrenberg 1834

Table 1. Checklist of genus *Sinophysis*, *Bispinodinium*, *Cabra* and *Prorocentrum* described from Korean coastal area. The newly recorded species are marked with asterisks (*) and 'n' indicates a newly recorded species in Korean waters by Shin (2016), 'f' indicates a species recorded only in floristic lists (Lee and Kim 2015). The terms 'val' and 'syn' refer to a valid name and a synonym, respectively.

Species name	Shim <i>et al.</i> (1981)	Han and Yoo (1983)	Yoo and Lee (1986)	Shim (1994)	Mun <i>et al.</i> (1995)	Shin <i>et al.</i> (2005)	Shah <i>et al.</i> (2013)	Lee and Kim (2015)	Han <i>et al.</i> (2016)	Shin (2016)	Lee and Kim (2017)	Present study
* <i>Sinophysis canaliculata</i>												•
* <i>Bispinodinium angelaceum</i>												•
* <i>Cabra armorica</i>												•
<i>Prorocentrum aporum</i> ^f			•	•		•						
<i>Prorocentrum arcuatum</i> ^f								•				
<i>Prorocentrum balticum</i>	•		•	•								
* <i>Prorocentrum bimaculatum</i>												•
<i>Prorocentrum clipeus</i>	•			•		•				•		
<i>Prorocentrum compressum</i>				•								
= val. <i>Tryblionella compressa</i>												
<i>Prorocentrum concavum</i>				•		•				•		
<i>Prorocentrum cordatum</i>		•	•	•		•				•		
= syn. <i>Prorocentrum minimum</i>												
<i>Prorocentrum cornutum</i> ^f								•				
<i>Prorocentrum dactylus</i> ^f								•				
<i>Prorocentrum dentatum</i>			•							•		
<i>Prorocentrum emarginatum</i>												
<i>Prorocentrum fukuyoi</i>							•					
<i>Prorocentrum gracile</i>												
= syn. <i>Prorocentrum sigmoides</i>												
<i>Prorocentrum hoffmannianum</i> ⁿ												•
= syn. <i>Prorocentrum belizeanum</i> ⁿ												
<i>Prorocentrum koreanum</i>									•			
<i>Prorocentrum leve</i> ⁿ												
<i>Prorocentrum lima</i>				•		•						
<i>Prorocentrum maculosum</i>												
<i>Prorocentrum mexicanum</i> ^f											•	
<i>Prorocentrum micans</i>				•		•						
<i>Prorocentrum nanum</i> ^f	•	•	•	•								
<i>Prorocentrum oblongum</i>	•											
<i>Prorocentrum rhalymum</i>												
<i>Prorocentrum rostratum</i> ^f												
<i>Prorocentrum ruetzlerianum</i> ⁿ												
<i>Prorocentrum scutellum</i> ^f												
<i>Prorocentrum sipadanensis</i>												
<i>Prorocentrum triestinum</i>												
<i>Prorocentrum tropicale</i>												
* <i>Prorocentrum tsawwassenense</i>												•
No. of species	4	3	5	6	7	8	6	22	2	15	3	5

Holotype species: *Prorocentrum micans* Ehrenberg.

Description: Small to medium sized (15–100 µm) bilateral thecate dinoflagellates with 2 apical heterodynamic flagella. The shape is globular, lanceolate or oval. Thecal plates are composed of two smooth valve-shaped plates with pores or spines. Both flagella emerge from one pore. In the flagellar region are an additional 7–14 small plates (Guiry and Guiry 2018).

Numbers of names and species: There are 119 species names in the database at present, as well as 4 infraspecific names. Of the species names, 75 have been flagged as accepted taxonomically (Guiry and Guiry 2018).

***Prorocentrum bimaculatum* Chomérat et Saburova
2012 (Fig. 1f and g)**

Synonym: No synonym.

References: Hoppenrath *et al.* 2014, p. 135, figs. 62, 64A.

Specimen examined: Serial No. LJB2017010.

Description: Cells are long oval. The surface of the plate is exceptionally smooth with tiny pores. The two cingular areas are located above and below the center without a pore. The periflagellar area is wide V-shaped with a short collar.

Size: 50–55 µm long, 38–43 µm wide in lateral view.

Sampling: Apr. 2017. Wangsan beach in Incheon (37° 27'20.97" N, 126°22'17.67" E).

Habitat: Marine species.

Distribution: South-west Asia: Kuwait (Chomérat *et al.* 2012).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2017 and reported as a newly recorded species in the coastal waters of Korea in the present study.

***Prorocentrum tsawwassenense* Hoppenrath et Leander
2008 (Fig. 1h–k)**

Synonym: No synonym.

References: Hoppenrath *et al.* 2014, p. 152, fig. 63.

Specimen examined: Serial No. LJB2017011.

Description: Cells are oval. The surface of thecal plate has large pores as radial row, and the center of the plate is smooth and pores don't exist. The periflagellar area is wide U-shaped, with collar.

Size: 40–55 µm long, 30–48 µm wide in lateral view.

Sampling: Apr. 2017. Wangsan beach in Incheon (37°

27'20.97" N, 126°22'17.67" E).

Habitat: Marine species.

Distribution: North America: British Columbia (Hoppenrath and Leander 2008; Chomérat *et al.* 2011).

Note: This species was reported as an unrecorded indigenous species by NIBR in 2017 and reported as a newly recorded species in the coastal waters of Korea in the present study.

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