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〈Original article〉

New Records of Two Genera *Mesoporos* and *Prorocentrum* (Prorocentraceae, Prorocentrales, Dinophyceae) in Korean Waters

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Abstract - The order Prorocentales currently includes two genera *Prorocentrum* Ehrenberg and *Mesoporos* Lillick. The *Prorocentrum* genus is a predominant group throughout the year found in Korean waters. To date, the *Prorocentrum* genus includes 31 species and the *Mesoporos* genus has only one species in Korean waters. In this study, we identified one *Mesoporos* species and three *Prorocentrum* species around a coast of Jeju Island, and described them as newly recorded species in Korean waters.

Key words : dinoflagellates, Jeju Island, *Mesoporos*, Prorocentraceae, *Prorocentrum*

INTRODUCTION

In recent years, water temperature around Jeju Island has been increasing due to climate change caused by global warming (Yeh and Kim 2010). There has been low salinity phenomena due to Changjiang River runoff from China (Moon *et al*. 2010). The marine environment of the surrounding sea around Jeju Island and Korean peninsula has been changing. In addition, species diversity due to introduction of alien species is changing as well. Compared with studies of environmental change phenomenon, recent research on phytoplankton diversity around Korean waters is scant. This study has been conducted to investigate the species in terms of unrecorded and new species not described in Korean waters as part of projects funded National Institute of Biological Resources (NIBR) from 2006.

Prorocentroid dinoflagellates differ in morphology from other dinoflagellates. This species lacks a cingulum and a sulcus, and reveals an apical insertion of flagella (Dodge 1975). The order Prorocentales currently includes two genera such as *Prorocentrum* Ehrenberg and *Mesoporos* Lillick (Hoppenrath *et al*. 2009). Among two genera, *Prorocentrum* genus is a predominant group throughout the year in Korean waters and includes some toxic species such as *P. balticum* and *P. lima* in tropical areas (Hoppenrath *et al*. 2014). To date, *Prorocentrum* genus includes 31 species and *Mesoporos* genus has only one species in Korean waters (Table 1), since Shim *et al*. (1981) described four species from the southern coast of Korea for the first time, followed with five species reported by Yoo and Lee (1986) and six species reported by Shim (1994), respectively. Recently, Shin (2016) described 19 *Prorocentrum* species, and Han *et al*. (2016) found a new *Prorocentrum* species from coastal waters of Korea, respectively. Some benthic *Prorocentrum* species were reported by Shah *et al*. (2013). Lee and Kim (2015) listed one species of *Mesoporos* genus and 22 species of *Prorocentrum* genus from Korean waters (Table 1). In this study, we identified one *Mesoporos* species and three *Prorocentrum* species around coast of Jeju Island, and described as newly recorded species in Korean waters.

MATERIALS AND METHODS

Samplings were conducted at coastal stations around Jeju

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Table 1. Checklist of family Prorocentraceae in Korean waters (newly recorded and re-described species are marked with asterisks (*) and sharps (#) in this study, respectively, and 'n' indicates a species newly recorded in Korean waters by other researchers, 'f' a species recorded only in floristic lists (Lee and Kim 2015), 'val' a valid name and 'syn' a synonym, respectively)

Species name	Shim *et al*. (1981)	Han and Yoo (1983)	Yoo and Lee (1986)	Shim (1994)	Mun *et al*. (1995)	Shin *et al*. (2005)	Shah *et al*. (2013)	Lee and Kim (2015)	Han *et al*. (2016)	Shin (2016)	Present study
#*Mesoporos perforatus*								●		●	●
Prorocentrum aporum[f]								●			
Prorocentrum arcuatum[f]								●			
Prorocentrum balticum	●		●	●	●	●		●		●	
Prorocentrum belizeanum[n]										●	
Prorocentrum clypeus							●	●			
Prorocentrum compressum = val. *Tryblionella compressa*	●			●		●		●		●	
Prorocentrum concavum						●	●	●		●	
Prorocentrum cornutum[f]								●			
Prorocentrum dactylus[f]								●			
Prorocentrum dentatum			●		●			●		●	
Prorocentrum emarginatum							●	●			
Prorocentrum fukuyoi							●	●			
Prorocentrum gracile = syn. *Prorocentrum sigmoides*					●	●		●		●	
Prorocentrum koreanum[n]									●		
Prorocentrum leve[n]										●	
Prorocentrum lima				●	●	●	●	●		●	
**Prorocentrum maculosum*											●
Prorocentrum mexicanum[f]								●			
Prorocentrum micans	●	●	●	●	●	●		●	●	●	
Prorocentrum cordatum = syn. *P. minimum*		●	●	●	●	●		●		●	
Prorocentrum cordatum = syn. *P. minimum* var. *marieleboure*										●	
Prorocentrum cordatum = syn. *P. minimum* var. *triangulatum*										●	
Prorocentrum nanum								●		●	
Prorocentrum oblongum	●							●			
Prorocentrum rhathymum							●	●		●	
Prorocentrum rostratum								●		●	
Prorocentrum ruetzlerianum[n]										●	
Prorocentrum scutellum								●		●	
**Prorocentrum sipadanensis*											●
Prorocentrum triestinum		●	●	●	●	●		●		●	
**Prorocentrum tropicale*											●
No. of species	4	3	5	6	7	8	6	23	2	19	4

Table 2. Comparison of morphological features of species described in this study (Cited by Hoppenrath 2013)

Key of species	*M. perforatus*	*P. maculosum*	*P. sipadanensis*	*P. tropicale*
Cell shape	Oval, round or Chordate in valve view	Oval to ovoid	Round to oval	Broad oval to ovoid
Cell size				
Length (μm)	14–27	40–50	18–19	50–55
Width (μm)	18–21	30–40	15–16	40–45
Periflagellar area				
Shape	Narrow U-shaped	Wide V-shaped	Wide V-shaped	Wide V-shaped
Collar on left plate	No	No	Yes	Yes
Thick flange	No	Both	No	Yes
Wing-shaped spine	Yes	No	No	No
Protrusions	Yes	No	No	No
Platelet list(s)	No	Yes	Yes	No
No. of platelets	Unknown	8	8	8 or 9
Flagellar pore	Unknown	Yes	Yes	Yes
Theca ornamentation	Foveate	Foveate	Foveate	Foveate / Reticulate-foveate
Pore pattern	No, Row around	No, scattered	Yes	No
Marginal pores	Yes	Yes	Yes	No
Central pores	Yes	Devoid	Devoid	No
Pore size (Large >0.1 μm or small ≤ 0.1 μm)	Both	Both	Small	Large
Intercalary band	Smooth (Vertical Str.)	Smooth	Smooth (Horiz. Str.)	Granulated
Nucleus	Posterior	Oval	Unknown	Posterior (No in LM)

Island and East China Sea from 2006–2016, as the station's informations are mentioned in Shah *et al*. (2013) and Lee *et al*. (2014). Plankton samples were obtained by using a 20-μm-mesh plankton net and fixed with formaldehyde (final concentration of approximately 1%) or glutaraldehyde (final concentration of approximately 1%). Planktonic dinoflagellates were identified by using light microscope (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. To allow for more detailed observations, dinoflagellate cells were isolated with a micropipette, placed on a cover slip, air-dried and coated with gold for observation under a field emission scanning electron microscope (JSM-6700F; JEOL, Tokyo, Japan).

For species identification, several monographs were used, that were reported from different oceans, such as the Indian Ocean (Taylor 1976), Japan's adjacent sea (Yamaji 1984), the British and Atlantic Ocean (Dodge 1982), the Kuroshio Current (Fujioka 1990), Korean waters (Shim 1994), and Gulf of Mexico (Okolodkov 2014) with some critical criteria (Hoppenrath *et al*. 2013; Table 2). A dinoflagellate classification of the new combination with the family Prorocentraceae was cited from AlgaeBase (http://www.algaebase.org) (Guiry and Guiry 2017).

RESULTS AND DISCUSSION

A total of four species of two genera (*Mesoporos*, *Prorocentrum*) of the family Prorocentraceae from the coast of Jeju Island were identified and classified below. Among them, three species were described as newly recorded species in Korean waters in this study, and one species as a re-described species. Newly recorded and re-described species were marked with asterisks (*) and sharps (#), respectively. 'C' indicates a currently accepted name, 'S' a synonym, 'P' a preliminary AlgaeBase entry based on the species database of AlgaeBase (Guiry and Guiry 2017), respectively.

Systematics of the family Prorocentraceae from Korean waters

Class Dinophyceae Fritsch
Order Prorocentrales Lemmermann
Family Prorocentraceae Stein
Genus *Mesoporos* Lillick

#*Mesoporos perforatus* (Gran) Lillick C
Genus *Prorocentrum* Ehrenberg
Prorocentrum aporum (Schiller) Dodge C
Prorocentrum arcuatum Issel
Prorocentrum balticum (Lohmann) Loeblich C
Prorocentrum belizeanum Faust C
Prorocentrum clipeus Hoppenrath C
Prorocentrum compressum (Bailey) Abé ex Dodge S
= *Tryblionella compressa* (Bailey) Poulin C
Prorocentrum concavum Fukuyo C
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 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 cordatum (Ostenfeld) Dodge C
= *Prorocentrum minimum* (Pavillard) Schiller S
= *Prorocentrum minimum* var. *marieleboure* (Park et Ballantine) Hulburt S
= *Prorocentrum minimum* var. *triangulatum* (Martin) Hulburt S
Prorocentrum nanum Schiller C
Prorocentrum oblongum (Schiller) Abé P
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

Taxonomic description of unrecorded species.

Genus *Mesoporos* Lillick 1937

Lectotype species: *Mesoporos globulus* (Schiller) Lillick 1937.

Description: Cell is round, oval or heart-shaped. It is in the form of a locked valves due to the edge. A flagellar area is V-shaped at the anterior of the cell. Each wall plate has a conical dented situation in the center, inconspicuous in dorsi-ventral view but very clear in lateral view. This is the characteristic key of *Mesoporos* from *Prorocentrum*. It has two flagella at the anterior end of the cell for moving forward with a spiraling motion. Chloroplasts of various types, with yellow-brown color.

***Mesoporos perforatus* (Gran) Lillick 1937 (Fig. 1a)**

Basionym: *Exuviaella perforate* Gran.

Synonym: Homotypic synonym: *Exuviaella perforate* Gran, *Porella perforate* (Gran) Schiller, *Porotheca perforate* (Gran) Silva, *Dinoporella perforate* (Gran) Halim. Heterotypic synonym: *Exuviaella bisimpressa* Schiller, *Porella adriatica* Schiller, *Porella globulus* Schiller, *Porella asymmetrica* Schiller, *Mesoporos globulus* (Schiller) Lillick, *Mesoporos adriaticus* (Schiller) Lillick, *Mesoporos asymmetricus* (Schiller) Lillick, *Mesoporos bisimpressus* (Schiller) Lillick, *Dinoporella globulus* (Schiller) Silva, *Porotheca globulus* (Schiller) Silva, *Porotheca bisimpressa* (Schiller) Silva, *Porotheca asymmetrica* (Schiller) Silva, *Porotheca adriatica* (Schiller) Silva.

References: Dodge 1982, p. 29, Figs. 2a, b; Shin 2016, p. 87; Omura *et al*. 2012, p. 55.

Specimen examined: Serial No. LJB2015019 / NIBR No. NIBRDN0000000012.

Description: Cells are oval or round shape in dorso-ventral view. In each plate row of small pore is arrange around the center pore. There are two chloroplasts and they are located under each plate, sometimes contours are visible. The nucleus is present at the posterior part of the cell.

Size: 14−27 μm long, 18−21 μm wide.

Sampling: 25 Mar 2015. Sehwa coast in Jeju Island (33° 31′29.8″N, 126°51′40.5″E).

Habitat: Marine and planktonic species.

Distribution: Australia and New Zealand: New Zealand (Chang *et al*. 2012); Asia: China (Liu 2008); Atlantic Islands: Canary Islands (Gil-Rodriguez *et al*. 2003; Afonso-Carrillo 2014), Europe: Adriatic Sea (Dodge 1982), Bal-

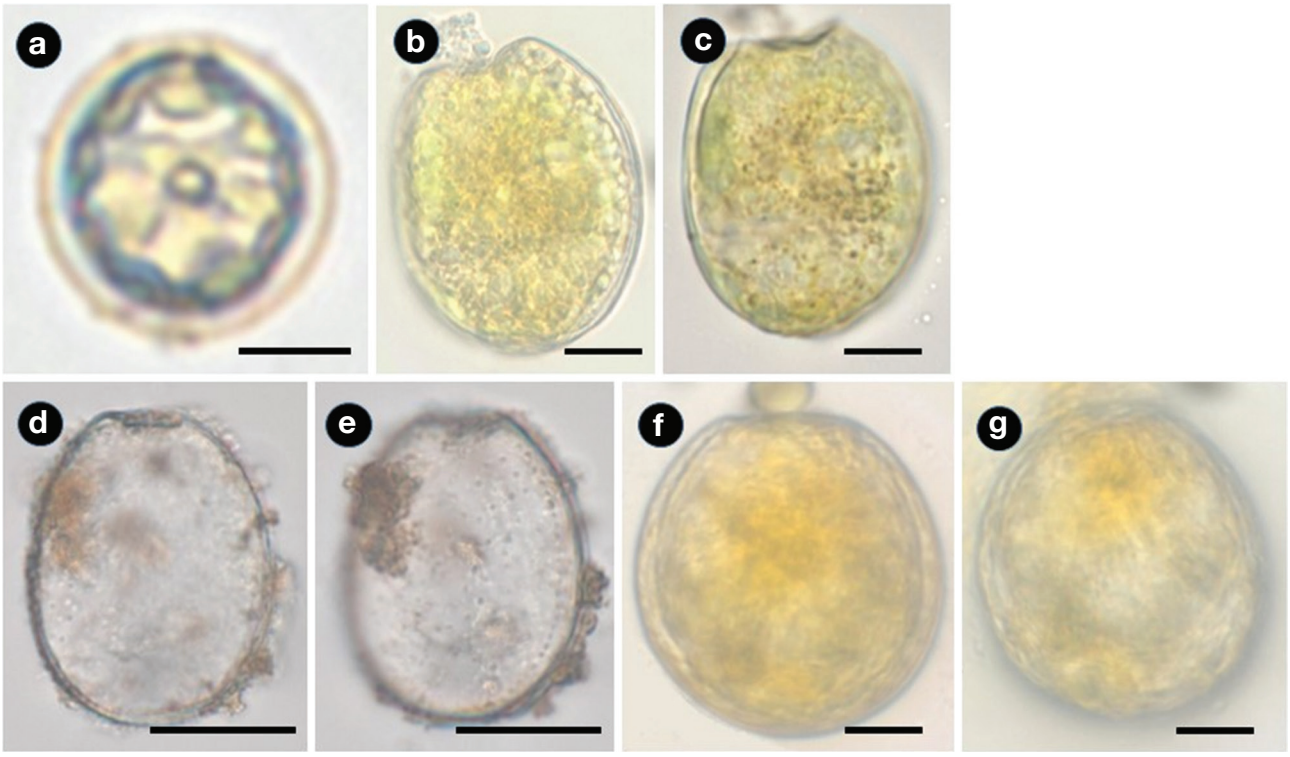

Fig. 1. Light micrographs of the genus *Mesoporos* and *Prorocentrum*. (a) *Mesoporos perforates*, right lateral view, (b) *Prorocentrum maculosum*, right lateral view, (c) *Prorocentrum maculosum*, left lateral view, (d) *Prorocentrum sipadanensis*, right lateral view, (e) *Prorocentrum sipadanensis*, left lateral view, (f) *Prorocentrum tropicale*, right lateral view, (g) *Prorocentrum tropicale*, left lateral view. Scale bars, 10 μm.

tic Sea (Hällfors 2004), Black Sea (Gómez and Boicenco 2004), Britain (Parke and Dixon 1976; Dodge 1982), Croatia (Vilicic *et al*. 2009), Helgoland (Hoppenrath 2004), Mediterranean (Gómez 2003), Norway (Dodge 1982); Polar: Antarctic/Sub Antarctic Islands (McMinn and Scott 2005).

Note: This species was reported as unrecorded indigenous species by NIBR in 2015 (Lee and Kim 2015), described by Shin (2016), and re-described in the present study.

Genus *Prorocentrum* Ehrenberg 1834

Holotype species: *Prorocentrum micans* Ehrenberg.

Description: Cell size ranges from small to medium (15−100 μm). The shape of the cells is round, lanceolate or oval and flattened to the dorso-ventral side. Thecal plates are composed of two smooth valve-shaped plates with pores or spines on the surface. It consists of two flagella on apical of the cell and this flagella region has 7−14 small plates. All species have 1−2 chloroplasts on cell plates. This species is distributed globally and only two species were found in freshwater in Australia and the rest were marine species. The heterogeneous habitat of this species is diverse, planktonic, epiphytic, benthic, and some species live in sand. Sometimes this species blooms enough to change the color of the sea. Some species produce harmful toxic substances such as *P. lima* and related species have a ciguatera and okadaic acid, some populations of *P. minimum* also cause shellfish poisoning.

Prorocentrum maculosum Faust 1993 (Fig. 1b, c)

Synonym: Homotypic synonym: *Exuviaella maculosum* (Faust) McLachlan, Boalch et Jahn.

References: Faust 1993, p. 410, figs. 1−6; Omura *et al*. 2012, p. 57; Hoppenrath *et al*. 2014, p. 136, Fig. 62.

Specimen examined: Serial No. LJB2015020 / No NIBR No. LM photo only.

Description: The cell is round or oval. Thecal surface consists of scattered large pores and a marginal row of large pores except for the center of the plate. The flagellar area is

wide V-shaped, with collar and lists. It has eight plates. A round nucleus is posterior of the cell.

Size: 40−50 μm long, 30−40 μm wide.

Sampling: 25 Mar 2015. Tap-dong coast in Jeju Island (33° 32′18″N, 126°41′2″E).

Habitat: Marine and benthic species, found in the sand and subtropical area.

Distribution: Central America: Twin Cays, Belize (Faust 1993), Panama (Chomérat *et al*. 2011); Europe: Salt Island, British Virgin Islands (Zhou and Fritz 1993); North America: Caribbean, Maxico (Almazán-Becerril *et al*. 2015).

Note: This species was reported as unrecorded indigenous species by NIBR in 2015 and reported as newly recorded species in Korea waters in the present study.

***Prorocentrum sipadanensis* Mohammad-Noor, Daugbjerg et Moestrup 2007 (Fig. 1d, e)**

Synonym: No synonym.

References: Mohammad-Noor *et al*. 2007, p. 655, figs. 12a-e, 23a, b; Hoppenrath *et al*. 2014, p. 137, Fig. 63.

Specimen examined: Serial No. LJB2016014 / No NIBR No. LM photo only.

Description: The cell is small and has a round oval shape. The surface has pores that are widely distributed at irregular intervals. There are no pores in the center of the plate and several pores are spread widely around it. The flagellar area is wide and V-shaped, consisting of eight plates, with lists.

Size: 18−19 μm long, 15−16 μm wide.

Sampling: 11 Aug 2015. Hallim beach in Jeju Island (33°23′39″N, 126°14′23″E).

Habitat: Marine and benthic species.

Distribution: Asia: Sipadan Island, Malaysia (Mohammad-Noor *et al*. 2007).

Note: This species was reported as unrecorded indigenous species by NIBR in 2016 and reported as newly recorded species in Korea waters in the present study.

***Prorocentrum tropicale* Faust 1997 (Fig. 1f, g)**

Synonym: No synonym.

References: Faust 1997, p. 854, figs. 7−12, 16 (as *Prorocentrum tropicalis*); Hoppenrath *et al*. 2014, p. 137, Fig. 63.

Specimen examined: Serial No. LJB2015021 / No NIBR No. LM photo only.

Description: The cells are wide oval or ovoid. The thecal surface is foveated like pits. The distribution pattern of pores is like *Prorocentrum concavum*. The flagellar area is broad, V-shaped, have a collar and eight or nine plates.

Size: 50−55 μm long, 40−45 μm wide.

Sampling: 19 Jan 2015. Sagae beach in Jeju Island (33°13′ 52.3″N, 126°18′37.8″E).

Habitat: Marine species and attached to tropical coral rubble.

Distribution: Central America: Lagoon at Carrie Bow Cay, Belize (Faust 1997).

Note: This species was reported as unrecorded indigenous species by NIBR in 2015 and reported as newly recorded species in Korea waters in the present study.

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