Turk. J. Fish.& Aquat. Sci. 19(1), 7-19
http://doi.org/10.4194/1303-2712-v19_1_02

RESEARCH PAPER

Turkish Journal of FISHERIES and AQUATIC SCIENCES

New Records of Haptophyte Species from the Northeastern Mediterranean Sea for Algal Flora of Turkey

Merve Sahin[1], Elif Eker-Develi[2,*]

[1] Mersin University, Institute of Graduate Studies in Science, Department of Biotechnology, 33343, Ciftlikkoy, Mersin, Turkey.
[2] Mersin University, Faculty of Education, 33169,Yenisehir, Mersin, Turkey.

Article History
Received 25 October 2017
Accepted 13 February 2018
First Online 18 February 2018

Corresponding Author
Tel.: +90.324 3412815
E-mail: elifeker@gmail.com

Keywords
Calcified and noncalcified haptophytes
Northeastern Mediterranean Sea
First record.

Abstract

Chrysochromulina alifera, *Chrysochromulina lanceolata*, *Chrysochromulina parkeae*, *Haptolina cf. ericina*, *Umbellosphaera irregularis, Umbellosphaera tenuis, Umbilicosphaera foliosa, Syracosphaera molischii, Rhabdosphaera clavigera var stylifera* and *Ophiaster formosus* were recorded for the first time along the Turkish coasts. Non-calcified haptophyte species *Chrysochromulina alifera, C. lanceolata, C. parkeae* and *H. cf. ericina* were observed in live samples since formaldehyde damages cells. Among them only *C. alifera* could be observed with SEM. Either SEM pictures or light microscope images of other species were presented. Although previously reported along Turkish coasts *Syracosphaera pulchra* was a coccolithophore species most frequently observed after *Emiliania huxleyi* in the study area. *Scyphosphaera apsteinii, Calciosolenia brasiliensis* and *Coronosphaera mediterranea*, which were also reported previously along Turkish Seas, were among the rare species encountered in the sampling region.

Introduction

Haptophytes are primarily unicellular, phototrophic and mostly marine microalgae possesing a unique organelle called haptonema, extending between the two flagella. This phylum is classified mainly based on the morphology of calcified or noncalcified scales. While coccolithophores have mineralized inorganic scales at some stage in their life cycle (Billard & Inouye, 2004; Winter & Siesser, 1994), Haptophyte families such as Chrysochromulinaceae have organic scales during their all life cycle (Edvardsen *et al*., 2011). While there are few studies related to species composition of calcifying haptophytes along Turkish coasts (Aktan, Luglie, Aykulu & Sechi, 2003; Balkıs, 2004; Polat & Piner, 2002; Eker-Develi, 2004), there is not even a study dealing with noncalcifying haptophytes in Turkish seas. This phylum of phytoplankton was sometimes disregarded in check lists of phytoplankton groups along Turkish Seas probably due to small size of its species (Polat, 2002; Taş & Okuş, 2006; Taş 2013; Aktan, Balkıs and Balkıs, 2014). Haptophyte species identifed along Turkish coasts are mainly based on light microscope observations. These species are consisted of *Anacanthoica acanthos, Calciosolenia brasiliensis*, *C. murrayi*, *Syracosphaera pulchra*, *Emiliania huxleyi*, *Scyphosphaera apsteinii*, *Coronosphaera mediterranea, Discosphaera tubifera, Rhabdolithes claviger* and *Coccolithus pelagicus* (Polat & Piner, 2002; Aktan *et al*. 2003; Koray 2001; Balkıs, 2004; Eker-Develi, 2004; Baytut, & Gönülol 2016). There are a few more species identified with light microscope in Eker-Develi (2004) and Polat & Piner (2002) but they should be verified by electron microscope images.

Extant coccolithophores are widespread around the oceans from tropical to polar regions (Chang and Northcote, 2016; Winter and Siesser, 1994). While most other phytoplankton groups prefer high nutrient regions, coccolithophore diversity is highest in warm, low productivity “blue water” regions (Winter & Siesser, 1994). However, under certain conditions coccolithophores such as *Emiliania huxleyi* (Lohmann) Hay & Mohler bloom in cool and high nutrient waters as in Norwegian Fjords (Berge, 1962). *E. huxleyi* blooms were also observed along Turkish coastal region of the Black Sea and in the Dardanelles previously (Türkoğlu, 2008; Eker, Georgieva, Senichkina & Kideys, 1999).

In the present study our aim was to investigate nanoplanktic haptophytes having both organic and inorganic scales in the northeastern Mediterranean Sea where there are not any specific study about this group of phytoplankton community. Majority of the studies related to haptophytes are on the western

Mediterranean Sea, Adriatic Sea and Aegean Sea (Cerino, Malinverno, Fornasaro, Kralj & Cabrini, 2017; Cros & Fortuño, 2002; Dimiza *et al*., 2015; Dimiza, Triantaphyllou & Dermitzakis, 2008a; Dimiza, Triantaphyllou & Dermitzakis, 2008b; Kleijne, 1993; M*alinverno,* Dimiza, Triantaphyllou, Dermitzakis & Corselli, 2008; Puigserver, Chretiennot-Dinet & Nezan, 2003; Šupraha, Ljubešić, Mihanović & Henderiks, 2016).

Material and Methods

Sea water samples were taken with a plastic bucket from the Erdemli coast (36°601198'N, 34°312138' E) in the north-eastern Mediterranean Sea during 2015-2016 (Figure 1). Live samples were investigated under microscope directly. In addition, 300 mL seawater was filtered through 1.3 mm diameter and 0.2 µm pore size polycarbonate filters after fixing with borax buffered formaldehyde to have a final concentration of 1.5% and examined with a Zeiss Supra55 field emission scanning electron microscope after coating with platinum using the Quorum Q150R Sputter Coater instrument. For investigation of *Chrysochromulina alifera* Parke & Manton culture, which was isolated on 30 July 2015 using diluted F/20 Medium, cells were fixed with 2% osmium tetraoxide, dehydrated in a graded ethanol series of 25%, 50%, 75%, 95% and 100% for ca. 10 min, critical point dried and examined under SEM same as formaldehyde fixed samples (Zingone, Throndsen & Forlani, 1995). References used for the identification of phytoplankton species were Young, Brown & Lee (2017), Winter & Siesser (1994), Bérard -Therriault, Poulin & Bossé (2000), Puigserver, *et al*. (2003), Chrétiennot-Dinet, Desreumaux and Vignes-Lebbe (2014). Databases checked for previous records of species in the Mediterranean Sea and along Turkish coasts included Gönülol (2017), Guiry and Guiry (2017) and Young *et al*. (2017).

Results

Calcified and noncalcified haptophyte taxa found in the northeastern Mediterranean Sea during 2015-2016 were listed and discussed in the present investigation. 4 new haptophyte species for the Turkish coasts belonging to *Chrysochromulina* genus were reported. Extant coccoliths belonging to *Umbellosphaera tenuis*, *U. irregularis* and *Umbilicosphaera foliosa* were found for the first time along Turkish seas. Six species belonging to Syracosphaerales order, *Syracosphaera molischii*, *Ophiaster formosus*, *Rhabdosphaera clavigera* var. *stylifera, Coronosphaera mediterranea*, *Syracosphaera pulchra* and *Calciosolenia brasiliensis* were identified during the study period. Former three species were new for the Turkish coasts. *Scyphosphaera apsteinii* belonging to Zygodiscales order, which was reported in Turkish waters previously, was also among the haptophyte species observed once in the sampling area.

Phylum Haptophyta
Class Coccolithophyceae
Subclass Prymnesiophycidae
Order Prymnesiales
Family Chrysochromulinaceae
Genus *Chrysochromulina* Lackey, 1939

Species *Chrysochromulina alifera* Parke & Manton in Parke, Manton & Clarke 1956 (Figures. 2, 3).

Description: Cells are saddle-shaped with large lateral curved wings. Cell length 4.5-20 µm with a haptonema 7-16 times the cell length (160 µm), the two flagella are approximately equal and 2.5-4 times the cell length. Two golden-brown chloroplasts. Spine scales cover the cell with a circular to ellipsoid base (Figure 2d). Spines are shorter than the diameter of the scales. Cells were isolated on 30 July 2015. Water temperature and salinity were 27 °C and 39 psu in the sampling area. Species similar to *C. alifera* were observed under light microscope during the year with highest numbers during spring and summer months.

Distrubition in Turkey: First record along Turkish seas.

Species *Chrysochromulina parkeae* Green & Leadbeater 1972 (Figure 4).

Description: Cells are elongate (~20 µm) having two equal flagella ~25 µm in length, haptonema shorter.

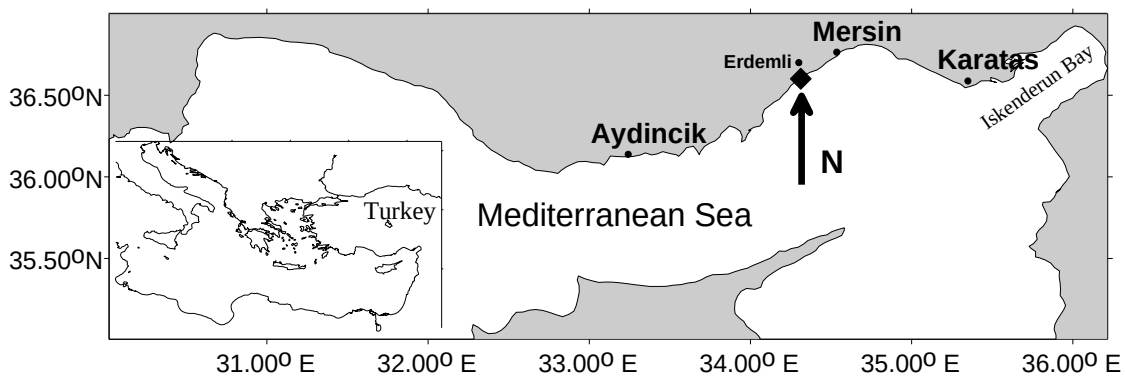

Figure 1. Sampling region.

Posess spine scales almost equal to body length at both anterior and posterior sides of the cell. It was observed on 29 April, 11 May and 27 May 2016 samples. Seawater temperature and salinity were 21 °C, 21 °C and 23 °C, 39, 39.2 and 38.9 respectively.

Distrubition in Turkey: First record along Turkish coasts.

Species *Chrysochromulina lanceolata* Chrétiennot-Dinet, Nezan & Puigserver in Puigserver *et al*., 2003 (Figure 5a-c)

Description: Cells are lancet-shaped having two asymmetric anterior arms and a posterior tail. Cells length is ~28-30 μm having two almost equal flagella ~38 μm. Haptonema is shorter than the flagella, ~22 μm in length and extended forward during resting. Swim both anteriorly and posteriorly. A refringent body is present in the posterior part, towards the tail. A lobate protrusion in the ventral side between the tail and arms is present. They swim both forward and backward direction. One of the arms is truncate at the end. It was observed on 27 May and 24 June 2016. Seawater temperature and salinity were 23 °C and

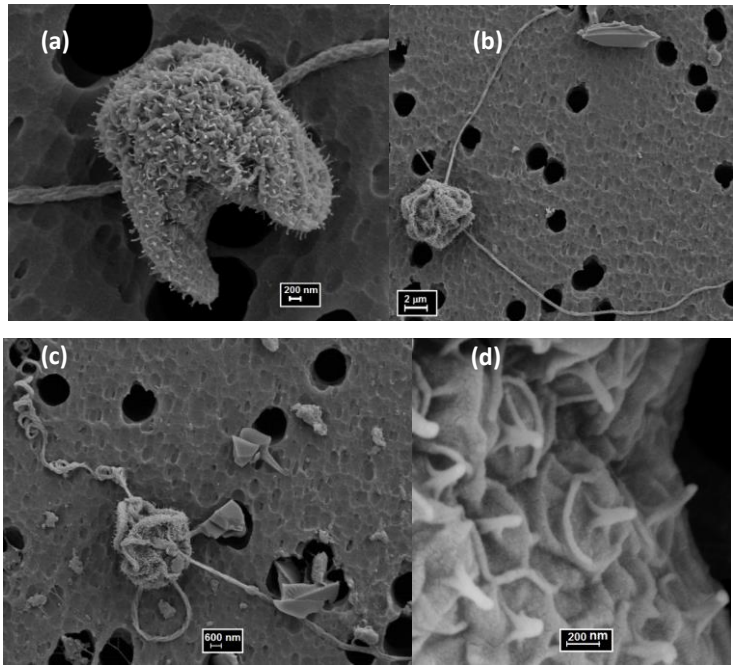

Figure 2. *Chrysochromulina alifera* cells from different positions (a) posterior side, (b) lateral side (c) ventral and lateral side (d) its organic scales.

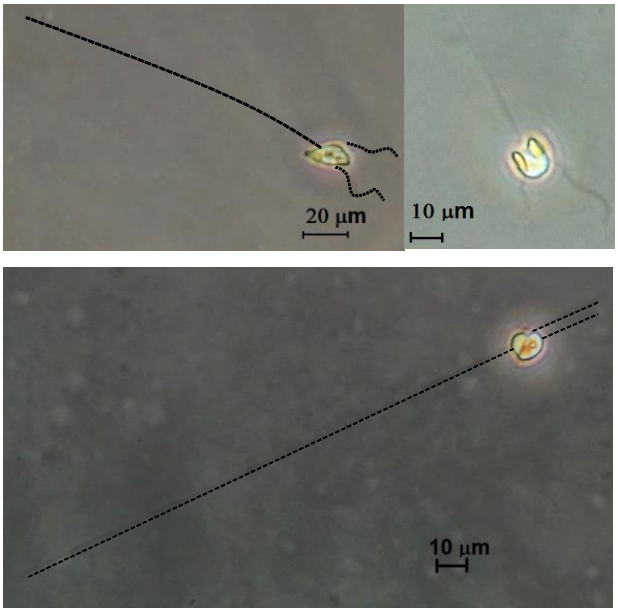

Figure 3. Live samples of *Chrysochromulina alifera*.

38.9, 27 °C and 39.5, respectively. *Chrysochromulina* cf. *lanceolate* was observed on 11 May 2016 (Figure 5d-e). One of the arms was very short. The length of body, haptonema and flagellates were ~35 μm, ~15 μm and ~39 μm respectively. Water temperature and salinity were 21 °C and 39.2.

Distrubition in Turkey: First record along Turkish coasts.

Genus *Haptolina* Edvardsen & Eikrem, 2011

Species *Haptolina cf. ericina* (Parke & Manton) Edvardsen & Eikrem in Edvardsen *et al*. 2011 (Figure 6)

Basionym *Chrysochromulina ericina* Parke & Manton

Description: Cells ovoid to oblong, 5–10 μm long, haptonema is thinner and longer than the two equal flagella when extended. Flagella are homodynamic. Body is covered with spiny unmineralised scales. It was observed on 6 April 2016 and 18 July 2016. Seawater temperature and salinity were 19 °C and 39.3, 31 °C and 38.6 respectively.

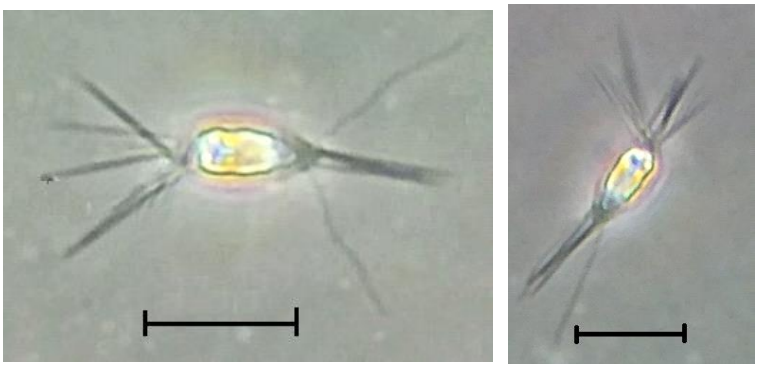

Figure 4. Live cells of *Chrysochromulina parkeae* (scale bars = 20 μm).

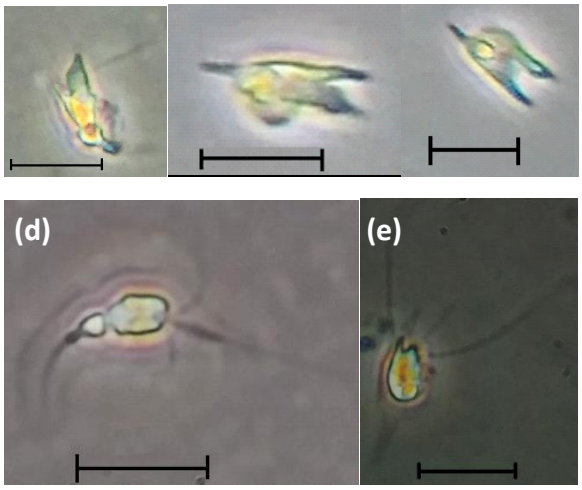

Figure 5. (a-c) Live cells of *Chrysochromulina lanceolata* from different positions, (d-e) *Chrysochromulina* cf. *lanceolata* from dorsal and lateral views (scale bars = 20 μm).

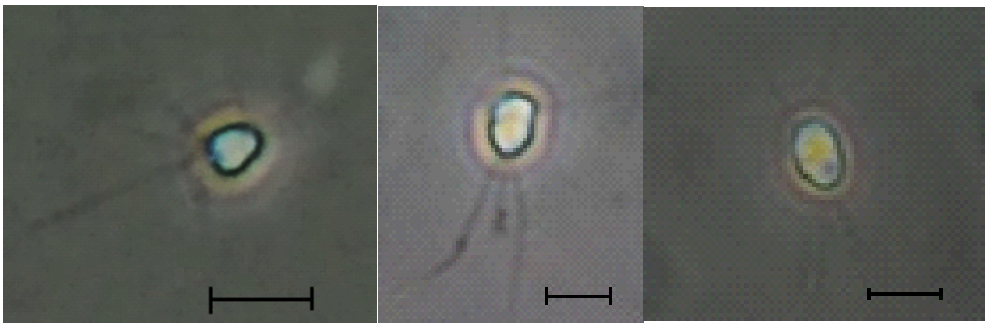

Figure 6. Live cells of *Haptolina cf. ericina* (scale bars = 10 μm).

Distrubition in Turkey: First report along Turkish coasts.

PhylumHaptophyta

Class Haptophyta incertae sedis

Order Haptophyta incertae sedis

Family Umbellosphaeraceae

Genus *Umbellosphaera* Paasche in Markali & Paasche 1955

Species *Umbellosphaera irregularis* Paasche in Markali & Paasche 1955 (Figure 7)

Description: Size of the protoplast is ~6-10 μm, the diameter of complete coccolithophore is ~10-20 μm. It has an angular view due to the shape of coccoliths.

Coccliths, having a funnel shaped structure without ridges on the distal part, varied from elliptical to circular with a diameter of 4.5-9 μm at the widest part. Distally concave liths give the cell an irregular appearance. There are about 15-20 radiating elements on coccoliths. It was observed on 11 November 2015 and 15 November 2016 in the samples. Seawater temperature and salinity were 22 °C and 39 on 11 November 2015.

Distrubition in Turkey: First report along Turkish coasts.

Species *Umbellosphaera tenuis* (Kamptner) Paasche in Markali & Paasche 1955 (Figurer 8a, b).

Basionym *Coccolithus tenuis* Kamptner

Synonyms: *Ellipsodiscoaster lidzii* Boudreaux and Hay, 1969

Discoaster murrayi Black & Barnes 1961

Umbilicosphaera rosaceus Lecal 1967

Description: The protoplast of this species has a diameter of 7-10 μm. The complete coccosphere is 10-16 μm in diameter. Cells have a rather smooth surface due to partly overlapping convex distal rims of coccoliths. Coccoliths are convex distally and relatively highly calcified. There are sub-radial major ridges and secondary anticlockwise diverging ridges on the outer surface. Coccoliths of *Umbellosphaera tenuis* was observed on 3 February 2016 and 15 November 2016. Seawater temperature and salinity were 16 °C and 38.6 on 3 February 2016.

Distrubition in Turkey: First report along Turkish coasts.

Phylum Haptophyta

Class Coccolithophyceae

Subclass Prymnesiophycidae

Order Coccolithales

Family Calcidiscaceae

Genus *Umbilicosphaera* Lohmann 1902

Species *Umbilicosphaera foliosa* (Kamptner ex Kleijne) Geisen in Sáez *et al*. 2003 (Figure 8c)

Basionym *Cycloplacolithus foliosus* Kamptner 1963

Homotypic Synonym(s)

Cycloplacolithella foliosa (Kamptner) Haq 1968

Heterotypic Synonym(s)

Umbilicosphaera mirabilis Lohmann 1902

Cyclococcolithus mirabilis (Lohmann) Kamptner 1954

Description: Coccoliths are circular showing a

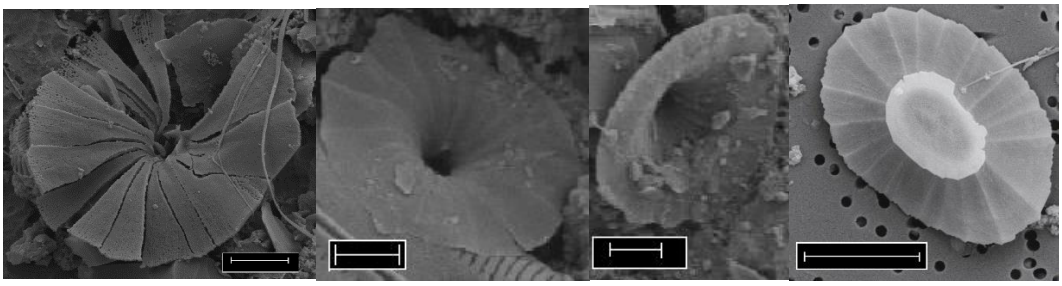

Figure 7. $CaCO_3$ scales of *Umbellosphaera irregularis* (scale bars = 2 μm).

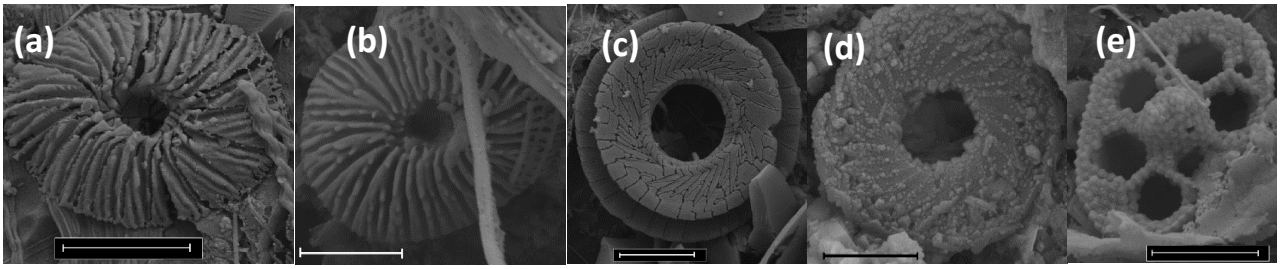

Figure 8. Mineralized coccoliths of (a) *Umbellosphaera tenuis* type IIIb (b) *Umbellosphaera tenuis* type II, (c) *Umbilicosphaera foliosa* (d) *Umbilicosphaera cf. foliosa* (e) *Coronosphaera mediterranea* type *wettsteinii* (scale bars = 2 μm).

similar distal shield structure with *Calcidiscus,* however the central tube is larger and open. Sutures on distal shield is vigorously kinked. Central area is narrower than in *U. sibogae* coccoliths. Proximal shield is bicyclic, concave and smaller than the distal shield. It was observed on 15 November 2016. A coccolith similar to *C. foliosa* was observed on 15 March 2016 from the distal shield view (Figure 8d). Seawater temperature and salinity were 17 °C and 38.5.

Distrubition in Turkey: First report along Turkish coasts.

Phylum Haptophyta

Class Coccolithophyceae

Subclass Prymnesiophycidae

Order Syracosphaerales

Family Syracosphaeraceae

Genus *Coronosphaera* Gaarder 1977

Species *Coronosphaera mediterranea* type *wettsteinii* (Lohmann) Gaarder in Gaarder and Heimdal 1977 (Figure 8e)

Basionym *Zygosphaera wettsteini* Kamptner 1937

Synonyms: *Calyptrolithina wettsteinii* (Kamptner 1937) Norris 1985

Description: This is the holococcolith type of *C. mediterranea*. Liths are elliptical in shape having a size about ~5 μm. 4-6 irregular pores exists on the distal surface. *Coronosphaera mediterranea* coccoliths were seen on 9 March and 6 April 2016. Seawater temperature and salinity were 16 °C and 38.6, 19 °C and 38.3 respectively.

Family Syracosphaeraceae

Genus *Syracosphaera* Lohmann, 1902

Species *Syracosphaera molischii* Schiller 1925 (Figure 9a)

Homotypic Synonym

Caneosphaera molischii (Schiller) Gaarder 1977 Ziveri,

Heterotypic Synonym(s)

Syracosphaera corrugis Okada & McIntyre 1977

Syracosphaera elatensis Winter 1979

Description: According to Young *et al*. (2003), *Syracosphaera molischii* found in the present study belongs to type 4. Distal flange is smooth and broad with tooth-like protrusions towards the central area. There are irregular concave ridges formed from upward growing laths in the central structure. Coccoliths were observed on 3 February 2016. Seawater temperature and salinity were 16 °C and 38.6.

Distrubition in Turkey: First report along Turkish coasts.

Species *Syracosphaera pulchra* Lohmann 1902 (Figure 9b-c)

Description: Coccospheres are ovoid in shape, having endothecal body caneoliths and circum-flagellar muroliths with bifurcate ending spines. The rim of caneoliths has three flanges, the distal-wall flage is corrugated, mid-wall flange is conspicuous, inner wall-cycle is prominent, the central area is filled by two circles of thin and short concentric radial laths.

Coccolith are oval and have lenths 5-7 μm. Coccospheres were observed on several occasions on 10 and 22 September 2015, 9 and 25 February 2016, 2, 15 and 22 March 2016, 6 April 2016. Seawater temperature changed from 29 °C to 17 °C, salinity varied from 37.7 to 38.5 in these sampling dates. Holococcolithophore phase, formerly *Calyptrosphaera oblonga* Lohmann, 1902.

Distrubition in Turkey: Previously reported in the Marmara Sea by Balkıs (2004), Balkıs and Taş (2016) and in the north eastern Mediterranean Sea (Eker-Develi, 2004).

Family Syracosphaeraceae

Genus *Ophiaster* Gran, 1912

Species *Ophiaster formosus* Gran, 1912 (Figure 10a)

Synonyms*: Bernardosphaera stellata* Lecal-Schlauder 1951

Description: Coccospheres have short and broad string of posterior appendages (osteoliths). *Ophiaster hydroideus* has longer and thinner osteoliths. The length of the link coccoliths are about twice the body length. It was observed on 16 December 2015. Seawater temperature and salinity were 18 °C and 39.4.

Species *Ophiaster cf. formosus* Gran 1912 (Figure 10b)

Description: Body coccoliths are elliptical muroliths. Outer wall of the rim is high and non-imbricate. Axial structure is not apparent. Laths are overlapped with a few short, separate transversal laths in the central area. A coccolith belonging to this species was observed on 17 February 2016. Seawater temperature and salinity were 13 °C and 38.5. Body caneoliths length is 2.8 μm.

Distrubition in Turkey: First report along Turkish coasts.

Order Syracosphaerales

Family Calciosoleniaceae

Genus *Calciosolenia* Gran 1912

Species *Calciosolenia brasiliensis* (Lohmann) Young in Young *et al.* 2003 (Fig. 10c)

Basionym *Cylindrotheca brasiliensis* Lohmann 1919

HomotypicSynonym(s)

Cylindrotheca brasiliensis Lohmann 1919

Anoplosolenia brasiliensis (Lohmann) Deflandre 1952

Synonyms: *Calciosolenia grani* Schiller 1925

Calciosolenia grani closterium Schiller 1925

Calciosolenia grani cylindrothecaeformis Schiller 1925

Calciosolenia tenuis Bernard & Lecal (1960)

Scapholithus ganoretus Kamptner (1967)

Scapholithus malenus Kamptner (1967)

Description: Liths are oblique rectangular in shape. There are very regular bars which merge to

form mildly curved axial ridge in the central area. Coccoliths were ~6.4 μm in length which is similar to previously reported values of 5-7 μm in Ziveri, (2004). Liths were observed on 17 February 2016. Seawater temperature and salinity were 13 °C and 38.5.

Distrubition in Turkey: Previously reported along Turkish coasts by Polat and Piner (2002) and Koray (2001).

Order Syracosphaerales

Family Rhabdosphaeraceae

Genus *Rhabdosphaera* Haeckel, 1894

Species *Rhabdosphaera clavigera* var. *stylifera* (Lohmann) Kleijne and Jordan, 1990 (Figure 11)

Basionym: *Rhabdosphaera stylifer* Lohmann, 1902

Description: Coccosphere is composed of discoidal exothecal rhabdoliths and helatoform endothecal rhabdoliths. Both exothecal and endothecal rhabdoliths are elliptical in shape, endothecal rhabdoliths have helatoform spines.

Dimension: coccosphere diameter without processes is ~8-10 μm. It was observed on 30 March 2016 and 24 June 2016. Seawater temperature and salinity were 17 °C and 38.7, 27 °C and 39.5 respectively.

Distrubition in Turkey: First report along Turkish coasts.

Subclass Prymnesiophycidae

Order Zygodiscales

Family Pontosphaeraceae

Genus *Scyphosphaera*

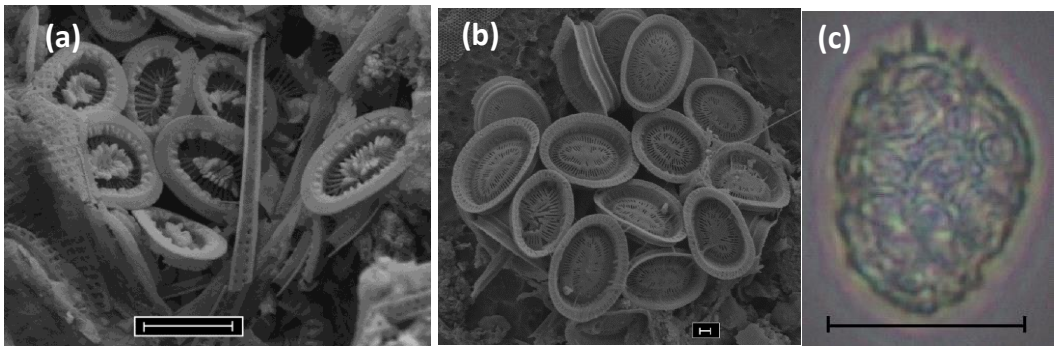

Figure 9. Scales of (a) *Syracosphaera molischii* type 4 (scale bar = 2 μm) and (b) *Syracosphaera pulchra* (scale bar = 600 nm), (c) a cells seen under ligth microscope (scale bar = 20 μm).

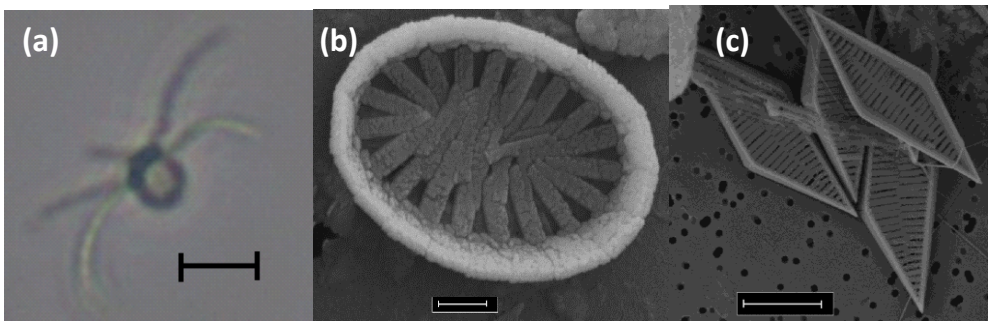

Figure 10. (a) *Ophiaster formosus* (scale bar = 5 μm), (b) A scale belonging to *Ophiaster cf. formosus*, (scale bar = 400 nm), (c) *Calcic brasiliensis* (scale bars = 2 μm).

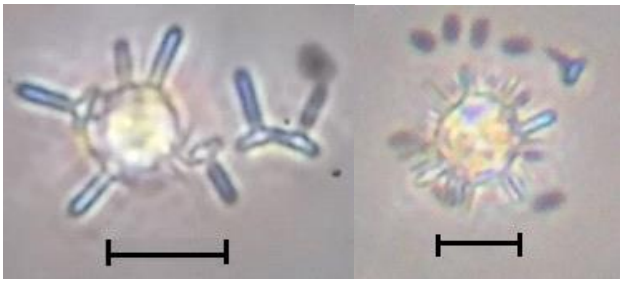

Figure 11. *Rhabdosphaera clavigera var stylifera* (scale bar = 10 μm).

Species *Scyphosphaera apsteinii* Lohmann 1902 (Figure 12)

Basionym: *Scyphosphaera apsteini* Lohmann, 1902

Synonyms *Pontosphaera scutellum* Kamptner (1952)

Description: Species is dimorphic having vase-shaped lopadoliths with a convex outline and flat ovoid cribriliths similar to the ones of *Pontosphaera japonica*. However, body coccoliths of *S. apsteinii* are less regular than of *P. japonica* (Young *et al*. 2017). There are morphological variabilities in this species (Lohman 1902). *Dimensions*. Coccosphere long axis ~40 µm, discoliths length ~7-10 µm , lopadoliths length ~11-14 µm. Species was observed on 3 February 2016. Seawater temperature and salinity were 16 °C and 38.6.

Distrubition in Turkey: Previously reported along Turkish coasts by Koray (2001) and Koray *et al*. (2000).

Discussion

A total of ten new haptophyte species were recorded along the Turkish Seas in the present investigation. Their worldwide distribution was shown on Table 1. Although found in the western

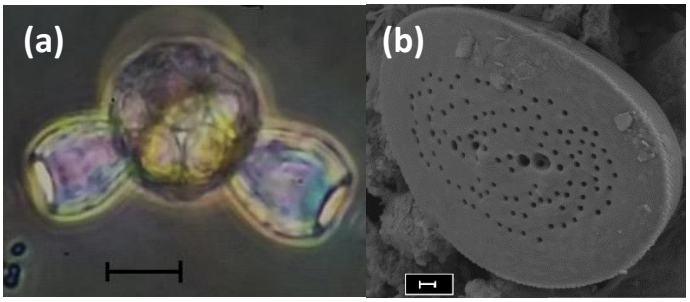

Figure 12. (a) *Scyphosphaera apsteinii* cell with three lopadoliths and cribriliths seen from inside of a lopadolith (scale bar = 10 µm) (b) a cribrilith observed with SEM (scale bar = 400 nm).

Table 1. Worldwide distribution of haptophyte species found in the present investigation

Species	Mediterranean	Black Sea	North Sea	Norwegian Sea	Baltic	Adriatic	Arabian	China Sea	Atlantic	Indian	Australia	Pacific	Red Sea	New Zealand
Calciosolenia brasiliensis	X[3, 32, 42]					X[12, 33]			X[19, 32, 34, 35]	X[32]	X[32]	X[32]		X[28]
Chrysochromulina alifera	X[1, 30]		X[27]	X[7, 9]	X[11]			X[15]	X[31]		X[25]			X[23]
Chrysochromulina lanceolata	X[1]								X[16]					
Chrysochromulina parkeae	X[30]		X[27]	X[9]					X[37]		X[25]			X[23]
Coronosphaera mediterranea	X[2, 3]	X[6, 22]				X[12]		X[14]	X[17, 19, 34, 35]	X[26]	X[41]			X[28]
Haptolina cf. ericina	X[30]		X[38]	X[8, 9]	X[10]				X[39]		X[25]	X[40]		X[24]
Ophiaster formosus	X[3, 42]					X[12]			X[18, 19]	X[26]				
Rhabdosphaera clavigera var. stylifera	X[33, 36, 42]					X[33]			X[19, 36]	X[36]		X[36]	X[36]	
Scyphosphaera apsteinii	X[3, 5, 42]					X[12]			X[17, 19, 34, 35]			X[20]		X[24, 28]
Syracosphaera molischii	X[3, 5, 42]					X[33]			X[17, 34, 35, 36]	X[26]		X[36]	X[36]	
Syracosphaera pulchra	X[2, 3, 5, 42]	X[22]				X[33]		X[14]	X[17, 19, 34, 35, 38]	X[26]	X[24]			X[24]
Umbellosphaera irregularis	X[32]						X[13]	X[14]	X[17, 32, 34]	X[26]	X[32, 41]	X[29, 32]		
Umbellosphaera tenuis	X[3, 32, 42]						X[13]	X[14]	X[17, 19, 32, 34]	X[26]	X[32]	X[29, 32]		X[28]
Umbilicosphaera foliosa	X[5, 42]							X[14]	X[17, 21, 32, 36]	X[26]	X[32, 41]	X[29, 32, 36]		

1 Puigserver, Chrétiennot-Dinet & Nezan (2003), 2 Geisen *et al*. (2002), 3 Cros and Fortuno (2002), 4 Malinverno, Triantaphyllou, Stavrakakis, Ziveri & Lykousis (2009), 5 Percopo, Siano, Cerino, Sarno & Zingone (2011), 6 Baytut & Gönülol (2016), 7 Calbet, Sazhin, Nejstgaard, Berger & Tait (2014), 8 Leadbeater (2011), 9 Throndsen, Hasle, & Tangen (2007), 10 Majaneva *et al*. (2012), 11 Hällfors (2004), 12 Vilicic, Marasovic & Miokovic (2002), 13 Andruleit, Stager, Rogalla & Cepek (2003), 14 Liu (2008), 15 Li, Yu, Wang, Li, Li & Qin (2016), 16 Seoane *et al*. (2009), 17 Ziveri, Broerse, Hinte, Westbroek & Honjo (2000), 18 Gran (1912), 19 Moita & Vilarinho (1999), 20 López-Fuerte, Gárate, Lizárraga, Siqueiros-Beltrones & Yabur (2015), 21 Baumann, Saavedra-Pellitero, Böckel & Ot (2016), 22 BSPC Editorial Board (2017), 23 Moestrup (1979), 24 Rhodes *et al*. (2012), 25 LeRoi & Hallegraeff (2004), 26 Patil *et al*. (2017), 27 Manton & Leadbeater (1974), 28 Chang & Northcote (2016), 29 Hagino & Okada (2005), 30 Leadbeater (1974), 31 Parke *et al*. (1956), 32 Heimdal (1997), 33 Cerino *et al*. (2017), 34 Bergesch (2010), 35 Afonso-Carrillo (2014), 36 Winter & Siesser (1994), 37 Throndsen (1997), 38 Parke & Dixon (1976), 39 Bergesch, Odebrecht, & Moestrup (2008), 40 Edvardsen *et al*. (2011), 41 Hallegraeff & Jeffrey (1984), 42 Dimiza *et al*. (2015).

Mediterrnean Sea previously, non-calcifying haptophytes *Chrysochromulina alifera*, *C. parkeae*, *C. lanceolata* and *C.* cf. *ericina* (Puigserver *et al.*, 2003) were found first time in the Levantin basin of the Mediterranean Sea and along Turkish coasts. It was striking that the ratio of haptonema length : cell length (16:1) in *C. alifera* (Fig. 3) was twice higher than the value previously reported in the western Mediterranean Sea (Puigserver *et al*., 2003). According to Parke *et al*. (1956), this ratio was 2-2.5:1 in the North Atlantic Sea. *Chrysochromulina parkeae* was first reported in the Mediterranean Sea during 1971-1972 (Leadbeater, 1974) and it was not recorded in this sea until the present investigation. There are relatively few records in literature about its presence (Table 1). It was difficult to identify non-calcifying haptophyte species *C. cf. ericina* since we do not have electron microscope images. *H. hirta* and *C. spinifera* also have spines similar to the ones that we have observed. However, *C. spinifera* has shorter haptonema than flagella (see the long haptonema in our species Fig. 6) and the shape of *C. hirta* is spherical, not oval or heart shaped as our species (Edwardsen *et al*., 2011). It was also recorded only once in the Mediterranean Sea by Leadbeater (1974). *C. lanceolata* is a new species first identified in the western Mediterranean Sea (Puigserver *et al*. 2003). It was also reported in the Atlantic Ocean (Seoane, Eikrem, Arluzea & Orive, 2009) before the present study (Table 1). *Umbellosphaera irregularis* was reported in the Mediterranean Sea previously (Kleijen, 1993; Heimdal, 1997) but it is the fist record in the Turkish coasts. It was previously reported as a tropical species (Winter & Siesser 1994). *Umbellosphaera tenuis* and *Umbilicosphaera foliosa* were also found in the Aegean Sea region of the Mediterranean Sea previously (Dimiza *et al.*, 2008a; Dimiza *et al*., 2015) but they are the first reports for the Turkish coasts. *U. tenuis* was also observed in the southern part of the eastern Mediterranean (Oviedo, Ziveri, Alvarez & Tanhua, 2015). They are reported as tropical and subtropical species in literature (Perch-Nielsen, 1985; Hallegraeff & Jeffrey, 1984). *Syracosphaera molischii* and *Ophiaster formosus* belonging to Syracosphaerales order are also first reports for the Turkish waters. They were reported in the Adriatic Sea previously (Vilicic, Marasovic & Miokovic, 2002). *Ophiaster formosus* is a species very similar to *Ophiaster hydroideus* morphologically in SEM images (Young *et al*. 2017). A scale found in the present investigation probably belong to *O. formosus* and seem to be slightly different shown by Young *et al.* (2017) (Fig. 10b). Percopo, Siano, Cerino, Sarno & Zingone (2011) found S. *molischii* type 2 in the western Mediterranean previously. *Rhabdosphaera clavigera var stylifera* observed in the present study could be same with *Rhabdolithes claviger* reported along Turkish coastal waters (Koray, 2001), unfortunately there is no photograph in the publication for comparison. *Scyphosphaera apsteinii, Coronosphaera mediterranea*, *Syracosphaera pulchra* and *Calciosolenia brasiliensis* found in the present study were reported along Turkish waters and in the Mediterranean Sea previously (Baytut & Gönülol, 2016; Koray, 2001; Koray *et al*., 2000; Polat & Piner, 2002; Vilicic *et al*., 2002; Balkıs, 2004; Dimiza *et al*., 2015; Balkıs & Taş, 2016). *Syracosphaera pulchra* was the most frequent coccolithophore species that we have coincided after *Emiliania huxleyi*. During our sampling it was observed in eight different dates, mostly in spring and autumn. Mediterranean Sea is one of the most nutrient-poor regions of the global ocean (Dugdale & Wilkerson, 1988). Thus, high diversity of coccolithophores is expected. Eastern Mediterranean is even more nutrient-poor than the western part (Krom, Kress, Brenner & Gordon, 1991; Yacobi *et al*., 1995; Psarra, Tselepides & Ignatiades, 2000). However, eastern Mediterranean coccolithophore studies are limited with the Aegean Sea (Malinverno *et al*., 2008; Dimiza *et al*., 2008; Dimiza *et al*., 2015). According to our literature survey, this is the first study related to haptophyte species composition along the coast of southern Turkey.

Acknowledgement

This study was supported by TÜBİTAK 115Y767 and BAP 2016-2-TP-2-1912 projects.

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