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Full Length Research Paper

Dinoflagellate cyst assemblages in the surface sediments from Izmir bay, Aegean sea, Eastern Mediterranean

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The present study was conducted on dinoflagellate cyst assemblages from Izmir Bay, Aegean Sea subject to high human impact. Sediment cores were taken from twelve stations. Twenty-eight dinoflagellate cyst types, representing nine genera, were identified. The most common cysts were those of *Lingulodinium machaerophorum, Polykrikos kofoidii, Quinquecuspis concreta* and *Dubridinium caperatum.* Potentially toxic species were widely distributed in the study area. This finding is also important to know the seed-bank areas in the Bay of Izmir.

Key words: Dinoflagellate cysts, cyst assemblage, cyst morphology, Izmir Bay, surface sediments.

INTRODUCTION

Dinoflagellates are microscopic unicellular organisms belonging to the division of Dinoflagellata (Fensome et al., 1993). Together with diatoms and coccolithophorids, dinoflagellates constitute important primary producers. They inhabit most types of aquatic environments, from lakes to open ocean, and occur at all latitudes from the equator to polar seas (de Vernal and Marret, 2007).

Some dinoflagellate species produce resting cysts in their life cycle. These cysts can germinate in optimal environments after a certain resting period and vegetative cells are regarded as seeds for future blooms (Anderson and Wall, 1978). More than 200 species of marine dinoflagellates are known to produce resting cysts (Head, 1996). Although the number of the cyst producing species is small comparing to the total number of extant dinoflagellates, the former contains many harmful species that is more than 16 species have been known to cause a red tide and seven species to be toxic (Matsuoka and Fukuyo, 2000).

Cysts are important in studies of dinoflagellate ecology and biogeography (Dale, 1983). These data sets were used to define relationships between the distribution of dinocyst assemblages and hydrographic parameters, notably the temperature, salinity, sea-ice cover and productivity or eutrophication. The cysts found in sediment will indicate to some extent which species of motile dinoflagellate cells are present in the water column. Cyst surveys can thus give early warning of the presence and abundance of toxic species in a given area (Orlova et al., 2004).

Dinoflagellate cysts can be useful indicators of the development or presence of eutrophication in recent marine environments (Head, 1996; Dale et al., 1999; Matsuoka, 1999). For example, some cysts are used as indicator for oceanographic features: *Spiniferites mirabilis* as a warm temperate water indicator, whereas *Operculodinium centrocarpum* as a cold water, *Tuberculodinium vancompoae* as tropical to subtropical inner neritic regions, *Lingulodinium machaerophorum* as eutrophic water indicators and *Brigantedinium spp*., *Selenopemphix quanta* and *Protoperidinium nudum* as a trace elements (Zn and Pb) indicators (Versteegh, 1994; Dale et al., 1999; Matsuoka, 1999; Zonneveld and Marret, 2003; Sangiorgi and Dongers, 2004).

During the last four decades, dinoflagellate cysts from recent marine sediments have been studied in many areas of the world: the United States, in Japan, Australia and New Zealand, in Europe, China, India, Russia, among other locations (Wall and Dale, 1968; Bolch and

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Hallegraff, 1990; Nehring, 1997; Sonneman and Hill, 1997; Matsuoka, 1999; Devillers and de Vernal 2000; Persson et al., 2000; Orlova et al., 2004; Pospelova et al., 2004; Sprangers et al., 2004; Holzwarth, 2007).

However to our knowledge, there are few studies describing the modern cyst assemblages and their distribution with palynological records (Mudie et al., 2002, 2004; Giannakourou et al., 2005) in the Aegean Sea, Eastern Mediterranean. The aim of this study is to describe the dinoflagellate cyst assemblages presently occuring in the study area and focus on their morphology. These observations are compared to investigation of cyst composition in Izmir Bay, Aegean Sea.

MATERIALS AND METHODS

Study area

The study area, Izmir Bay is one of the largest embayment in the Eastern Aegean Sea in the eastern Mediterranean. The bay is roughly “L” shaped. The leg of the “L” is about 20 km wide and 40 km long and the base of the “L” is about 5 - 7 km wide and 24 km long. Izmir Bay has limited freshwater input and typical tropic-subtropical characteristics. This bay has been divided into three sections (outer, middle and inner) according to their physical characteristics to their content of the different water masses (Sayin, 2003).

Izmir Bay is highly disturbed environment due to the rapid increase of the population and development of industry. The sources of pollution are the untreated domestic and industrial wastes, agricultural pollution, atmospheric pollution and shipping. Nitrogen is the limiting element in the Izmir Bay. Phosphate which originates from detergents is an important source for eutrophication in the bay, especially in the inner bay. The sediment of Izmir Bay is highly contaminated due to industrial and domestic wastes. The waste water treatment plant began to treat the wastes about 60% of capacity between 2000 - 2001 and full capacity after 2001. The quality of the marine environment in the Middle and Inner parts of the bay has not yet noticeably improved. Although the capacity of waste water plant is sufficient for removal of nitrogen from the wastes, it is inadequate for removal of phosphate (Kucuksezgin et al., 2006).

Sampling and sample preparation

In this study, 12 surface sediment samples were collected once in Izmir Bay in 2008 (Figure 1) and sampling locations, water depth and sediment types were shown in Table 1.

Sediment samples were collected with TFO (Tokyo University Fisheries and Oceanography Laboratory Gravity Core) corer. The samples for dinoflagellate cyst analysis were treated using the palynological method suggested by Matsuoka and Fukuyo (2000). Upper 2 cm of cores were cut and immediately preserved in a refrigerator in the dark at 4°C to prevent cyst germination. In the palynological procedure, sediments were processed with ca. 10% HCl and ca. 47% HF to remove calcium carbonate and silicate materials. Then the samples were repeatedly washed with distilled water to remove acid until the pH values were almost 7.0. The chemically treated samples were sonicated for 30s and then successively sieved through two different stainless steel meshes with 125 and 20 µm opening sizes and the sediments retained on latter screen were transferred into a plastic tube and suspended in 10 ml distilled water. Observation was carried out under an inverted microscope (Olympus IX71) equipped with a camera at magnifications 100, 200 and 400 times. The terminology used for describing the dinoflagellate cysts essentially followed the works of Wall and Dale (1968); Dale (1983); Matsuoka et al. (1989); Matsuoka and Fukuyo (2000) and Matsuoka et al. (2004).

RESULTS

Twenty–eight dinoflagellate cysts, representing 9 genera, were identified from the Izmir Bay, Aegean Sea (Table 2). One different cyst type also was found in this study. Many cysts were observed as living and empty forms. On the basis of previous studies, cysts-theca relationships are summarized in Table 3.

Systematic description

A detailed description and illustration were given for only of those cysts that represent newly recorded taxa data unidentified species and potentially toxic species.

Gonyaulacoid group

Cyst type of Alexandrium minutum

The cyst was reniform in lateral view and almost circular in apical view. The living cyst had red accumulation body. The cell wall was smooth and covered with an amorphous, transparent, mucilaginous material containing detritus. Cyst body: 21 - 34 µm in length, 19 - 29 µm in width (n = 50). Motile cells of *A. minutum* were observed before in Izmir Bay, Aegean Sea (Koray and Buyukisik, 1988). Distribution: station 8.

***Lingulodinium machaerophorum* [(Deflander and Cookson) Wall (Figure 2)]:** The cyst was round and transparent. Cyst wall was ornamented with long-stout and hollow processes (8 - 20 µm length, n = 50) pointing toward tips. Cyst diameter was 32 - 44 µm (n = 50). Previously found in plankton in Izmir Bay and responsible for red-tide events (Koray, 1984). Distribution: all stations.

***Operculodinium centrocarpum* [(Deflandre and Cookson) Wall (Figure 3)]:** Spherical cyst with two-layered wall and densely ornamented with numerous processes between 3 and 10 µm (n = 25). The processes were slender, erect and have minutely distally expanded tips. Cyst diameter was 27 - 38 µm (n = 50). Some specimens have the trapezoidal archeophyle. Previously found in plankton in Izmir Bay (Koray and Buyukisik, 1988). Distribution: all stations.

***Operculodinium israelianum* [(Deflandre and Cookson) Wall (Figure 4)]:** Chorate cyst with a subspherical to ovoidal central body. Endophragm was thin and smooth and periphragm was relatively thick and

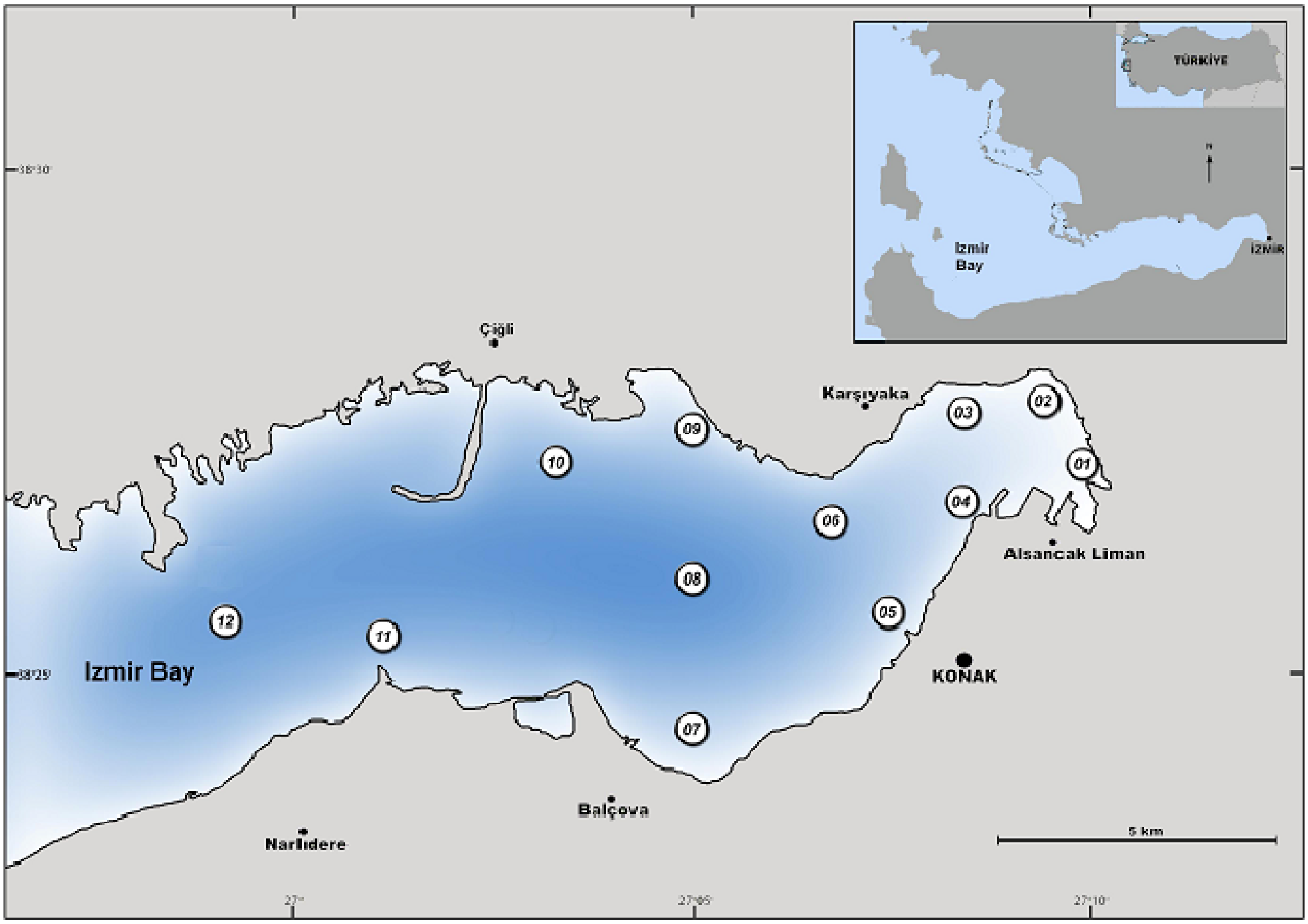

Figure 1. Location of the sampling sites in Izmir Bay, Turkish Aegean sea.

Table 1. Geographical coordinates of sampling sites with water depth and sediment type in Izmir Bay, Aegean Sea.

Site	Location	Depth (m)	Latitude (N)	Longitude (E)	Sediment type
1	Meles	5	38 27. 08	27 09. 90	Mud
2	Bayraklı	6	38 27.70	27 09.40	Mud
3	Alaybey	9	38 27.59	27 08.41	Mud
4	Alsancak	10	38 26.71	27 08.37	Mud
5	Pasaport	15	38 25.61	27 07.44	Mud
6	Karşıyaka	13	38 26.50	27 06.72	Mud
7	Göztepe 1	13	38 24.45	27 04.99	Mud
8	Göztepe 2	18	38 25.94	27 04.97	Mud
9	Bostanlı	5	38 27.43	27 04.99	Mud
10	Mavişehir	11	38 27.11	27 03.27	Mud
11	Balçova	16	38 25.39	27 01.08	Mud
12	Narlıdere	11	38 26.08	26 59.04	Mud

and shows apperently granular to fibro-pitted structure. Peripragm alone made up the processes of which distribution was apparently evently non-tubular but basically may be intratabular. Processes were numerous and usually short conical with acuminate distal tips. Proximal base of processes carried some striations. Cyst body diameter: 38 - 65 µm (n = 17), processes length: 2 - 5 µm (n = 50). Distribution: stations 2, 5 - 12.

Table 2. The presence and absence of dinoflagellate cysts at each station.

		Sampling site											
		1	2	3	4	5	6	7	8	9	10	11	12
Autotrphic group	**Gonyaulacales**												
	Alexandrium minutum type	-	-	-	-	-	-	-	+	-	-	-	-
	Lingulodinium machaerophorum	+	+	+	+	+	+	+	+	+	+	+	+
	Operculodinium centrocarpum	+	+	+	+	+	+	+	+	+	+	+	+
	Operculodinium israelianum	-	+	-	-	+	+	+	+	+	+	+	+
	Spiniferites bentorii	+	+	+	+	+	+	+	+	+	+	+	+
	Spiniferites bulloideus	+	+	+	+	+	+	+	-	+	+	+	+
	Spiniferites cf. *delicatus*	+	+	+	+	+	+	+	+	+	+	+	+
	Spiniferites hyperacanthus	+	+	+	+	+	+	+	+	+	+	+	+
	Spiniferites mirabilis	+	-	+	+	+	+	+	+	+	+	+	+
	Spiniferites sp.	+	+	+	+	+	+	+	+	+	-	-	+
	Peridiniales												
	Scripsiella sp1.	+	+	+	+	+	+	+	+	+	+	+	+
	Scripsiella sp2	-	+	+	+	+	+	-	-	-	-	-	-
	Gymnodiniales												
	Polykrikos kofoidii	+	+	+	+	+	+	+	+	+	+	+	+
	Polykrikos schwartzii	+	+	+	+	+	+	+	+	+	+	+	+
Heterotrophic group	**Peridiniales**												
	Brigantedinium irregulare	-	+	+	+	+	+	+	+	+	+	+	+
	Brigantedinium simplex	-	-	-	-	-	-	+	+	+	+	+	+
	Brigantedinium asymmetricum	-	+	+	+	+	+	+	+	+	+	+	+
	Diplopelta parva	-	-	+	+	+	+	+	+	+	+	+	+
	Dubridinium caperatum	+	+	+	+	+	+	+	+	+	+	+	+
	Protoperidinium nudum	+	+	+	+	+	+	+	+	+	+	+	+
	Protoperidinium obtusum	-	-	-	-	+	+	+	+	+	+	+	+
	Quinquecuspis concreta	+	+	+	+	+	+	+	+	+	+	+	+
	Selenopemphix quanta	+	+	+	+	+	+	+	+	+	+	+	+
	Stelladinium stellatum	-	+	+	+	-	+	+	+	+	+	+	+
	Votadinium calvum	+	+	+	+	+	+	+	+	+	+	+	+
	Votadinium spinosum	+	+	+	+	+	+	+	+	+	+	+	+
	Xandarodinium xanthum	+	+	+	-	+	+	+	+	-	-	-	-
	Unidentified cysts												
	Type A	-	-	+	+	-	+	-	+	+	+	-	-

Spiniferites bentorii **[(Rossignol) Wall and Dale (Figure 5)]:** Proximochorate cyst with an ovoidal central body and a pronounced apical protuberance. Appressed endophragm and periphragm between processes form a thick wall and the periphragm surface was microgranulate. Paratabulation was expressed by very low parasutural septa formed between gonal and occasionally intergonal processes. When fully formed processes were slender and delicate with bifurcating tips. Otherwise, processes were usually short, and had a fenestrate base. Cyst body: 37 - 65 µm in length, 33 - 51 µm in width (n = 50). Distribution: all stations.

S. bulloideus **[(Deflandre and Cookson) Sarjent sensu Wall and Dale (Figure 6)]:** Cyst was covered with ornaments and wall was colourless with solid processes. Cysts with only gonal processing. Cysts wall surface was smooth and diameter smaller than 40 µm. Cyst diameter was 24 - 39 µm (n = 50). Distribution: stations 1 - 7, 9 - 12.

Spiniferites **cf.** ***delicatus*** **(Deflandre and Cookson) Sarjent sensu Wall and Dale:** Proximocorate cyst with an ovoidal body and peripragm and endophragm both microgranulate to reticulate. Paratabulation was expressed by high granular membranous parasutural flanges connecting the gonal processes, which are supported by skeletal rods. In plan view process tips had a characteristic petaloid shape. Cyst body: 31 - 42 µm in length, 27 - 36 µm in width (n = 4). Distribution: all station.

Table 3. List of dinoflagellate cysts observed in the study area and cyst-theca relationship based on literature survey.

Palynological name of cysts	Biological name of species	References
Gonyaulacoid group		
-	*Alexandrium minutum*	Bolch et al., 1991
Lingulodinium machaerophorum	*Lingulodinium polyedrum*	Wall and Dale, 1968; Nehring, 1997
Operculodinium centrocarpum	*Prorocentrum reticulatum*	Wall and Dale, 1968; Sonneman and Hill, 1997; Nehring, 1997
Operculodinium israelianum	*Prorocentrum reticulatum*	Zonnaveld and Marret, 2003.
Spiniferites bentorii	*Gonyaulax digitalis*	Wall and Dale, 1968
Spiniferites bulloideus	*Gonyaulax scrippsae*	Wall and Dale, 1968
Spiniferites hypercanthus	*Gonyaulax spinifera*	Matsuoka and Fukuyo, 2000
Spiniferites mirabilis	*Gonyaulax spinifera*	Sonneman and Hill, 1997
Spiniferites cf. *delicatus*	*Gonyaulax sp.*	
Peridinoid group		
Scripsiella spp.	-	Matsuoka ve Fukuyo, 2000
Gymnodinoid group		
-	*Polykrikos kofoidii*	Matsuoka et al., 2009
-	*Polykrikos schwartzii*	Matsuoka et al., 2009
Protoperidinoid group		
Brigantedinium simplex	*Protoperidinium conicoides*	Nehring, 1997, Sonneman and Hill, 1997
Brigantedinium irregulare	*Protoperidinium denticulatum*	Wall and Dale, 1968
Brigantedinium asymmetricum	*Protoperidinium sp.*	Matsuka et al., 2004
-	*Diplopelta parva*	Matsuoka, 1988; Bolch and Hallegraeff, 1990,
Dubridinium caperatum	*Preperidinium meunieri*	Wall and Dale, 1968; Matsuoka 1988; Bolch and Hallegraeff, 1990
-	*Protoperidinium nudum*	Wall and Dale, 1968
-	*Protoperidinium obtusum*	Matsuka et al., 2004
Quinquecuspis concreta	*Protoperidinium leonis*	Wall and Dale, 1968
Selenopemphix quanta	*Protoperidinium conicum*	Bolch and Hallegraeff, 1990
Stelladinium stellatum	*Protoperidinium compressum*	Matsuoka and Fukuyo, 2000
Votadinium spinosum	*Protoperidinium oblongum*	Bolch and Hallegraeff, 1990; Sonneman and Hill, 1997
Votadinium calvum	*Protoperidinium claudicans*	Wall and Dale, 1968
Xandarodinium xanthum	*Protoperidinium divaricatum*	Reid, 1977, Bolch and Hallegraeff, 1990;Nehring, 1997

S. hypercanthus **[(Rossignol) Sarjent (Figure 7)]:** Cyst was covered with ornaments and wall was colourless with solid processes. Cysts with gonal and intergonal processing. Cysts wall surface was smooth and processes was only solid. Cyst diameter was 24 - 36 µm (n = 33). Distribution: all stations.

S. mirabilis **(Rossignol) Sarjent (Figure 8):** *S. mirabilis* was a proximochorate cyst with an ovoidal, slightly elongate body, circular in polar view. The periphragm surface was microgranulate. Paratubulation was weakly expressed by very low parasutural septa (sometimes completely absent). The antapical area was ornamented by processes that were connected by a high sutural flange. Stout, rigid, hollow gonal processes and intergonal processes ornament the remainder of cyst body. Cyst body: 36 - 50 µm in length, 29 - 47 µm in width (n = 4). Distribution: stations 1, 3 - 12.

Spiniferites. sp. **(Figure 9):** Cyst was covered with ornaments and wall was colourless. Cysts with gonal or intergonal processing. Cysts wall surface was smooth and cyst shape was elongate. Cyst body: 20 - 28 µm in length, 18 - 25 µm in width (n = 15). Distribution: stations 1 - 9, 12.

Peridinoid group

Scripsiella **sp 1 (Figure 10):** These types of cysts had calcareous processes, but the processes were melted after hydrochloric acid treatment (%10). Then a pockmarked cyst surface was left. Orange or red accumulation

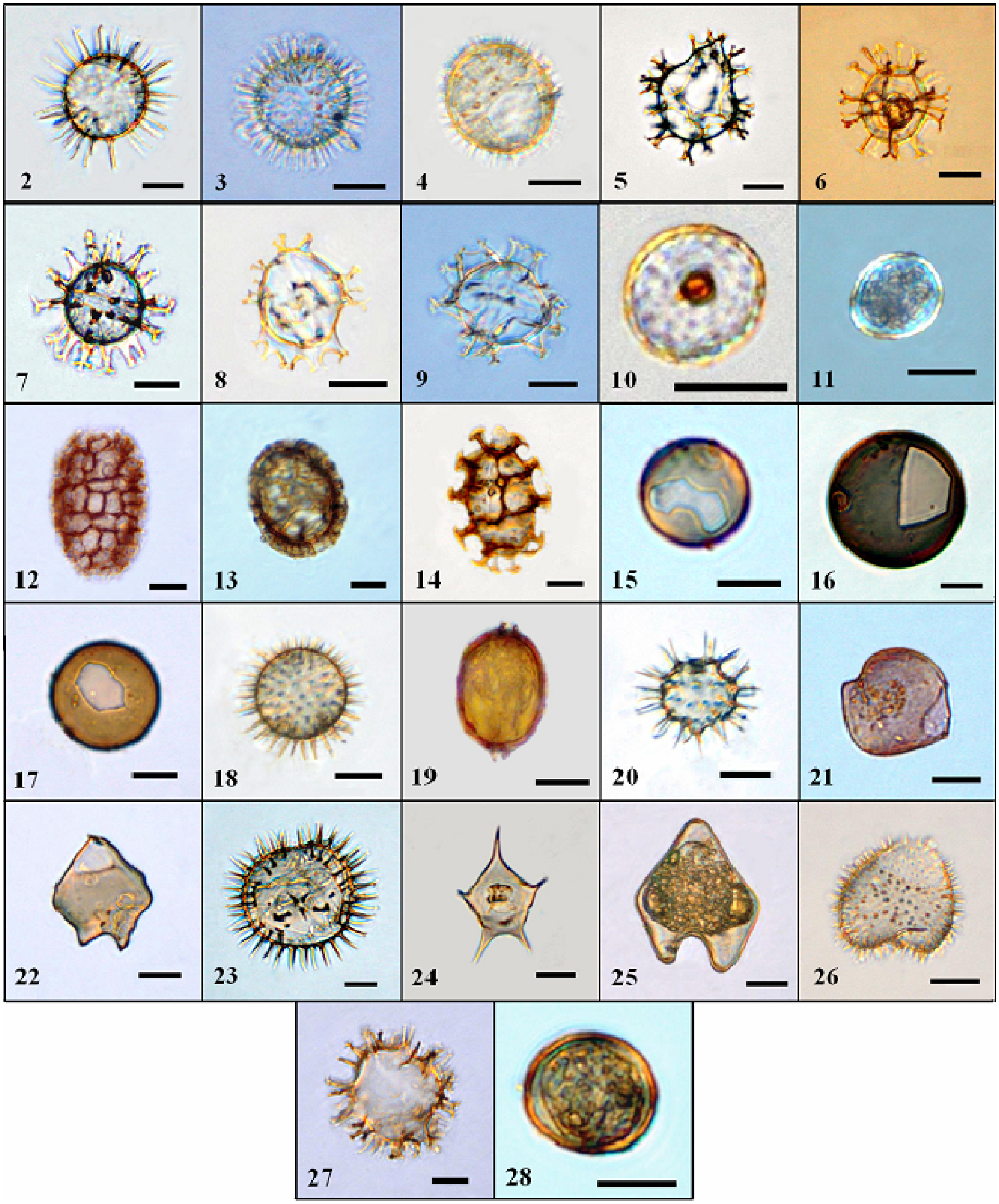

Figure 2 - 28. Dinoflagellate cysts recorded from modern sediments in Izmir Bay, Turkish Aegean Sea: (2) *Lingulodinium machaerophorum*; (3) *Operculodinium centrocarpum*; (4) *Operculodinium israelianum*; (5) *Spiniferites bentorii*; (6) *Spiniferites bulloideus*; (7) *Spiniferites hyperacanthus;* (8) *Spiniferites mirabilis*; (9) *Spiniferites* sp.; (10) *Scripsiella* sp1.; (11) *Scripsiella* sp2.; (12-13) *Polykrikos kofoidii*; (14) *Polykrikos schwartzii*; (15) *Brigantedinium irregulare*; (16) *Brigantedinium simplex*; (17) *Brigantedinium asymmetricum*; (18) *Diplopelta parva*; (19) *Dubridinium caperatum*; (20) *Protoperidinium nudum*; (21) *Protoperidinium obtusum*; (22) *Quinquecuspis concreta*; (23) *Selenopemphix quanta*; (24) *Stelladinium stellatum*; (25) *Votadinium calvum*; (26) *Votadinium spinosum*; (27) *Xandarodinium xanthum*; (28) Unidentified Cysts Type A. Scale bars (—) 20 µm.

body often appeared. Cyst body: 22 - 32 µm in length, 21 - 28 µm in width (n = 50). Distribution: all stations.

***Scripsiella* sp. 2 (Figure 11):** These cysts were different from *Scripsiella* sp.1 with green/blue protoplasmic contents and cyst included great amount. Cyst body: 23 - 30 µm in length, 20 - 27 µm in width (n = 50). Distribution: stations 2 - 6.

Gymnodinodinian group

***Polykrikos kofoidii* Chatton (Figures 12 and 13):** Proximochorate cyst with an ellipsoidal body. Coarsely reticulate ornaments covered over all cysts. Cyst wall was pale or greenish brown, consisting of two or three layers; endophragm, periphragm and exophragm. The endophragm and periphragm were appressed except for ornaments. The endophragm was relatively thick and no ornamentation. The periphragm was thin and smooth except for ornaments. Archeophyle was formed at the polar end, probably apical part, and roundly polygonal in shape. Cyst body: 57 - 92 µm in length and 41 - 60 µm in width (n = 50). Distribution: all stations.

***Polykrikos schwartzii* Butschli (Figure 14):** Proximochorate cyst with an elongate body. Cyst wall was dark brown, consisting of two or three layers; endophragm, periphragm and exophragm. The endo-phragm and periphragm were appressed except for ornaments. The endophragm was relatively thick without surface ornamentation. The periphragm was fibrous, thin and smooth except for ornaments. Shelf-like ornaments and process sometimes rising from fibrous periphragm were distributed over the cyst. Near the bases of these ornaments, wrinkles were developed on the periphragm. Basically five rows of shelf-like ridges were developed. The morphology of these shelf-like ridges and processes were extremely variable. In some cysts shelf-like ridges were occasionally disconnected and undulate. In the latter case, the unconnected ridges become small circle and finally make a process. These processes were hollow and short cylindrical to infundibular with an opening others in different rows, forming an incomplete reticulate structure. Archeophyle was termic (roundly polygonal in shape), formed at the polar end, probably the apical part. Cyst body: 79 - 88 µm in length and 53 - 57 µm in width (n = 4). Distribution: all stations.

Protoperidinoid group

***Brigantedinium irregulare* Matsuoka (Figure 15):** The darkbrown spherical cysts (30 - 75 µm) was smooth walled (n = 45). The elongated and lunate archeophyle was formed by the loss of one or two intercalary paraplates. Distribution: stations 2 - 12.

***Brigantedinium simplex* Reid (Figure 16):** Circular cysts in dorsal view at times appearing compressed in ventroposterior view to give an oval outline. The wall was thin, single, duble layered, Brown in colour with hexagonal, subtrapezoidal, mid-dorsal archeophyle. In one specimen, the operculum although partially open remained attached by tendrils to other wall. Small specimens usually have a smooth surface whereas larger forms may be rugulate or microgranular. Thickenings of the wall marking sulcal flagellar pore scars and apical and antapical projections were noted a number of suitably orientated specimens. Cyst diameter was 27 - 43 µm (n = 15). Distribution: stations 7 - 12.

***Brigantedinium asymmetricum* Matsuoka (Figure 17):** Cyst was round and brownish wall without ornaments and. Cysts spherical shaped with a single layered wall. Archeophyle corresponding to 2a paraplate and irregular expanded. Cyst diameter was 34 - 54 µm (n = 35). Distribution: stations 2 - 12.

Diplopelta parva* (Abé) Matsuoka (Figure 18)*: The cyst was round and brownish wall. Cyst wall was ornamented with large and spinate processes (3 - 9 µm long) pointing toward tips (n = 25). Cyst diameter was 25 - 38 µm (n = 50). Distribution: stations 3 - 12.

***Dubridinium caperatum* (Pavillard) Elbröchter (Figure 19):** Cyst was brownish wall and spherical body shape. Cysts with a two layered wall and archeophyle terophylic epicystal. Cyst body: 31 - 52 µm in length, 28 - 47 µm in width (n = 50). Distribution: all stations.

***Protoperidinium nudum* (Meunier) Balech (Figure 20):** *P. nudum* was a proximochorate cyst with a subspherical body, brown in colour and ornamented with numerous processes. This was the different from *S. quanta* in a smaller size and not compressed apical/antapically. Cyst was covered with needle-like spines. Cyst body: 28 - 59 µm in length, 20 - 56 µm in width (n = 50). Distribution: all stations.

***Protoperidinium obtusum* (Karsten) Parke and Dodge (Figure 21):** Cyst body shape was peridinoid or like heart without ornaments. Antapical horns were short and cyst wall was brownish. Cyst body: 35 - 65 µm in length, 35 - 64 µm in width (n = 7). Distribution: stations 5 - 12.

***Quinquecuspis concreta* (Reid) Head (Figure 22):** Cysts without ornaments and cysts processing brownish wall. Cysts body shape was peridinoid with hexagonal archeophyle. Cyst body: 46 - 69 µm in length, 42 - 71 µm in width (n = 25). Distribution: all stations.

***Selenopemphix quanta* (Bradford) Matsuoka (Figure 23):** *S. quanta* was a proximochorate cyst with a sub-spherical body, apically-antapically compressed, brown in colour and ornamented with numerous processes. Processes were solid, with sharp or blunt terminations, occurring along the cingular margins and in rows on the episome and hyposome, but not in the sulcus. Archeophyle was intercalary (2a'), elongated with rounded angles. Cyst body: 44 - 86 µm in length, 41 - 78 µm in width (n = 50). Distribution: all stations.

Stelladinium stellatum **(Wall And Dale) Reid (Figure 24):** The brownish cysts were dorso-ventrally compressed. Horns, including one apical one, two antapical and two lateral ones. Cyst body: 60 - 68 µm in length, 41 - 60 µm in width (n = 5). Distribution: stations 2 - 4, 6 - 12.

Votadinium calvum Reid **(Figure 25)*:*** This cyst was a smooth heart-shape with two round antapical horns. Large and broad archeophyle was often found. Cyst body: 47 - 74 µm in length, 45 - 61 µm in width (n = 5). Distribution: all stations.

Votadinium spinosum **Reid (Figure 26)*:*** This cyst was a smooth heart-shape with two round antapical horns and numerous short spines. Large and broad archeophyle was often found. Cyst body: 47 - 57 µm in length, 46 - 59 µm in width (n = 6). Distribution: all stations.

Xandarodinium xanthum **Reid (Figure 27)*:*** A species of Xandarodinium with a concave ventral area and convex dorsal areas. Wall thin with a smooth surface. Processes have eliptical circular or elongate bases in plan view; form as extensions. Ventral surface and anterior dorsal surface, smooth and not ornamented by processes. Cyst diameter: 57 - 69 µm (n = 4). Distribution: stations 1 - 3, 5 - 8.

Unidentified cyst, Type A (Figure 28): Cyst body was ovoidal and spherical shaped without ornaments. Cysts wall was brownish colour and wall surface was not smooth. Cysts body: 25 - 39 µm in length, 25 - 36 µm in width; (n = 50). Distribution: stations 3, 4, 6, 8, 9, 10.

DISCUSSION

The composition of dinoflagellate cyst assemblages in recent sediments from the Agean Sea, Western Mediterranean has been examined only in few studies (Montresor et al., 1998; Giannakourou et al., 2005). Instead, most studies have focused on fossil records and vertical distribution of the dinoflagellate cysts in the Aegean Sea (Mudie et al., 2002, 2004).

To our knowledge, this is the first detailed study that examined recent dinoflagellate cyst assemblages and description of their morphology in Izmir Bay. Twenty-eight dinoflagellate cyst types, representing nine genera were identified in the 12 surface sediments obtained from Izmir Bay, Aegean Sea.

The Izmir Bay dinoflagellate cyst assemblages of this study are comparable to other modern dinoflagellate cyst assemblages, such as those described from the Aegean Sea. Mudie et al. (2004) have collected sediment samples in Black Sea, Marmara Sea and Aegean Sea and found modern and palynological cysts in these samples. Giannakourou et al. (2005) have studied vertical distribution in five stations and also analyzed the top 10 cm of these sediments in Thermaios Gulf (Greece, Aegean Sea). Montresor et al. (1998) have studied modern cysts with core and sediment trap in Gulf of Naples (Italy, Mediterranean Sea). The comparison of our species was compared with these studies in Table 4. Many cysts showed different distribution however; *Lingulodinium machaerophorum* were found in all regions. The species composition of cysts is more similar in both seas in Italy and Greece (Montresor et al. 1998; Giannakourou et al., 2005).

Izmir bay has eutrophic characteristics (Kontas et al., 2004; Kucuksezgin et al., 2006). *L. machaerophorum* was an indicator cyst for eutrophic bay and seas (Dale et al., 1999; Matsuoka, 1999; Zonneveld and Marret, 2003). *L. machaerophorum* was determined at all stations in the bay. Hence, our results support the previous studies and eutrophic characteristic of the bay.

L. machaerophorum cysts in recent marine sediments are mainly found in coastal and neritic environments (Marret and Scourse, 2002; Zonneveld and Marret, 2003). Planktonic stage of this cyst has been found before and recorded as a Red-tide causing species of the Izmir Bay (Koray, 1984; Koray et al., 1992).

Process length variation of *L. machaerophorum* was initially related to salinity variations in Black Sea by Wall et al. (1973) and subsequently investigated in other regions (Dale, 1996; Nehring, 1997; Mudie et al., 2002; Marret et al., 2009). In the latest study Mertens et al. (2009), showed a relationship between process length and both summer salinity (positive relation) and temperature (negative relation). In our study area average salinity was 30% and temperature was 12°C. Our measurements of processes length average was 14 µm (n = 50) and coincides with the previous study (15 µm) conducted in Black and Marmara Seas.

Surveys of cyst assemblages in sediments are also useful in that they may reveal species seldom observed in the plankton, owing to rare, short–lived or difficult to identify vegetative stages (Hesse et al., 1996).

In our case, several dinoflagellate cysts recovered from sediment samples and have revealed the presence of dinoflagellate species that have not been recorded earlier from the bay in planktonic stage. Koray (2001) established the check-list of phytoplankton species in Turkish Seas. Vegetative cells of these cysts were not recorded in the check-list.

The cysts form of *Gonyaulax scrippsae, Protoperidinium denticulatum, Diplopelta parva, Preperidinium meunierii, P. nudum, P. obtusum* and *P. compressum* were encountered in Izmir bay. Furthermore, the cyst of *Polykrikos kofoidii, P. schwartzii, Protoperidinium*

Table 4. Comparison of our data with the data of other studies.

Cyst types	Izmir Bay[a]	Thermaios Gulf (Greece)[b]	Aegean Sea[c]	Marmara Sea[c]	Black Sea[c]	Gulf of Naples (Italy)[d]
Top of sediment (cm)	2	10	10	10	10	2
A. minutum type	+	+	-	-	-	-
L. machaerophorum	+	+	+	+	+	+
O. centrocarpum	+	+?	+	+	-	+
O. israelianum	+	+?	-	-	-	-
S. bentorii	+	+	-	+	+	-
S. bulloideus	+	+	-	+	-	+
S. cf. delicatus	+	-	+	-	-	-
S. hyperacanthus	+	+	-	-	-	-
S. mirabilis	+	+	+	+	-	+
P. kofoidii	+	+	-	-	+	+
P. schwartzii	+	+	-	-	-	+
B. irregulare	+	-	-	-	-	-
B. simplex	+	+	-	-	-	-
B. asymmetricum	+	?	-	-	-	-
D. parva	+	-	-	-	-	+
D. caperatum	+	+	-	-	-	+
P. nudum	+	-	-	-	-	+
P. obtusum	+	-	-	-	-	-
Q. concreta	+	+	-	+	-	+
S. quanta	+	+	-	-	-	+
S. stellatum	+	+	-	+	+	-
V. calvum	+	-	-	+	-	+
V. spinosum	+	-	-	-	-	+
X. xanthum	+	+	-	-	-	+

[a]Present study; [b]Giannakourou et al. (2005); [c]Mudie et al. (2004); [d]Montresor et al. (1998).

oblongum and *P. conicoides* were also determined in the bay. Vegetative stages of these species have not been recorded in previous studies (Koray, 1984, 1987; Koray et al., 1992, Sabancı ve Koray, 2001, 2005).

Operculodinium centrocarpum has a cosmopolitan distribution and very broad tolerance for a wide range of temperature and salinity (Rochon et al., 1999). *O. centrocarpum* is also a toxic species that produces yessotoxins (Satake et al., 1997) and has been associated with large mussel mortalities on the west coast of South Africa (Horstman, 1981). In our study cyst of *O. centrocarpum* widely distributed in the bay and this finding indicate the seed–bank in the bay.

Lingulodinium machaerophorum, Polykrikos kofoidii, Dubridinium caperatum and *Quinquercuspis concreta* were showed broad distribution at all stations. However, *Alexandrium minutum* type cyst was observed station 8. Vegetative cells of this cyst were widely distributed in the bay before and responsible species of Red-tide events (Koray, 1984; Koray et al., 1992). In modern sediments high relative and absolute numbers of cysts of heterotrophic Protoperidinium have been found in areas with high nutrient content and high productivity in surface waters, such as upwelling areas (Sprangers et al., 2004). *Selenopemphix quanta* the cyst of heterotrophic taxon, is the only to show a relationship with productivity. Dale and Fjellså (1994) also suggested that this taxon is a high productivity indicator. In our results, there were many heterotrophic Peridinium cysts with broad distribution in the bay and also *Selenopemphix quanta* were determined at all stations. Since the Izmir bay is high productive area (Sunlu et al., 2008) our results coincides with the other studies. We have demonstrated that dinoflagellate cyst studies were very useful to know the planktonic assemblages of the coastal marine environments.

More detailed and extensive investigations in the Aegean Sea coastal waters would no doubt yield more information about cyst assemblages.

Our study also showed that cysts of potentially toxic and harmful species widely distributed in the bay and can be a risk factor and early warning about harmful algal blooms.

Cysts are useful indicator for environmental parameters (salinity, eutrophication) and refer to their ecologic importance in the aquatic systems. Nutrient concentration, turbulence, sea surface temperature and salinity are related to composition of dinoflagellate cyst assemblages (Versteegh, 1994; Dale et al., 1999; Matsuoka, 1999; Zonneveld and Marret, 2003; Sangiorgi and Dongers, 2004). Therefore further studies are needed to investigate dinoflagellate cyst abundance, distribution and active environmental parameters in the bay of Izmir.

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