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RESEARCH PAPER

The distribution of the potentially harmful dinoflagellate species *Polykrikos hartmannii* in the İzmir Bay

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Abstract

This study investigated the status of *Polykrikos hartmannii*, a dinoflagellate species with the ability to cause excessive blooms, in the İzmir Bay between 2022 and 2025. Previously reported in the Black Sea and the Sea of Marmara, the species began to be seen in the İzmir Bay in 2022. It began to bloom in the spring of 2023, and between September and November of the same year, it proliferated to the point of covering the entire bay in a brown-red color, attracting the attention of local authorities and scientists. The species, which has also been encountered in monitoring studies conducted in the bay for the last three years, exhibited excessive blooms, particularly in November 2023, and was detected at concentrations of 12.58×10^6 cells L^{-1} at station 8 and 8.86×10^6 cells L^{-1} at station 9. It is thought that the species, which reproduced so excessively that it covered the entire İzmir bay between 2023 and 2024, was most likely transported to the bay via ballast tanks.

Introduction

Just as the role of single-celled phytoplanktonic organisms distributed in marine and freshwater environments in the food chain is crucial, dinoflagellates, the second link in the food chain, are also crucial in helping us understand changes in marine ecosystems (Shin et al., 2011). *Polykrikos*, the genus name of *Polykrikos hartmannii*, a toxin-secreting dinoflagellate, was given by Bütschli, who described the species *schwartzii* in 1873 (Bütschli, 1873). Zimmerman was the first to provide the morphological description of the species as *hartmannii* under the genus *Polykrikos* in 1930 (Zimmerman, 1930). A second polykrikoid genus, *Pheopolykrikos*, was first discussed by Chatton in 1933 and given the species name *beauchampii*, known for its lack of a cyst stage (Chatton, 1933). The species was later studied as *Pheopolykrikos* by Matsuoka & Fukuyo (Matsuoka and Fukuyo, 1986). *Pheopolykrikos* was initially thought to differ from *Polykrikos* in that it possessed the same number of nuclei as its zooids and could differentiate into single cells (Chatton 1933, 1952). Furthermore, *Pheopolykrikos beauchampi*i, like *Polykrikos hartmannii*, is photosynthetic but lacks phagocytosis (Chatton 1933).

Today, the current scientific species name *Polykrikos hartmannii* is used, and *Pheopolykrikos hartmanni* is considered a synonym. While there are many studies identifying *P. hartmannii*, which is found to be distributed in temperate and tropical seas, there are few reports on its ecology (Lee et al., 2015), distribution (Gómez, 2012), and toxin (Dzhembekova et al., 2022). *P. hartmannii* is a dinoflagellate species that exhibits the potential for overgrowth and forms cysts under adverse conditions (Steidinger, 1975; Wall, 1975; Anderson and Wall, 1978; Prakash, 2011). The impact of toxic dinoflagellate blooms on fish and mussel farms, mass fish kills in coastal areas, and disruptive effects on ecosystem balance are significant (Wang, 2008; Twiner et al., 2008; Wagoner et al., 2010; Ignatiades and Gotsis-Skretas, 2010; Farabegoli et al., 2018; Bothelo et al., 2029). Toxins produced by dinoflagellates accumulate in the tissues of organisms, particularly fish and mussels, that feed on zooplanktonic organisms. It also causes various forms of poisoning in humans who consume fish and mussels (Yasumoto and Murata, 1993; Landsberg, 2002). Although the toxin has not yet been identified, *P. hartmannii* has been classified as a HAB (Anderson et al., 2021) because it causes massive fish kills through excessive proliferation (Badylak & Phlips, 2004; Tang et al., 2013; Thangaraj et al., 2017). *P. hartmannii* is listed as a Harmful Algal Blooming species (HAB) by the World Register of Marine Species (WORMS), AlgaeBase, and UNESCO's Taxonomic Reference List of Harmful Micro Algae. The WORMS AphiaID number is 109898, and the full species name is *Polykrikos hartmannii* W.M.Zimmermann, 1930.

Studies on harmful algal blooms have shown that phytoplankton blooms are locally intense in the Mediterranean and Sea of Marmara (Caroppo, 2001; Balkıs and Aktan, 2004; Aktan et al., 2005) and have been increasing since the 1970s (Ferrante et al., 2013). Harmful algal blooms are thought to be caused by the transport of species in boat ballast tanks (Hallegraeff and Bolch 1998), human-induced marine pollution (Nixon 1995), and global warming (Smayda 1990; Hallegraeff 1993, 2010).

When looking at research on harmful algal blooms in the Izmir Bay, the first report of excessively prolific dinoflagellate species was conducted by Wilhelm Nümann (1929-2022) in 1955 (Nümann, 1955). During a brief stay in Türkiye, Nümann conducted research and identified *Gymnodinium* sp. as the species that caused mass fish kills by coloring the Izmir Bay brownish red in August. Other species that occasionally proliferate excessively in the Izmir Bay and cause low oxygen levels and fish kills are the diatoms *Cylindrotheca closterium* (Ehrenberg) Reimann and J.C.Lewin, 1964, *Pseudo-nitzschia delicatissima* (Cleve) Heiden, 1928, *Pseudo-nitzschia pseudodelicatissima* (Hasle) Hasle, 1993, *Pseudo-nitzschia pungens* (Grunow ex Cleve) G.R.Hasle, 1993, *Skeletonema costatum* (Greville) Cleve, 1873, and the dinoflagellates are: *Alexandrium minutum* Halim, 1960, *Alexandrium tamarense* (Lebour) Balech, 1995, *Dinophysis acuminata* Claparède and Lachmann, 1859, *Dinophysis caudata* Saville-Kent, 1881, *Dinophysis fortii* Pavillard, 1924, *Dinophysis sacculus* F.Stein, 1883, *Gymnodinium catenatum* H.W.Graham, 1943, *Karenia brevis* (C.C.Davis) Gert Hansen and Moestrup, 2000 (=*Gymnodinium breve*), *Lingulaulax polyedra* (F.Stein) M.J.Head, K.N.Mertens and R.A.Fensome, 2024 (=*Gonyaulax polyedra*), *Noctiluca scintillans* (Macartney) Kofoid and Swezy, 1921 (=*Noctiluca miliaris*), *Prorocentrum rotundatum* Schiller, 1928 (=*Dinophysis rotundata*), *Prorocentrum lima* (Ehrenberg) F.Stein, 1878, *Protoceratium reticulatum* (Claparède and Lachmann) Bütschli, 1885 (=*Gonyaulax grindleyi*). Following studies in İzmir Bay focused on classification of unarmored dinoflagellate species (Geldiay and Ergen, 1968), distribution of species adapted to pollution (Koray, 1987; Koray et al., 1999; Çolak

Sabancı and Koray, 2001), comprehensive atlas including drawings and photographs of the dinoflagellate species (Koray et al., 2007).

Polykrikos hartmannii and its synonym *Pheopolykrikos hartmannii* have been studied in lagoons and estuarine zones in marine environments. It was first seen in the United States (Martin, 1929) and Germany (Zimmermann, 1930), where it was named and illustrated. Cysts belonging to the species were subsequently identified and photographed in Japan (Takayama, 1985), South Korea (Kim et al., 1990), and Antarctica (Byun et al., 2013). Species has been recorded in Portugal (Moita and Vilarinho, 1999), India (Godhe et al., 2000), the Gulf of Mexico (Morquecho and Lechuga-Devéze, 2003), the Atlantic Ocean (Pospelova et al., 2004), the Tyrrhenian Sea and the Mediterranean Sea (Gómez, 2003). *P. hartmannii* has been identified and studied in the West Pacific, China (Wang et al., 2004), Indonesia (Mizushima et al., 2007), Canada (Price and Pospelova, 2011), and Spain (Gómez, 2012). The species was identified in the Black Sea (Ukraine and Romania coasts) in 2015 (Moncheva, 2015) in 2016 in Türkiye Gemlik Bay (Balkıs et al., 2016), in Israel (Rubino et al., 2017), in Bulgaria (Dzhembekova et al.,2017), in Güllük Bay (Aktan and Keskin, 2017) and in Ukraine (Krakhmalny et al., 2018) its cysts were studied. Recently *P. hartmannii* reported in Malaysia and Singapore (Hii et al., 2021) and in Romania (Dzhembekova et al., 2022). The first study reporting the species *Polykrikos hartmannii* in Izmir Bay was conducted by Çolak Sabancı and colleagues (Çolak Sabancı et al., 2025).

The current study contributes to the investigations of *P. hartmannii* by evaluating different sampling locations within the bay over a longer time frame (2022–2025), providing complementary data on the spatial and temporal of the bloom of the species.

Materials and Methods

Seawater samples were collected from nine stations on the sea surface. Samples were collected a total of eight times: in April and September between 2022 and 2024 as part of the annual İzmir Bay monitoring project, which is ongoing and renewed every year, and in April and June in 2025. 5-liter surface water samples were collected from 9 selected stations in the central and inner İzmir bay (Fig. 1). When the species overpopulated and became the dark brown-red coloration in the inner and middle bay coasts in November 2023, extra seawater samples from stations 8 and 9 were also collected and examined. After the monitoring project ended in April 2025, one more sampling was carried out in June 2025. The coordinates of the sampling stations are given in Table 1 (Table 1).

Physicochemical measurements of seawater were made in situ using digital sensors. Salinity (ppt) was measured using the YSI Pro30 (Conductivity Meter), temperature (°C) using YSI Pro 400, dissolved oxygen (mg/L) using the YSI Pro20 (Dissolved Oxygen Meter), and pH using the YSI Ph100 (EcoSense pH100A Meter) digital sensor equipments.

Statistical analysis was conducted to determine whether there was any change in the physical and chemical data for April and September between 2022 and 2024.

Laboratory studies

Samples were fixed in situ with 4% buffered formaldehyde solution and brought to the laboratory at the same day. After two 10-day sedimentation periods in the dark, they were placed in tubes and labeled. All samples were examined with an Olympus BX-43F phase-contrast microscope. Photographs of *P. hartmannii* were taken at various growth stages and their lengths were measured. Counts were made using both the single-drop counting method (Lackey, 1938) and the Sedgewick-Rafter counting chamber. Qualitatively, species lists were generated according to stations and seasons using spreadsheet software. During the annual monitoring in the bay, the distribution of other dinoflagellate species across stations were also examined. Using their abundance information, the changing proportions of *P. hartmannii* within the total dinoflagellate population were calculated and tabulated using spreadsheet software. In microscopic studies on the *P. hartmanni* species, the studies of Martin, 1929; Hulburt, 1957 and Tomas, 1997 were used. Regarding dinoflagellate species transported in ballast tanks, the studies of Anderson, 1995; Landsberg, 2002 and Hallegraeff and Bolch, 1992, 1998 were used. The latest status regarding the various synonyms and final nomenclature of the species was checked from the AlgaeBase (Guiry and Guiry, 2025) and WoRMS (WoRMS, 2025) web pages.

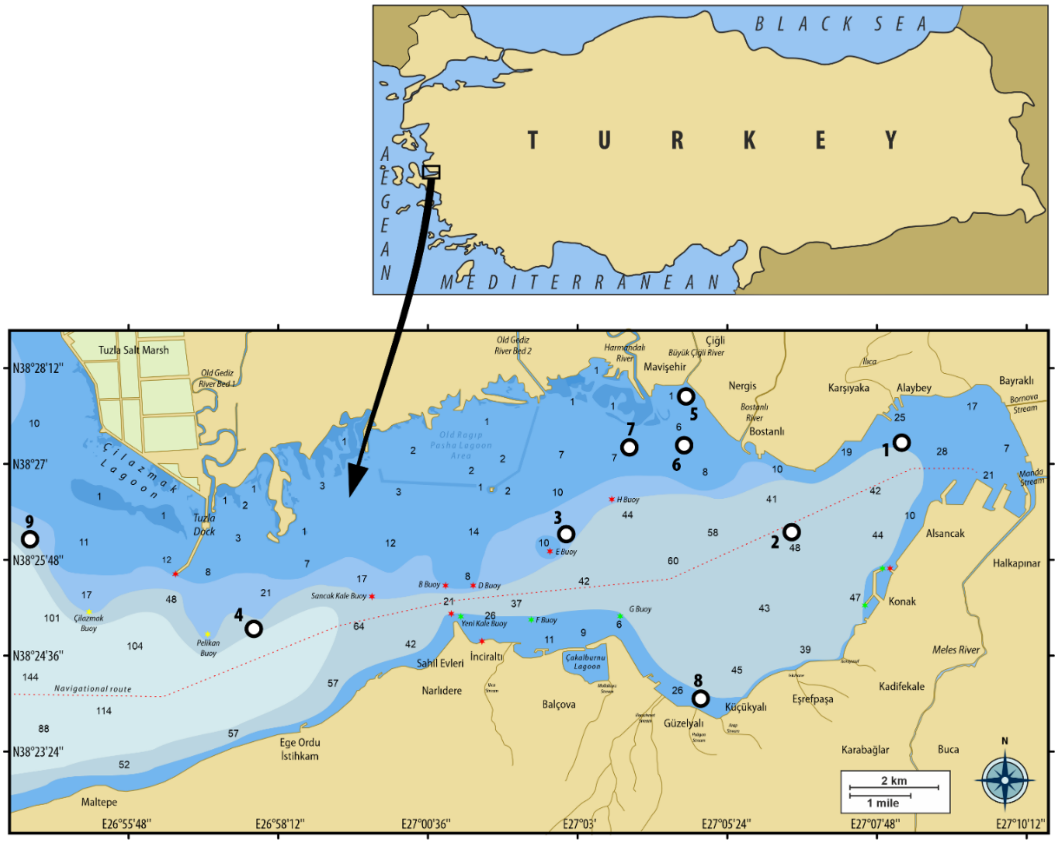

Figure 1. The locations of the 9 sampling stations selected from İzmir Bay

Table 1. Coordinates of the sampling stations

	Coordinates
1	38°27'15"N 27°08'14"E
2	38°26'08"N 27°06'27"E
3	38°26'03"N 27°02'40"E
4	38°25'13"N 26°57'58"E
5	38°27'55.31"N 27° 4'43.21"E
6	38°27'17.89"N 27° 4'46.52"E
7	38°27'11.17"N 27° 3'53.81"E
8	38°24'3.81"N 27° 4'43.25"E
9	38°26'22.02"N 26°52'52.80"E

Statistical analysis

Physicochemical data obtained as temperature (°C), salinity (ppt), dissolved oxygen (mg/L), and pH were analyzed using one-way analysis of variance (ANOVA) (Girden, 1992) using spreadsheet software. Temperature, salinity, dissolved oxygen, and pH values for April and September were compared using one-way analysis of variance to determine whether there was any change in these values. Ftab, Fcal, and p values were obtained for April and September as a result of the analysis and comparison of the values. It was concluded that a change was present when Ftab values were less than Ftab values ($p<0.05$), and that no change was present when Ftab values were greater than Ftab values ($p>0.05$).

Results

In this study, *P. hartmannii*, which began to be detected in the bay in April 2022, was observed to have a cylindrical structure, measuring 60-80 µm long and 40-48 µm wide, with small brownish ocher chromatophores, a 50-70 µm long flagellum, a prominent dark nucleus, and the formation of pseudocolonies (Fig. 2). Due to the species lacking armor, its fixed and light microscopic examination was difficult because it lyses and loses its specific characteristics after a short time. Microscopic examination of samples taken from sample bottles fixed with lugol and formalin solutions brought to the laboratory revealed that the species had lysed and disintegrated. When it was observed that the species had lost its morphological structure, live specimens were brought from the stations to continue the study (Fig. 3).

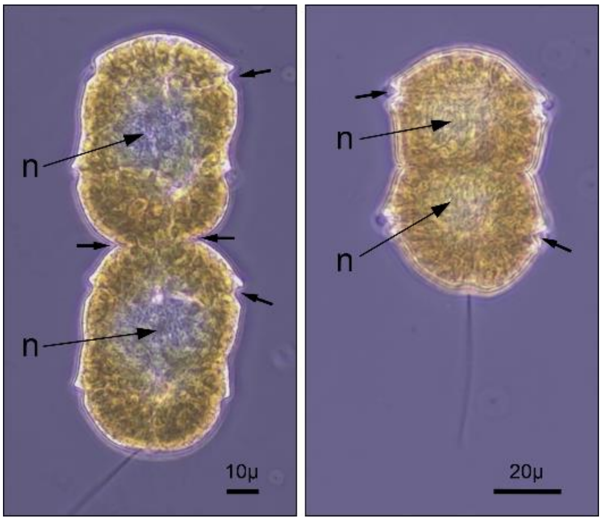

Figure 2. Appearance of *P. hartmannii* observed in Izmir Bay (n: nucleus)

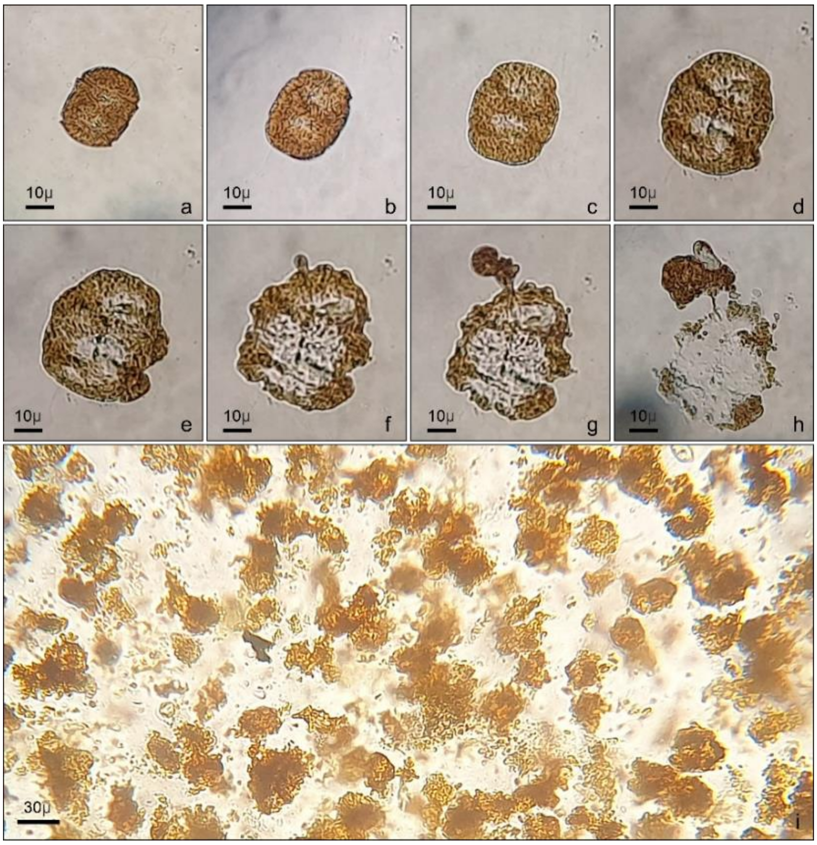

Figure 3. Lysis stages of *P. hartmannii* during light microscope examination (a-h), a general view of collectively lysed cells during bloom (i)

Table 1. Average abundance (cell L⁻¹) of *P. hartmannii* between 2022 and 2025 in İzmir Bay

	2022		**2023**			**2024**		**2025**	
Stations	Apr	Sept	Apr	Sept	Nov	Apr	Sept	Apr	June
1	78	240	11.200	40.950		27.750	56.500	13.640	858
2	31	32	9.200	34.000		24.050	22.500	43.400	663
3	35	70	8.400	31.680		20.350	38.130	81.840	351
4	0	37	7.600	15.600		29.600	20.400	12.834	189
5	0	78	10.400	11.600		34.040	26.250	6.240	126
6	0	76	9.760	9.920		28.860	28.800	4.836	84
7	0	66	9.600	7.840		25.530	55.500	7.409	105
8	19	120	10.800	10.160	12.580.000	53.650	11.700	4.875	504
9	0	80	6.000	31.200	8.860.000	51.800	44.850	2.964	21

In terms of abundance, the highest concentrations of *P. hartmannii* were detected as 12.58×10^6 cell L^{-1} at station 8 and 8.86×10^6 cell L^{-1} at station 9 in November 2023. The possible ichthyotoxic species, which increased in the bay from April 2022 onwards, was most frequently encountered in 2023 and 2024 (Table 1).

In this study, the highest seawater temperature was 25.9°C at station 2 in September 2023, and the lowest was 16.0°C at station 2 in April 2023 (Table 2). When the excessive bloom occurred, the sea water temperature was measured as 20.4 °C at station 8 and 21.9 °C at station 9 in November 2023.

The highest salinity (ppt) was 37.6 at station 5 in April 2025, and the lowest was 28.9 at station 4 in April 2025 (Table 3). Dissolved oxygen was measured as 11.5 mg/L at station 7 in September 2023, and as 4.2 mg/L at station 7 in September 2022 (Table 4). The highest pH was 9.2 at station 3 in September 2022, and the lowest was 8.1 at station 1 in September 2023 (Table 5).

Table 2. Temperature values in seawater between April 2022 and April 2025.

Temperature (°C)							
Stations	**Apr 2022**	**Sep 2022**	**Apr 2023**	**Sep 2023**	**Apr 2024**	**Sept 2024**	**Apr 2025**
1	18.3	25.0	17.5	25.4	18.5	25.5	19.4
2	18.5	24.8	16.0	25.9	18.6	25.4	17.0
3	17.3	24.9	17.0	25.4	18.6	25.5	17.9
4	16.2	25.1	17.0	24.7	17.8	25.1	18.1
5	19.2	22.7	17.6	25.3	19.1	24.9	21.9
6	16.9	24.3	17.2	24.5	18.6	24.7	18.3
7	16.8	24.1	17.3	24.9	17.2	24.9	17.9
8	18.6	25.1	16.5	25.2	17.1	25.3	18.2
9	18.9	24.7	16.8	25.1	18.2	25.1	19.2

Table 3. Salinity values in seawater between April 2022 and April 2025.

Salinity (ppt)							
Stations	**Apr 2022**	**Sep 2022**	**Apr 2023**	**Sep 2023**	**Apr 2024**	**Sept 2024**	**Apr 2025**
1	33.1	36.8	33.0	36.3	32.5	37.0	32.6
2	33.1	36.7	32.9	36.2	32.6	36.6	32.1
3	32.6	36.5	32.8	36.1	32.7	35.9	31.2
4	31.2	30.9	30.7	34.2	30.7	35.8	28.9
5	31.2	30.9	30.7	34.2	30.7	37.2	37.6
6	33.3	36.6	31.9	36.8	32.1	37.1	37.4
7	33.3	36.6	32.4	36.2	32.3	37.3	37.1
8	33.1	36.7	33.2	36.2	33.2	35.9	30.8
9	33.1	36.6	32.8	36.3	32.9	36.8	32.4

Table 4. Dissolved oxygen values in seawater between April 2022 and April 2025.

Dissolved oxygen (mg/lt)							
Stations	**Apr 2022**	**Sep 2022**	**Apr 2023**	**Sep 2023**	**Apr 2024**	**Sept 2024**	**Apr 2025**
1	7.70	6.20	11.0	8.10	9.7	6.60	11.2
2	7.50	6.50	10.0	7.10	9.9	7.50	10.4
3	7.80	7.10	9.70	7.30	9.6	6.64	11.1
4	8.40	4.70	9.40	9.80	9.3	6.40	11.1
5	9.60	6.70	8.60	8.00	8.5	10.0	9.90
6	8.80	4.80	6.90	7.50	6.3	8.50	9.50
7	8.80	4.20	7.50	11.5	6.8	7.20	9.70
8	7.80	6.90	10.2	7.60	9.0	6.40	10.9
9	7.90	6.40	10.5	8.40	8.8	6.90	11.0

Table 5. pH values in seawater between April 2022 and April 2025.

pH							
Stations	**Apr 2022**	**Sep 2022**	**Apr 2023**	**Sep 2023**	**Apr 2024**	**Sept 2024**	**Apr 2025**
1	8.20	9.00	8.30	8.10	8.50	8.40	8.50
2	8.40	9.10	8.40	8.20	8.50	8.50	8.40
3	8.40	9.20	8.30	8.70	8.50	8.50	8.50
4	8.60	8.50	8.20	8.20	8.50	8.50	8.60
5	8.40	8.60	8.70	8.60	8.70	8.70	8.20
6	8.40	8.30	8.60	8.30	8.70	8.70	8.60
7	8.30	8.20	8.50	8.50	8.70	8.70	8.50
8	8.20	8.70	8.20	8.30	8.50	8.50	8.50
9	8.20	8.70	8.50	8.20	8.90	8.40	8.40

Four physicochemical data for the months of April and September were compared using the one-way analysis of variance (ANOVA) method ($p<0.05$) (Girden, 1992). For temperature, $F_{cal}=4.624>F_{tab}=2.901$ was determined in April and $F_{cal}=4.272>F_{tab}=3.403$ in September, and it was observed that there were temperature differences between the April and September months depending on the years at the sampling stations in the bay. No statistically significant difference was observed for salinity between April and September depending on the years ($p>0.05$). When the dissolved oxygen values were evaluated statistically, $F_{cal}=7.942>F_{tab}=2.901$ in April and $F_{cal}=8.721>F_{tab}=3.403$ in September, it was observed that there was a difference in dissolved oxygen values between the April and September months ($p<0.05$). When the pH values were evaluated statistically for the months of April and September, it was determined that $F_{cal}=3.928>F_{tab}=2.901$ in April and $F_{cal}=4.824>F_{tab}=3.403$ in September, and therefore, pH changes were found to be very small in the April and September months depending on the years at the selected stations ($p<0.05$).

During the monitoring studies conducted between 2022 and 2025, and during the November 2023 bloom (samples taken from two stations), *P. hartmannii* was found to be present among the species belonging to the dinoflagellate class. The species increased from April 2022 onwards, and from September 2023 onwards, it became the most frequently observed species among the dinoflagellate class. The most recent sampling was in June 2025, and the percentage of *P. hartmannii* in this month was 37% (Fig. 4)

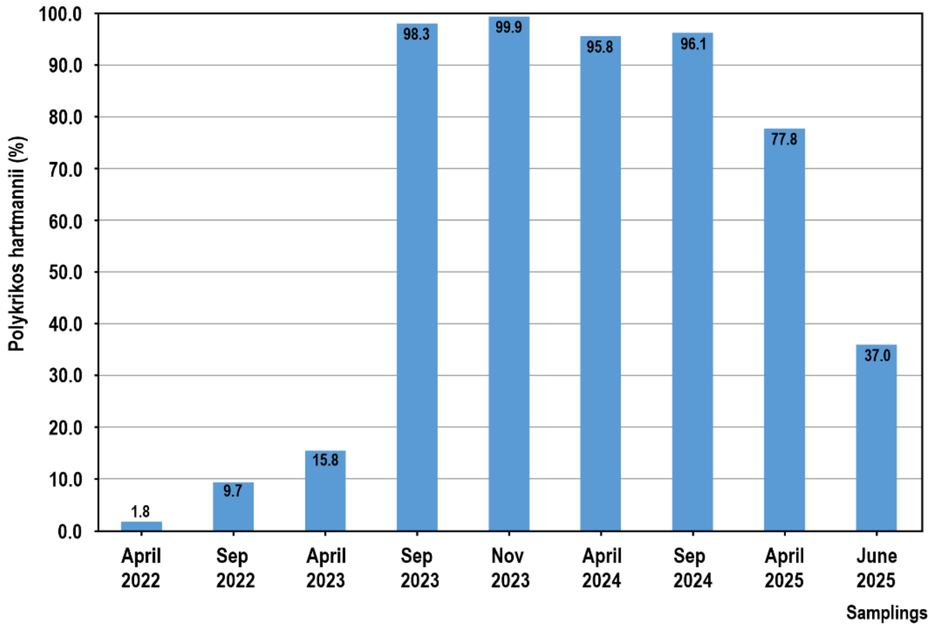

Figure 4. Distribution percentage of *P. hartmannii* in Izmir Bay between April 2022 and June 2025

Discussion

Studies on the dinoflagellate species *P. hartmanii* by various researchers are given above. In many studies, the synonymous name and the last name of the species are mentioned only in the species lists. Details about the species are given in other studies. Cell sizes of *P. hartmannii* in studies conducted by various researchers since 1957 are given in Table 6. The length measurements made during the microscope studies of *P. hartmannii* observed in Izmir Bay are consistent with those of other researchers (Table 6).

Table 6. Length and width measurements related to the *P. hartmannii* species

Author	Country	Region	Length (µm)	Width (µm)
Hulburt, 1957	USA	Massachusetts coasts	60-68	42-47
Tang, 2013	USA	New York coasts	44-60	39-46
Gárate-Lizárraga, 2014a	Mexico	Gulf of California	58-70	40-46
Gárate-Lizárraga, 2014b	Mexico	Bahía de La Paz	70-74	60-64
Escobar-Morales ve Becerril, 2015	USA, Mexico	Gulf of Mexico and the Mexican Pacific	90-100	35-40
Çolak Sabancı ve ark., 2025	Türkiye	İzmir Bay	39,7-34,6	39,6-44,5
This work	Türkiye	İzmir Bay	60-80	40-48

Figures of studies on the chloroplasts, nematocysts and pseudocolonies of the two zooid species previously studied by Martin in 1929, Zimmerman in 1930, Chatton in 1952 and Hulburt in 1957 are shown in Figure 1, and a drawing of the species identified in Izmir Bay is added (Figure 5).

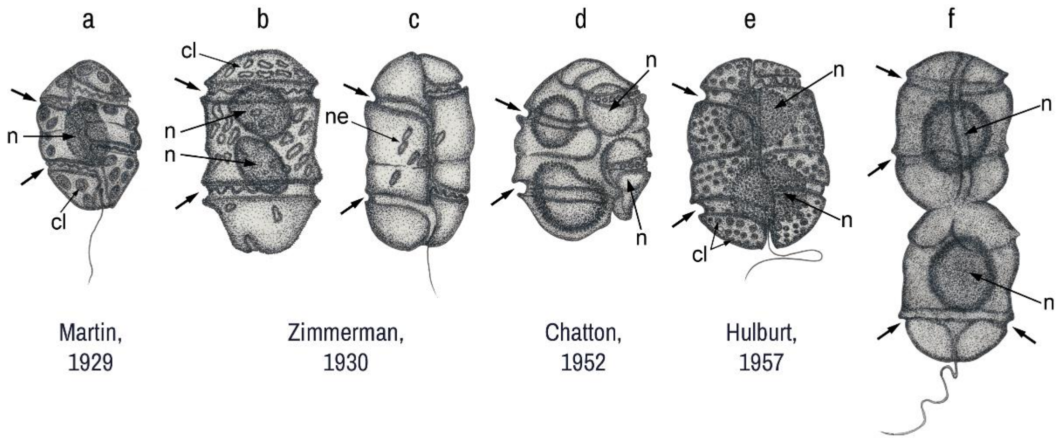

Figure 5. Drawings of some researchers working with the *Polykrikos* species during the stages of species identification

(a) *Polykrikos barnegatensis* from Martin 1929. Ventral view, chloroplasts and one central nucleus (n)

(b) Dorsal view showing the two nuclei (n) and chloroplasts (cl)

(c) Dorsal (b) and ventral (c) views of *Polykrikos hartmanni* from Zimmermann 1930

(d) Ventral view showing nematocysts

(e) *Polykrikos hartmanni* from Hulburt 1957. Ventral view showing the two nuclei (n) and chloroplasts.

(f) Dorsal view of *Polykrikos hartmanni* observed as a pseudocolony in Izmir Bay. Note in all drawings the two transverse furrows (arrows) and the visible border between the two zooids (arrowheads) of the pseudocolony (Modified (not to scale) drawings by Levent Yurga, adapted from Hoppenrath et al., 2013 and Reñé et al. (2013), redrawn for illustrative purposes under fair use in this study.)

P. hartmannii, an unarmored and toxic dinoflagellate, has been reported to feed primarily on other unarmored toxic dinoflagellates, particularly *Margalefidinium polykrikoides* (=*Cochlodinium polykrikoides*), which is responsible for fish mortalities and adverse impacts on mussel farms, as well as on *Gymnodinium catenatum*, a known PSP-producing species (Lee et al., 2015; Lim et al., 2017; Silva et al., 2023). Culture experiments demonstrated a clear feeding preference for *M. polykrikoides*, whereas abundant diatoms (*Skeletonema costatum*) and several other dinoflagellates (*Akashiwo sanguinea, Lingulodinium polyedra*, *Prorocentrum cordatum* (=*P. minimum*), *P. micans* and *Scrippsiella acuminata* (=*S. trochoidea*) were not consumed (Lee et al., 2015). The most preferred prey, the chain-forming *M. polykrikoides,* exhibited a consumption rate of approximately 28% under natural conditions (Lee et al., 2015).

Despite these observations, detailed information on the phagotrophic feeding mechanism of *P. hartmannii* remains limited. Morphological observations from Kuwaiti waters described by Saburova indicate that the species forms two-zooid pseudocolonies with numerous chloroplasts and poorly visible nematocysts, which are only discernible shortly before cytolysis, potentially obscuring direct evidence of feeding structures or behavior (Al-Yamani & Saburova, 2019).

In the present study, *M. polykrikoides, L. polyedra, P. cordatum, P. micans, Salpingella acuminata* and *A. sanguinea* were recorded at stations 1, 2 and 8 between April 2022 and June 2025, coinciding with the occurrence of *P. hartmannii*. However, *M. polykrikoides* was observed only rarely and did not form blooms, and no cysts of *P. hartmannii* were detected.

ANOVA statistical comparisons of salinity between stations in April and September between 2022 and 2025 revealed no difference. Since no statistical change was observed in the salinity values of April and September the proliferation of the species in the bay has nothing to do with the salinity in the sea water. Salinity changes are related to the species producing more cysts. The encystation activity of *P. hartmannii* is related to changes in nitrate and salinity in the environment (Dzhembekova et al., 2024). Furthermore, the species can reproduce in direct proportion to environmental salinity (Liu et al., 2023).

Grazing by zooplanktonic organisms, especially copepods, and consumption by dinoflagellates of toxic phytoplanktonic organisms and other toxic dinoflagellates as food does not harm the feeders; they accumulate the toxins in their bodies and when they are consumed by organisms at higher levels as food (Teegarden and Cembella, 1996), the toxins are passed on to organisms at higher levels of the food chain. As a result of this transfer, fish, seabirds, marine mammals and humans are affected by the toxins (Turner et al., 2000).

The dinoflagellate species *P. hartmannii*, whose toxic mechanism is not yet understood (Tang et al., 2013; Deng et al., 2023), was first observed in the Black Sea (coast of Crimea, Ukraine) in 1991 (Senichkina et al., 2001). In subsequent years, it continued to be observed in the Black Sea (Bulgaria, Romania, Ukraine) in studies especially on dinoflagellate cysts (Mudie et al., 2017; Krakhmalny et al., 2018; Dzhembekova et al., 2024). The species has also been reported from Güllük Bay in the Southern Aegean Sea (Aktan and Keskin, 2017). In a comprehensive study on dinoflagellate cysts, it was reported from the Sea of Marmara (Balkis et al., 2016). When the studies on the *P. hartmannii* species in the checklist of marine dinoflagellates on the coasts of Türkiye are examined, it is known that 22 studies were conducted in the Black Sea, 22 in the Sea of Marmara, and 62 in the Aegean Sea (Çolak Sabanci, 2024). Although it was seen in the sampling studies in Izmir Bay that started in 2022 and continued until April 2025, the first record of the species was made in 2025 by (Sabancı et al., 2025). The species, which started to be seen in April 2022, did not show excessive proliferation during the monitoring studies conducted throughout 2022. In the official monitoring studies conducted in the Bay of Izmir during April 2023 and especially in November 2023, it has intense bloom throughout the entire bay and dominated the native dinoflagellate species in the bay. In November 2023, it has over-proliferated to an extent never observed before. It is thought that the species, which was detected in studies conducted in the Black Sea and the Marmara Sea between 1991 and 2024 (Moncheva, 2015; Dzhembekova et al., 2024) and later started to be seen in the Bay of Izmir from 2022 onwards, is most likely due to being transported in the ballast tanks of ships. This highlights the importance of monthly monitoring in the bay. It will be easy to record species most likely transported via ballast tanks, and it will also enable monitoring of species that are experiencing seasonal overgrowth among the bay's native species.

Although the number of studies conducted on the transportation of HAB-causing organisms in ballast tanks is low (Sonak et al., 2018), it is thought that ballast tanks play an important role in the spread of HAB-causing species (Anil et al., 2002). It has been known for a long time that diatoms, dinoflagellates and their resting cysts, whether toxic or not, are transported in significant amounts in ballast tanks, along with vertebrates and invertebrates (Ostenfeld, 1908), and the groups of organisms transported in ballast tanks are being studied (Hallegraeff and Bolch, 1992; Hallegraeff 1998; Hamer et al., 2001; Yurga 2021).

Although the molecular structure of the toxin contained in the species has not yet been identified, there are studies on the biological effects (ichthyotoxin) of the toxin. It has been reported that *P. hartmannii* species causes indeed ichthyotoxic poisoning that leads to mass fish kills due to excessive blooms in (910 - 1,370 cell mL^{-1}) USA (Badylak and Phlips, 2004); distributed along the entire Gulf of México coast and causing 100% mortality on Sheepshead minnow *(Cyprinodon variegatus)* on Long Island, New York (Tang et al., 2013) and listed as a harmful dinoflagellat species in the USA HAB History work (Anderson et al., 2021) and in South Korea (Thangaraj et al., 2017). Other studies on its excessive blooms were conducted in China (Huang and Dong, 2001), in USA (Sonak et al., 2018; Phillipp et al., 2017), *P. hartmannii* is listed in the UNESCO Taxonomic Reference List of Harmful Micro Algae in the USA and is currently monitored at FWRI (2025). The recently obtained results suggest that, in addition to hypoxia, this species may contribute toward fish kills in neritic habitats (Tang et al., 2013).

Although a study by Çolak Sabancı et al., 2024 reported a maximum of 48.000 cells L^{-1} in November (Çolak Sabanci et al., 2025), the increase was found to be greater at stations 8 and 9 in this study (12.58 x 10^6 cell L^{-1} at station 8 and 8.86 × 10^6 cells L^{-1} at station 9). The amount at these two stations in November 2023 was counted three times and the average was taken. It is thought that the significant bloom seen in İzmir Bay in November 2023 was caused by streams loaded with domestic and industrial waste constantly flowing into the bay. Due to population growth, biological treatment facilities are sometimes insufficient. The concentrations of copper and other elements, especially phosphate, in the bay should be monitored throughout the year for this species. It has been found that the bloom of the *P. hartmannii* in the environment is correlated with $PO_4{}^{-P}$ (Hii et al., 2021).

The Ege University Faculty of Fisheries is working with the Izmir Metropolitan Municipality to address *P. hartmannii*, which was first observed in small numbers in the Izmir Bay in April 2022 and has shown seasonal proliferations in subsequent monitoring studies. The studies are being carried out with the support of İzmir Water and Sewerage Administration (İZSU), Ege University Faculty of Fisheries and The Scientific and Technological Research Council of Türkiye (TÜBİTAK) and Marmara Research Center in the Bay of Izmir, Türkiye. *P. hartmannii*, whose toxicity will be confirmed by scientific studies conducted in the coming years and whose toxin will be identified, has attracted the attention of scientists, the Izmir Metropolitan Municipality, and the press since its initial detection in 2022. It is believed that this dinoflagellate species was responsible for the mass fish kills observed intermittently in the bay between 2023 and 2025. This possible toxic species should be periodically monitored, along with the collection of physical and chemical parameters in the bay.

Conclusions

The ichthyotoxic dinoflagellate *Polykrikos hartmannii*, despite its specific toxin remaining unidentified to date, it is noteworthy that the species, thought to have been transported via ballast tanks starting in 2022, has proliferated to the point of covering the entire bay, as it did throughout 2023 and 2024. The increase observed in November 2023 is unparalleled compared to previous increases of dinoflagellate species in the bay. Overgrowths of dinoflagellate species are known to reduce seawater quality and cause mass fish kills in coastal areas. *P. hartmannii* is thought to be responsible for the mass fish kills observed in the bay between 2023 and 2024. An examination of the species' abundance distribution using physicochemical parameters revealed no significant decrease, particularly in oxygen levels. Pollution has been increasing in the bay since in the the beginning 2020s, and the excessive bloom of *P. hartmannii* is thought to be related to this pollution. Therefore, it is important to sample chlorophyll-a, nitrate, and other nutrients in monitoring studies of dinoflagellate species with the potential for overgrowth in the bay, including *P. hartmannii*, and other HABs. Furthermore, the dinoflagellate species P. hartmannii should be also carefully monitored periodically during these studies. Whether toxic or not, monitoring of potentially overgrowth HAB species will also provide resources for future studies on marine ecosystem biodiversity.

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Ethics Approval

The author declares that this study complies with research and publication ethics

Informed consent

Not available

Conflict of Interest Statement

There is no conflict of interests for publishing their study

Data availability statement

The data sets generated during and/or analysed during the current study will be provided by the corresponding author upon the request of the editor or reviewers.

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