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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Checklist of marine pelagic diatoms from the Turkish side of the Aegean Sea

Ege Denizi'nin Türkiye kıyılarındaki pelajik denizel diyatomların kontrol listesi

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Abstract: This study presents a comprehensive checklist of marine diatoms recorded along the Turkish coast of the Aegean Sea, based on the evaluation of 41 literature studies. A total of 194 diatom species, belonging to 75 genera, were identified in the pelagic waters of the region, with 32 species recognized as harmful. Among them, several species exhibited bloom events or reached high cell concentrations. The study also highlights significant research gaps, particularly the limited application of molecular techniques and some species are known to have domoic acid-producing potential, but their toxicity remains unexamined in this region due to the lack of dedicated studies. Future research should prioritize integrating molecular methods and domoic acid analyses to improve species identification, assess harmful algal bloom (HAB) risks, and strengthen long-term monitoring strategies. Furthermore, regularly updating species checklists is essential for developing comprehensive datasets, enhancing biodiversity assessments, and advancing phytoplankton research along the Turkish coast of the Aegean Sea.

Keywords: Aegean Sea, Türkiye, marine diatom, checklist

Öz: Bu çalışma, Ege Denizi'nin Türkiye kıyılarında kaydedilen denizel diyatom türlerine ilişkin bir kontrol listesi oluşturmak amacıyla 41 literatür çalışmasının değerlendirilmesiyle hazırlanmıştır. Bölgedeki pelajik sularda toplamda 75 cinse ait 194 diyatom türü tespit edilmiş olup, bunlardan 32'si zararlı tür kategorisine girmektedir. Bu türler arasında bazıları aşırı üreme göstermiştir. Bu çalışma, özellikle moleküler tekniklerin sınırlı kullanımı ve bazı türlerin domoik asit üretme potansiyeline sahip olmasına rağmen, bu bölgede toksisite değerlendirmelerinin eksikliği gibi önemli araştırma boşluklarını ortaya çıkarmaktadır. Gelecekteki araştırmalar, tür tespitinin doğruluğunu artırmak, zararlı alg üreme (HAB) risklerini değerlendirmek ve uzun vadeli izleme stratejilerini güçlendirmek için moleküler yöntemlerin ve domoik asit analizlerinin entegrasyonuna öncelik vermelidir. Ayrıca, tür kontrol listelerinin düzenli olarak güncellenmesi, kapsamlı veri setlerinin oluşturulması, biyolojik çeşitlilik değerlendirmelerinin geliştirilmesi ve Ege Denizi'nin Türkiye kıyılarındaki fitoplankton araştırmalarının ilerletilmesi açısından kritik öneme sahiptir.

Anahtar kelimeler: Ege Denizi, Türkiye, denizel diyatom, kontrol listesi

INTRODUCTION

Phytoplankton, a diverse group of prokaryotic and eukaryotic microorganisms, form the foundation of marine food webs and contribute approximately 50% of the total annual global primary production, regulating biogeochemical processes and influencing climate dynamics (Litchman et al., 2015; Mattei and Scardi, 2021). Among phytoplankton, diatoms represent one of the most dominant eukaryotic groups, thriving across all latitudes, from polar to tropical regions, and occupying a wide range of aquatic habitats (Assmy and Smetacek, 2009). They contribute approximately 20–25% of global primary production (Round, 1990), highlighting their major role in oceanic productivity. Their widespread distribution is attributed to their efficient survival mechanisms and highly adaptable growth strategies (Dhar et al., 2015). A key factor in their ecological success is their ability to utilize silica for frustule synthesis, a process that requires minimal energy expenditure compared to other structural components (Raven, 1983). Diatoms require nutrient-rich environments and turbulence to remain in suspension, supporting their growth and are commonly found in coastal regions due to freshwater inputs, upwelling systems and anthropogenic influences with ecological changes and hydrodynamic processes, contribute to elevated nutrient levels that enhance phytoplankton growth and promote bloom formation (Bates and Trainer, 2006; Litchman, 2007; Davidson et al., 2014; Feist and Levin, 2016). Although diatoms are also present in open ocean waters, their ecological role and abundance are significantly higher in coastal zones, where they contribute substantially to silica cycling and marine productivity (Tréguer and De La Rocha, 2013).

Diatoms are eukaryotic microorganisms classified within the Domain Eukaryota, Kingdom Chromista and Phylum Bacillariophyta. They are represented by a total of 19,126 extant species, which are further divided into three distinct classes: Bacillariophyceae (15,258 species), Coscinodiscophyceae (1,819 species), and Mediophyceae (2,049 species), as registered in an online database (Guiry and Guiry, 2025). However, this number is continuously updated due to the discovery of new species and ongoing taxonomic revisions. Among these, 31 of them are considered harmful algae (Hallegraeff et al., 2021). 17 of which are known to produce domoic acid and cause Amnesic Shellfish Poisoning. The majority of these ASP-producing diatoms belong to the genus *Pseudo-nitzschia* (15 species), while species from the genera *Halamphora* and *Nitzschia* have also been identified as domoic acid producers, (Zingone et al., 2021). Research on diatom ecology, taxonomy and distribution has been a subject of scientific interest for centuries.

The study of diatoms has a long history, dating back to the early 18th century, when they were first observed and illustrated by an unidentified English microscopist (Mann, 2010). In the following years, after mid-to-late 19th century illustrations became instrumental in the systematics and biogeography of diatoms across various seas, as documented in atlases and monographs (Ehrenberg 1832; 1839; 1841; 1851; 1854; Smith, 1853; Schmidt et al., 1874-1959; Cleve, 1894–1895; Karsten, 1899, 1906; Peragallo and Peragallo, 1897–1908; Lebour, 1930; Cupp, 1943; Sournia, 1986; Tomas, 1997; Witkowski et al., 2000). To visualize fine structural details that cannot be observed under light microscopy, scanning electron microscopy (SEM) began to be used for diatoms in the early to mid-20th century (Gaul et al., 1993 and therein). By the end of the 20th century, the first DNA sequence analysis of diatoms was conducted, marking a significant advancement in their taxonomic and phylogenetic studies (Medlin et al., 1988). Since then, research has continued with the application of new genetic regions and primers, further enhancing the accuracy of species identification and phylogenetic resolution, and ecological impacts (Medlin et al., 1996; Medlin et al., 2004; Theriot et al., 2009; Kooistra et al., 2008; Zimmermann et al., 2014; Piredda et al., 2018; Bailet et al., 2020; Martin et al., 2022; Wang et al., 2022; Gaonkar and Campbell., 2023; Smucker et al., 2024).

Phytoplankton research along the Turkish coast of the Aegean Sea began in the 1950s, following a catastrophic algal bloom event that resulted in a significant fish kill, as documented by Nümann (1955). This event represents the first documented phytoplankton study in Türkiye. Despite being the first recorded bloom event, species-level identifications did not begin until the early 1960s and research on phytoplankton gradually expanded over time. The earliest documented study specifically focusing on phytoplankton in the Aegean Sea was conducted by Ergen (1967). Since then, studies on phytoplankton composition, bloom dynamics, and ecological interactions have continued to develop in the region. Among these, several publications have reported diatom blooms or high cell concentration along Turkish coasts of Aegean Sea (Koray et al., 1992; Koray, 1995; Metin and Cirik, 1999; Bizsel et al., 2001; Çolak Sabancı and Koray, 2001; Yurga et al., 2005; Gençay and Büyükışık, 2006; Sabancı and Koray, 2007; Yucel Gier et al., 2008; Balkıs, 2009; Sabancı and Koray, 2011a; Sabancı and Koray, 2011b; Güreşen and Aktan Turan, 2014; Yurga, 2022). The study includes a compilation of diatom species that have been documented in the literature as bloom-forming, reaching high cell concentrations, or have been identified as harmful algal bloom (HAB) species.

This study aims to compile a collective and comprehensive checklist of diatom species reported in the marine pelagic zone along the Turkish coast of the Aegean Sea, based on previous peer-reviewed publications, thereby consolidating dispersed data into a unified regional reference. Additionally, we aim to identify species that exhibited bloom events or reached high cell concentrations as documented in the literature. The study also aims to highlight understudied areas and research gaps in marine pelagic diatom research across Turkish side of the Aegean Sea.

MATERIALS AND METHODS

This study is based on a review of diatom literature covering the sampling of diatom species recorded in pelagic regions along the Turkish coasts of the Aegean Sea, focusing solely on marine studies.

The Aegean Sea, a sub-basin of the Eastern Mediterranean located between Greece and Turkey, has the longest coastline along Turkey's western shores, stretching 3,484 km. Turkish coast of the Aegean Sea is divided into three regions: the North, Middle, and South Aegean. Each of these regions is characterized by distinct environmental features that influence marine productivity. The North Aegean is influenced by freshwater input from the Dardanelles and surrounding river systems, leading to broader nutrient variability and more diffuse pollution. The Middle Aegean is subject to intense industrial activity and high population, especially near urbanized coastal areas. In contrast, the South Aegean is heavily affected by seasonal tourism, where fluctuations in wastewater loads pose challenges for treatment infrastructure. While the Aegean Sea is generally considered oligotrophic, localized nutrient enrichment, especially in semi-enclosed bays and gulfs can significantly increase pelagic productivity, often driven by anthropogenic pressures (ÇŞİDB and TUBİTAK-MAM, 2021 therein)

The literature review consisted of 41 references focusing on pelagic diatoms, and studies conducted along the Aegean Sea between 1960 and 2024. Only articles published in peer-reviewed journals were included in the references. Other sources, such as master's and doctoral theses, environmental impact assessment reports, monitoring reports, private sector project studies, and review articles, were excluded. To categorize species based on their occurrence across studies, Soyer's frequency index (Soyer, 1970) was applied. This index calculates the frequency (F) of each species using the formula: $F (\%) = (Na/Nn) \times 100$. (Na: Number of studies in which the species was recorded, Nn: Total number of studies) Based on the calculated frequency, species were classified into three categories: constant ($F \geq 50\%$), common ($25\% \leq F < 50\%$), and rare ($F < 25\%$). The reviewed literature revealed that phytoplankton sampling in the pelagic region of the Aegean Sea was conducted using plankton nets, and Nansen bottles for sample collection, with formaldehyde and Lugol's solution being the most used preservatives for sample fixation.

The nomenclature of the taxa reported in this study has been updated according to Guiry and Guiry (2025). Some species have been recorded under different names based on their final taxonomic classification. Taxa labeled as "sp." or "confer" in the species lists were excluded, as their identification requires further verification. The identification of diatom species recognized as harmful on a global scale was conducted using the IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae database (Lundholm et al., 2009) and the AlgaeBase database (Guiry and Guiry, 2025).

RESULTS

There are 41 studies conducted in the pelagic region of the Turkish part of the Aegean Sea between 1960 and 2024. Among these, 28 studies were carried out in the Middle Aegean Sea, 10 in the North Aegean Sea and 8 in the South Aegean Sea. Notably, some studies included multiple sampling sites, resulting in a total of 46 distinct pelagic sampling regions along the Turkish Aegean coast. Among these studies, visual materials such as light micrographs and illustrations were provided regional variation: 3 light micrographs were included in studies from the North Aegean, 3 from the Middle Aegean, and 1 from the South Aegean. Additionally, illustrations were presented in 2 studies from Middle Aegean, and 1 study each from North and South Aegean regions. Notably, no studies included electron micrographs (Table 1).

According to results from phytoplankton research conducted over the years a total of 194 species have been identified in the pelagic region of the Aegean Sea, 32 of which are recognized globally as harmful species (Table 2).

Table 1. List of literature used in this study (*: Indicates qualitative studies, **: Indicates quantitative studies, n/a: Sampling date not available, +L: Light micrograph included, – :No visual representation provided, +I: illustration included, N: North Aegean Sea, M: Middle Aegean Sea, S: South Aegean Sea).

Author	Sampling Date	Visual Material	Area
1. Ergen (1967) *	n/a	L, I	M
2. Gökalp (1972) *	1970	I	N-S
3. Gökpınar and Koray (1983) *	n/a	I	M
4. Koray (1987) *	1980-1984	L	M
5. Koray (1988) *	1978-1985	L	M
6. Koray (1990) *	1982-1984	–	M
7. Koray et al. (1992) **	1980-1990	–	M
8. Koray and Kesici (1994) *	1990-1991	–	S
9. Koray et al. (1994) *	1990-1991	–	S
10. Koray (1995) **	1978-1990, 1985-1986, 1989-1990	–	M
11. Bizsel et al. (1997) *	1993-1994	–	M
12. Metin and Cirik (1999) **	1993-1994	–	M
13. Koray et al. (1999) *	1996	–	M
14. Koray et al. (2000) *	1994-1997	–	M
15. Demir and Atay (2000) **	1997	–	S
16. Bizsel et al. (2001) **	1993-1994	–	M
17. Çolak Sabancı and Koray (2001) **	1998-1999	–	M
18. Demir (2001) **	1999	–	M
19. Koray (2004) **	1980–2002	–	N-M-S
20. Gençay and Büyükışık (2004) **	1992-1993	–	M
21. Sabancı and Koray (2005) **	1998-2001	–	M
22. Balkıs (2005) *	2000-2001	L	N
23.Yurga et al. (2005) **	2004-2005	–	M
24. Gençay and Büyükışık (2006) **	1994-1995	–	M
25. Kükrer and Aydın (2006) **	2003-2004	–	M
26. Sabancı and Koray (2007) **	1998-2000- 2001-2002	–	M
27. Aktan Turan et al. (2007) **	2006	–	S
28. Yücel Gier et al. (2008) **	2000-2001	–	M
29. Balkıs (2008) *	2001	L	N
30. Balkıs (2009) **	2000-2001	–	N
31. Sabancı and Koray (2011a) **	1998-2001	–	M
32. Altuğ et al. (2011) *	2006-2007	–	N
33. Sabancı and Koray (2011b) **	2008-2010	–	M
34. Çolak Sabancı and Koray (2012) **	2008-2010	–	M
35. Taş (2014) **	2002-2004	L	S
36. Ağlaç and Balkıs (2014) **	2003-2004	L	N
37. Güreşen and Aktan Turan (2014) **	2009-2010	–	N
38. Yurga (2015) **	2000-2015	–	M
39. Yurga (2022) **	1990-2016, 2017-2020	–	M
40. Akçaalan et al. (2023) *	2021	–	N
41. Şahin (2024) *	2014-2016	–	N-M-S

Table 2. Checklist of diatom species reported from the previous 41 papers. The numbers following a species name in the checklist refer to the list of literature.

Species List	Literature
Coscinodiscophyceae	
Actinoptychus splendens (Shadbolt) Ralfs 1861	41
Asterolampra grevillei (Wallich) Greville 1860	4, 8, 9, 10, 14, 17, 26, 30, 35, 36
Asterolampra marylandica Ehrenberg 1844	1,4, 8, 9, 10, 14, 17, 21, 26, 30, 31, 33, 35, 36, 41
Asterolampra vanheurckii Brun 1891	8
Asteromphalus flabellatus (Brébisson) Greville 1859	4, 10, 14, 35
Asteromphalus heptactis (Brébisson) Ralfs 1861	4, 8, 10, 35
Coscinodiscus centralis Ehrenberg 1839	23, 41
Coscinodiscus concinnus W.Smith 1856	4, 10, 13, 14, 36
Coscinodiscus granii L.F.Gough 1905	4, 7, 10, 13, 14, 26, 30, 33, 38, 39, 41
Coscinodiscus janischii A.W.F.Schmidt 1878	41
Coscinodiscus pavillardii Forti 1922	4, 10, 14, 26
Coscinodiscus perforatus Ehrenberg 1844	1,4, 30, 36, 41
Coscinodiscus radiatus Ehrenberg 184	4, 10, 13, 14, 26, 30, 32, 36, 41
Coscinodiscus wailesii Gran & Angst 1931	13, 41
Dactyliosolen antarcticus Castracane 1886	23
Dactyliosolen blavyanus (H.Peragallo) Hasle 1975	13, 18
Dactyliosolen fragilissimus (Bergon) Hasle 1996	3, 4, 10, 13, 14, 17, 18, 21, 23, 26, 27, 30, 31, 32, 33, 35, 41
Dactyliosolen mediterraneus (H.Peragallo) H.Peragallo 1892	4, 5, 8, 9, 10, 12, 13, 14, 17, 23, 26, 30, 35, 36
Eupyxidicula turris (Greville) S.Blanco & C.E.Wetzel 2016	10, 14
Guinardia delicatula (Cleve) Hasle 1997	4, 10, 12, 14, 17, 21, 26, 30, 31, 32, 33, 35, 36
Guinardia flaccida (Castracane) H.Peragallo 1892	4, 8, 9, 10, 12, 13, 14, 17, 18, 21, 23, 26, 30, 31, 33, 35, 36, 41
Guinardia striata (Stolterfoth) Hasle 1996	3, 4, 8, 9, 10, 13, 14, 17, 18, 21, 23, 26, 30, 31, 32, 33, 35, 36, 38, 41
Guinardia tubiformis (G.R.Hasle) Hasle 1996	12
Melosira inflexa (Roth) Guiry 2019	30, 41
Melosira varians C.Agardh 1827	41
Neocalyptrella robusta (G.Norman ex Ralfs) Hernández-Becerril & Meave 1997	3, 4, 8, 9, 10, 13, 14, 17, 21, 23, 26, 30, 31, 33, 36, 41
Paralia sulcata (Ehrenberg) Cleve 1873	4, 10, 14
Pseudosolenia calcar-avis (Schultze) B.G.Sundström 1986	1, 2, 3, 4, 8, 9, 10, 12, 13, 14, 15, 17, 21, 23, 26, 27, 30, 31, 32, 33, 35, 36, 39, 41
Rhizosolenia acuminata (H.Peragallo) H.Peragallo 1907	4, 10, 30
Rhizosolenia alata Brightwell 1858	2, 3, 4, 15, 18
Rhizosolenia bergonii H.Peragallo 1892	4, 10
Rhizosolenia castracanei H.Peragallo 1888	2, 3, 4, 8, 10, 14, 30, 36, 41
Rhizosolenia hebetata f. *semispina* (Hensen) Gran 1908	3, 4, 10,35
Rhizosolenia hebetata J.W.Bailey 1856	2, 4, 30, 41
Rhizosolenia imbricata Brightwell 1858	2, 3, 4, 8, 9, 10, 13, 14, 17, 21, 23, 26, 30, 31, 33, 35, 38, 41
Rhizosolenia styliformis T.Brightwell 1858	1, 3, 4, 5, 8, 9, 10, 12, 14, 15, 17, 23, 25, 26, 30, 35, 36, 41
Rhizosolenia temperei H.Peragallo 1888	3, 4, 8, 9, 10
Sundstroemia pungens (Cleve-Euler) Medlin, Lundholm, Boonprakob & Moestrup 2021	41
Sundstroemia setigera (Brightwell) Medlin 2021	3, 4, 10, 13, 14, 17, 18, 21, 23, 26, 30, 31, 33, 39, 41
Triceratium pelagicum (J.L.B.Schröder) Sournia 1968	4, 10
Mediophyceae	
Bacteriastrum biconicum Pavillard 1916	41
Bacteriastrum comosum Pavillard 1916	41
Bacteriastrum delicatulum Cleve 1897	4, 8, 9, 10, 12, 13, 14, 17, 18, 21, 23, 26, 30, 31, 33, 35, 36, 41
Bacteriastrum elegans Pavillard 1916	4, 8, 10, 17, 21, 26, 30, 31, 33, 36, 38
Bacteriastrum elongatum Cleve 1897	4, 10, 12, 30, 35, 41
Bacteriastrum furcatum Shadbolt 1853	41
Bacteriastrum hyalinum Lauder 1864	4, 8, 9, 10, 12, 13, 14, 17, 21, 23, 26, 30, 31, 33, 36, 41
Bacteriastrum mediterraneum Pavillard 1916	4, 10, 21, 26, 31, 38
Biddulphia biddulphiana (J.E.Smith) Boyer 1900	4, 8, 10, 13, 18, 30, 38, 41
Biddulphiella tridens (Ehrenberg) P.A.Sims & M.P.Ashworth 2022	4, 8, 10
Cerataulina pelagica (Cleve) Hendey 1937	4, 8, 10, 13, 14, 17, 21, 23, 26, 30, 31, 32, 33, 36, 37, 41
Chaetoceros affinis Lauder 1864	2,4, 8, 9, 10, 12, 13, 14, 15, 17, 18, 20, 21, 23, 24, 26, 30, 31, 33, 35, 38, 41
Chaetoceros anastomosans Grunow 1882	4, 8, 10, 14, 18, 30, 41
Chaetoceros atlanticus Cleve 1873	4, 10,12, 14, 18, 30, 41
Chaetoceros atlanticus var. *neapolitanus* (Schroeder) Hustedt 1930	4, 8, 10
Chaetoceros borealis Bailey 1854	4, 10, 13, 35, 41

Table 2. Continued.

Species List	Literature
Chaetoceros brevis F.Schütt 1895	4, 9, 10, 14, 15, 18, 26, 30, 38, 41
Chaetoceros coarctatus Lauder 1864	4,5, 8, 9, 10, 13, 14, 41
Chaetoceros compressus Lauder 1864	4, 8, 10, 13, 14, 17, 18, 26, 30, 35, 41
Chaetoceros constrictus Gran 1897	4, 8, 10, 13, 14, 17, 21, 26, 31, 41
Chaetoceros costatus Pavillard 1911	4, 8, 10, 12, 13, 14, 18, 23, 30, 35, 36, 41
Chaetoceros curvisetus Cleve 1889	4, 8, 10, 12, 13, 14, 18, 23, 30, 35, 41
Chaetoceros dadayi Pavillard 1913	4, 5, 8, 9, 10, 13, 17, 23, 26, 30, 36, 41
Chaetoceros danicus Cleve 1889	4, 8, 10, 14, 30, 35, 36, 39, 41
Chaetoceros debilis Cleve 1894	13, 41
Chaetoceros decipiens Cleve 1873	4, 8, 9, 10, 12, 13, 14, 15, 17, 18, 20, 21, 23, 26, 30, 31, 33, 35, 36, 38, 41
Chaetoceros densus (Cleve) Cleve 1899	13, 39, 41
Chaetoceros diadema (Ehrenberg) Gran 1897	4, 10, 13, 14, 30, 35, 36, 41
Chaetoceros didymus Ehrenberg 1845	17, 18, 21, 23, 26, 30, 31, 33, 36, 41
Chaetoceros didymus var. *anglicus* (Grunow) Gran 1908	4, 10, 13,38
Chaetoceros diversus Cleve 1873	4, 8, 9, 10, 14, 17, 26, 35, 41
Chaetoceros eibenii Grunow 1882	4, 10, 30, 35, 36
Chaetoceros holsaticus F.Schütt 1895	14, 30, 35, 36
Chaetoceros laciniosus F.Schütt 1895	4, 8, 10, 13, 14, 23, 26, 35, 41
Chaetoceros lauderi Ralfs ex Lauder 1864	4, 10, 13, 30, 35
Chaetoceros lorenzianus Grunow 1863	4, 8, 9, 10, 12, 14, 17, 18, 23, 26, 30, 35, 41
Chaetoceros messanensis Castracane 1875	4, 10, 12, 14, 30, 35, 36, 41
Chaetoceros neapolitanus Schröder 1900	36
Chaetoceros neogracilis VanLandingham 1968	4, 8, 10, 13, 14, 17, 21, 26, 31, 35
Chaetoceros peruvianus Brightwell 1856	4, 8, 9, 10, 13, 14, 21, 23, 26, 27, 30, 31, 35, 36, 41
Chaetoceros proschkinae Gogorev 2006	41
Chaetoceros protuberans Lauder 1864	4, 10, 13, 14, 23
Chaetoceros pseudocurvisetus Mangin 1910	4, 8, 10, 13, 14, 30, 36, 38, 41
Chaetoceros radicans F.Schütt 1895	41
Chaetoceros rostratus Ralfs 1864	4, 8, 9, 10, 13, 14, 17, 26, 30, 36, 38
Chaetoceros saltans Cleve 1897	18
Chaetoceros similis Cleve 1896	41
Chaetoceros simplex Ostenfeld 1902	26, 35, 41
Chaetoceros socialis H.S.Lauder 1864	18, 30, 36, 41
Chaetoceros subsecundus (Grunow ex Van Heurck) Hustedt 1930	2
Chaetoceros tenuissimus Meunier 1913	41
Chaetoceros teres Cleve 1896	4, 8, 10, 13, 30, 35, 41
Chaetoceros tetrastichon Cleve 1897	4, 10, 14, 30, 41
Chaetoceros tortissimus Gran 1900	4, 8, 9, 10, 13, 14, 35
Chaetoceros wighamii Brightwell 1856	4, 8, 10, 14, 35
Chaetoceros willei Gran 1897	4,10,14,35
Climacosphenia elongata Bailey 1854	38
Climacosphenia moniligera Ehrenberg 1843	9, 13, 18, 23, 24, 26, 33, 35, 41
Detonula confervacea (Cleve) Gran 1900	35, 41
Detonula pumila (Castracane) Gran 1900	4, 8, 10, 13, 17, 21, 23, 26, 30, 31, 33, 38, 41
Ditylum brightwellii (T.West) Grunow 1885	4, 10, 13, 14, 17, 21, 23, 26, 30, 31, 33, 36, 41
Eucampia cornuta (Cleve) Grunow 1883	13, 17, 21, 23, 26, 30, 31, 33, 36
Eucampia zodiacus Ehrenberg 1839	4, 8, 10, 12, 13, 14, 17, 21, 23, 26, 30, 31, 33, 36, 41
Helicotheca tamesis (Shrubsole) M.Ricard 1987	4, 10, 26, 35, 38
Hemiaulus chinensis Greville 1865	4, 10, 13, 17, 21, 26, 30, 31, 33, 36, 41
Hemiaulus hauckii Grunow ex Van Heurck 1882	4, 8, 9, 10, 12, 13, 14, 17, 18, 21, 23, 26, 27, 30, 31, 32, 33, 35, 36, 37, 41
Hemiaulus membranaceus Cleve 1873	4, 8, 10, 14, 26
Lauderia annulata Cleve 1873	4, 10, 12, 13, 14, 17, 21, 26, 30, 31, 33, 41
Lennoxia faveolata H.A.Thomsen & K.R.Buck 1993	41
Leptocylindrus danicus Cleve 1889	4, 8, 9, 10, 12, 13, 14, 15, 17, 18, 21, 23, 24, 26, 30, 31, 32, 33, 35, 38, 41
Leptocylindrus minimus Gran 1915	4, 6, 8, 9, 10, 13, 14, 17, 21, 23, 26, 30, 31, 33, 37, 38
Lithodesmium undulatum Ehrenberg 1839	4, 8, 10, 14, 30, 36, 38
Neobrightwellia alternans (Casas-Monroy & Bailey) M.P.Ashworth & P.A.Sims 2022	4, 8, 10, 30
Plagiogrammopsis vanheurckii (Grunow) Hasle, Stosch & Syvertsen 1983	4, 8, 10
Planktoniella sol (G.C.Wallich) Schütt 1892	29, 41
Proboscia alata (Brightwell) Sundström 1986	3, 4, 8, 9, 10, 12, 13, 14, 17, 21, 23, 26, 27, 28, 30, 31, 32, 33, 35, 36, 37, 41

Table 2. Continued.

Species List	Literature
Proboscia indica (H.Peragallo) Hernández-Becerril 1995	3, 4, 8, 9, 10, 13, 14, 17,21, 23, 26, 31, 33, 35
Skeletonema costatum (Greville) Cleve 1873	4, 8, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 23, 25, 26, 30, 31, 33, 35, 36, 37, 39, 41
Stephanocyclus meneghinianus (Kützing) Kulikovskiy, Genkal & Kociolek 2022	30
Thalassiosira allenii H.Takano 1965	7, 14, 19, 20, 39, 41
Thalassiosira angustelineata (A.W.F.Schmidt) G.Fryxell & Hasle 1977	7, 10, 12, 14, 17, 19, 20, 21, 26, 31, 39, 41
Thalassiosira decipiens (Grunow ex Van Heurck) Jørgensen 1905	4, 10, 13, 14, 38
Thalassiosira eccentrica (Ehrenberg) Cleve 1904	13, 14, 30, 41
Thalassiosira gravida Cleve 1896	4, 6, 7, 10, 12, 13, 14, 17, 19, 20, 21, 26, 30, 31, 33, 36, 39, 41
Thalassiosira leptopus (Grunow) Hasle & G.Fryxell 1977	1, 18, 38
Thalassiosira nordenskioeldii Cleve 1873	14
Thalassiosira subtilis (Ostenfeld) Gran 1900	26, 35, 38, 41
Toxarium undulatum Bailey 1854	8, 10, 14, 30, 35
Trieres mobiliensis (Casas-Monroy & Bailey) Ashworth & E.C.Theriot 2013	4, 10, 13, 14, 23, 30, 33, 35, 36, 41
Bacillariophyceae	
Achnanthes adnata Bory 1822	39, 41
Achnanthes armillaris (O.F.Müller) Guiry 2019	4, 8, 10, 14, 17, 21, 26, 31, 35, 41
Amphora marina W.Smith 1857	41
Amphora ovalis (Kützing) Kützing 1844	41
Asterionella formosa Hassall 1850	41
Asterionella notata Grunow ex Van Heurck 1881	4, 8, 10, 17, 26, 30
Asterionellopsis glacialis (Castracane) Round 1990	1, 4, 8, 9, 10, 14, 18, 21, 23, 26, 30, 31, 35, 41
Bacillaria paxillifera (O.F.Müller) T.Marsson 1901	4, 8, 9, 10, 12, 14, 15, 17, 26, 30, 32, 36, 41
Bleakeleya notata (Grunow) Round 1990	13
Campylodiscus neofastuosus Ruck & Nakov 2016	30
Cocconeis placentula Ehrenberg 1838	18
Cocconeis scutellum Ehrenberg 1838	30, 41
Coronia decora (Brébisson) Ruck & Guiry 2016	30, 41
Cyclophora tenuis Castracane 1878	39
Cylindrotheca closterium (Ehrenberg) Reimann & J.C.Lewin 1964	4,6,7,8,10,12,13,14,17,18,20,21,23,24,25,26,30,31,32,33,35,36,37,38,39,40,41
Diploneis bombus (Ehrenberg) Ehrenberg 1853	41
Diploneis crabro (Ehrenberg) Ehrenberg 1854	30, 41
Entomoneis alata (Ehrenberg) Ehrenberg 1845	30, 36, 41
Entomoneis gigantea (Grunow) Nizamuddin 1983	14, 17, 26, 41
Fragilaria crotonensis Kitton 1869	4, 10, 13, 41
Grammatophora marina (Lyngbye) Kützing 1844	4, 8, 10, 12, 14, 24, 26, 30, 35, 38, 41
Gyrosigma acuminatum (Kützing) Rabenhorst 1853	14, 24, 33
Gyrosigma balticum (Ehrenberg) Rabenhorst 1853	4, 10, 14, 41
Gyrosigma fasciola (Ehrenberg) J.W.Griffith & Henfrey 1856	41
Gyrosigma reversum (W.Gregory) Hendey 1986	22,3
Hyalosira delicatula Kützing 1844	8, 9
Licmophora abbreviata C.Agardh 1831	4, 8, 9, 10, 12, 14, 15, 17, 18, 21, 23, 24, 25, 26, 30, 31, 33, 35, 36, 41
Licmophora ehrenbergii (Kützing) Grunow 1867	33
Licmophora flabellata (Greville) C.Agardh 1831	14, 30, 41
Licmophora gracilis (Ehrenberg) Grunow 1867	14, 18, 41
Licmophora paradoxa (Lyngbye) C.Agardh 1828	14
Lyrella lyra (Ehrenberg) Karayeva 1978	22, 30
Microtabella interrupta (Ehrenberg) Round 199	1
Navicula zostereti Grunow 1860	14
Nitzschia incurva Grunow 1878	30
Nitzschia insignis W.Gregory 1857	32
Nitzschia longissima (Brébisson ex Kützing) Grunow 1862	1, 2, 4, 8, 10, 12, 13, 14, 15, 17, 18, 21, 24, 25, 26, 30, 31, 33, 35, 41
Nitzschia sigma (Kützing) W.Smith 1853	4, 8, 10, 13, 14, 18, 21, 23, 26, 31, 33
Nitzschia tenuirostris Manguin 1952	41
Petrodictyon gemma (Ehrenberg) D.G.Mann 1990	36
Phaeodactylum tricornutum Bohlin 1898	4, 6, 7, 10, 12, 39
Plagiotropis lepidoptera (W.Gregory) Kuntze 1898	18
Pleurosigma angulatum (J.T.Quekett) W.Smith 1852	18, 41
Pleurosigma delicatulum W.Smith 1852	13, 18
Pleurosigma elongatum W.Smith 1852	4, 8, 9, 10, 12, 13, 14, 15, 17, 18, 21, 23, 24, 26, 31, 33, 38, 41

Table 2. Continued.

Species List	Literature
Pleurosigma formosum W.Smith 1852	41
Pleurosigma normanii Ralfs 1861	4, 8, 10, 12, 13, 14, 30, 35, 36
Podocystis perrinensis Ricard 1979	30
Psammodictyon panduriforme (W.Gregory) D.G.Mann 1990	30
Pseudo-nitzschia calliantha Lundholm, Moestrup & Hasle 2003	38
Pseudo-nitzschia delicatissima (Cleve) Heiden 1928	21, 27, 30, 31, 32, 33, 35, 36, 39, 41
Pseudo-nitzschia fraudulenta (Cleve) Hasle 1993	30
Pseudo-nitzschia pseudodelicatissima (Hasle et al.) Hasle 1993	23, 26, 30, 36, 38, 39
Pseudo-nitzschia pungens (Grunow ex Cleve) Hasle 1993	7, 10, 12, 13, 14, 17, 21, 23, 26, 28, 30, 31, 33, 35, 36, 38, 39, 41
Pseudo-nitzschia seriata (Cleve) H.Peragallo 1899	1, 4, 5, 27, 32, 37, 38
Rhabdonema adriaticum Kützing 1844	1, 4, 10, 14, 35
Striatella unipunctata (Lyngbye) C.Agardh 1832	4, 8, 9, 10, 13, 14, 15, 17, 18, 21, 23, 24, 26, 30, 31, 33, 35, 36, 41
Tetramphora ostrearia (Brébisson) Mereschkowsky 1903	4, 10, 30
Thalassionema frauenfeldii (Grunow) Tempère & Peragallo 1910	1, 2, 4, 8, 9, 10, 13, 14, 15, 17, 21, 23, 24, 26, 30, 33, 35, 36, 41
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	1, 2, 4, 8, 10, 12, 13, 14, 15, 17, 18, 21, 23, 24, 26, 30, 31, 32, 33, 35, 36, 41
Thalassiothrix heteromorpha var. *mediterranea* (Pavillard) Hallegraeff 1986	4, 8, 9, 10, 14, 17, 21, 23, 24, 26, 30, 31, 33, 35, 36
Thalassiothrix longissima Cleve & Grunow 1880	14, 17, 26, 30, 32
Trachyneis aspera (Ehrenberg) Cleve 1894	22, 30
Tryblionella compressa (Casas-Monroy & Bailey) Poulin 1990	12, 30, 32, 34, 41
Ulnaria ulna (Nitzsch) Compère 2001	4, 8, 10, 14, 41

In terms of species diversity, the class Bacillariophyceae is represented by 65 species across 37 genera, Mediophyceae by 89 species across 24 genera, and Coscinodiscophyceae by 40 species across 14 genera. At the genus level, *Chaetoceros* (Mediophyceae) ranks first, representing the highest species diversity with 45 species. It is followed by *Rhizosolenia* (Coscinodiscophyceae) with nine species. The third position is shared by *Bacteriastrum* (Mediophyceae) *Thalassiosira* (Mediophyceae) and *Coscinodiscus* (Coscinodiscophyceae), each represented by eight species.

Chaetoceros affinis, Chaetoceros decipiens, Cylindrotheca closterium, Hemiaulus hauckii, Leptocylindrus danicus, Proboscia alata, Pseudosolenia calcar-avis, Skeletonema costatum, Thalassionema nitzschioides are the constant species. *Asterionellopsis glacialis, Asterolampra marylandica, Bacillaria paxillifera, Bacteriastrum delicatulum, Bacteriastrum elegans, Bacteriastrum hyalinum, Cerataulina pelagica, Chaetoceros compressus, Chaetoceros costatus, Chaetoceros curvisetus, Chaetoceros dadayi, Chaetoceros lorenzianus, Chaetoceros peruvianus, Chaetoceros rostratus, Coscinodiscus granii, Dactyliosolen fragilissimus, Dactyliosolen mediterraneus, Detonula pumila, Ditylum brightwellii, Eucampia zodiacus, Grammatophora marina, Guinardia delicatula, Guinardia flaccida, Guinardia striata, Hemiaulus chinensis, Lauderia annulata, Leptocylindrus minimus, Licmophora abbreviata, Neocalyptrella robusta, Nitzschia longissima, Nitzschia sigma, Pleurosigma elongatum, Proboscia indica, Pseudo-nitzschia pungens, Rhizosolenia imbricata, Rhizosolenia styliformis, Striatella unipunctata, Sundstroemia setigera, Thalassionema frauenfeldii, Thalassiosira angustelineata, Thalassiosira gravida, Thalassiothrix heteromorpha* var. *mediterranea* are the frequent species.

Among 194 species, eight exhibited bloom events, four of which are classified as harmful. (Table 3) In the pelagic region of the Aegean Sea, these bloom events, with cell densities ranging between 10^5-10^7 cells L^{-1}, with the majority occurring in Izmir Bay. *Cylindrotheca closterium* exhibited the highest bloom frequency, being recorded four times, twice in spring (Koray et al., 1992; Kükrer and Aydın, 2006), once in summer (Altuğ et al., 2011), and once in autumn (Çolak Sabancı and Koray, 2001), *Chaetoceros neogracilis* followed with three recorded bloom events, all in spring (Çolak Sabancı and Koray, 2001; Aktan Turan et al., 2007; Altuğ et al., 2011) while *Pseudo-nitzschia pungens* was observed blooming twice, once in spring (Koray et al., 1992) and twice in winter (Aktan Turan et al., 2007; Altuğ et al. 2011), *Phaeodactylum tricornutum* bloomed twice, both in summer (Koray et al., 1992; Koray, 1995), *Leptocylindrus minimus* (Yurga, 2022), *Skeletonema costatum* (Bizsel et al., 2001), *Thalassiosira allenii* and *Thalassiosira angustelineata* (Koray et al., 1992) were recorded blooming once in spring.

Several diatom species exhibited high cell concentrations in the Aegean Sea, among these, *Cerataulina pelagica, Chaetoceros affinis, Climacosphenia moniligera, Coscinodiscus granii, Dactyliosolen fragilissimus, Grammatophora marina, Gyrosigma acuminatum, Hemiaulus hauckii, Leptocylindrus danicus, Leptocylindrus minimus, Licmophora abbreviata, Nitzschia longissima, Pleurosigma elongatum, Proboscia alata, Pseudo-nitzschia pseudodelicatissima, Striatella unipunctata, Sundstroemia setigera, Thalassionema frauenfeldii, Thalassionema nitzschioides, Thalassiosira gravida,* and *Thalassiothrix heteromorpha var. mediterranea* were observed at high concentrations, ranging between 10^3 and 10^5 cells L^{-1}. Some of these species have been associated with visible water discoloration when reaching high concentrations (Table 3).

Table 3. Bloom- high concentration species and their frequency index (Soyer, 1970) reported from previous 41 papers (*** indicates species that exhibited bloom events, with cell densities between 10^5-10^7 cells L^{-1}).

Status	Constant	Common	Rare
IOC-HAB		*Pseudo-nitzschia pungens****	*Pseudo-nitzschia alliantha* *Pseudo-nitzschia delicatissima* *Pseudo-nitzschia fraudulenta* *Pseudo-nitzschia pseudodelicatissima* *Pseudo-nitzschia seriata*
HAB	*Cylindrotheca closterium**** *Skeletonema costatum****	*Cerataulina pelagica* *Chaetoceros curvisetu* *Chaetoceros dadayi* *Chaetoceros peruvianus* *Chaetoceros rostratus* *Guinardia delicatula* *Guinardia flaccida* *Leptocylindrus minimus****	*Amphora ovalis* *Chaetoceros atlanticus* *Chaetoceros borealis* *Chaetoceros coarctatus* *Chaetoceros danicus* *Chaetoceros debilis* *Chaetoceros densus* *Chaetoceros eibenii* *Chaetoceros socialis* *Chaetoceros tetrastichon* *Chaetoceros wighamii* *Coscinodiscus centralis* *Coscinodiscus concinnus* *Coscinodiscus wailesii* *Coscinodiscus wailesii* *Thalassiosira nordenskioeldii* *Thalassiosira subtilis*
Bloom (>10^5)		*Thalassiosira angustelineata****	*Chaetoceros neogracilis**** *Phaeodactylum tricornutum**** *Thalassiosira allenii****
High concentration (10^3-10^5)	*Chaetoceros affinis* *Hemiaulus hauckii* *Leptocylindrus danicus* *Thalassionema nitzschioides*	*Dactyliosolen fragilissimus* *Licmophora abbreviata* *Nitzschia longissima* *Pleurosigma elongatum* *Proboscia alata,* *Striatella unipunctata* *Sundstroemia setigera,* *Thalassionema frauenfeldii,* *Thalassiosira gravida,* *Thalassiothrix heteromorpha var. mediterranea*	*Climacosphenia moniligera* *Coscinodiscus granii* *Grammatophora marina* *Gyrosigma acuminatum*

DISCUSSION

According to the results obtained from research on phytoplankton, the diatom flora of pelagic region in the Turkish part of the Aegean Sea is represented by 194 species belonging to 75 genera. Among phytoplankton species, the genus *Chaetoceros,* with 45 recorded species, exhibits the highest species diversity among the identified taxa. This finding is consistent with previous literature, which identifies *Chaetoceros* as one of the most species-rich diatom genera within marine phytoplankton (Malviya et al., 2016). This high diversity can be attributed to the genus's broad ecological tolerance and its ability to adapt to various environmental conditions.

Among the constant species identified based on the frequency index (Soyer, 1970) *Skeletonema costatum* (Metin and Cirik, 1999, Bizsel et al., 2001) and *Cylindrotheca closterium* (Koray et al., 1992; Çolak Sabancı and Koray, 2001; Kükrer and Aydın, 2006; Altuğ et al., 2011) are notable for both exhibiting bloom events and being capable of producing mucilage substances (Alcoverro et al.,2000; Najdek et al,2005; Demir Yılmaz et al., 2023); This phenomenon was observed only once in Gökçeada, where they co-occurred with and *Gonyaulax fragilis*, leading to the formation of mucilage clouds that caused water turbidity, which remains the only reported mucilage occurrence in the Turkish side of the Aegean Sea (Güreşen and Aktan Turan, 2014). Also, *Cylindrotheca closterium* alone has been reported to cause water discoloration during bloom events, particularly in İzmir Bay (Koray et al., 1992; Yurga, 2022).

Phytoplankton studies in Türkiye began 70 years ago in İzmir Bay, located along the Turkish coast of the Aegean Sea. Most of the phytoplankton research conducted in the Aegean Sea has also been carried out in İzmir Bay, where bloom events have been most frequently recorded. The high number of recorded bloom events in İzmir Bay within the Aegean Sea may be partially attributed to the greater research effort in the region. However, it should not be disregarded that İzmir Bay is also subject to significant anthropogenic pressures, such as industrial pollution and urbanization (Lemenkova, 2016; Sökmen Yılmaz and Yılmaz, 2019), which may contribute to bloom formation. Additionally, spring is the dominant season for phytoplankton blooms in the region, with most blooms occurring in İzmir Bay, except for a single spring bloom of *Cylindrotheca closterium* recorded in Çandarlı Bay. This seasonal dominance of spring blooms aligns with general phytoplankton bloom patterns reported in the literature (Assmy and Smetacek, 2009). This pattern is consistent with broader trends observed in the Northwestern Mediterranean Sea where spring bloom frequency has increased over the past seven years (Grossi et al., 2024), suggesting that oceanographic and climatic factors may be influencing phytoplankton dynamics in water column.

In all studies conducted in the Aegean Sea, light microscopy has been the primary method for species identification. However, Akçaalan et al., (2023) is the only study that has additionally applied molecular methods alongside light microscopy, exclusively implemented in Gökçeada, North Aegean Sea. Molecular studies aimed at determining species composition in Türkiye have predominantly focused on the Marmara Sea (Akçaalan et al., 2023; Doğan et al., 2024a; 2024 b; Tekdal et al., 2024; Kaleli et al., 2024). Since this field is new in Türkiye, obtaining more reliable results requires the use of diverse genetic regions and primers (Malviya et al., 2016; Stuart et al., 2024) should be regularly conducted across all Turkish seas. Expanding the use of molecular techniques would minimize species misidentification, improve the detection of small-sized taxa, and contribute to the development of molecular reference libraries.

It is well known that *Pseudo-nitzschia* species have the potential to cause Amnesic Shellfish Poisoning due to their ability to produce domoic acid. However, studies investigating domoic acid production along the Turkish coasts have primarily focused on the Marmara Sea (Dursun et al., 2016; Tas et al., 2016; Dursun et al., 2017, 2018; Dursun, 2021a; 2021b), with only one study conducted in the Mediterranean Sea (Eker Develi and Konucu, 2020). While *Pseudo-nitzschia* species found in the Aegean Sea are known to have toxin-producing potential, no studies have specifically investigated domoic acid production or its toxic effects in this region. Additionally, although harmful species have been detected in the stomach contents of black mussels (*Mytilus galloprovincialis*) in the İzmir Bay, Aegean Sea (Lök et al., 2010), the extent of their toxicity remains unclear. In the Greek part of the Aegean Sea, Kaniou-Grigoriadou et al. (2005) investigated the presence of domoic acid in black mussels (*Mytilus galloprovincialis*) and Venus clams (*Venus verrucosa*). Their two-year study revealed that domoic acid was detected only during the spring season in tissue samples. These research gaps highlight the need for toxicity studies to assess the potential risks posed by harmful phytoplankton in the Aegean Sea and to determine their impact on marine ecosystems and human health.

CONCLUSION

This study highlights significant research gaps in phytoplankton studies in the Aegean Sea, despite its long history of investigations within Turkish waters. The Middle Aegean Sea has been the most extensively studied area. The predominant reliance on light microscopy remains a major constraint; none of the reviewed studies included electron micrographs, which is a critical limitation, especially for diatom species with morphological features that require high-resolution imaging for accurate identification. Without such evidence, proposing new species remains questionable. In addition, the limited application of molecular techniques and the absence of toxicity assessments create uncertainties regarding species diversity, bloom dynamics, and potential ecological risks. To prevent misidentification, particularly among morphologically similar species, electron micrographs and molecular tools should be integrated into future taxonomic research. The lack of systematic toxicity evaluations is particularly concerning, as even harmful species at low concentrations may pose environmental and public health risks Future research should prioritize integrating molecular approaches, conducting toxicity screenings, and refining long-term monitoring strategies. Expanding these efforts will provide a clearer understanding of phytoplankton ecology and improve our ability to assess the risks associated with harmful algal blooms (HABs) in the region.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conceptualization and design of the study. The manuscript was written and revised by the listed authors, all of whom have read and approved the final version. This publication is derived from. Edanur Erbaş's master's thesis.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for the study.

DECLARATION OF AI USE

We have not used AI-assisted technologies in creating this article.

DATA AVAILABILITY

For any questions, the corresponding author should be contacted.

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