



Black Sea Dinoflagellata (History of the Research and Current Biodiversity)

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Abstract

For centuries scientists in many disciplines have engaged in extensive exploration of the Black Sea biodiversity. For instance, investigations on Black Sea algae date back to 1866. Traditionally, the Black Sea was considered relatively poor in species richness compared to many other seas. However, recent investigations had shown that there was a need to seriously revise our perception of Black Sea species variety, especially of phytoplankton diversity. Many exciting advances in the studying of microalgae have taken place in the last decade, as new theoretical frameworks have been identified, new technologies to observe organisms in the field and the laboratory have been developed. Hence, new data were analysed leading to discovering numerous unknown previously phytoplankton species for the Black Sea or correcting the taxonomic descriptions of the familiar species in line with the changes in modern taxonomy. Consequently, a major revision of the check list of Black Sea phytoplankton species was undertaken.

This paper presents the history of Black Sea dinoflagellates research and the most comprehensive inventory so far prepared for them. So far, the dinoflagellates check-list compiled consists of 456 species, 467 varieties and forms, including well-known, and more than 200 new species which have been reported during the last two decades. To date, representatives of 10 orders, 37 families and 79 genera of dinoflagellates have been found in the Black Sea. The most diverse order is Gymnodiniales, followed by Peridinales, Gonyaulacales, Dinophysiales, Procoentrales, Noctilucales, Ptychodiscales, Phytodiniales, Suessiales, and a few specimen still remain unidentified, as they most probably belong to currently unspecified genera. As the phytoplankton taxonomy develops fast nowadays and new species are being constantly found, the Black Sea check-list of dinoflagellates (http://phyto.bss.ibss.org.ua/wiki/Main_Page) is under regular update and will be annually updated.

Keywords: Phytoplankton, dinoflagellates, check-list.

Introduction

Research on the Black Sea Dinoflagellata can be divided into four main periods which vary in the level of involvement of different Black Sea states or in priorities of investigations: 1886–1949, 1950–1969, 1970 – late 1990's, and late 1990's – present days.

Beginning of the *first period* was marked by the work of Pereyaslavtseva (1886) with the initial list of marine planktonic algae published, including 19 Dinoflagellata species identified in samples collected near Sevastopol (Ukraine). The work of Minkevich (1900) included already 22 species. In the list compiled by Geineman (1903) only 4 species were mentioned and 8 more were listed in the works of Zernov (1904, 1913). In 1886-1917, the most significant work on the Black Sea phytoplankton was the Reinhard (1909) article, in which a list of 44

species and intra-specific taxa was presented. Research on the Black Sea plankton continued during the early Soviet times (Usachev, 1928; Morozova-Vodyanitskaya, 1936, 1937; Mihaylovskaya, 1936). In 1930's, the Black Sea algae were also studied by scientists from other countries. For instance, Petkov (1932) presented algae species recorded in Bulgarian coastal waters. The Morozova-Vodyanitskaya's paper published in 1948 is worth special attention. The whole first period of the Black Sea phytoplankton research was summarized by this author. The mentioned article included 100 Dinoflagellata species and intra-specific taxa belonging to 13 families and 22 genera. Stroikina (1940, 1950) actively conducted research in 1940's to 1950's and discovered 35 Dinoflagellata species near Karadag (Crimea).

In the beginning of the *second period* of Black Sea phytoplankton research, another articles of

Morozova-Vodyanitskaya (1954, 1957, 1958) were published and it included new 58 species and intra-specific taxa. In 1950-1969, consequent works of the same author (e.g. in 1957 and 1958) were dedicated to further qualitative research on the Black Sea phytoplankton which largely improved the knowledge.

Substantial contribution to the Black Sea phytoplankton research was provided by Ivanov. Total 695 species and intra-specific taxa from different orders (all inclusive, not only dinoflagellates) were mentioned in his works (Ivanov, 1964, 1965), as special attention was paid to the North-Western part of the Black Sea (Ivanov, 1957, 1959a, 1959b, 1960, 1964, 1967, 1977).

Essential phytoplankton research was conducted by Kondratjeva and Belogorskaya (1961); Kondratjeva (1967). In her publications valuable results were presented, highlighting the daily and seasonal phytoplankton dynamics in the Black Sea (Kondratjeva, 1958, 1963). In 1950's-60's, Black Sea Dinoflagellata species were extensively studied by other scientists as well (Kiselev, 1950; Mashtakova, 1958, 1964; Alfimov, 1959; Duka, 1959; Delalo, 1961; Koshevoy, 1959; Bodeanu and Chirila, 1960; Sinyukova, 1960; Moshkina, 1961; Denisenko, 1964; Ivanov and Krzhelinska, 1964; Greze, 1965; Belogorskaya and Kondratjeva, 1965; Petipa, 1965; Kuzmenko, 1966; Pitsyk, 1950, 1954; Prokudina, 1952). Apart from Soviet algologists, much was done by Romanian and Bulgarian specialists in this period (Skolka, 1960a, 1960b, 1963; Petrova, 1957, 1963, 1964, 1965).

The most valuable publication on phytoplankton, which included almost all data collected till mid 1960's, was the Ivanov (1965) article with a list of 171 Dinoflagellata species and intra-specific taxa presented. However, this article did not include data collected by other scientists during the same period, which were mostly published a few years later (Georgieva, 1961, 1969; Lanskaya, 1969; Senicheva, 1971; Senichkina, 1973; Roukhiyajnen, 1970a, 1970b, 1970c, 1971; Kovaleva, 1969; Makarova, 1969; Kuzmenko, 1966; Pitsyk, 1967a, 1967b, 1971). Among the articles listed above, especially important was the research published by Makarova (1969), in which issues concerning phytoplankton dynamics and relationships between the Black Sea, Sea of Azov and the Caspian Sea microflora had been discussed.

Total 177 Dinoflagellata species and intra-specific taxa, presented by 17 families and 25 genera, were registered in the Black Sea phytoplankton during the whole period from 1950 to 1969. As a result of the research conducted in the second period of the 'Black Sea Dinoflagellata history' another 90 species (93 intra-specific taxa) were added to the Black Sea check-list of dinoflagellates.

The **third period** (1970-late 1990s) of the Black Sea Dinoflagellata research is characterized by lower

interest to this group of organisms from taxonomical point of view and reduction in number of faunal species-specific works, in general. Though, in the end of 1970's an interesting article was published by Pitsyk (1979) dedicated to the plankton taxonomic composition. The author referred to 205 Dinoflagellata intra-specific taxa for the Black Sea. Unfortunately, this article does not contain a full species list. In 1970's-90's, Black Sea Dinoflagellata were mentioned in the publications of many scientists and their quantitative dynamics was thoroughly analyzed (Roukhiyajnen, 1975; Ivanov, 1977; Gomoiu, 1977; Bodeanu and Usurelu, 1979; Bodeanu, 1993; Nezlin and Zernova, 1983; Senicheva, 1983; Senichkina 1983; Ilyasch, 1984; Ilyasch and Fedorov, 1985; Sukhanova *et al.*, 1987 and 1991; Bitjukov *et al.*, 1993; Nesterova, 1979, 1985, 1987; Petrova-Karadjova, 1984, 1990).

A lot was achieved by D. A. Nesterova (1976, 1977a, 1977b, 1979, 1980a, 1980b, 1982, 1985, 1986, 1987, 1988) in her research on the role of dinoflagellates in the Black Sea ecosystem, especially in the North-Western part of the Sea. Most valuable among her works were those where phytoplankton dynamics had been quantitatively reported in detail, which made possible to notice and further attend the wide-ranging fluctuations of algal biomass/density that took place in the Black Sea ecosystem under anthropogenic influence. D. A. Nesterova underlined that the progressive eutrophication of the Black Sea was the reason for the mass proliferation of phytoplankton with frequency and level being obviously abnormal, and especially, for the increased share of dinoflagellate species in the community on the expenses of diatoms. The influence of eutrophication on the phytoplankton species composition, succession and seasonal/inter-annual dynamics was comprehensively analysed and modeled in the works of Vinogradova (1992) and Vinogradova and Velikova (1992). Summarized research (Krakhmalny, 1994a, 1994b; Zaitsev, Alexandrov, 1998; Zaitsev *et al.*, 1999), and notices on new species findings (Minicheva and Eremenko, 1993) completed the third period. In the publications of the third period of the marine Dinoflagellata research in total 48 new intra-specific taxa for the Black Sea were mentioned.

The last, **fourth period** (from the end of 1990's till present) is characterized by a growing interest to the Black Sea algal research by the coastal countries that were previously less involved: Turkey (Ozturk, 1999; Turkoglu and Koray, 2002; Eker-Develi and Velikova, 2009) and Georgia (Gvarishvili, 1998a, 1998b; Komakhidze and Mazmanidi, 1998). Ukrainian planktonologists continued their extensive taxonomical and ecological research (Bryantseva, 2000, 2008; Bryantseva *et al.*, 1996, 2003, 2008; Krakhmalny, 2001, 2005; Krakhmalny and Terenko, 2002a, 2002b; Terenko L.M. 2000, 2001, 2002, 2005,

2007, 2009, 2010a, 2010b, 2011; Terenko G.V., 2004; Nesterova et al., 2006; Dereziuk, 2008; Senichkina et al., 2001, 2004; Senicheva, 2004, 2008), as well as Bulgarian (Konsulov, 1998; Moncheva and Krastev, 1997; Moncheva et al., 2001; Moncheva and Parr, 2010; Velikova, 1998; Velikova and Larsen, 1999), Romanian (Petranu, 1997; Bodeanu, 2002; Bodeanu et al., 2004; Boicenco, 2010, 2011) and Russian specialists (Mikaelyan, 1997, 2008; Vershinin and Morton, 2005; Vershinin and Moruckhov, 2003; Vershinin et al., 2005; Vershinin and Velikova, 2008). Several check-lists of Black Sea phytoplankton species were published (Zaitsev and Alexandrov, 1998; Krakhmalny and Panina, 2000; Gomez and Boicenco, 2004; Krakhmalny et al., 2006; Nesterova et al., 2006).

Results and Discussion

As a result of the research conducted during the last ten years, basing on more advanced methods (scanning and electron microscopes and genetic analysis), the species composition of Black Sea Dinoflagellata was replenished by almost 200 new species for the Sea and, consequently, the last check-list comprises 456 species (467 species and intra-specific taxa). This active replenishment was also due to objective increase in the number of species related to introduction of non-native organisms via ship ballast water into the Black Sea. Though, probably some of the species observed may have not established in the Black Sea as they were on one occasion recorded in port areas. Intensification of hydrobiological research (more frequent observations in time and space) in all Black Sea countries was in place as well which was another reason for the rapid growth of the Black Sea phytoplankton check list. Nowadays, the Black Sea Dinoflagellata are represented by 10 orders, 37 families and 79 genera (Table 1). Most diverse is order Gymnodiniales - 6 families, 18 genera and 144/145 species/varieties and forms: *Amphidinium* (22/23), *Achradina* (2/2), *Akashiwo* (1/1), *Cochlodinium* (10/10), *Gymnodinium* (56/56), *Gyrodinium* (31/31), *Herdmania* (1/1),

Karenia (2/2), *Katodinium* (4/4), *Nematodinium* (1/1), *Paulsenella* (1/1), *Pheopolykrikos* (1/1), *Plectodinium* (1/1), *Polykrikos* (4/4), *Torodinium* (2/2), *Tovellia* (1/1), *Warnowia* (2/2), *Woloszynskia* (2/2). Second are Peridiniales – 10, 27, 134/136: *Azadinium* (1/1), *Bysmatrum* (1/1), *Centrodinium* (1/1), *Corythodinium* (2/2), *Dinosphaera* (1/1), *Diplopelta* (1/1), *Diplopsalis* (4/5), *Diplopsalopsis* (2/2), *Dissodinium* (1/1), *Durinskia* (2/2), *Glenodinium* (4/4), *Glochidinium* (1/1), *Heterocapsa* (3/3), *Kryptoperidinium* (2/2), *Lessardia* (1/1), *Oblea* (1/1), *Oxytoxum* (14/14), *Pentapharsodinium* (2/2), *Peridiniopsis* (3/3), *Peridinium* (11/12), *Podolampas* (3/3), *Preperidinium* (1/1), *Protooperidinium* (67/67), *Scrippsiella* (2/2), *Sphaerodinium* (1/1), *Thecadinium* (1/1), *Zygabikodinium* (1/1). They are followed by Gonyaulacales - 7, 15, 88/95: *Alexandrium* (7/7), *Amylax* (3/3), *Gonyaulax* (21/21), *Amphidoma* (1/1), *Ceratium* (4/11), *Cladopyxis* (2/2), *Goniodoma* (2/2), *Lingulodinium* (1/1), *Heterodinium* (2/2), *Neoceratium* (34/43), *Palaeophalacroma* (1/1), *Peridiniella* (2/2), *Protoceratium* (2/2), *Pyrophacus* (2/2), *Pyrocystis* (4/4); Dinophysiales – 3, 4, 46/46: *Amphisolenia* (1/1), *Dinophysis* (38/38), *Oxyphysis* (2/2), *Phalacroma* (5/5); Prorocentrales – 1, 2, 28/29: *Mesoporus* (1/1), *Prorocentrum* (27/28); Noctilucales – 4, 6, 8/8: *Kofooidinium* (1/1), *Spatulodinium* (1/1), *Petalodinium* (1/1), *Scaphodinium* (1/1), *Noctiluca* (1/1), *Pronoctiluca* (3/3); Ptychodiscales - 2, 2, 2/2: *Kolkwitzella* (1/1), *Ptychodiscus* (1/1); Phytodiniales – 1, 2, 2/2: *Cystodinium* (1/1), *Hyphodinium* (1/1); Suessiales – 1, 1, 1/1: *Prosoaulax* (1/1) and species with uncertain taxonomical position (Uncertain ord.): *Micracanthodinium* (2/2), *Pseliodinium* (1/1).

A few specimen found in samples remain unidentified, as they most probably belong to currently unspecified (unknown) genera, which would require genetic research to substantiate the latter.

The work on the Black Sea check-list of dinoflagellates continues and updates will be regularly provided to reflect changes in taxonomy and findings of new species, as both happen often nowadays.

Table 1. Black Sea Dinoflagellates

| Order | Number of: | | | |
|----------------|------------|--------|---------|-------------------------------|
| | Families | Genera | Species | Including varieties and forms |
| Gymnodiniales | 6 | 18 | 144 | 145 |
| Peridiniales | 10 | 27 | 134 | 136 |
| Gonyaulacales | 7 | 15 | 88 | 95 |
| Dinophysiales | 3 | 4 | 46 | 46 |
| Prorocentrales | 1 | 2 | 28 | 29 |
| Noctilucales | 4 | 6 | 8 | 8 |
| Ptychodiscales | 2 | 2 | 2 | 2 |
| Phytodiniales | 1 | 2 | 2 | 2 |
| Suessiales | 1 | 1 | 1 | 1 |
| Uncertain | 2 | 2 | 3 | 3 |
| Total | 37 | 79 | 456 | 467 |

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