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Color range of euglenoid (*Euglenophyceae*) blooms

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Abstract. The presence of autotrophs, heterotrophs and mixotrophs among euglenoid taxa, multiple means of nutrition, and high tolerance to a wide range of thermal living conditions contribute to their colonization of various types of water bodies in different climatic zones. The formation of water "blooms" by euglenoids occurs during accelerated development and intensive cell division of these organisms. Euglenoids outcompete other microalgae and produce significant biomass under favorable conditions. The ability to produce temporal, reproductive and protective cysts also contributes to rapid bloom formations. Our observations suggest that their features probably make them model organisms for observing environmental changes in small water bodies. So far, little attention has been given to the species-dependent color variation of euglenoid blooms. Long-time research on euglenoid taxonomy, biogeography and habitat observations allow observers to recognize different blooms depending on the species causing the phenomenon: *Euglena sanguinea*, *E. mutabilis*, *E. clara*, *E. hemichromata*, *E. geniculata*, *E. agilis*, *Euglenaria anabaena*, *Euglenaformis chlorophoenica*, *Monomorphina pyrum*, *Phacus pleuronectes*, *Ph. orbicularis*, *Lepocinclis ovum*, *Trachelomonas volvocina*, *T. volvocinopsis* and *T. caudata.* The color range of euglenoid blooms are presented here for the first time.

Key words: color range, ephemeric water bodies, euglenoid blooms, global warming

Introduction

"Blooming" of water – the process of rapid, mass development of algae that dramatically changes the color of the growth medium (water, soil, surface of various natural and industrial materials) due to the high productivity of algae from hundreds of thousands to tens of millions of cells/ml is widely known in all continents including Arctic and Antarctic. It has planetary significance and has been officially known since the XII century from the lakes of England (Shafiq-ur-Rehman, 1998). The causative agents of this process are cyanobacteria, dinoflagellates, green algae and diatoms, as well as euglenoids and other taxonomic groups of algae. Mass development of cyanobacteria (Li et al. 2018; Adamski et al. 2024) is characteristic for lenthic water bodies (reservoirs, lakes and ponds) and less frequent in ephemeral ponds and soils. As for green algae, "blooming" is common in fish ponds and ponds of sewage treatment plants, occasionally estuaries, industrial and natural materials and soil. Euglenoids appear in high concentrations in small and shallow reservoirs including fish ponds, ditches, irrigation canals and rice fields with high levels of organic and chemical pollution (Huber-Pestalozzi 1955; Sirenko 1968; Reynolds & Walsby 1975; Starmach 1983; Wołowski 1998, 2011).

Blooms in water bodies due to euglenoid algae have been recorded for almost two centuries and are characteristic of water bodies on different continents (Ehrenberg 1830, 1838; Carter 1869; Kashyop 1908; Hardy 1911; Naumann 1915, 1925; Mainx 1927; Kol 1929; Härdtl 1935; Szabados 1936; Johnson 1939; Gojdics 1939, 1953; Baumeister 1954; Huber-Pestalozzi 1955; Davis 1956; Xavier et al. 1991; Khan 1993; Kadiri 2011; Mandal et al. 2016; Wołowski et al. 2017; Poniewozik & Juráň 2018; Juráň 2019; Janse van Vuuren & Levanets 2020). This phenomenon is caused by species of *Euglena* Ehrenberg, *Euglenaria* E.W., Linton, A. Karnkowska, J. Kwiatowski, *Lepocinclis* Perty, *Monomorphina* Mereschkowsky, *Phacus* Dujardin and *Trachelomonas* Ehrenberg genera, which are the primary causative agents of this process (Bednarz 1974; Komárková 1977; Boyd & Tucker 1998;

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Wołowski 1998; Rahman et al. 2007, 2014; Ligęza & Wilk-Woźniak 2011; Duangjan et al. 2014; Wołowski et al. 2017; Juráň 2019).

The rapid mass development of euglenoids changes the color of water from green to yellow-green, orange-red and brown. According to Shafiq-ur-Rehman (1998), the species exhibit a circadian color change, from green at dawn to blood-red during the day and again green at dusk. This color is determined by the pigment composition (chlorophyll *a*, *b* and a wide range of carotenoids: β-carotene, diatoxanthin, diadinoxanthin, heteroxanthin and neoxanthin) of this taxonomic group (Goodwin 1976, 1980; Liaaen-Jensen 1977, 1978; Rowan 1989; Grung & Liaaen-Jensen 1993). The variability of euglenoid cell color is manifested at the species and genus level (Duangjan et al. 2014; Wołowski et al. 2017), depending on a number of environmental factors. The aim of our work is to understand the phenomenon of water blooms due to the rapid, mass development of these flagellated microorganisms, create a scale of potential colors as the initial diagnostic feature of water blooms and determine the specific color gamut.

Material and methods

The microorganisms observed in the present study were euglenoids occurring in natural, small water bodies, such as ditches, ponds, and fishponds in Poland, Slovakia, Lithuania, Romania, UK, Thailand, and the USA. Fresh material (planktonic biomass) was collected in small plastic jars (25 ml), transported to laboratory and observed using a Nikon ECLIPSE 600 light microscope with Nomarski phase contrast. Photomicrographs were taken with a Nikon DS-Fi I camera. Data from studies conducted from 2011 to 2018 and archival data since 1990 were analyzed. The color specification was based on the European Color Scale – RGB (https://www.rapidtables.com/web/color/RGB_Color.html#rgb-format).

Results and discussion

Taxonomy of *Euglenaceae* causing blooms

Altogether, the blooms were caused by 15 taxa belonging to the *Euglenophyceae* family *Euglenaceae*: 6 – *Euglena* genus, 1 – *Euglenaria*, 1 – *Euglenaformis* M.S. Bennett & Triemer, 1 – *Monomorphina*, 3 – *Phacus*, and 3 – *Trachelomonas* species (Tab. 1, Figs 1–6). All of these species are recognized as cosmopolitan taxa that prefer waters rich in organic compounds. These taxa are also known to tolerate industrial pollution (Wołowski 1998, 2011) and waters contaminated with heavy metal compounds (Wołowski et al. 2008, 2013, 2015; Turnau et al. 2009).

Most species of *Euglenaceae* are organisms that have green color, due to the high content of chlorophyll *a* & *b*. There are also those which, at high temperature and high light intensity, get a distinct red color due to a high concentration of granules (0.5 μm) of hematochrome in the cell. The dispersion of hematochrome throughout the cells cause them to turn red, making their mass appearance noticeable to the naked eye on the water surface (Fig. 1A–D). The color change process occurs quickly and persists for 5–40 minutes, sometimes up to 2 hours, depending on the species and temperature (after Buetow 1968). In the first phase of a bloom, cells are usually only partially red and floating freely among the green ones. Longer exposure to bright light at high temperatures causes the formation of palmelloid stages, a characteristic red-colored neustonic film, that exhibit different intensities of red depending on the rippling of the water surface (Fig. 1A–D). This phenomenon occurs in closed shallow reservoirs that heat up easily at the perimeters of ponds and lakes.

This was also confirmed by our research conducted in Thailand (2010–2015). We observed *E. sanguinea* blooms in several places (Fig. 2A–N), but noticed a massive appearance of the palmella stage of *E. sanguinea* only in one location (a ditch around a rice field) (Fig. 2E). Occasionally *Euglenaria chlorophenica* was blooming in garden pond at Chang Mai University (Fig. 2O–R). We observed different blooms in fish ponds at Maejo University, Chiang Mai, including a reddish-brown bloom caused by a mixture of *E. sanguinea* and *Trachelomonas volvocina*

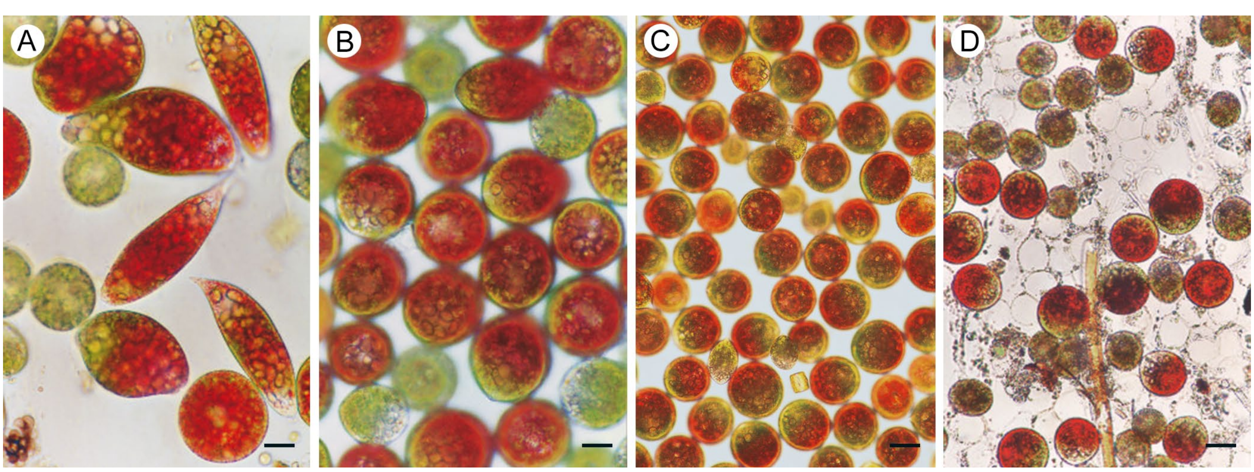

Figure 1. Bloom development phases: Community of *Euglena sanguinea* free-floating cells before the formation of the palmelloid stage (A); Cells in the palmella stage during a bloom – red with carotenoids in the foreground, green in the background (B–C); Neuston film built by a layer of palmella stage (D). Scales: A–B = 10 μm; C–D = 20 μm.

Table 1. Species of euglenoids causing the different color blooms of water.

Name of taxa	Collection site	Bloom color and remarks
Euglena sanguinea Ehrenberg	Large fish pond, Chiang Mai, Thailand, 18°48′57″N, 99°00′18″E	yellow-brownish; pH: 8.2
	Ditch around rice field, Thailand, 18°18′54.12″N, 99°22′50″E	yellow-brownish; pH: 7.2, water temperature: 32°C
	Moat surrounding villages, Thailand, 18°34′31.80″N, 99°0′13.68″E	yellow-brownish; pH: 7.2, water temperature: 29°C
	Rice field, Thailand, 18°18′54.12″N, 99°00′22.50″E	green-brown-red; pH: 8.2, water temperature: 33.5°C
	Fish ponds at Maejo University, with Mekong Giant Catfish, Thailand, 18°53′55.80″N, 99°00′59.94″E	red-brown; pH: 7.88, water temperature: 32°C
	Garden pond at the Pa Ko Dam, Tobacco station, Chiang Rai, Thailand, 19°47′5.52″N, 99°44′39.24″E	yellow-aquamarine through green to reddish brown; together with 204 other taxa of euglenoids; pH: 7.09, water temperature: 24.2°C
	Small shallow pond in Vilnius, Lithuania, 54°43′13″N, 25°15′49.6″E	green to red brown
E. mutabilis F. Schmitz	"Purple" acid mine drainage pond in Wieściszowice, Poland, 50°50′23″N, 15°58′42″E	grey-green, its communities made of gentle, cotton-like aggregations; pH: 3–4.8, water temperature: 15–17°C
	Steregoiu Mine River Valley near Rosia Poieni mine, Romania, 46°18′37″N, 23°09′50″E	green thin cotton-like layer covered the bottom surface in shallow water; pH: 2.9–3.0, water temperature: 19°C
E. clara Skuja	Temporary pond along the road of Chiang Mai, Thailand, 18°48′27.42″N, 99°14′3.96″E	green-red, mixed with *Phacus longicauda*; pH: 8, water temperature: 31°C
E. hemichromata Skuja	Rice field – soil preparing under the rice cultivation, Thailand, 18°18′54.12″N, 99°00′22.50″E	green colored, together with *E. anabaena*; pH: 6.9, water temperature: 27.2°C
E. geniculata Dujardin	Garden pond at the Stadium 700 years old, Chiang Mai, Thailand, 18°50′22″N, 98°57′33″E	green,with oxygen bubbles present in the biomass film; pH: 7.5, water temperature: 25°C
	Wastewater treatment plant, Mikołów, Poland, 50°09′49″N, 18°54′14″E	floating mats, brown-green; pH: 7–8, water temperature: 22°C
	Fish pond, Rožmberg Třebon, Czech Republic, 49°02′31″N, 14°45′55″E	grey-green; pH: 8.5, water temperature: 16°C
E. agilis H.J. Carter	Stream "Graniczna Woda", Poland, in slowly flowing water, 50°30′18″N, 18°54′50″E	green, palmella stage, highly polluted by thallium and other heavy metal compounds (Cd, Pb, Zn); pH: 7–7.5, water temperature: 20°C
	Ditch in front of Lanlao Restaurant, Lamphun province, Thailand, 18°34′45″N, 99°00′15″E	luscious green; pH: 8.55, water temperature: 26.3–31°C
Euglenaria anabaena (Mainx) Karnkowska-Ishikawa & E.W. Linton	Rice field – soil preparing under the rice cultivation, Thailand, 18°18′54.12″N, 99°22′50″E	green, together with *E. hemichromata*; pH: 6.9, water temperature: 27.2°C
	Ditch in front of Lanlao Restaurant, Lamphun province, Thailand, 18°34′45″N, 99°00′15″E	dark green; pH: 7.21, water temperature: 28.2°C
Euglenaformis chlorophoenica (Schmarda) Zakryś & Lukomska	Garden pond at Chiang Mai University, Thailand, 18°48′26″N, 98°58′00″E	red-brown; pH: 9.4, water temperature: 38.6°C
Monomorphina pyrum (Ehrenberg) Mereschkowsky	Pond by the road to the pig farm, Ściborzyce village, Poland, 50°17′42″N, 19°54′ 27″E	light green; pH: 7.0–7.5, water temperature: 15°C
Phacus tortus (Lemmermann) Skvortzov	Temporary pond along the road, Thailand, 18°48′27.42″N, 99°14′3.96″E	green-red, mixed with *Euglena clara*; pH: 8, water temperature: 31°C
Ph. pleuronectes (O.F. Müller) Nitzsch ex Dujardin	Stream "Graniczna Woda", Poland, 50°30′18″N, 18°54′50″E	transparent, high thallium concentrations; pH: 7–7.5, water temperature: 19°C
Ph. orbicularis Hübner	Stream "Graniczna Woda", Poland, 50°30′18″N, 18°54′50″E	transparent, high thallium concentrations; pH: 7–7.5, water temperture: 19°C
Lepocinclis fusiformis (Carter) Lemmermann	Field pond in front of Bualuang Restaurant, Lampung Province, Thailand, 18°36′41.70″N, 99°2′3.18″E	transparent water; pH: 7.95, water temperature: 26–29°C
Trachelomonas volvocina (Ehrenberg) Ehrenberg	Fish ponds at Maejo University, Chiang Mai, Thailand, 8°53′55.80″N, 99°00′59.94″E	red-brown; pH: 7.5, water temperature: 34.5
T. volvocinopsis Svirenko	In garden pond at Chiang Mai University, Thailand, 18°47′36.00″N, 98°57′4.02″E	transparent, shallow with *Lotus* (plants); pH: 6.14–6.97, water temperature: 27.7–30.4°C
T. caudata group (Ehrenberg) F. Stein	Village pond in Kaniwola, Łęczyńsko-Włodawskie Lake district (previously used as a site where clay was being mined), Poland, 51°21′51″N, 23°01′45″E	transparent with other loricated taxa, *Trachelomonas hispida*, shallow water; pH: 6.23–8.83, water temperature: 17.2–18.3°C

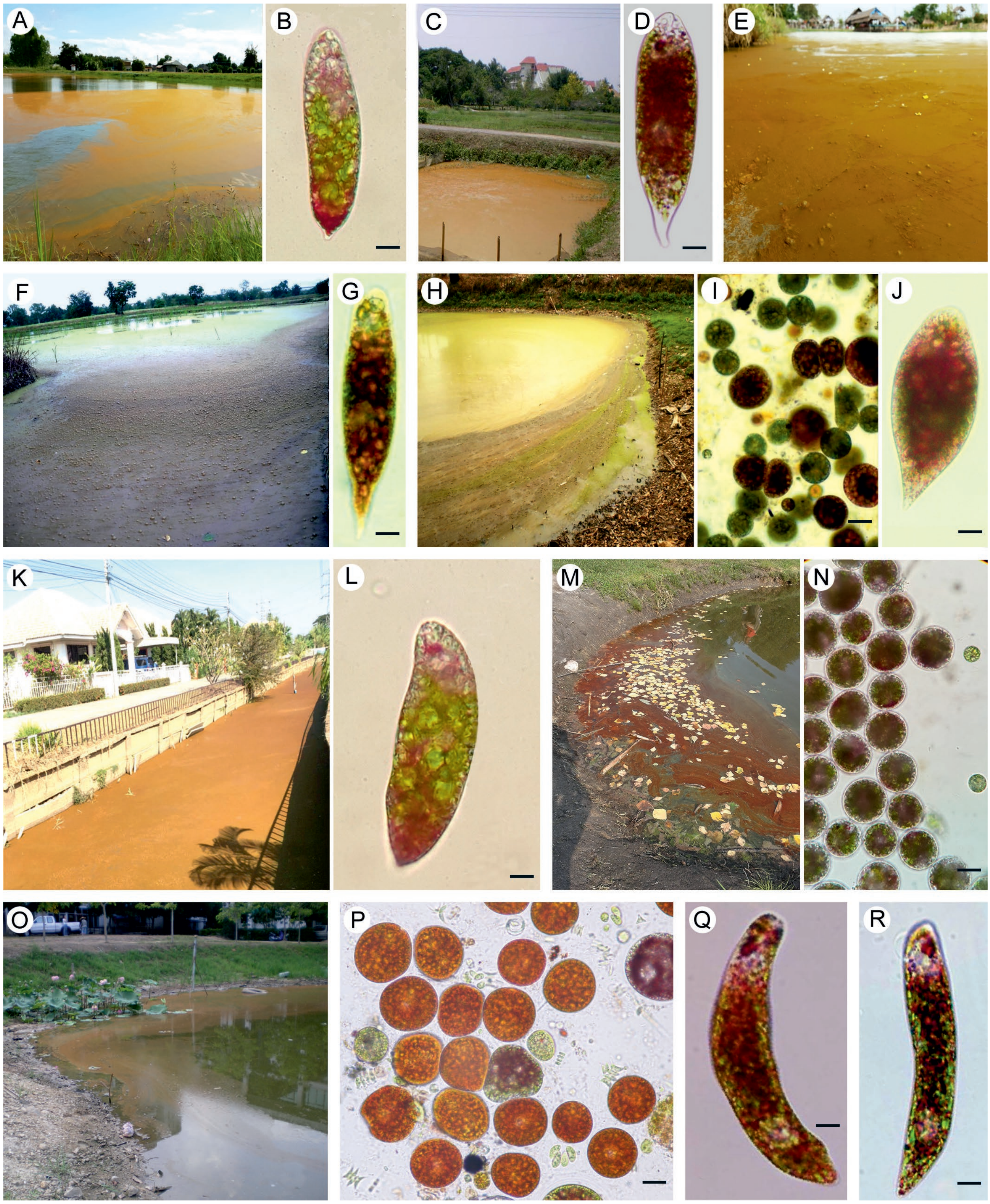

Figure 2. Examples of *Euglena sanguinea* blooms: Large fish pond, Chiang Mai, Thailand (A–B); Fish pond in Maejo University, Chiang Mai, Thailand (C–D); Ditch around rice field (E); Rice field (F–G); Garden pond at the Pa Ko Dam Tobacco station, Chiang Rai (H–J); Moat surrounding villages et Chiang Mai, Thailand (K–L); Small shallow pond in Vilnius, Lituania (M–N); *Euglenaformis chlorophoenica* blooms, garden pond at Chiang Mai University, Thailand (O–R). Scales: B, D, G, J, L, Q, R = 10 μm; I, N, P = 20 μm.

(Fig. 2C–D). An interesting multi-species euglenoid bloom was observed in the garden pond located at the Pa Ko Dam Tobacco Station, Chiang Rai. In total, 204 taxa of euglenoids were recorded in this pond with high diversities of *Trachelomonas* (93 taxa), *Phacus* (38), *Strombomonas* (28), but primarily *E. sanguinea* causing the blooms. The bloom was multi-colored on the perimeter of the pond (Fig. 2A, C, E–F, H, M, O).

Our comprehensive and long-term observations have shown that several other *Euglenaceae* taxa, besides *E. sanguinea*, can cause water blooms. These studies confirmed the fact that among euglenas, the most frequently reported blooms are *Euglena sanguinea*, which often causes dangerous toxic blooms (Karnkowska-Ishikawa et al. 2013; Kulczycka et al. 2018). The problem has been recently reported, for example, from South Africa (Kruger National

Park, Mpumalanga Province and Limpopo Province) by Janse & Levanets (2023). No harmful euglenoids were observed during our studies in Poland, the UK, Slovakia, Romania, the Czech Republic, the USA and Thailand.

For the first time we observed both *Euglena clara* and *Phacus longicauda* blooming in a temporary pond along the road out of Chiang Mai, Thailand (Fig. 3A–C). We also observed a bloom during soil preparing under rice cultivation. *Euglena hemichromata* together with *Euglenaria anabaena* were blooming (Fig. 3I–K). In a village pond in Kaniwola (Poland), we observed a mixture of several taxa: *Trachelomonas*, *Strombomonas* and *Lepocinclis* (Fig. 4B–C, G, I, K).

A spectacular bloom was caused by *E. geniculata*. It formed a green film on the water surface with oxygen bubbles embedded in the bloom biomass in the Garden Pond located at the 700 year old Stadium, Chiang Mai (Fig. 3D–E). It is important to note that the blooms took

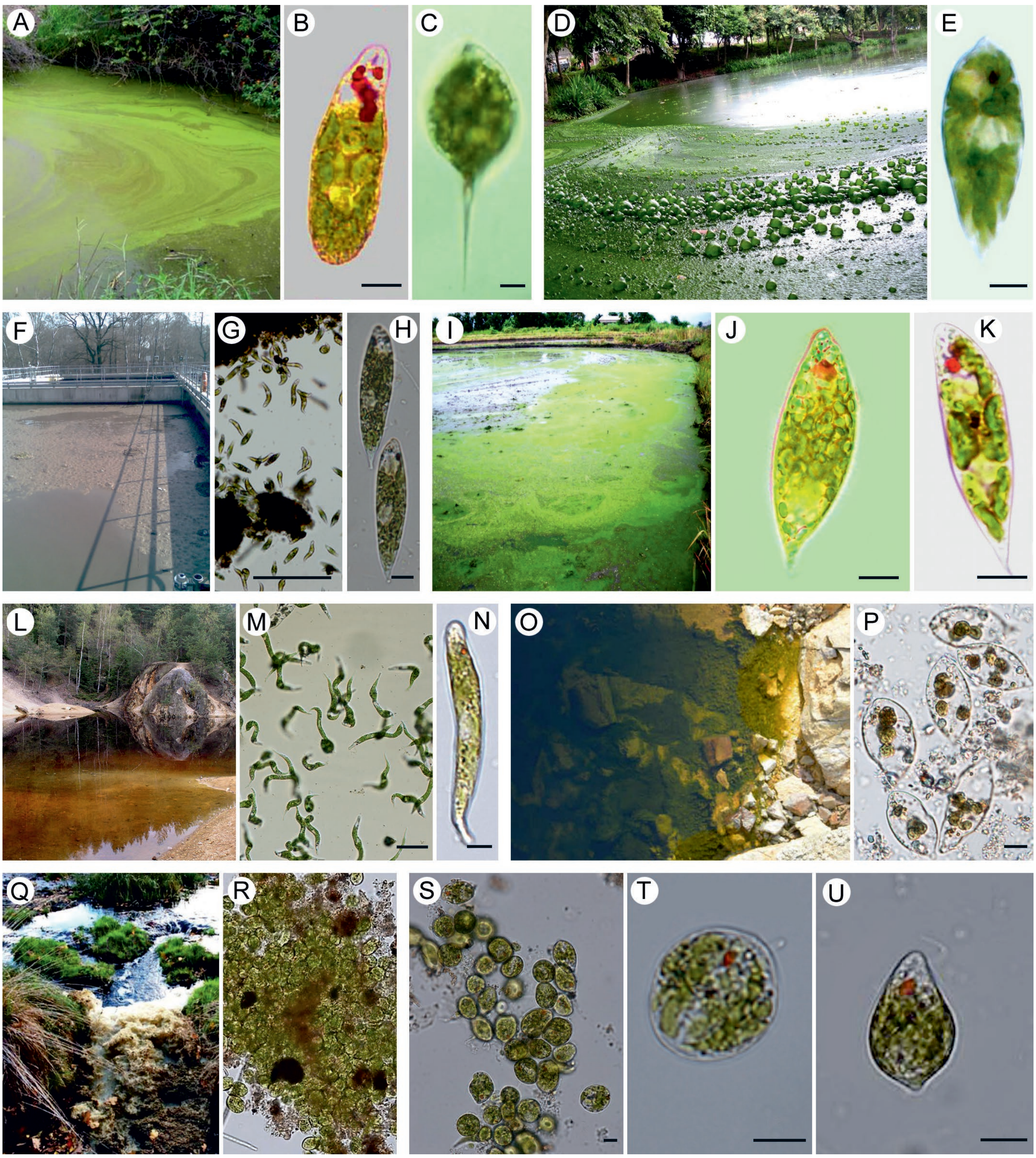

Figure 3. Examples of green blooms: Surface of a temporary pond in Thailand (A), with *Euglena clara* (B) and *Phacus tortus* (C) bloom; Green bloom, on the surface of the garden pond at the old stadium, Chiang Mai, Thailand (D), caused by: *Euglena geniculata* (E); Surface of a basin at the sewage treatment plant, Poland (F), *Euglena geniculata* bloom (G–H); Surface of the rice field (I), *Euglena hemichromata* (J) and *Euglenaria anabaena* (K) caused the green bloom; Acid mine drainage pond in Wieścieszowice, Poland (L) with *Euglena mutabilis* bloom (M–N); Steregoiu Mine River Valley near Rosia Poieni Mine, Romania (O) with *Euglena mutabilis* blooms and pallmelloid stage of cells (P); "Graniczna Woda" stream, Poland (Q), conglomeration cells of *Euglena agilis* and *Euglena pseudoviridis* (R), cells of *Euglena agilis* and *E. pseudoviridis* (S–U). Scales: B–C, E, G–H, J–K, M–N, P, S–U = 10 µm; M = 50 µm.

place at pH 10 and the remaining water parameters were as follows: Alkalinity – 120 mg/L as $CaCO_3$, Conductivity – 164 µS/cm, DO – 10.6 mg/l, BOD – 9.5 mg/L, PO_4^{3-} 0.03 mg/L, NO_3^- 0.6 mg/l, NH_4^+ 0.3 mg/L. Also interesting was the bloom of *E. geniculata* in the wastewater treatment plant in Mikołów, Poland (Fig. 3F–H). This taxon frequently blooms in water highly polluted with organic matter, such as ammonia compounds. A similar bloom was also observed in the Czech Republic on a cow farm located in Třebon (Wołowski 1992).

Periodically, we observe unialgal blooms. In 2010–11, we observed *Euglena agilis* en masse in slowly flowing water in a "Graniczna Woda" stream (Fig. 3Q–U). This water was highly polluted by thallium and other heavy metal compounds (Cd, Pb, Zn). In the samples taken from this stream, we also documented that two taxa of *Phacus* can survive and show high species diversity in the presence of high thallium (TI) concentrations (*Ph. pleuronectes*, *Ph. orbicularis*). In 2013, we observed a different type of euglenoid bloom in an acid mine drainage pond (Purple Pond) in Wieściszowice, Poland, caused by *Euglena mutabilis* (Fig. 3L–N). The dense cells formed gentle cotton-like aggregations. A similar phenomenon, but on a larger scale, was recently recorded in the Steregoiu Mine River Valley near the Rosia Poieni Mine in Romania (Fig. 3O–P). The bloom of *E. mutabilis* covered the bottom of the river as a thin cotton-like layer in the shallow water, sometimes creating delicate clusters of hundreds of aggregations. This species is extremely resistant to various types of toxic pollutants and was also noted in a settling basin for radioactive waste (Lackey 1958).

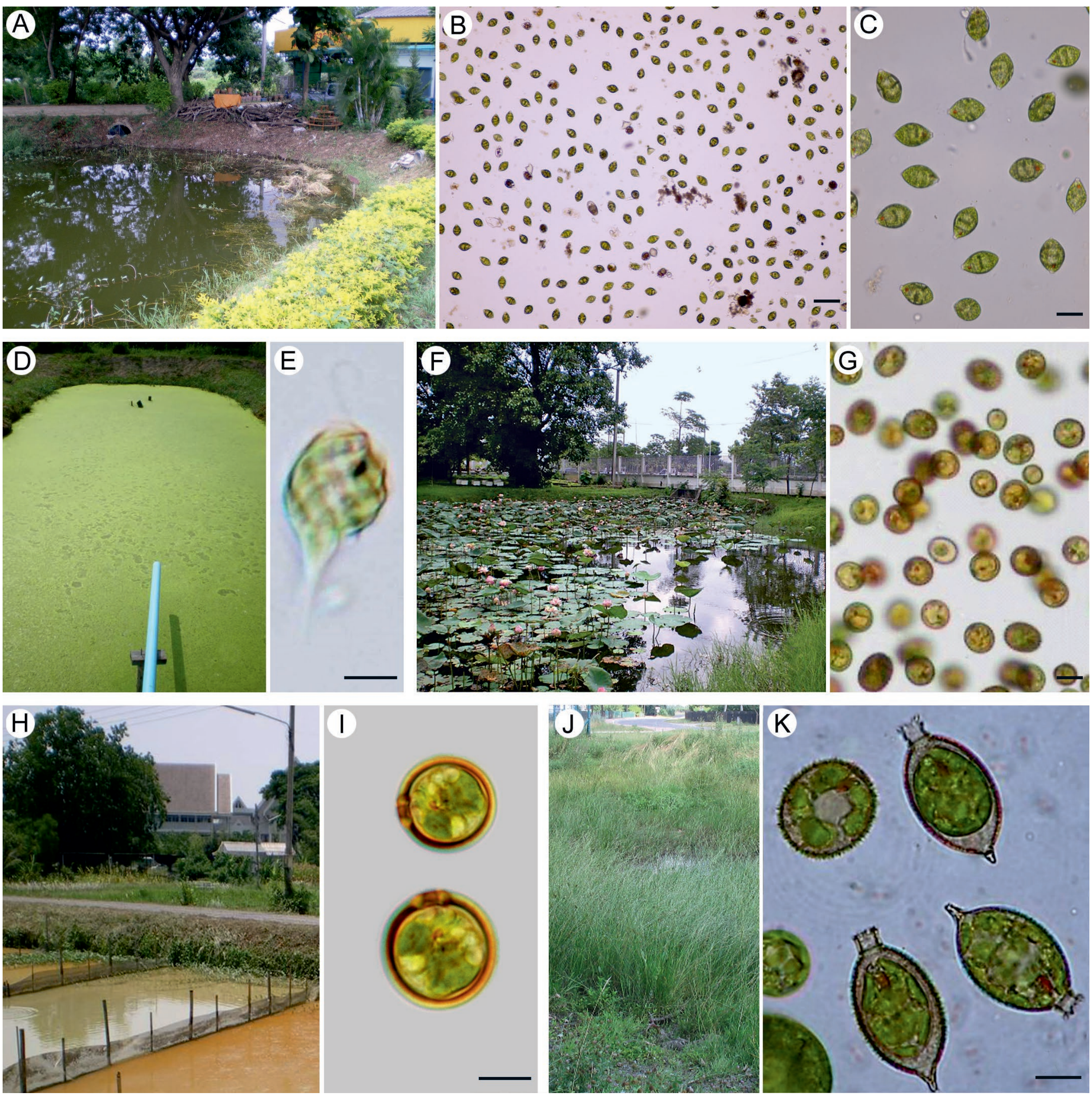

Figure 4. Euglenoid blooms: on the surface of a field pond, Lamphun Province, Thailand (A) caused by: *Lepocinclis fusiformis* (B–C); on the surface of a village pond at a pig farm, Poland (D) caused by *Monomorphina pyrum* (E); in the garden pond at Chiang Mai University, Thailand (F) caused by *Trachelomonas volvocinopsis* (G); on the surface of the fish pond at Maejo University, Thailand (H) caused by *Trachelomonas volvocina* (I); in the village pond in Karniwola, Poland (J) caused by *Trachelomonas caudata* and *T. hispida* (K). Scales: E, I, K = 10 µm; C, G = 20 µm; B = 60 µm.

Transparent blooms caused by loricated euglenoid taxa, such as *Strombomonas* and *Trachelomonas* (Fig. 4F–G, J–K), are often more common. Usually, when these taxa constitute a mono-culture bloom in the field without causing changes to the water color, they can only be observed by examining the samples under a light microscope. Blooms caused by loricated taxa, are often referred to as "diffuse" blooms because they do not change the water color due to the lack of neustonic cluster formation as seen with representatives of the genera *Euglena* and *Euglenaria*. This diffuse bloom phenomenon, caused by *Trachelomonas caudata* and *T. hispida*, was observed in a very shallow village pond that was almost completely overgrown with vegetation in Kaniwola, Łęczyńsko-Włodawskie Lake district, Poland (Fig. 4J–K). The pond had a very high concentration of organic matter from decaying plant parts. There was also a high concentration of biogenes, including eugenic ammonium (ranging from 1.210 to 3.110 mg/L), that are readily used by euglenoids. A similar bloom was observed in a shallow, transparent garden pond with Lotus (plants) in Chiang Mai University, Thailand (Fig. 4F–G). A high concentration of *Trachelomonas volvocinopsis* was also observed in this pond (Fig. 4F–G). A colorless, transparent bloom (mass development) of *Lepocinclis fusiformis* (Carter) Lemmermann was observed in a field pond in front of the Bualuang Restaurant, Lamphun Province, Thailand (Fig. 4A–C).

An algae bloom caused by a species of the genus *Monomorphina*, *M. pyrum*, was first observed in 1986 (Poland, Ściborzyce village, Krakowsko-Częstochowska Upland) in a pond polluted by sewage from a pig farm (Wołowski 1998). The surface of the pond was covered by a green foam (Fig. 4D–E).

Variability of water blooms caused by euglenoid taxa

During our research and literature review, the mass appearances (blooms) of *Euglena sanguinea* were most often noted, probably due to the easily observed prominent red color caused by 73 compounds of hematochrome and annexatio (Grung & Liaaen-Jensen 1993; Wołowski et al. 2013; Deli et al. 2014; Yao et al. 2022). The data collected and observations made of blooms caused by different species of *Euglenaceae* allowed us to create a color range that can help identify the type of bloom and its cause. Blooms come in a range of colors (yellow, green, red, purple and brown) that fall within the range of basic warm and cool colors. Undoubtedly, colors are an autecological feature of the species that create them (Fig. 5).

The color range of blooms caused by euglenoid taxa

Among the green blooms, we observed a rare bloom caused by *Monomorphina pyrum* forming a light foam on the surface of the pond. A similarly bright green bloom was caused by two taxa, *Phacus longicauda* and *Euglena clara*. The latter taxa imparted a decisive bloom compactness by forming pallmeloid stages. A more succulent green bloom was caused by *Euglena hemichromata* and *Euglenaria anabaena* (Fig. 3I–K). This bloom created a rather stiff film that covered 80% of the pond surface. An interesting yellowish-brown bloom was observed and caused by the massive development of *Trachelomonas volvocina*. It was puzzling to observe a mixed bloom of *Euglena sanguinea* and *E. hemichromata* adjacent to a *T. volvocina* bloom. This unusual bloom formed a strong, streaky yellow-green-red mixed film on the surface near the edges of the pond. *Euglena sanguinea* blooms take on a variety of very interesting textures and colors. Early-stage blooms are usually green under favorable conditions. High light intensities generally cause the color to turn red, but not always immediately. Thus, *E. sanguinea* blooms often manifest themselves over a wide range of colors. They may form mixed blooms ranging in color from green to red, then orange to burgundy and finally to orange-brown in the late-stage bloom. Frequently, rapid cell division occurs under stressful conditions, leading to the formation of pallmeloid stages of various types

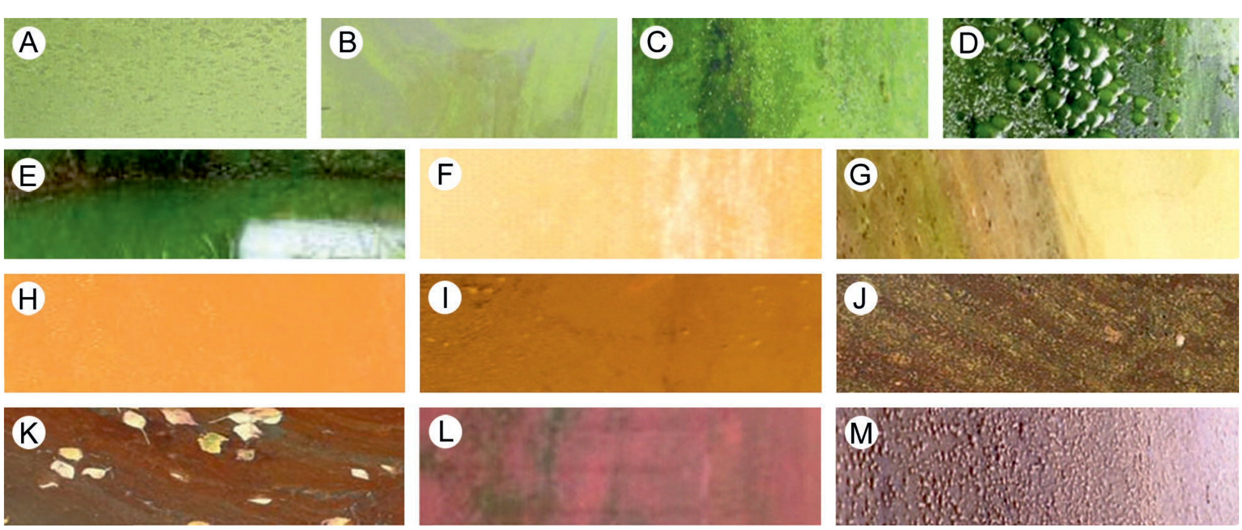

Figure 5. The color range of blooms caused by different species of euglenoids: A – green bloom caused by *Monomorphina pyrum*; B – light green-yellow blooms caused by *Euglena clara* and *Phacus longicauda*; C – green bloom caused by *Euglenaria anabaena* and *E. hemichromata*; D – deep green caused by *Euglena geniculata*; E – smooth deep green caused by *Euglena agilis* and *E. anabaena*; F – beige-yellow blooms caused by *Trachelomonas volvocina*; G – multicolor blooms from light brown, brown, green, red to yellow caused by *Euglena sanguinea* and *E. hemichromata*; H–M – *Euglena sanguinea* blooms in various shades of orange, brown, brown-red, red, purple, and red-violet.

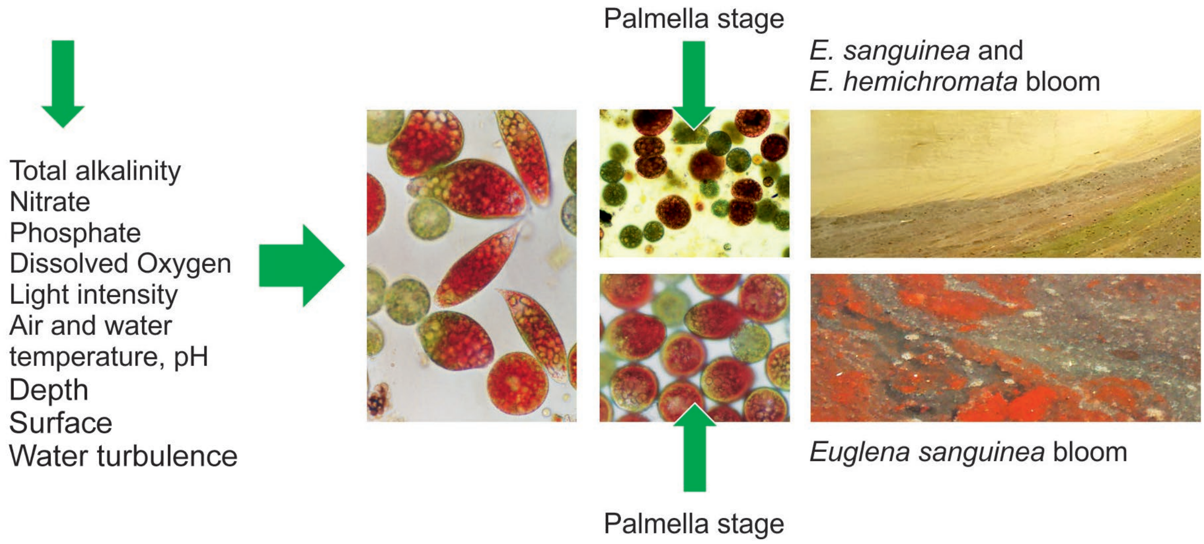

Figure 6. Basic chemical and physical factors influencing the mass development of euglenoids.

(Hindák et al. 2000). These stages create a film on the surface of the reservoir allowing the blooms to persist for quite a long time, sometimes even until the pond is dry. It also happens that the blooms are imperceptible and do not give color effect, most often with the mass productivity of the loricated taxa of *Euglenaceae*, *Trachelomonas* and *Strombomonas.*

Conclusions

Given the ongoing process of global warming, the phenomenon of water blooms caused by the massive development of euglenoids is becoming more common. It is known that with the increase of air temperature, all physical and chemical parameters of water automatically change (Shampa 2016). We observed that reservoirs become shallower, thus the concentration of nutrients such as phosphates and nitrates increase, which promotes the mass development of, among others, euglenoids. During one bloom, water temperature and different physicochemical parameters in one of Thailand's ponds were extremely high (temperatures up to 38.6°C; N-NH_4: 4.0–5.6 mg/L; BOD: 42.8–45.6 mg/L; conductivity: 0.7–0.9 mS/cm; pH: 8.4–9.4). Many observations showed that *Euglena sanguinea* most frequently caused algae blooms (Fig. 6). This species possesses a high carotenoid content resulting in spectacular red blooms, which is probably the reason that this phenomenon is noted all over the world. In small ponds, both in temperate and tropical climates, we often noted blooms caused by *Euglena sanguinea*, *E. geniculata*, *Euglenaria caudata*, *Monomorphina pyrum*, *Trachelomonas volvocinopsis*, and *T. volvocina*. In tropical zones, we also noted that the blooms were much denser, often forming thick and solid films on the water surface causing anoxic conditions. Our results have shown that these microorganisms can be used as indicators of the presence of high concentrations of organic and inorganic pollutants. After additional research, they might be used as bioremediation organisms, since they are able to rapidly incorporate several undesirable chemical compounds in their biomass. Euglenoids can be treated as biological indicators of water quality because they are organisms that react rapidly to changes in environmental conditions, including temperature. Certainly, further observations of the autecology of *Euglenaceae* species and their entire communities will help us to discover and evaluate the occurrence of environmental changes.

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