

PIGMENTED EUGLENOPHYTES OF THE GENERA *EUGLENA*, *EUGLENARIA*, *LEPOCINCLIS*, *PHACUS* AND *MONOMORPHINA* FROM THE SOUTHEASTERN UNITED STATES

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Abstract: The biogeography and taxonomy of euglenophytes from the southeastern United States were studied in material from lakes, ponds and rivers of Alabama, Georgia, Kentucky, Mississippi, North Carolina and Tennessee. The 68 taxa found, 26 of which are new for this region, belong to the genera *Euglena* (26 taxa), *Euglenaria* (2), *Lepocinclis* (13), *Phacus* (25) and *Monomorpha* (2). The taxa occurred at low density, sometimes as a single specimen. Euglenophyte diversity was highest in ponds; rivers had the fewest taxa. Euglenophytes were present in most plankton samples.

Key words: biogeography, Euglenophyceae, *Euglena*, *Euglenaria*, *Lepocinclis*, *Monomorpha*, *Phacus*, taxonomy

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INTRODUCTION

The extensive research done on euglenophytes in the United States has largely dealt with biochemical, molecular and phylogenetic aspects, but there have also been quite a number of floristic studies on this group of algae. Floristic studies on the southeastern United States giving records of euglenophytes include the following: Bovee (1960), Lackey and Lackey (1967), McCoy (1967), Patrick *et al.* (1967), Woodson (1969), Dillard and Crider (1970), Whitford (1979), Zakryś and Walne (1994) and Wołowski and Walne (1997, 2007). Dillard (2000) compiled 246 euglenoid species reported from this region. Rosowski (2003) summarized information about photosynthetic euglenoids in North America as a whole, but gave descriptions for only 10 photosynthetic euglenoid genera, together with detailed bibliographic information. A study initiated by Walne and carried out by Zakryś and Wołowski (Zakryś & Walne 1994; Wołowski & Walne 1997, 2007) gave more

data on euglenophyte diversity, focussing on green euglenophytes in the southeastern United States. Altogether 56 taxa were described and illustrated with original drawings. These taxa belonged to *Euglena* (together with an identification key for those taxa), *Eutreptia*, *Lepocinclis*, *Phacus* and *Strombomonas*. The drawings show particular elements of cell structure in detail. Wołowski and Walne (2007) dealt with *Trachelomonas* (63 taxa) and gave more information about *Strombomonas* (5 taxa) from this region; 26 taxa were new for the southeastern United States. In addition to detailed descriptions of taxa and physical and chemical data, that paper provided extensive SEM and LM micrographs with details of the morphology of *Trachelomonas* and *Strombomonas* loricae. Colorless Euglenophyceae were included in another paper (Wołowski & Walne 1997), with 22 taxa from the following genera: *Anisonema*, *Astasia*, *Cyclidiopsis*, *Entosiphon*, *Gyropaigne*, *Hyalophacus*, *Khawkinea*, *Menoidium*, *Peranemopsis*, *Petalomonas*, *Pseudoperanema* and *Rhabdomonas*.

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All were accompanied by original drawings and some also by micrographs.

The present paper reports similar data for *Euglena*, new *Euglenaria*, *Lepocinclis*, *Phacus* and *Monomorphina*, to supplement the research on other euglenophytes from the southeastern United States, with information about cosmopolitan taxa and others not previously presented for this region. Only 16 of them were described as common or very common by Dillard (2000). The other 52 are new or rare for this region.

MATERIALS AND METHODS

The research was done during a 7-month period in 1994. Samples were collected from 59 sites, including lakes, farm and fish ponds, and rivers in six states of the southeastern United States (Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee) (Fig. 1). The samples were obtained from different microhabitats: surface waters, bottom (mud and sediments), water from squeezed mosses and vascular plants. The samples were kept cool during transport to the laboratory and taxonomic studies. Taxonomic identification, measurements, photographs, drawings and descriptions were made from living material. For microscopic observation a Zeiss research microscope fitted with bright-field, Nomarski and phase-contrast optics, and Cambridge Stereoscan 300 (SEM) was used. Micrographs were taken with an Olympus automatic photographic system, and drawings were made using a camera lucida system. Water physicochemistry was measured directly in the field and include pH, specific conductance, temperature and oxidation/reduction potential. All measurements were

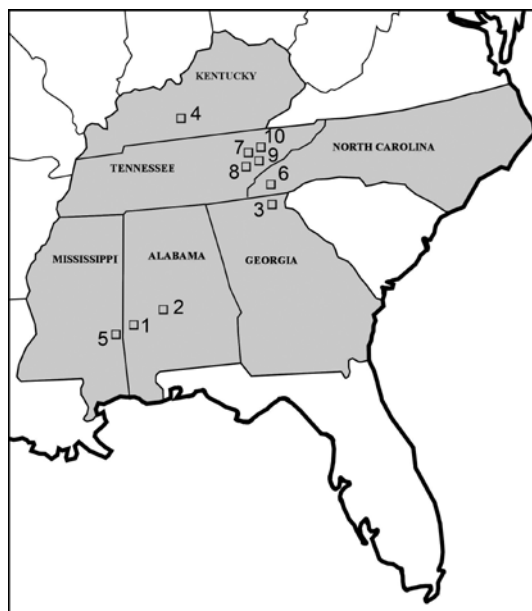


Fig. 1. Location of the collection sites. 1 – Sumter County, 2 – Tuscaloosa Co., 3 – Sky Valley, 4 – Warren Co., 5 – Lauderdale Co., 6 – Macon Co., 7 – Anderson Co., 8 – Blount Co., 9 – Knox Co., 10 – Union Co.

made with a portable Hanna Water Tester and the results are given in Table 1.

RESULTS

We determined 68 taxa. Each one is briefly described and illustrated with original drawings and in some cases by LM micrographs. The

Table 1. Physicochemical parameters of water (ranges of values) at sampling localities. T – temperature, EC – electrolytic conductivity, ORP – oxidation/reduction potential.

Locality	pH	T [°C]	EC [mS/cm]	ORP [mV]
Alabama, Sumter County	8.5–9.8	31.0–35.0	0.21–2.27	9–110
Alabama, Tuscaloosa County	5.7–9.3	27.0–33.5	0.05–0.13	4–170
Georgia, Sky Valley	7.3	25.5	0.23	136
Kentucky, Warren County	5.6–9.3	14.7–28.2	0.15–0.93	142–169
Mississippi, Lauderdale County	6.0–8.0	28.6–34.9	0.17–0.90	19–184
North Carolina, Macon County	5.9–7.0	16.0–19.0	0.18–0.27	100–169
North Carolina, Anderson County	6.6–7.2	21.0–22.3	0.17–0.20	232–233
Tennessee, Blount County	9.9	10.0	–	–
Tennessee, Knox County	9.2–9.8	10.0–12.0	–	–
Tennessee, Union County	7.5	22.6	2.02	1

descriptions are completed with information on habitat (dl – decaying leaves, gm – green mat, m – bottom mud, n – neuston, p – plankton, pb – peat bog, sq – squeezed mosses or vascular plants, ss – surface scum); that information is given in Table 2.

Taxonomy generally follows Pringsheim

(1956), Leedale (1967) and Wołowski (1998), with changes related to photosynthetic euglenoids from Milanowski *et al.* (2001, 2006), Marin *et al.* (2003), Brosnan *et al.* (2005), Wołowski and Hindák (2005), Triemer and Farmer (2007), Ciugulea and Triemer (2010), Linton *et al.* (2010) and Wołowski (2011).

Table 2. List of *Euglena* Ehrenb., *Euglenaria* Karnkowska & E. W. Linton, *Lepicinclis* Perty, *Phacus* Dujard. and *Monomorpha* Mereschkowski taxa found in the southeastern United States. AL – Alabama, GA – Georgia, KY – Kentucky, MS – Mississippi, NC – North Carolina, TN – Tennessee; dl – decaying leaves, gm – green mat, m – bottom mud, n – neuston, p – plankton, pb – peat bog, sq – squeezed mosses or vascular plants, ss – surface scum.

Taxon	AL	GA	KY	MS	NC	TN
<i>Euglena</i> cf. <i>gaumei</i>	gm	.	.	.	.	.
<i>E. antefossa</i>	p	.	.	.	m	.
<i>E. pavlovskoensis</i>	gm, m	.	.	.	.	.
<i>E. limnophila</i>	.	.	sq	p	.	.
<i>E. limnophila</i> var. <i>swirenkoi</i>	.	.	sq	.	.	.
<i>E. tuberculata</i>	.	.	.	.	m	.
<i>E. geniculata</i>	.	sq, n	.	.	b	.
<i>E. cuneata</i>	pb	.	.	.	.	.
<i>E. tristella</i>	.	.	.	.	.	p
<i>E. viridis</i>	p, ss	.	.	.	b	p
<i>E. stellata</i>	.	.	.	.	b	.
<i>E. hemichromata</i>	.	n	.	m, n, m, p	b	.
<i>E. proxima</i>	.	.	sq	.	.	p
<i>E. ehrenbergii</i>	p	.	.	.	.	m
<i>E. cf. etllei</i>	.	.	.	.	.	m
<i>E. agilis</i>	gm	.	.	m, n	.	p
<i>E. chlamydotheca</i>	.	.	n	.	.	.
<i>E. granulata</i>	p	.	.	.	.	.
<i>E. sociabilis</i>	.	n	.	.	.	.
<i>E. velata</i>	.	.	.	.	m	.
<i>E. obtusa</i>	.	.	m	m, n	.	.
<i>E. splendens</i>	p	.	m	dl	.	.
<i>E. satelles</i>	.	.	m	.	.	.
<i>E. vermicularis</i>	.	.	.	.	p	.
<i>E. vagans</i>	.	.	m	.	.	.
<i>E. mutabilis</i>	gm, p	sq	.	.	.	p
<i>Euglenaria anabaena</i>	.	.	n	.	.	.
<i>E. caudata</i> var. <i>caudata</i>	p, m	n	m	m, p	m	.
<i>Lepocinclis ovum</i> var. <i>ovum</i>	n	.	.	.	.	m
<i>L. texta</i> var. <i>texta</i>	p, m	.	p	m, n, dl, p	p	m, p
<i>L. salina</i> fo. <i>obtusa</i>	m	.	.	.	.	.
<i>L. cylindrica</i>	.	.	.	m	.	.
<i>L. steinii</i>	.	.	.	.	.	m
<i>L. marssonii</i>	.	.	m	.	.	.
<i>L. acus</i>	p, gm	.	.	p	.	.

Table 2. Continued.

Taxon	AL	GA	KY	MS	NC	TN
<i>L. spirogyroides</i>	p, gm, m	.	.	p	.	p
<i>L. fusca</i>	gm	.	.	.	.	.
<i>L. oxyuris</i>	gm	.	.	p	m	.
<i>L. oxyuris</i> var. <i>maior</i>	.	.	m	.	.	p
<i>L. oxyuris</i> fo. <i>lata</i>	.	.	.	.	m	.
<i>L. tripteris</i>	gm, m, p	.	m	.	sq	.
<i>Phacus parvulus</i>	.	.	.	.	.	m
<i>Ph. pusillus</i>	.	.	.	.	.	m
<i>Ph. dangeardii</i>	.	.	.	.	.	m
<i>Ph. fominii</i>	gm	.	.	.	.	.
<i>Ph. acuminatus</i>	m	.	.	.	.	gm
<i>Ph. oscillans</i>	.	.	.	.	.	p
<i>Ph. undulatus</i>	m	.	.	.	.	.
<i>Ph. unguis</i>	gm	.	.	.	.	m
<i>Ph. orbicularis</i>	p	.	m	m	.	gm, p
<i>Ph. pleuronectes</i>	gm, n-gm	.	.	m, dl	.	m
<i>Ph. ankylonoton</i>	.	.	.	.	.	m
<i>Ph. hamelii</i>	.	.	.	m	.	.
<i>Ph. triqueter</i>	gm, sq	.	p	.	.	m
<i>Ph. alatus</i>	.	.	.	p	.	.
<i>Ph. curvicauda</i>	.	.	p	p	.	m
<i>Ph. raciborskii</i>	gm	.	.	.	.	.
<i>Ph. longicauda</i>	p	.	.	p	p	m
<i>Ph. longicauda</i> var. <i>attenuata</i>	p	.	.	.	.	.
<i>Ph. longicauda</i> var. <i>rotunda</i>	p	.	.	.	.	.
<i>Ph. circumflexus</i>	p	.	.	.	.	.
<i>Ph. ephippion</i>	.	.	sq	.	.	.
<i>Ph. helikoides</i>	.	.	.	p	.	.
<i>Ph. smulkowskianus</i>	.	.	.	.	.	m
<i>Ph. monilatus</i>	p	.	.	.	p	.
<i>Ph. sp.</i>	gm	.	.	.	.	.
<i>Monomorphina pyrum</i>	gm	.	.	.	.	.
<i>M. splendens</i>	m	.	m	.	.	.

TAXONOMICAL DESCRIPTIONS

Euglena Ehrenb. 1838

Euglena cf. ***gaumei*** P. Allorge & M. Lefèvre 1931
Fig. 2

Cell 140 µm long and 14 µm wide, cylindrical to crescent-shaped, ended with hyaline cauda at posterior end. Cell with numerous small chloroplasts and two large paramylon bodies. Pellicle longitudinally striated.

SITES: Alabama, Tuscaloosa County, small duck pond in University of Alabama area.

OCCURRENCE. Earlier reported from Florida by McCoy (1967)

Euglena antefossa L. P. Johnson 1944 Fig. 3

Cell 162.5 µm long and 20 µm wide with 30 µm long cauda. Cell long, cylindrical, with longitudinally striated pellicle. Chloroplasts small and plate-shaped; paramylon grains on both sides of nucleus.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 22; North Carolina, Macon County, Patton and White Roads pond.

OCCURRENCE. Earlier reported from Alabama by Zakryś and Walne (1994).

NOTE. The cell is similar to *Lepocinclis oxyuris* but is more elongated and not twisted (as *L. oxyuris* is).

Euglena pavlovskoensis (Elenkin & Poljansky) T. G. Popova 1951 Fig. 4

Euglena intermedia var. *pavlovskoensis* Elenkin & Poljansky 1938

Cells 77–95 µm long and 10–13 µm wide. Cells cylindrical, quite often bent; posterior end gradually tapering to narrow hyaline tail. Pellicle finely spirally striated. Central nucleus with two large oval-shaped paramylon grains; chloroplasts small and numerous. Flagellum 1/2 the length of cell.

SITES: Alabama, Sumter County, Nixon's pond; Alabama, Sumter County, Livingston University duck pond; Alabama, Tuscaloosa County, small duck pond in University of Alabama area.

NOTE. The specimens are similar in cell organization and dimensions to *Lepocinclis oxyuris* and *Euglena antefossa*, but these specimens are not twisted (as *L. oxyuris* is) and are considerably smaller than specimens of *E. antefossa*.

Euglena limnophila Lemmerm. 1913 Fig. 5

Cell 70 µm long and 12 µm wide, cylindrical to fusiform. Cell with cauda 15 µm long at posterior end, which is clearly marked, sharp and hyaline.

SITES: Kentucky, Warren County, spring; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond.

OCCURRENCE. Earlier reported from Georgia by Patrick *et al.* (1967).

NOTE. Recently classified also as *Phacus limnophila* (Lemmerm.) E. W. Linton & Karnkowska (Ciugulea & Triemer 2010).

Euglena limnophila var. *swirenkoi* T. G. Popova 1955 Fig. 6a–d

Euglena swirenkoi Arnoldi 1922, *E. limnophila* var. *minor* Drezep. 1925

Cell 41 µm long, 10 µm wide and 7 µm thick, fusiform or bent with sharp elongated cauda at posterior end.

SITES: Kentucky, Warren County, spring.

NOTE. Recently classified as *Phacus limnophila* (Lemmerm.) E. W. Linton & Karnkowska (Ciugulea & Triemer 2010).

Euglena tuberculata Svirenko 1915 Fig. 7

Cells 45.0–45.8 µm long and 17.0–17.5 µm wide. Cells with long sharp tail-piece. Sides of cells folded; in cells are very numerous oval-shaped paramylon grains, densely crammed, which cover the chloroplasts, make the sides of the cell appear folded, or even form delicate swellings on the cell surface.

SITES: North Carolina, Macon County, Patton and White Roads pond.

Euglena geniculata Dujard. 1841 Figs 8 & 71

Cells 57.5–90.0 µm long and 10–15 µm wide, fusiform to cylindrical fusiform; each cell slightly narrowing at posterior end. Cells possess two star-shaped chloroplasts on both sides of centrally located nucleus.

SITES: Georgia, Sky Valley, Tahoe Road, lake; North Carolina, Macon County, Patton Road Golf Creek.

OCCURRENCE. Earlier reported from Georgia by Patrick *et al.* (1967) and from Alabama and Tennessee by Zakryś and Walne (1994).

Euglena cuneata E. G. Pringsh. 1956 Fig. 9

Cells 50–52 µm long and 22.5–25.0 µm wide, broadly cylindrical, rounded at both anterior and posterior ends; one large star-shaped chloroplast filling cell interior.

SITES: Alabama, Sumter County, Veterans of Foreign Wars, peat bog.

Euglena tristella S. P. Chu 1947 Figs 10 & 72

Cell 77.5 μm long and 20 μm wide, broadly fusiform, tapering at posterior end and rounded at anterior end. Specimens have three star-shaped chloroplasts similar to those in *E. geniculata* cells. Each chloroplast possesses a central pyrenoid group.

SITES: Tennessee, Union County, Brock Road, farm pond near barn.

Euglena viridis Ehrenb. 1838 Figs 11 & 73

Cells 42.5–48.5 μm long and 10–15 μm wide, fusiform to broadly fusiform, ended in tapering tail-piece. Cells widest at midlength of cell, forming characteristic bulge there.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 21; Alabama, Tuscaloosa County, Butterfield catfish pond 22; North Carolina, Macon County, Patton Road Golf Creek; Tennessee, Knox County, fish pond.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena stellata Mainx 1926 Fig. 12

Cells 35–40 μm long and 15.0–17.5 μm wide, fusiform with rounded anterior end, posterior end gradually narrowing; one star-shaped chloroplast in upper part of cell.

SITES: North Carolina, Macon County, Patton Road Golf Creek.

OCCURRENCE. Earlier reported from Tennessee by Zakryś and Walne (1994).

Euglena hemichromata Skuja 1948
Figs 13 & 74

Cells 65–89 μm long and 15.0–20.5 μm wide, broadly fusiform with gently narrowing posterior end; numerous small chloroplasts.

SITES: Georgia, Sky Valley, Tahoe Road, lake;

Mississippi, Lauderdale County, Toom Suba Creek; Mississippi, Lauderdale County, Kewanee pond; Mississippi, Lauderdale County, Kewanee Road, ditch; Mississippi, Lauderdale County, Toom Suba Creek; North Carolina, Macon County, Patton Road Golf Creek.

OCCURRENCE. Earlier reported from Alabama, North Carolina and Tennessee by Zakryś and Walne (1994).

Euglena proxima P. A. Dang. 1901 Fig. 14

Cell 50 μm long and 13 μm wide, broadly fusiform, slightly narrowed at anterior end and tapering at posterior end. Nucleus in central part of cell; small discoid chloroplasts.

SITES: Kentucky, Warren County, Jackson Orchard, big pond; Tennessee, Knox County, fish pond.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena ehrenbergii G. A. Klebs 1883
Figs 15a, b & 75

Cells 135–180 μm long and 10–30 μm wide, cylindrical, strongly elongated and flattened; some slightly twisted, intensely euglenoid movements. Nucleus usually in lower part of cell; very numerous small chloroplasts; paramylon grain in the form of a long rod.

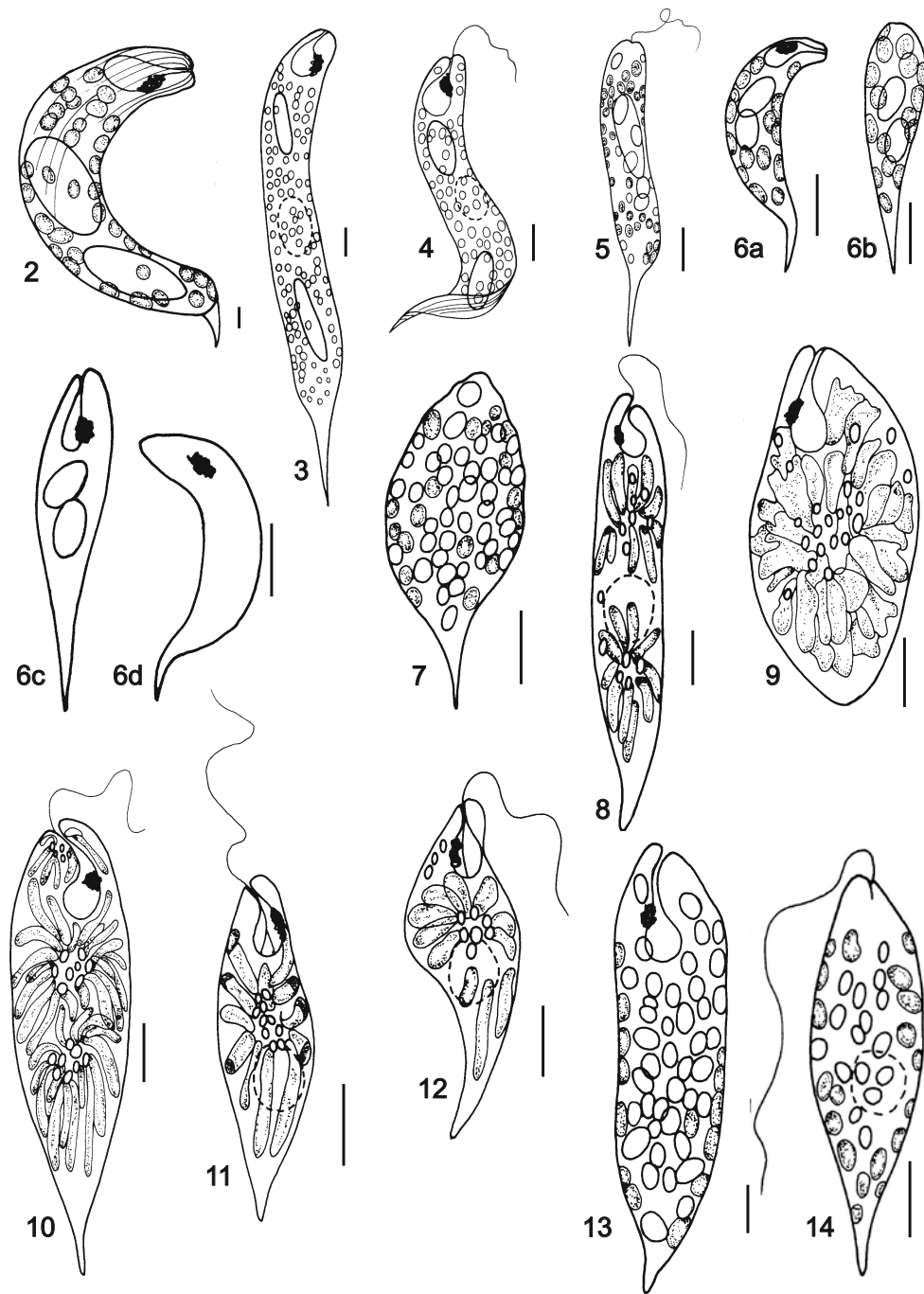
SITES: Alabama, Sumter County, W. Suffolk pond; Tennessee, Union County, Malueg Farm, upper pond.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena* cf. *ettlii Wołowski 1993 Fig. 16

Cells 39–40 μm long and 17.5 μm wide, broadly fusiform with one axial chloroplast having uneven edges. Nucleus in center of cell; paramylon grains small, oval and not numerous.

SITES: Tennessee, Knox County, puddle in Cherokee Park.



Figs 2–14. 2 – *Euglena* cf. *gaumei* P. Allorge & M. Lefèvre, 3 – *E. antefossa* L. P. Johnson, 4 – *E. pavlovskoensis* (Elenkin & Poljansky) T. G. Popova, 5 – *E. limnophila* Lemmerm., 6a, b, c, d – *E. limnophila* var. *swirenkoi* T. G. Popova, 7 – *E. tuberculata* Svirenko, 8 – *E. geniculata* Dujard., 9 – *E. cuneata* E. G. Pringsh., 10 – *E. tristella* S. P. Chu, 11 – *E. viridis* Ehrenb., 12 – *E. stellata* Mainx, 13 – *E. hemichromata* Skuja, 14 – *E. proxima* P. A. Dang. Scale bars = 10 µm.

Euglena agilis H. J. Carter 1856 Figs 18 & 80

Cells 22.0–27.5 μm long and 7.5–12.5 μm wide, short fusiform with two elongated chloroplasts, each with double pyrenoid.

SITES: Alabama, Sumter County, Nixon's pond; Mississippi, Lauderdale County, Kewanee pond; Tennessee, Union County, Brock Road, farm pond near barn.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena chlamydophora Mainx 1926 Fig. 19

Cell 40.5 μm long and 11 μm wide, broadly fusiform, narrowing at anterior and posterior ends; emergent flagellum 1/2 the length of cell. Chloroplasts small and not numerous; a few paramylon bodies in the form of oval grains.

SITES: Kentucky, Warren County, Jackson Orchard, big pond.

OCCURRENCE. Earlier reported from Georgia by Patrick *et al.* (1967), North Carolina by Morris *et al.* (1977).

Euglena polymorpha P. A. Dang. 1901

Fig. 21a, b

Cells 59–62 μm long and 20–29 μm wide, broadly oval with long tail-piece. Flagellum longer than cell length. Chloroplasts with irregular edges, each with double pyrenoids.

SITES: Georgia, Sky Valley, Tahoe Road, lake; Mississippi, Lauderdale County, Cobb's pond.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena granulata (G. A. Klebs) F. Schmitz 1884
Fig. 22***Euglena velata* var. *granulata*** G. A. Klebs 1883

Cell 78 μm long and 15 μm wide, cylindrical, ended with clearly formed hyaline cauda. Chloroplasts with small pyrenoids; nucleus in cell center.

SITES: Alabama, Sumter County, Nixon's pond.

OCCURRENCE. Earlier reported from Georgia by Patrick *et al.* (1967).

NOTE. The cell is similar to *E. caudata* representatives but its shape is clearly cylindrical while *E. caudata* is spindle-shaped to broadly fusiform.

Euglena sociabilis P. A. Dang. 1901

Figs 23 & 76

Cell 85 μm long and 15 μm wide, fusiform, anterior end finely elongated and rounded, posterior end tapering to slender cauda. Chloroplasts with elongated lobes arranged below periplast.

SITES: Georgia, Sky Valley, Tahoe Road, lake.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena velata G. A. Klebs 1883

Fig. 24

Cell 90.0 μm long and 18.5 μm wide; numerous elongated chloroplasts with double pyrenoids. Periplast slightly spirally striated; central nucleus, paramylon bodies in the form of circular or oval grains.

SITES: North Carolina, Macon County, Patton and White Roads pond.

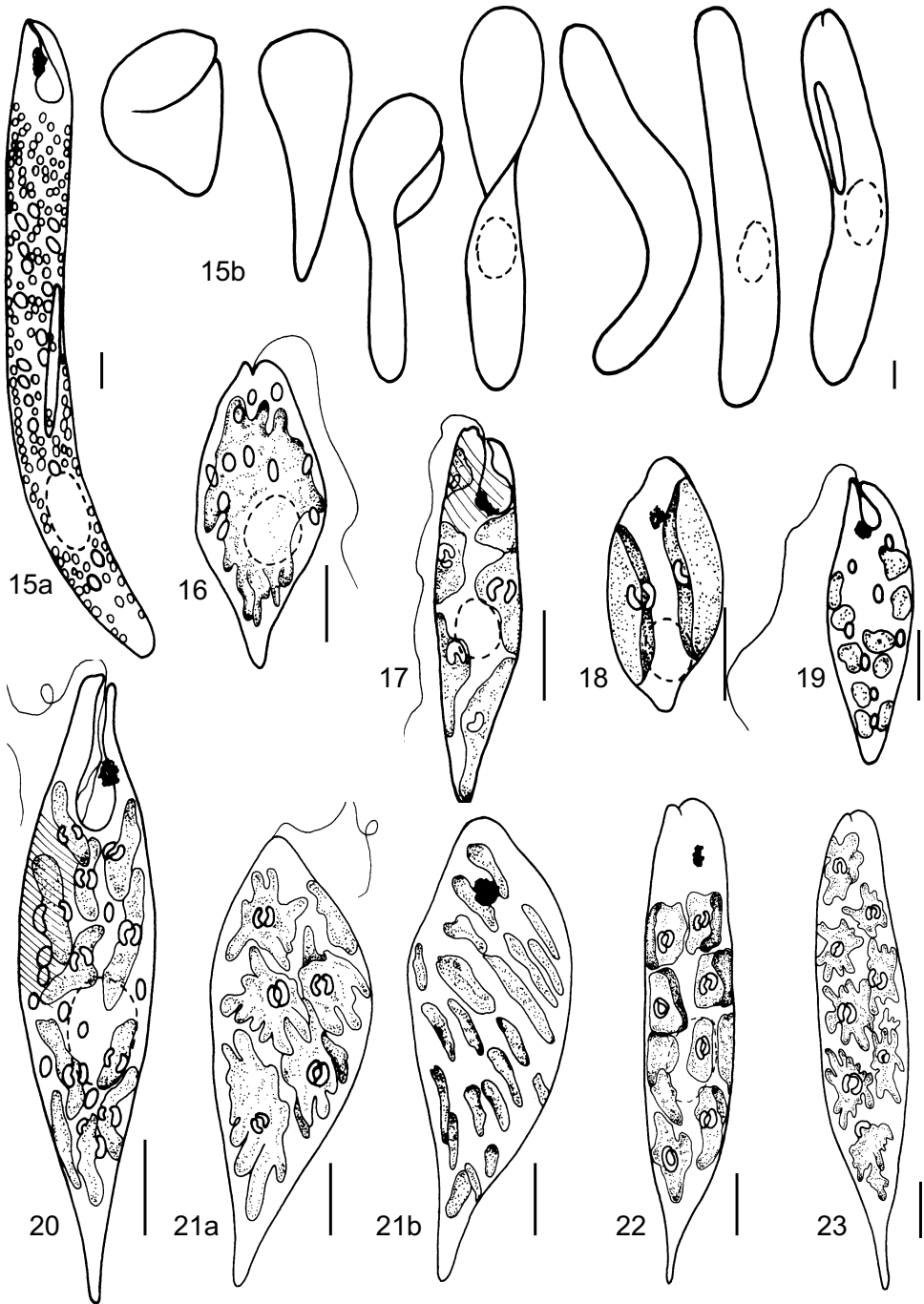
OCCURRENCE. Earlier reported from Tennessee by Lackey (1942, 1958), North Carolina by Smith (1958) and Alabama by Zakryś and Walne (1994).

Euglena obtusa F. Schmitz 1884

Fig. 25

Cells 125.0–137.5 μm long and 31.5–37.5 μm wide, broadly oval to slightly elongated, anterior and posterior ends rounded. Pellicle spirally striated; nucleus in lower part of cell; chloroplasts small and very numerous. Euglenoid movements creeping.

SITES: Kentucky, Warren County, Campgrounds



Figs 15–23. 15a, b – *Euglena ehrenbergii* G. A. Klebs, b – metabolic movement, 16 – *E. cf. ettlii* Wołowski, 17 – *Euglenaria anabaena* (Mainx) Karnkowska & E. W. Linton, 18 – *Euglena agilis* H. J. Carter, 19 – *E. chlamydophora* Mainx, 20 – *Euglenaria caudata* var. *caudata* (Hüber) Karnkowska & E. W. Linton, 21a, b – *Euglena polymorpha* P. A. Dang., 22 – *E. granulata* (G. A. Klebs) F. Schmitz, 23 – *E. sociabilis* P. A. Dang. Scale bars = 10 μ m.

of America pond; Mississippi, Lauderdale County, Kewanee pond.

Euglena splendens P. A. Dang. 1901

Figs 26 & 77

Cells 67–95 μm long and 27–32 μm wide, broadly oval to broadly fusiform, anterior end finely narrowing and rounded, posterior end with small projection.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 1; Alabama, Tuscaloosa County, quarry pond; Kentucky, Warren County, spring; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglena satelles Braslavskaja-Spektorova 1937

Fig. 28a–c

Cells 150–171 μm long and 15–16 μm wide, cylindrical, anterior and posterior ends rounded. Euglenoid movement slow and creeping, resulting in substantial change of cell shape. Nucleus in center of cell; chloroplasts parietal, without pyrenoids; paramylon bodies in the form of numerous small oval grains.

SITES: Kentucky, Warren County, spring.

NOTE. The specimens are similar to *Euglena deses* representatives. The difference is in the posterior end, which is rounded in *E. satelles*. *Euglena deses* specimens have a short, narrow projection.

Euglena vermicularis Proškina-Lavrenko 1937

Fig. 27

Cell 90 μm long and 10 μm wide, elongated and cylindrical with narrowing ends, posterior end attached to bottom substrate. Nucleus in center of cell; chloroplasts large, parietal, with rough edges; paramylon grains numerous, small and ovate.

SITES: North Carolina, Macon County, Shopes Farm, upper pond.

Euglena vagans Deflandre 1929 Fig. 29 & 102

Cells 63–71 μm long and 10 μm wide, cylindrical to short cylindrical with small V-shaped cauda. Nucleus in center, two large rod-shaped paramylon grains at both sides of nucleus; chloroplasts small, plate-shaped.

SITES: Kentucky, Warren County, spring.

NOTE. The specimens are longer and wider than given by Deflandre (1929).

Euglena mutabilis F. Schmitz 1884

Figs 30a, b & 78

Cells 57–65 μm long and 10–11 μm wide, cylindrical with narrowed ends; cells may be attached to substrate at posterior end. Cells bend while swimming. Chloroplasts large, 4–5, thin, flat, closely pressed to wall with pyrenoids.

SITES: Alabama, Sumter County, W. Suffolk pond; Alabama, Tuscaloosa County, quarry pond; Georgia, Sky Valley, Tahoe Road, lake; Tennessee, Blount County, Great Smoky Mountains National Park, stream.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Euglenaria Karnkowska & E. W. Linton 2010

Euglenaria anabaena (Mainx) Karnkowska

& E. W. Linton 2010 Fig. 17

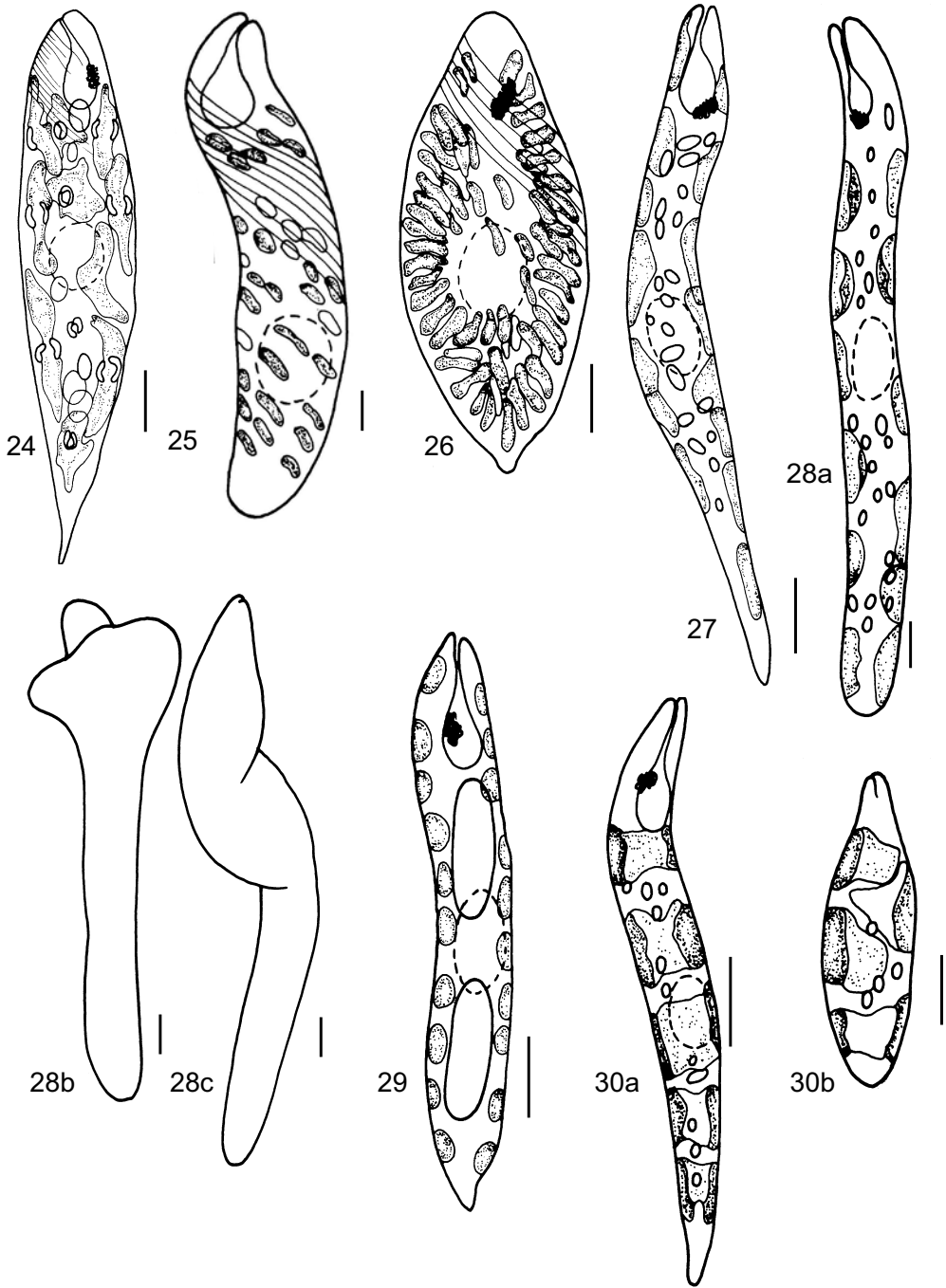
Cells 32.5–42.0 μm long and 10–11 μm wide, fusiform, slightly narrowing at posterior end; pellicle spirally striated. A few chloroplasts with double pyrenoids; emergent flagellum as long as cell.

SITES: Kentucky, Warren County, Beechbend Road, farm pond; Kentucky, Warren County, Jackson Orchard, big pond.

Euglenaria caudata var. *caudata* (Hüber)

Karnkowska & E. W. Linton 2010
Figs 20, 79 & 103

Cells 59–77(–137) μm long and 15–26 μm wide, spindle-shaped, elongated, narrowing at anterior end, posterior end with long tail-piece.



Figs 24–30. 24 – *Euglena velata* G. A. Klebs, 25 – *E. obtusa* F. Schmitz, 26 – *E. splendens* P. A. Dang., 27 – *E. vermicularis* Proškina-Lavrenko, 28a, b, c – *E. satellites* Braslavskaja-Spektorova, b, c – changes of cell shape, 29 – *E. vagans* Deflandre, 30a, b – *E. mutabilis* F. Schmitz. Scale bars = 10 μ m.

SITES: Alabama, Sumter County, W. Suffolk pond; Alabama, Tuscaloosa County, small duck pond in University of Alabama area; Alabama, Tuscaloosa County, Butterfield catfish pond (limestone sink); Georgia, Sky Valley, Tahoe Road, lake; Kentucky, Warren County, spring; Mississippi, Lauderdale County, Kewanee Road, ditch; North Carolina, Macon County, Patton and White Roads pond.

OCCURRENCE. As *Euglena caudata* common in southeastern United States (Dillard 2000).

Lepocinclis Perty 1852

Lepocinclis ovum (Ehrenb.) Minkiewicz 1898
Figs 31 & 81

Chloropeltis ovum F. Stein 1878, *Phacus ovum* (Ehrenb.) G. A. Klebs 1883, *Euglena ovum* Ehrenb. 1840, *E. zonalis* H. J. Carter 1859

Cell 33 μm long and 25 μm wide, obovoid, ended with short blunt projection; chloroplasts small; two large paramylon bodies.

SITES: Alabama, Tuscaloosa County, small duck pond in University of Alabama area; Tennessee, Knox County, puddle in Cherokee Park.

OCCURRENCE. Very common in southeastern United States (Dillard 2000).

Lepocinclis texta (Dujard.) Lemmerm.
var. *texta* Drezep. 1925 Figs 32, 82 & 104

Cells 35–45 μm long and 27.5–30.0 μm wide, ovoid, anterior end narrow, posterior end broadly rounded; pellicle spirally striated; small oval paramylon bodies.

SITES: Alabama, Sumter County, W. Suffolk pond; Alabama, Sumter County, Veterans of Foreign Wars, peat bog; Alabama, Sumter County, Livingston University duck pond; Alabama, Sumter County, Butterfield catfish pond (limestone sink); Kentucky, Warren County, Beechbend Road, farm pond; Kentucky, Warren County, Route 240/880, Campgrounds of America pond; Mississippi, Lauderdale County, Kewanee pond; Mississippi, Lauderdale County, Toom Suba Creek;

Mississippi, Lauderdale County, Kewanee pond; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond; North Carolina, Anderson County, Nolan's pond; Tennessee, Knox County, puddle in Cherokee Park; Tennessee, Union County, Brock Road, farm pond near barn.

OCCURRENCE. As *Euglena texta* common in southeastern United States (Dillard 2000).

Lepocinclis salina fo. *obtusata* (Hub.-Pest.)
W. Conrad 1934 Fig. 33

Lepocinclis Bütschlii var. *obtusata* Hub.-Pest. 1929

Cell 45 μm long and 25 μm wide, ovoid with small projection at posterior end; pellicle spirally striated from right to left; two large and some smaller ring-shaped paramylon grains.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 1.

Lepocinclis cylindrica (Korshikov) W. Conrad
1934 Fig. 34a, b

Lepocinclis ovum var. *cylindrica* Korshikov 1928

Cell 20 μm long and 10 μm wide, oval, slightly elongated; pellicle spirally striated from left to right; two large ring-shaped paramylon bodies.

SITES: Mississippi, Lauderdale County, Kewanee Road, ditch.

Lepocinclis steinii Lemmerm. 1901
Fig. 35a, b & 105

Cell 30 μm long and 10 μm wide, shortly fusiform with short cauda at posterior end; pellicle longitudinally striated; paramylon grains in the form of clearly visible large rings.

SITES: Tennessee, Knox County, small basin in Lynnhurst Cemetery.

Lepocinclis marssonii Lemmerm. 1904
Figs 36a, b, 83 & 106

Cells 30–35 μm long and 10.0–10.5 μm wide, elongated, ended with small projection, anterior end truncated; pellicle finely longitudinally stri-

ated; two ring-shaped paramylon bodies in parietal location.

SITES: Kentucky, Warren County, spring.

OCCURRENCE. Earlier reported from Alabama by Zakryś and Walne (1994).

Lepocinclis acus (O. F. Müller) B. Marin & Melkonian 2003 Figs 37 & 87

Cells 180–270 µm long and 10–15 µm wide, thin, needle-shaped or tightly spindle-shaped, truncate at anterior end, ended with sharp hyaline cauda; numerous and small discoid chloroplasts; paramylon bodies in the form of several thin rods.

SITES: Alabama, Sumter County, W. Suffolk pond, Alabama, Tuscaloosa County, Butterfield catfish pond 22; Mississippi, Lauderdale County, Cobb's pond.

Lepocinclis spirogyroides B. Marin & Melkonian 2003 Figs 38 & 86

Euglena spirogyra Ehrenb. 1830

Cells (95–)130–135 µm long and (10.0–)22.0–22.5 µm wide, elongated to longitudinally cylindrical with sharp hyaline cauda at posterior end; anterior end rounded; pellicle spirally striated and spirally verrucose.

SITES: Alabama, Sumter County, Nixon's pond; Alabama, Sumter County, Livingston University duck pond; Alabama, Tuscaloosa County, small duck pond in University of Alabama area; Alabama, Tuscaloosa County, Butterfield catfish pond (limestone sink); Alabama, Tuscaloosa County, Butterfield catfish pond 22; Alabama, Tuscaloosa County, Forest Lake Drive; Mississippi, Lauderdale County, Cobb's pond; Mississippi, Lauderdale County, Toom Suba Creek; Tennessee, Union County, Brock Road, farm pond near barn.

Lepocinclis fusca (G. A. Klebs) Kosmala & Zakryś 2005 Fig. 39

Euglena spirogyra var. *fusca* G. A. Klebs 1883

Cell 150 µm long and 23 µm wide, cylindrical,

gradually tapering and passing to sharp cauda; twist of cell is characteristic of that variety; pellicle spirally striated with warts.

SITES: Alabama, Sumter County, W. Suffolk pond.

Lepocinclis oxyuris (Schmarda) B. Marin & Melkonian 2003 Figs 40 & 84

Euglena oxyuris Schmarda 1846

Cells 85–155 µm long and 12.5–20.0 µm wide, cylindrical with anterior end rounded and posterior end with long (37.5 µm) hyaline cauda.

SITES: Alabama, Sumter County, Nixon's pond; North Carolina, Macon County, Patton and White Roads pond; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond.

Lepocinclis oxyuris var. *maior* T. G. Popova 1955 Fig. 41

Cells 380–480 µm long and 40–50 µm wide, similar to basic species but several times larger; some large rod-shaped paramylon grains.

SITES: Kentucky, Warren County, spring; Tennessee, Union County, Brock Road, farm pond near barn

Lepocinclis oxyuris fo. *lata* (Christjuk) T. G. Popova 1955 Fig. 42

Cell 199 µm long and 29 µm wide with hyaline cauda 33 µm long; cell curved with rounded ends; pellicle longitudinally striated; chloroplasts very numerous, small and discoid; two large ring-shaped paramylon bodies.

SITES: North Carolina, Macon County, Patton and White Roads pond.

Lepocinclis tripteris (Dujard.) B. Marin & Melkonian 2003 Figs 43a–c & 85

Euglena tripteris (Dujard.) G. A. Klebs 1883

Cells 69–80 (426) µm long and 9–15 (35) µm wide, cells elongated, triangular, slightly twisted with anterior end rounded, posterior end has sharp

hyaline cauda; pellicle finely striated longitudinally; two long rod- or ring-shaped paramylon grains. Flagellum shorter than cell.

SITES: Alabama, Sumter County, Nixon's pond; Alabama, Tuscaloosa County, Butterfield catfish pond (limestone sink); Alabama, Tuscaloosa County, Butterfield catfish pond 22; Kentucky, Warren County, spring; North Carolina, Anderson County, roadside pond.

Phacus Dujard. 1841

Phacus parvulus G. A. Klebs 1883
Figs 44 & 88

Cell 20 μm long and 11 μm wide, oval, ended by small blunt process; periplast very gently striated obliquely; one large circular paramylon grain in central part of cell.

SITES: Tennessee, Knox County, small basin in Lynnhurst Cemetery.

Phacus pusillus Lemmerm. 1910
Figs 45 & 89

Cell 24 μm long and 11 μm wide, oval or egg-shaped in outline with fold running along cell (to 1/3 third or 1/2 cell length); chloroplasts numerous, small and disc-shaped; two ring-like paramylon bodies.

SITES: Tennessee, Knox County, small basin in Lynnhurst Cemetery.

Phacus dangeardii Lemmerm. 1910
Fig. 46a, b

Cell 18.5 μm long and 11.0 μm wide, oval and flattened with shallow furrow running along cell; one oval, centrally situated paramylon grain.

SITES: Tennessee, Knox County, small basin in Lynnhurst Cemetery.

Phacus fomini Y. V. Roll 1938 Fig. 47a, b

Cell 40 μm long and 10 μm wide, round with small depression at top; pellicle longitudinally striated; one ring-like paramylon grain.

SITES: Alabama, Sumter County, Nixon's pond.

Phacus acuminatus A. Stokes 1881
Figs 48, 90 & 107

Cell 35 μm long and 24 μm wide with dorsal furrow running to 3/4 of cell length; posterior end with small straight projection; pellicle longitudinally striated; chloroplasts numerous, small, disc-shaped; two paramylon bodies disc-like in outline.

SITES: Alabama, Tuscaloosa County, University of Alabama lake; Tennessee, Knox County, small basin in Lynnhurst Cemetery.

OCCURRENCE. Common in southeastern United States (Dillard 2000).

Phacus oscillans G. A. Klebs 1883
Figs 49a, b & 91

Cell 22.0 μm long and 9.5 μm wide, asymmetrical, with two convoluted lobes along cell, in cross section triangular; pellicle spirally striated. Small chloroplasts, two large paramylon bodies.

SITES: Tennessee, Knox County, fish pond.

OCCURRENCE. Earlier reported from Alabama by Ratnasabapathy & Deason (1977).

Phacus undulatus (Skvortsov) Pochm. 1941
Fig. 50 & 108

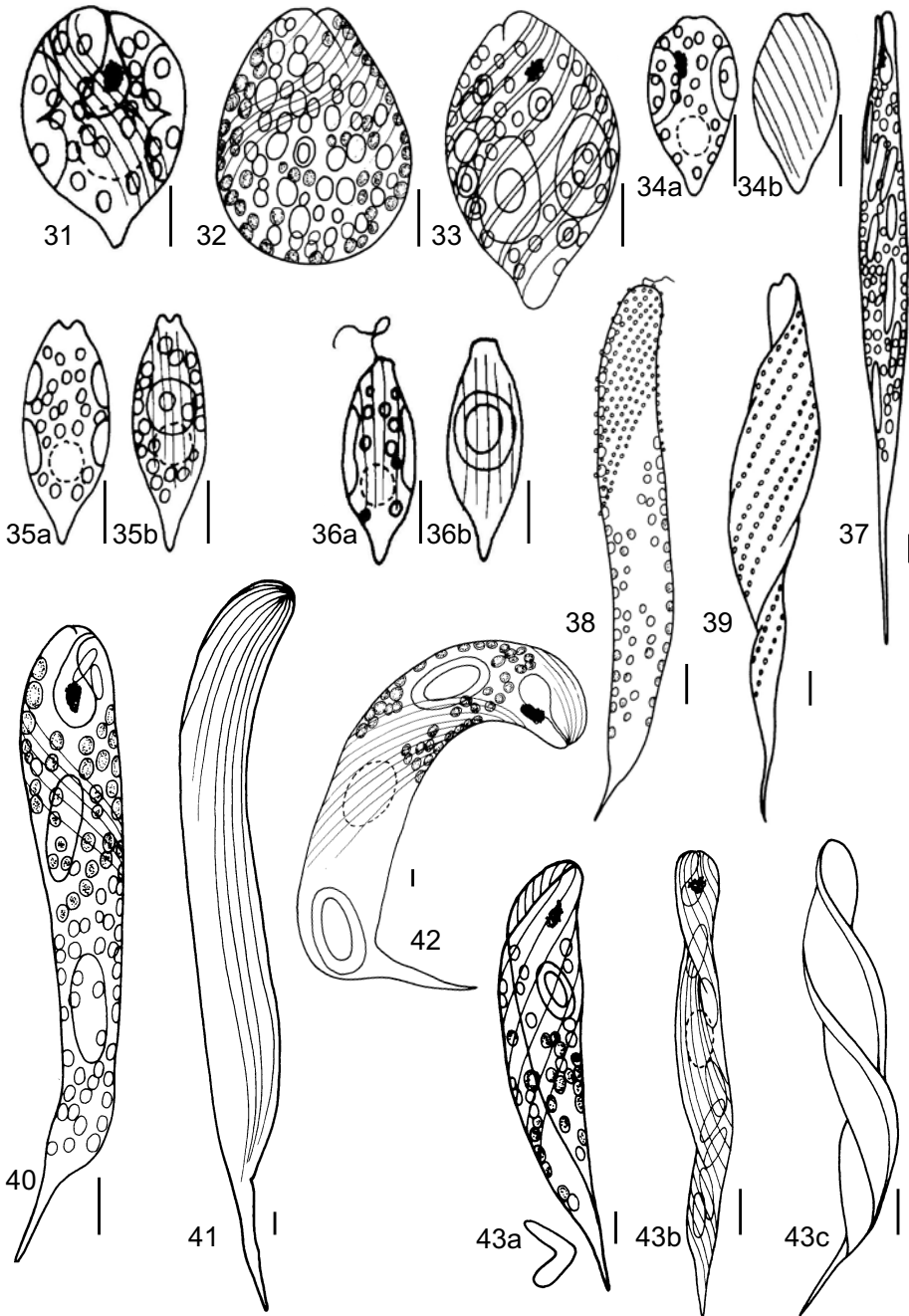
Phacus pleuronectes var. *insecta* Koczwara 1916; *Ph. anacoelus* var. *undulata* Skvortsov 1922

Cells 47–55 μm long and 30–35 μm wide, broadly oval, flattened, undulated at cell rim, ended by long, sharp, curved cauda; pellicle longitudinally striated; chloroplasts numerous, small; one central ring-shaped paramylon grain.

SITES: Alabama, Tuscaloosa County, University of Alabama lake.

Phacus unguis Pochm. 1941 Figs 51 & 92

Cells 35–37 μm long and 17–24 μm wide, obovoid in outline, distinctly undulate at rim,



Figs 31–43. 31 – *Lepocinclis ovum* (Ehrenb.) Minkiewicz, 32 – *L. texta* var. *texta* Drezep., 33 – *L. salina* var. *obtusa* (Hub.-Pest.) W. Conrad, 34a, b – *L. cylindrica* (Korshikov) W. Conrad, 35a, b – *L. steinii* Lemmerm., 36a, b – *L. marssonii* Lemmerm., 37 – *L. acus* (O. F. Müller) B. Marin & Melkonian, 38 – *L. spirogyroides* B. Marin & Melkonian, 39 – *L. fusca* (G. A. Klebs) Kosmala & Zakryś, 40 – *L. oxyuris* (Schmarda) B. Marin & Melkonian, 41 – *L. oxyuris* var. *maior* T. G. Popova, 42 – *L. oxyuris* var. *lata* (Christjuk) T. G. Popova, 43a, b, c – *L. tripteris* (Dujard.) B. Marin & Melkonian. Scale bars = 10 μm .

ended by short sharp cauda; pellicle longitudinally striated; chloroplasts small, disc-shaped; paramylon grain ring-shaped in outline.

SITES: Alabama, Sumter County, Nixon's pond; Tennessee, Knox County, small basin in Lynnhurst Cemetery.

Phacus orbicularis K. Hübner 1886

Figs 52a, b, 93 & 109

Cells 45.0–80.5 μm long and 30–45 μm wide with 8–20 μm long cauda, oval to round in outline; cells usually with 1–2 discoid paramylon grains.

SITES: Kentucky, Warren County, spring; Mississippi, Lauderdale County, Kewanee Road, ditch; Alabama, Tuscaloosa County, Forest Lake; Alabama, Tuscaloosa County, quarry pond; Mississippi, Lauderdale County, Kewanee Road, ditch; Tennessee, Knox County, small basin in Lynnhurst Cemetery; Tennessee, Union County, Brock Road, farm pond near barn.

OCCURRENCE. Very common in southeastern United States (Dillard 2000).

Phacus pleuronectes (Ehrenb.) Dujard. 1925

Figs 53, 94 & 110

Euglena pleuronectes Ehrenb. 1838

Cells 37–50 μm long and 29–35 μm wide, broadly oval, flat, slightly narrowed at anterior end, posterior end with short curved cauda.

SITES: Alabama, Sumter County, Nixon's pond; Alabama, Tuscaloosa County, Forest Lake Drive; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond; Mississippi, Lauderdale County, Kewanee Road, ditch; Tennessee, Union County, Malueg Farm, upper pond; Tennessee, Knox County, puddle in Cherokee Park; Tennessee, Union County, Malueg Farm, upper pond.

OCCURRENCE. Very common in southeastern United States (Dillard 2000).

Phacus ankylonoton Pochm. 1941 Fig. 54a, b

Cell 41 μm long and 20 μm wide, oval to slightly elongated with straight, hyaline cauda at

posterior end; pellicle longitudinally striated; one ring-shaped paramylon body.

SITES: Tennessee, Union County, Malueg Farm, small pond on right side.

Phacus hamelii P. Allorge & M. Lefèvre 1931

Fig. 55a, b

Cells 32.3–35.0 μm long and 17.0–17.5 μm wide, oval or tightly oval, ended by straight, sharp cauda with keel running along cell length; one disc-shaped paramylon grain.

SITES: Mississippi, Lauderdale County, Kewanee Road, ditch.

Phacus triqueter (Ehrenb.) Dujard. 1841

Figs 56a–c, 96 & 111

Cells 40–50 μm long and 25–35 μm wide, oval with characteristic wide keel running along cell; cells triangular in cross section; one large paramylon grain in centrally location.

SITES: Alabama, Sumter County, small duck pond in University of Alabama area; Alabama, Tuscaloosa County, Forest Lake; Kentucky, Warren County, Slim Is., Jackson Orchard small pond; Tennessee, Union County, Malueg Farm, upper pond; Tennessee, Knox County, small basin in Lynnhurst Cemetery; Tennessee, Union County, Malueg Farm, upper pond.

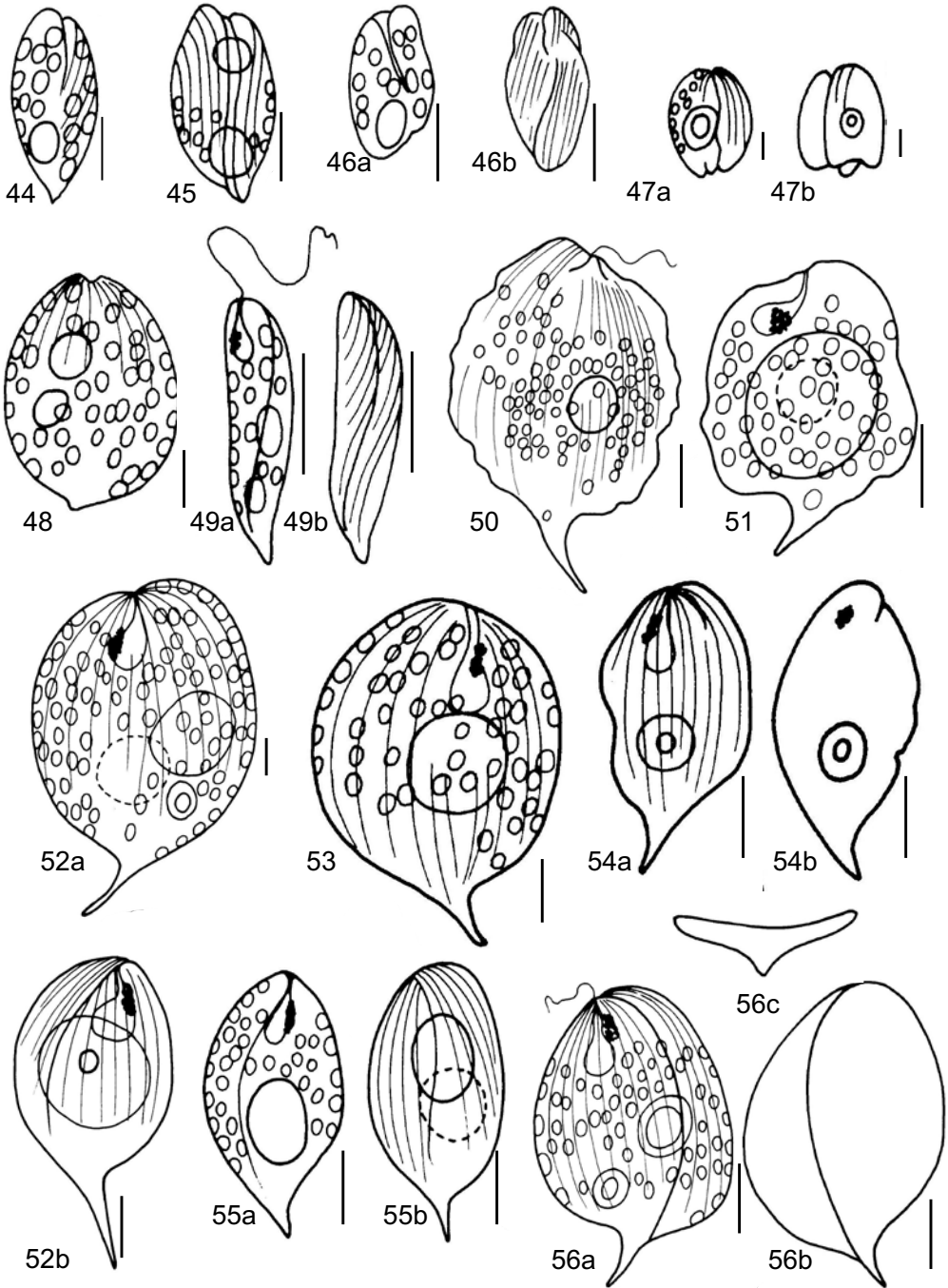
OCCURRENCE. Very common in southeastern United States (Dillard 2000).

Phacus alatus G. A. Klebs 1883 Fig. 57a, b

Cell 32.5 μm long and 23.0 μm wide, asymmetrical with sharp curved cauda; two large round paramylon bodies.

SITES: Mississippi, Lauderdale County, Kewanee Road, Beaver Pond.

OCCURRENCE. Earlier reported from Tennessee by Bevel (1938), Georgia by Patrick *et al.* (1967) and Kentucky by Taylor *et al.* (1977).



Figs 44–56. 44 – *Phacus parvulus* G. A. Klebs, 45 – *Ph. pusillus* Lemmerm., 46a, b – *Ph. dangardii* Lemmerm., 47a, b – *Ph. fominii* Y. V. Roll, 48 – *Ph. acuminatus* A. Stokes, 49a, b – *Ph. oscillans* G. A. Klebs, 50 – *Ph. undulatus* (Skvortsov) Pochm., 51 – *Ph. unguis* Pochm., 52a, b – *Ph. orbicularis* K.Hübner, 53 – *Ph. pleuronectes* (Ehrenb.) Dujard., 54a, b – *Ph. ankylonoton* Pochm., 55a, b – *Ph. hamelii* P. Allorge & M. Lefèvre, 56a, b, c – *Ph. triquetus* (Ehrenb.) Dujard. Scale bars = 10 µm.

Phacus curvicauda Svirenko 1915

Figs 58a, b, 97 & 112

Cells (21–)39–41 μm long and (18.0–)29.0–32.5 μm wide, oval to round, slightly asymmetrical, ended with bent hyaline cauda; two large paramylon bodies.

SITES: Kentucky, Warren County, Beechbend Road, farm pond; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond; Tennessee, Knox County, small basin in Lynnhurst Cemetery.

OCCURRENCE. Earlier reported from Georgia by Morris *et al.* (1977) and Mississippi by Williams *et al.* (1977).

Phacus raciborskii Drezep. 1925

Figs 59a, b & 95

Cells 35.0–37.5 μm long and 10.0–12.2 μm wide with cauda *ca* 10 μm long; cells irregular in outline, slightly twisted and bent, ended by sharp cauda; pellicle longitudinally striated; chloroplasts small, disc-shaped, one ring-like paramylon body.

SITES: Alabama, Sumter County, Nixon's pond.

Phacus longicauda (Ehrenb.) Dujard. 1841

Fig. 60

Euglena longicauda Ehrenb. 1838

Cells 65–166 μm long and 33–60 μm wide, oval to broadly oval, flattened with long straight cauda (25.0–68.5 μm) on posterior end; numerous small chloroplasts; single large paramylon grain in center, accompanied by 2–3 smaller ones.

SITES: Alabama, Sumter County, duck pond; Alabama, Tuscaloosa County, Butterfield catfish pond 1; Alabama, Tuscaloosa County, Forest Lake; Mississippi, Lauderdale County, Toom Suba Creek; Mississippi, Lauderdale County, Kewanee Road, Beaver Pond; North Carolina, Macon County, Shopes Farm, upper pond; Tennessee, Knox County, puddle in Cherokee Park.

OCCURRENCE. Very common in southeastern United States (Dillard 2000).

Phacus longicauda var. ***attenuata*** (Pochm.) Hub.-Pest. 1955

Fig. 61

Phacus longicauda subsp. *attenuata* Pochm. 1842

Cell 170 μm long and 65 μm wide with long and clearly curved cauda.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 1.

Phacus longicauda var. ***rotunda*** (Pochm.) Hub.-Pest. 1955

Fig. 62

Phacus longicauda subsp. *rotunda* Pochm. 1842

Cell 105 μm long and 32.5 μm wide with cauda 50 μm long; cell slightly asymmetrical.

SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 1.

Phacus circumflexus Pochm. 1941

Fig. 63 & 113

Cell 75 μm long and 38 μm wide, round with folded rim in upper part of cell; posterior end with long thick cauda; striation slightly oblique; some large disc-shaped paramylon bodies grouped in central part of cell.

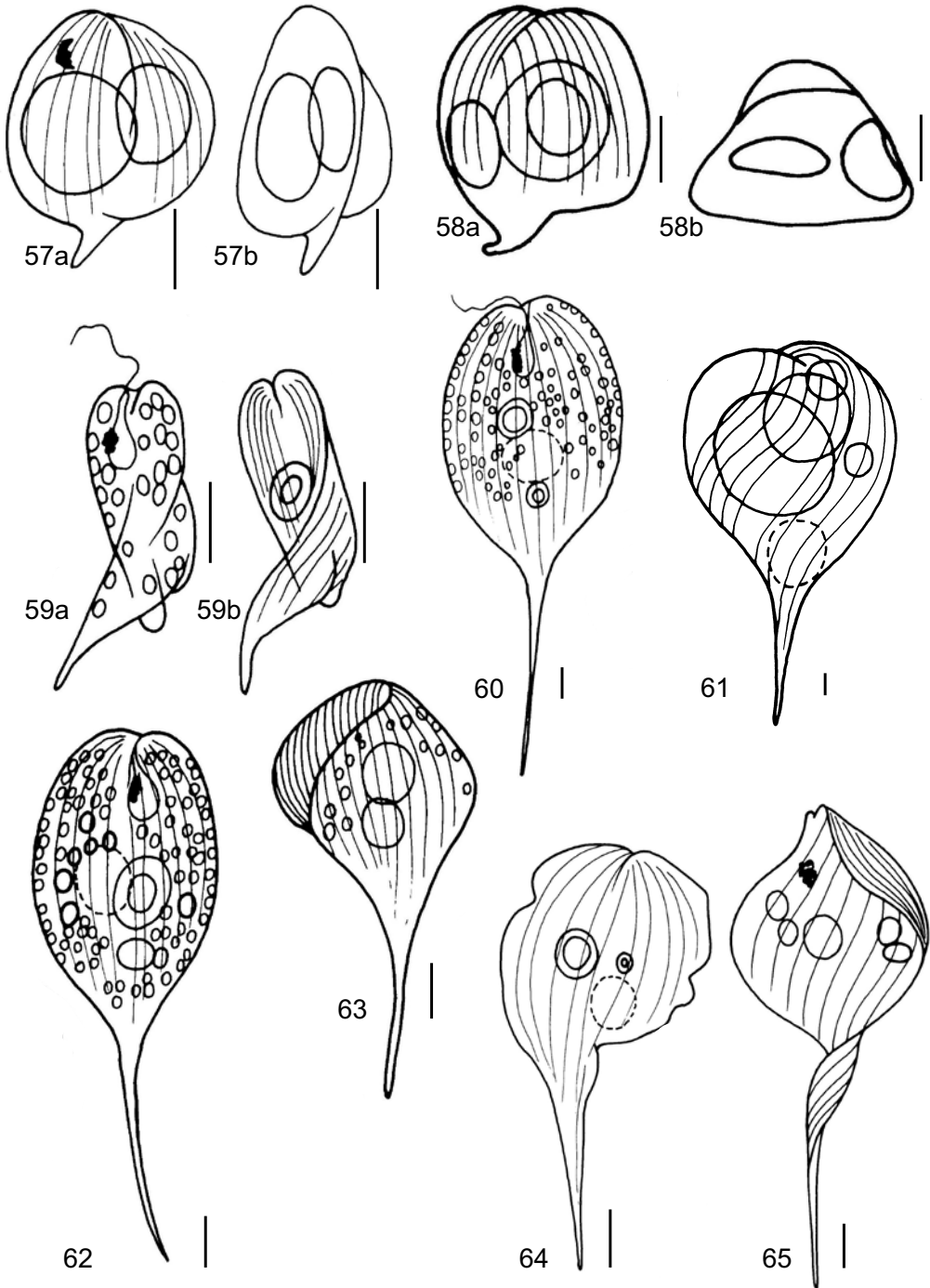
SITES: Alabama, Tuscaloosa County, Butterfield catfish pond 1.

NOTE. This taxon closely resembles *Phacus longicauda* (Ehrenb.) Dujard. 1841. Popova and Safonova (1976) classified it as *Ph. longicauda* var. *tortus* but according to Pochmann (1941) it should be separated as a species in view of its dissimilarity in the structure of the upper part of the cell.

Phacus ephippion Pochm. 1941

Figs 64 & 98

Cells 70–75 μm long (incl. 35 μm process) and 30–35 μm wide; cells round, ended by long, straight, sharp cauda; cell rim rugose and irregular in outline; chloroplasts small, numerous,



Figs 57–65. 57a, b – *Phacus alatus* G. A. Klebs, 58a, b – *Ph. curvicauda* Svirenko, 59a, b – *Ph. raciborskii* Drezep., 60 – *Ph. longicauda* (Ehrenb.) Dujard., 61 – *Ph. longicauda* var. *attenuata* (Pochm.) Hub.-Pest., 62 – *Ph. longicauda* var. *rotunda* (Pochm.) Hub.-Pest., 63 – *Ph. circumflexus* Pochm., 64 – *Ph. ephippion* Pochm., 65 – *Ph. helikoides* Pochm. Scale bars = 10 μ m.

disc-shaped; one ring-shaped centrally located paramylon grain.

SITES: Kentucky, Warren County, Jackson Orchard, big pond.

NOTE. The species resembles *Phacus longicauda* (Ehrenb.) Dujard. 1841. Popova and Safonova (1976) included it in *Ph. longicauda* var. *tortus*. We classified our specimen in *Ph. ephippion* according to Pochmann (1941).

Phacus helikoides Pochm. 1941

Figs 65, 99 & 114

Cells 105–116 μm long and 32–49 μm wide, 50–59 μm long, straight, sharp cauda at posterior end; cells twisted twice; some large paramylon bodies in central part.

SITES: Mississippi, Lauderdale County, Kewanee Road, Beaver Pond.

OCCURRENCE. Earlier reported from North Carolina by Schumacher and Whitford (1961), Kentucky by Dillard (1967) and Georgia by Morris *et al.* (1977).

NOTE. According to Popova and Safonova (1976) it should be classified as *Ph. longicauda* var. *tortus* fo. *helikoides*. According to Pochmann (1941) it is a separate species in view of differences in the upper part of the cell.

Phacus smulkowskianus (Zakryś) Kusber 1998
Figs 66a, b & 100

Euglena smulkowskiana Zakryś 1986, *Phacus similis* Christen 1962, *Ph. similis* fo. *minor* Bourrelly & Coute 1978

Cell 35 μm long and 15 μm wide, twisted three times and ended by straight cauda; pellicle stripes helically arranged in accordance with the twist of the cell; chloroplasts rather small, numerous; two large discoid paramylon grains.

SITES: Tennessee, Knox County, small basin in Lynnhurst Cemetery.

NOTE. The species is very similar to *Ph. helikoides* but the cells are smaller and the cauda is

shorter. In our opinion the type of cell structure differs.

Phacus monilatus (A. Stokes) Lemmerm. 1901
Figs 67a, b & 101

Chloropeltis monilata A. Stokes 1830

Cells 32.5–35.0 μm long and 20–21 μm wide, broadly oval to round with straight, short, thick process; pellicle densely covered with rows of warts; apical part with small papilla; chloroplasts numerous, small, discoid; paramylon in the form of two ring-shaped grains.

SITES: Alabama, Sumter County, W. Suffolk pond; North Carolina, Macon County, Shopes Farm, upper pond.

Phacus sp.

Fig. 68a–c

Cells 36.0–37.5 μm long and 12.0–12.5 μm wide, fusiform to triangular, twisted, star-shaped in cross section; apical part rounded, narrowing towards posterior end with cauda 10–11 μm long; pellicle longitudinally striated; chloroplasts numerous, small, plate-shaped; flagellum short – 1/4 of cell length or shorter.

SITES: Alabama, Sumter County, Nixon's pond.

NOTE. The species is similar to *Ph. raciborskii* but our taxon is more regular in outline. It is also similar to *Ph. trimarginatus* but this one is larger and has three ribs passing along the cell.

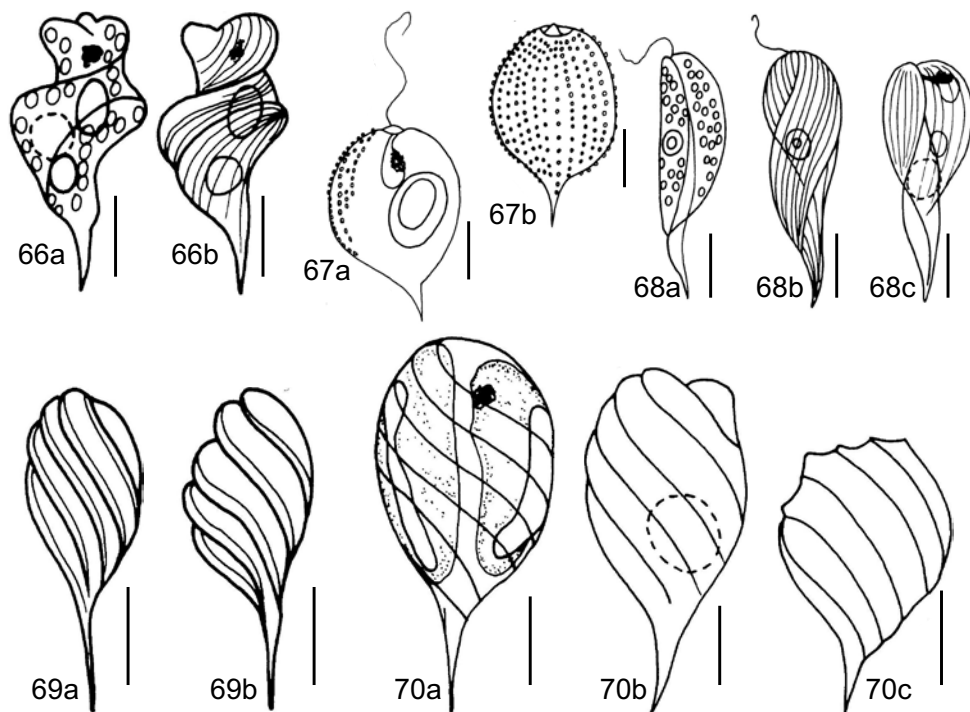
Monomorphina Mereschkovski 1887

Monomorphina pyrum (Ehrenb.) Mereschkovski 1887
Fig. 69a, b & 115

Euglena pyrum Ehrenberg 1832

Cells 32.5–33.0 μm long and 12.0–12.5 μm wide, pear-shaped and ended by straight cauda; pellicle spirally ribbed; small chloroplasts; two large bowl-shaped lateral paramylon grains.

SITES: Alabama, Sumter County, Nixon's pond.



Figs 66–70. 66a, b – *Phacus smulkowskianus* (Zakryś) Kusber, 67a, b – *Ph. monilatus* (A. Stokes) Lemmerm., 68a, b, c – *Ph. sp.*, 69a, b – *Monomorphina pyrum* (Ehrenb.) Mereschkovski, 70a, b, c – *M. splendens* (Pochm.) T. G. Popova. Scale bars = 10 μm

Monomorphina splendens (Pochm.) T. G. Popova
1947

Fig. 70a–c

Phacus splendens Pochm. 1942

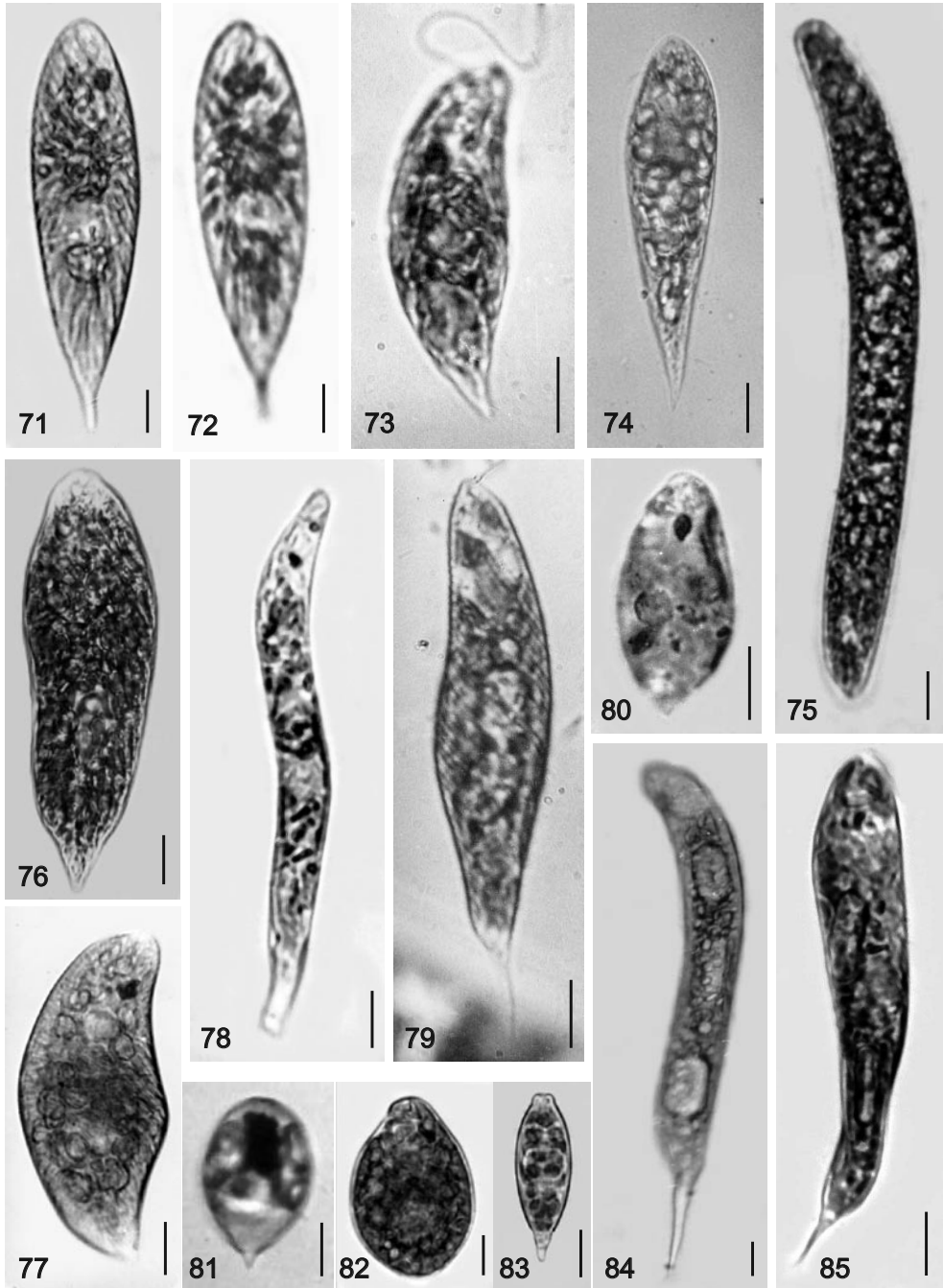
Cells 30–40 μm long and 16–18 μm wide, process 12–15 μm long, pear-shaped with straight cauda on posterior end, anterior end widely rounded; pellicle spirally ribbed; two large laterally situated chloroplasts, each accompanied by a large paramylon grain.

SITES: Alabama, Sumter County, duck pond; Kentucky, Warren County, Beechbend Road, farm pond; Kentucky, Warren County, spring.

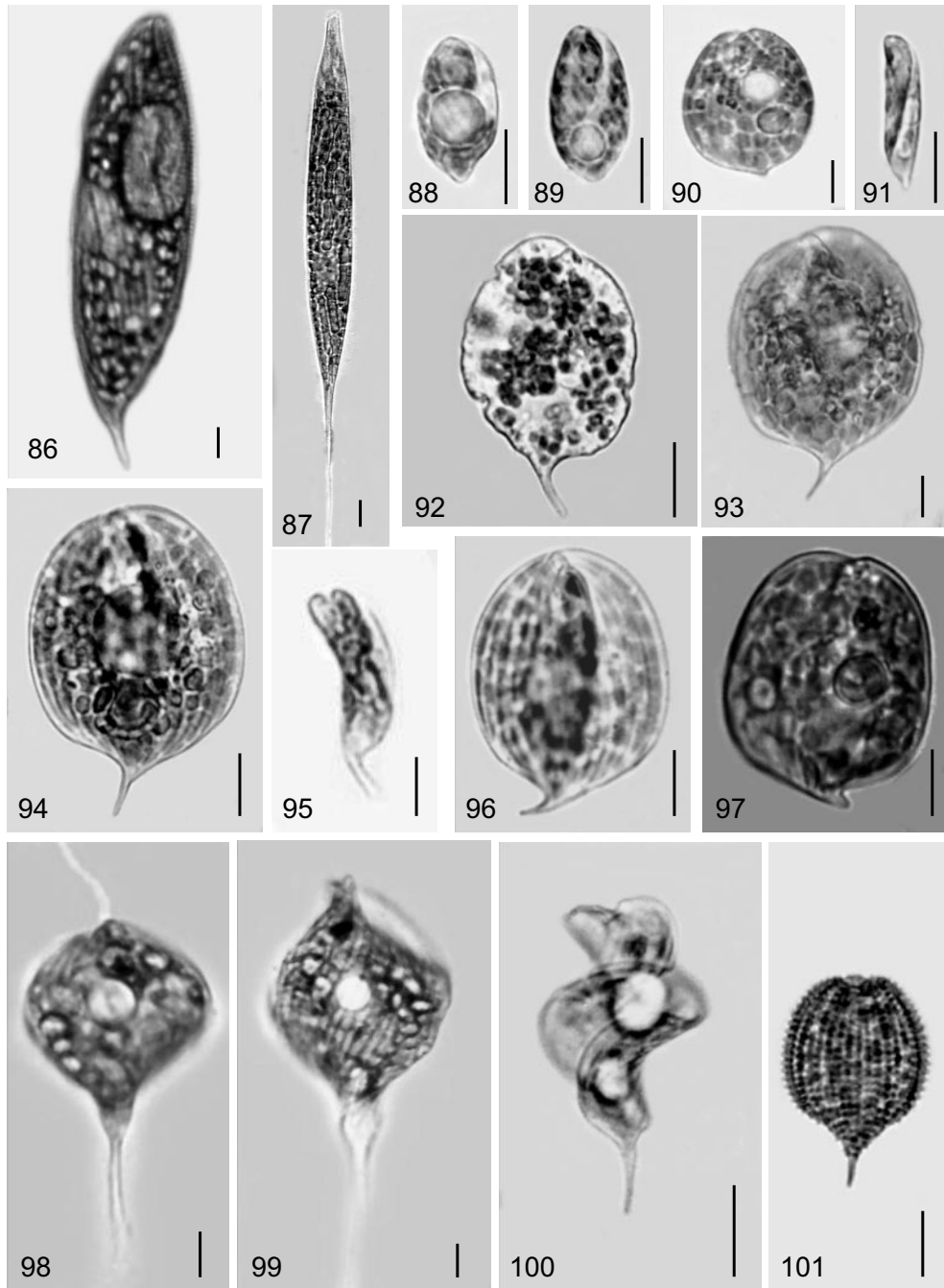
ECOLOGICAL ASPECTS

Physicochemical conditions varied in the studied habitats with euglenoids, especially with reference to water pH and temperature. They can be characterized as neutral to strongly alkaline;

only a few had pH < 7. Water temperature ranged from 10 to even 35°C, but the majority of the sites had water temperature above 20°C. A parameter that undoubtedly had an influence on the euglenoid community was specific conductance. The ion concentrations were moderate, usually 0.1–0.2 mS cm^{-1} but in some cases above 2.0 mS cm^{-1} (Table 1). The majority of the identified taxa were found in the littoral zone of the water bodies. The sites were associated with bottom habitat; the euglenoids developed in/on mud or green mud accumulated at the bottom, though quite a number of species also occurred in plankton (Table 2). In general, no taxa were closely connected with any zone of freshwater. Usually the same taxa were noted in different types of habitat. The richness of taxa was greatest in water bodies of Alabama (35) and Tennessee (25) and least in Georgia (5), but it should be stressed that in Georgia the fewest sites were studied.



Figs 71–85. 71 – *Euglena geniculata* Dujard., 72 – *E. tristella* S. P. Chu, 73 – *E. viridis* Ehrenb., 74 – *E. hemichromata* Skuja, 75 – *E. ehrenbergii* G. A. Klebs, 76 – *E. sociabilis* P. A. Dang., 77 – *E. splendens* P. A. Dang., 78 – *E. mutabilis* F. Schmitz, 79 – *Euglenaria caudata* var. *caudata* (Hüber) Karnowska & E. W. Linton, 80 – *Euglena agilis* H. J. Carter, 81 – *Lepocinclis ovum* (Ehrenb.) Minkiewicz, 82 – *L. texta* var. *texta* Drezep., 83 – *L. marssonii* Lemmerm., 84 – *L. oxyuris* (Schmarda) B. Marin & Melkonian, 85 – *L. tripteris* (Dujard.) B. Marin & Melkonian. Scale bars = 10 μ m.



Figs 86–101. 86 – *Lepocinclis spirogyroides* B. Marin & Melkonian, 87 – *L. acus* (O. F. Müller) B. Marin & Melkonian, 88 – *Phacus parvulus* G. A. Klebs, 89 – *Ph. pusillus* Lemmerm., 90 – *Ph. acuminatus* A. Stokes, 91 – *Ph. oscillans* G. A. Klebs, 92 – *Ph. unguis* Pochm., 93 – *Ph. orbicularis* K. Hübner, 94 – *Ph. pleuronectes* (Ehrenb.) Dujard., 95 – *Ph. raciborskii* Drezep., 96 – *Ph. triqueter* (Ehrenb.) Dujard., 97 – *Ph. curvicauda* Svirenko, 98 – *Ph. ephippion* Pochm., 99 – *Ph. helikoides* Pochm., 100 – *Ph. smulkowskianus* (Zakryś) Kusber, 101 – *Ph. monilatus* (A. Stokes) Lemmerm. Scale bars = 10 μ m.

DISCUSSION

The 68 taxa represent two groups, one with a flexible periplast (*Euglena* and *Euglenaria*) and the other with a rather rigid periplast (*Phacus* and *Monomorphina*); 28 taxa of the former type were identified, and 40 of the latter. Most are cosmopolitan, though their distribution is best documented from Europe (e.g., Wołowski 1989, 1998, 2003; Kusel-Fetzmann 2002) and South America (e.g., Tell & Conforti 1986; Conforti & Perez 2000). Some species have been noted frequently in the United States as well: for example, *Euglena viridis*, *E. proxima*, *E. ehrenbergii*, *E. agilis*, *E. polymorpha*, *E. sociabilis*, *E. splendens* and *E. mutabilis*. Within *Phacus* there were also species common in the southeastern United States: *Ph. acuminatus*, *Ph. orbicularis*, *Ph. pleuronectes*, *Ph. triqueter* and *Ph. longicauda*. Within *Lepocinclis* there were only two taxa considered common in the southeastern United States: *Lepocinclis ovum* var. *ovum* and *L. texta* (previously known as *Euglena texta*). In this study the most frequently noted taxa were *Euglenaria caudata* var. *caudata*, *Lepocinclis texta* var. *texta*, *Phacus pleuronectes* and *Ph. orbicularis*. Many of the others either are new for the region or their presence in southeastern American water bodies was based on old data, mainly Patrick *et al.* (1967), Morris *et al.* (1977), Williams *et al.* (1977) or even older.

The species determined in this study and apparently rare elsewhere in the world were *Euglena cuneata*, *E. tuberculata*, *Phacus fominii* and *Ph. ephippion*. The first was found in a peat bog in Alabama, the rest in ponds where they were collected from the surface of bottom mud or from squeezed plants. *Euglena cuneata* is known from the UK (Wołowski 2011) and recently it was recorded from the River Bahuda in eastern India (Bhakta *et al.* 2011). *Euglena tuberculata* was recorded from a lake in Turkey (Ersanlı & Gönüloğlu 2006) and

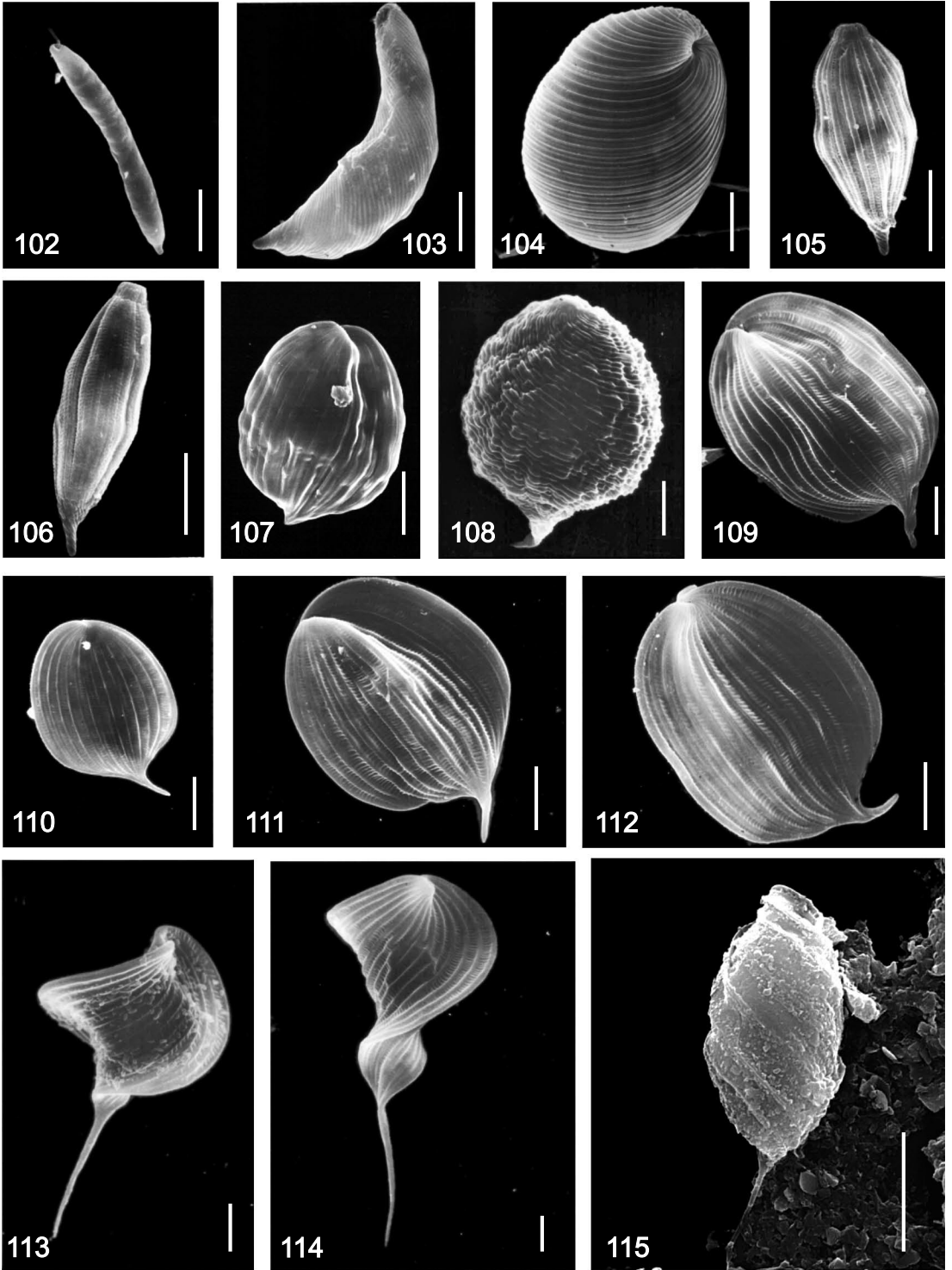
Romania (Cărăuș 2012). Until now *Phacus fominii* has been reported from only a few natural habitats in eastern and western Ukraine (Vetrova 2004). *Phacus ephippion* has been recorded from various locations, for example a pond in Bangladesh (Khondker *et al.* 2008) and some other tropical sites, but lacking illustrations to support identification. There is a record by Ratha *et al.* (2006) from a pond in eastern India, where a bloom occurred. However, the picture (Plate 3, Fig. 11) displays *Ph. tortus* so it probably is misidentified.

Some cosmopolitan widespread taxa such as *Euglena geniculata*, *Phacus pusillus* and *Ph. parvulus* have only one or two records or even none from the southeastern United States. This most likely is due to insufficient study of the euglenoid flora of this part of the United States

The majority of the taxa were associated with warm water with relatively high pH. Although they have a wide ecological spectrum with respect to physical and chemical properties they seem to be typical in such types of water. Many papers have documented the abundant development of euglenoids in countries with a warm climate (Heckmann *et al.* 1996; Conforti & Perez 2000; Wołowski & Walne 2007; Yamagishi 2010; Duangjan *et al.* 2012; Duangjan & Wołowski 2013); in the temperate zone they usually occur in summer or a warm autumn (Cabała 2003; Poniewozik 2009). There is a relative lack of studies on the environmental requirements of particular euglenophyte taxa.

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Figs 102–115. 102 – *Euglena vagans* Deflandre, 103 – *Euglenaria caudata* var. *caudata* (Hüber) Karnowska & E. W. Linton, 104 – *Lepocinclis texta* var. *texta* Drezep., 105 – *L. steinii* Lemmerm., 106 – *L. marssonii* Lemmerm., 107 – *Phacus acuminatus* A. Stokes, 108 – *Ph. undulatus* (Skvortsov) Pochm., 109 – *Ph. orbicularis* K. Hübner, 110 – *Ph. pleuronectes* (Ehrenb.) Dujard., 111 – *Ph. triqueter* (Ehrenb.) Dujard., 112 – *Ph. curvicauda* Svirenko, 113 – *Ph. circumflexus* Pochm., 114 – *Ph. helicoides* Pochm., 115 – *Monomorphina pyrum* (Ehrenb.) Mereschkovski. Scale bars = 10 μm.



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