

Free-living Heterotrophic Flagellates from Intertidal Sediments of Saros Bay, Aegean Sea (Turkey)

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Summary. This is the first study of free-living heterotrophic flagellates in intertidal sediments of Saros Bay, Aegean Sea (Turkey). In order to contribute to an understanding of the geographic distribution of free-living marine heterotrophic flagellates, we investigated the diversity of heterotrophic flagellates occurring in the bay from 25th June 2010 to 10th October 2010. Thirty eight species from 30 genera of heterotrophic flagellates and one unidentified taxon are reported with uninterpreted records based on light-microscopy. The records consist of one apusomonad, one cercomonad, two choanoflagellates, two cryptomonads, 12 euglenids, one heteroloboseid, one kathablepharid, three kinetoplastids, six stramenopiles, two thaumatomonads and seven of uncertain affinities. All of the morphospecies described here was previously reported elsewhere and appear to be cosmopolitan.

Key words: Protista, heterotrophic flagellates, Saros Bay, Aegean Sea, Turkey, biogeography, endemism.

INTRODUCTION

Heterotrophic flagellates have an important role in marine environments (Azam *et al.* 1983, Sherr and Sherr 1994, Patterson *et al.* 1989, Laybourn-Parry and Parry 2000, Lee and Patterson 2002), hence they are the consumers of bacteria and small phytoplankton, and food for larger zooplankton. Furthermore they facilitate remineralization and recycling of elements essential for phytoplankton and microbial growth (Sherr and Sherr 1988, Kirchman 1994, Pace and Vaqué 1994). As a con-

tribution to the study of heterotrophic flagellates, we have sought to understand the geographical distribution of morphospecies of these organisms (e.g. Larsen and Patterson 1990; Vørs 1992; Patterson *et al.* 1993; Ekebom *et al.* 1996; Patterson and Simpson 1996; Lee and Patterson 2000; Al-Qassab *et al.* 2002; Lee *et al.* 2003, 2005; Schroeckh *et al.* 2003; Lee 2002b, 2006, 2008, 2012).

Recently, there have been an increase in the studies on the taxonomy and distribution of marine species (references mentioned above), but still there are less studied regions of the world. This is the first study of heterotrophic flagellates in intertidal sediments in the Aegean Sea, which is a part of the Mediterranean Sea and located between the mainlands of Greece and Turkey. The aims of this study are to document the diver-

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sity of heterotrophic flagellates from Saros Bay of the Aegean Sea and to address issues of endemism.

Information on the general biology and ecology of the heterotrophic flagellate species described may be found in Patterson *et al.* (1989), Larsen and Patterson (1990), Patterson and Larsen (1991), Leadbeater and Green (2000) and Lee and Patterson (2000, 2002).

MATERIALS AND METHODS

This study was carried out at Saros Bay, Aegean Sea (Turkey) from 25th June 2010 to 10th October 2010 (N44°30'25.1", E26°41'36.2"). During the period, water temperature and salinity were in the ranges of 18–29°C and of 14.5–26.2 psu, respectively. Samples were collected monthly (n = 5) from intertidal sediments to a depth of about 1 cm from a 1 m². Samples were processed as described elsewhere (Larsen and Patterson 1990, Lee and Patterson 2000). Surface sediments were collected, larger macrofauna and plant material were usually removed by sieving, the residue placed in layers 1 cm deep in trays, allowed to settle for several hours, excess water drained off, and the material was covered with a sheet of lens tissue upon which 22×22 mm No. 1 coverslips were placed. After 24 h the coverslips were removed and flagellates were observed using a Leica DMR microscope equipped with a digital camera (Nikon D90 Model) and drawn. The flagellates were also recorded in movie files with the camera. The samples were maintained at room temperature (~20°C) for 5–7 days.

RESULTS

The nomenclature of some of the groups represented in this study is in compliance with the ICZN (International Code of Zoological Nomenclature 1999).

Actinomonas mirabilis Kent 1880/*Pteridomonas danica* Patterson *et* Fenchel 1985 (Figs 1a, 2a)

Observation: Cell is about 5 µm long and roundish, and has one flagellum. A ring of arms surrounds the flagellum. The single flagellum is about 2.5 times the cell length, emerges from a small depression at the anterior part of the cell and has an undulating beat. The cell is attached to the substrate posteriorly with a stalk which has nodes. One cell found.

Remarks: *Actinomonas mirabilis* is very similar to *Pteridomonas danica* in general appearance. As mentioned by previous studies (Larsen and Patterson 1990, Lee and Patterson 2000), *Actinomonas mirabilis* is not easily distinguished from *Pteridomonas danica* at the light microscopical level, but at the ultrastructural level

they can be distinguished because of the flagellar transitional bands in *P. danica* and a paraflagellar rod of *A. mirabilis*. *Actinomonas mirabilis*/*Pteridomonas danica* have been reported from marine sites worldwide.

Amastigomonas mutabilis (Griessmann 1913) Molina *et* Nerad 1991 (Figs 1b, 2b)

(= *Rhynchomonas mutabilis* Griessmann 1913)

(= *Thecamonas mutabilis* Larsen *et* Patterson 1990)

Observation: Cells are elliptical, 10 to 12 µm long, dorso-ventrally flattened and flexible, with a flexible sleeve around the base of the anterior flagellum. The anterior flagellum is about 0.2 times the cell length, and the posterior flagellum is slightly longer than the cell and attaches loosely in a slight groove. May have granules along side the posterior flagellum. Description based on observations of four cells.

Remarks: The genus *Amastigomonas* was created by De Saedeleer (1931) with *A. debrynei* and consists of 12 nominal species (Molina and Nerad 1991, Mylnikov 1999, Lee and Patterson 2000). The genus *Thecamonas* has been considered a junior synonym of the genus *Amastigomonas* (Molina and Nerad 1991; though see below). This species differs from the other species of these genera because of the granules located ventrally alongside the posterior flagellum, but some cells lack the granules, which were suggested to be distinctive by Larsen and Patterson (1990). Lee and Patterson (2000) mentioned that this species may be a synonym of *Amastigomonas bermudensis*. It has been reported from marine sites worldwide and previously reported length ranges from 7 to 20 µm in size (see Molina and Nerad 1991; Lee and Patterson 1998, 2000; Lee 2002b; Lee *et al.* 2003).

Recently Cavalier-Smith and Chao (2010) divided *Amastigomonas* into five genera: *Amastigomonas*, *Thecamonas*, *Podomonas*, *Manchomonas*, *Multimonas*. Although Cavalier-Smith and Chao (2010)'s study is comprehensive and significant, all the characters mentioned may not be applicable when identifying species with a light microscope. Thus we prefer to follow the Molina and Nerad (1991) in this study.

Ancyromonas micra (Cavalier-Smith 2008) Heiss *et al.* 2010 (Figs 1c, 2c)

(= *Planomonas micra* Cavalier-Smith 2008)

Observation: Gliding flagellate. Cells are oval shaped, 3.5–5 µm long and dorso-ventrally flattened. The cells have a shallow groove ventrally near an ante-

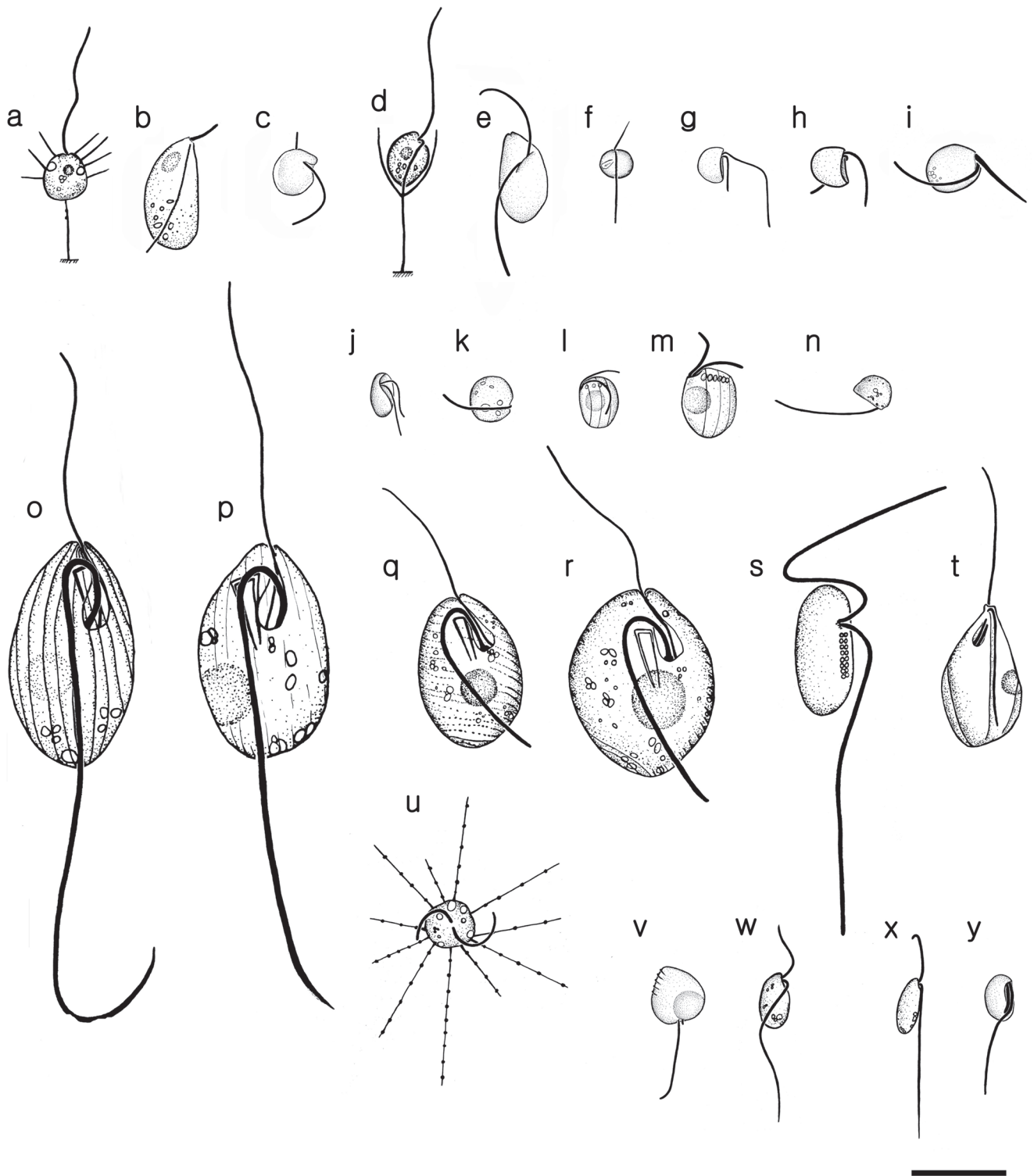


Fig. 1. a – *Actinomonas mirabilis*/*Pteridomonas danica*; b – *Amastigomonas mutabilis*; c – *Ancyromonas micra*; d – *Bicosoeca conica*; e – *Bordnamonas tropicana*; f – *Caecitellus parvulus*; g – *Cafeteria minuta*; h – *Cafeteria roenbergensis*; i – *Cyranomonas australis*; j – *Developayella elegans*; k – *Discocelis saleuta*; l – *Goniomonas amphinema*; m – *Goniomonas pasifica*; n – *Kiitoksia ystava*; o – *Dinema platysomum*; p – *Anisonema acinus*; q – *Heteronema exaratum*; r – *Heteronema ovale*; s – *Kathablepharis remigera*; t – *Notosolenus canellatus*; u – *Massisteria marina*; v – *Metromonas grandis*; w – *Neobodo designis*; x – *Neobodo saliens*; y – *Percolomonas similis*. Scale bar: 10 µm for all figures.

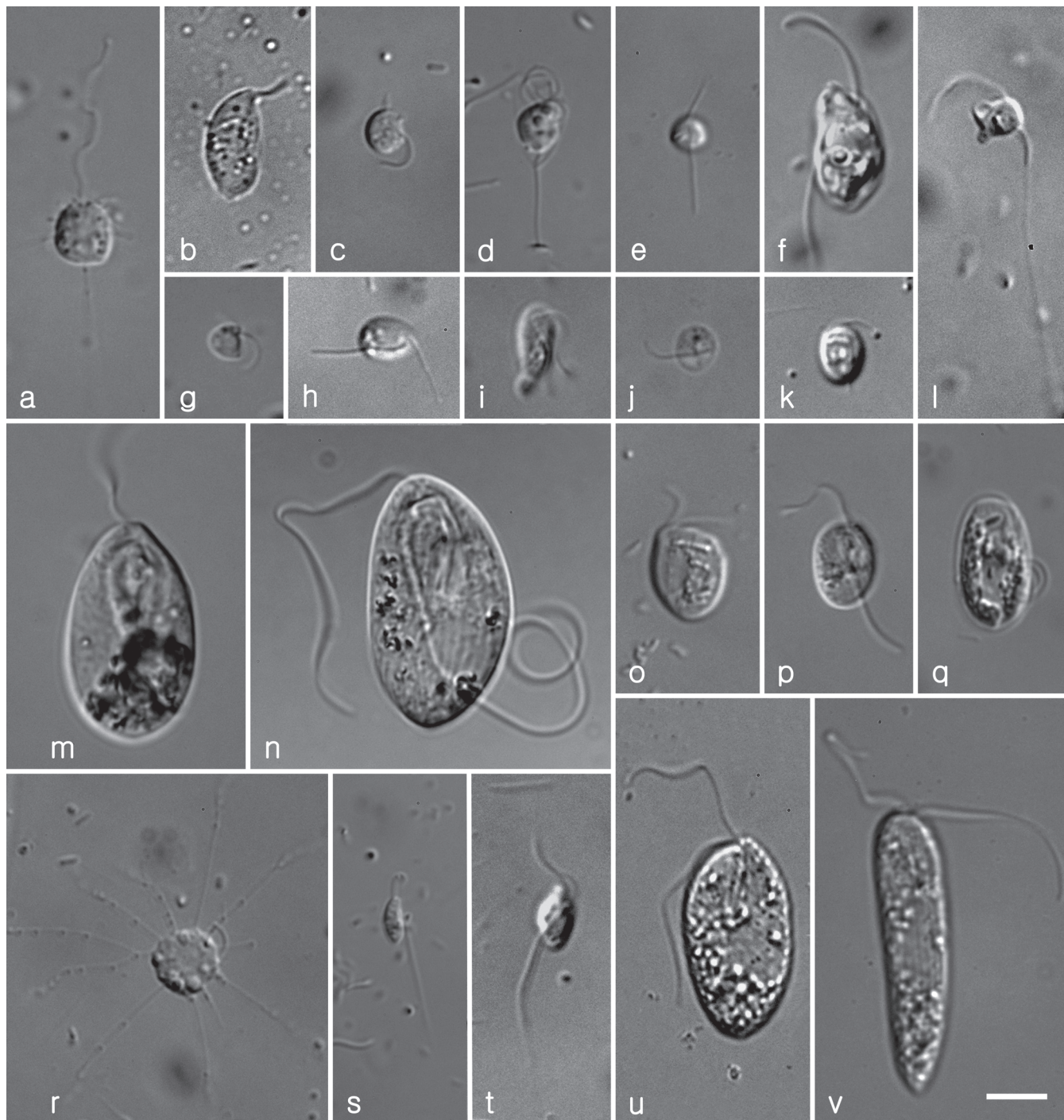


Fig. 2. **a** – *Actinomonas mirabilis*/*Pteridomonas danica*; **b** – *Amastigomonas mutabilis*; **c** – *Ancyromonas micra*; **d** – *Bicosoeca conica*; **e** – *Caecitellus parvulus*, note the mouth on the left-hand side; **f** – *Bordnamonas tropicana*; **g** – *Cafeteria roenbergensis*; **h** – *Cyranomonas australis*; **i** – *Developayella elegans*; **j** – *Discocelis saleuta*; **k** – *Goniomonas amphinema*; **l** – *Cafeteria minuta*, feeding cell; **m** – *Anisonema acinus*, dorsal view, note the ingestion organelle; **n** – *Dinema platysomum*, ventral view showing surface striations; **o** – *Goniomonas pacifica*; **p** – *Heteronema exaratum*, ventral view, general appearance of cell; **q** – *Kathablepharis remigera*; **r** – *Massisteria marina*; **s** – *Neobodo saliens*; **t** – *Neobodo designis*; **u-v** – *Heteronema ovale*, same cell; **u** – general appearance; **v** – extended cell. All micrographs are DIC images. Scale bar: 5 µm for all figures.

rio-lateral margin of the cell. The cells have a stiff and thickened anterior flagellum emerging from an anterior depression. The posterior flagellum is 1.5–2 times the length of the cell and acronematic. The cells move by gliding with the posterior flagellum trailing. Description based on records of two cells.

Remarks: Recently, detailed studies of this genus were carried out by Heiss *et al.* (2010, 2011) and Cavalier-Smith *et al.* (2008). According to Heiss *et al.* (2010), *Ancyromonas* has a junior synonym, *Planomonas* Cavalier-Smith 2008 and contains 7 nominal species: 5 marine – *A. sigmoides*, *A. cephalopora*, *A. melba*, *A. sinistra*, *A. micra*, 2 freshwater – *A. howeae*, *A. limna*. We assign our cells to *Ancyromonas micra* because our observations are in agreement with those of Cavalier-Smith *et al.* (2008) under the name of *Planomonas micra*. It is similar to *A. melba* Simpson and Patterson 1996, *A. magna* Zhang and Yang 1993 and *A. sinistra* Al-Qassab *et al.* 2002. *Ancyromonas micra* differs from *A. melba* because *A. melba* is larger. *Ancyromonas micra* is distinguished from *A. sinistra* because *A. sinistra* has a margin with the presumptive extrusomes and the cell body is flatter. This species is very similar to *A. sigmoides*, but can be distinguished because *A. micra* has a thicker anterior flagellum and a bigger rostrum. Due to their morphological similarity, *Ancyromonas micra* might have been reported elsewhere under the name *A. sigmoides*. *Ancyromonas micra* can be distinguished from a freshwater species *A. howeae* and *A. limna* by its thicker anterior flagellum and because *A. howeae* has a contractile vacuole.

***Anisonema acinus* Dujardin 1841 (Figs 1p, 2m)**

Observation: Cell is ovate, 23 μm long and flattened with a chisel-shaped ingestion organelle. Two flagella of unequal length emerge from a reservoir on the left side. The anterior flagellum beats actively with a sweeping motion and is about the same length with the cell. The posterior flagellum forms a hook after leaving the reservoir with a strong and broad distal region, lies on the ventral side, bends backwards and the proximal emergent part is readily visible only during jerking movement. The nucleus is located at the right side and the vacuole is at the left side and empties into the reservoir. One cell found.

Remarks: *Anisonema acinus* resembles *Dinema validum* Larsen *et* Patterson 1990 and *Dinema platysomum* (Skuja 1939) Lee *et* Patterson 2000 in general outline but *Anisonema* is distinguished from *Dinema* because *Dinema* is flexible with a thickened pellicle.

Anisonema acinus resembles *A. glaciale* Larsen *et* Patterson 1990 and *A. costatum* Christen 1962, but *A. acinus* differs from *A. glaciale* with its lack of frozen behaviour and with the location of its nucleus. *Anisonema acinus* is distinguished from *A. costatum* by the well developed spiral ribs of the pellicle of *A. costatum*. *Anisonema prosgeobium* was regarded as a junior synonym of *A. acinus* by Lee and Patterson (2000). This species is reported from marine sites in Australia, Danish Wadden Sea, and Fiji with the cell length of 21 to 48 μm and from Kuwait with the cell length of 35 to 61 μm (Larsen 1987, Larsen and Patterson 1990, Al-Qassab *et al.* 2002, Lee *et al.* 2003, Lee 2006a, Lee 2012, Al-Yamani and Saburova 2010).

***Bicosoeca conica* Lemmermann 1912 (Figs 1d, 2d)**

Observation: Cell is about 4.5 μm long, located in a conical lorica which is about 5.5 μm long with a stalk about 6.5 μm long. Two flagella are of unequal length and arise near the anterior end of the cell. The anterior flagellum is about 3 times the cell length and beats with a high amplitude sine wave, and the posterior flagellum is slightly longer than the cell and attaches to the lorica. The lorica attaches to the substrate using a stalk, which is about 10 μm long. One cell found.

Remarks: Generally, our observation is in agreement with those of Larsen and Patterson (1990). *Bicosoeca conica* is similar to *B. gracilipes* James-Clark 1967 which has a cylindrical lorica. *Bicosoeca conica* was reported from marine sites in subtropical Australia, Brazil, the Pacific and the Atlantic (Larsen and Patterson 1990, Patterson *et al.* 1993, Vørs *et al.* 1995, Lee 2001) with cell length of 4 μm . The species of *Bicosoeca* have been distinguished by the shape of the lorica, but the boundaries among many species are not clear, and this genus needs more attention. Thus, many synonyms may exist in the genus, and further work is required to clarify the identities of species in this genus.

***Bordnamonas tropicana* Larsen *et* Patterson 1990 (Figs 1e, 2f)**

Observation: Cells are 7 to 12 μm long and slightly flattened. The cells are anteriorly narrow and posteriorly broad. Two slightly thickened flagella are similar in length, insert subapically in the right ventral side of the cell and are about the cell length. The flagella are not acronematic. The anterior flagellum beats stiffly in a sigmoid arc and the posterior flagellum curves near its flagellar insertion and is directed posteriorly. The cells

glide or skid rapidly close to the substrate. Description based on observations of three cells.

Remarks: *Bordnamonas tropicana* has been reported from marine sites worldwide with cell lengths of 4–20 µm (Larsen and Patterson 1990; Vørs 1992a, b; Patterson *et al.* 1993; Ekeboom *et al.* 1996; Patterson and Simpson 1996; Lee and Patterson 1998, 2000; Lee 2001, 2002; Al-Qassab *et al.* 2002). Cell appearance is entirely consistent with the descriptions of Larsen and Patterson (1990) and Lee and Patterson (2000). This species resembles *Bodo curvifilus* Griessmann 1913 in that the anterior flagellum is held anteriorly in a curve, but can be easily distinguished by the swimming pattern, the thickness of the flagella and the anterior mouth visible by light microscope. This species is also distinguished from other bodonids by the swimming pattern and the thickness of the flagella.

***Caecitellus parvulus* (Griessmann 1913) Patterson *et al.* 1993 (Figs 1f, 2e)**

(= *Bodo parvulus* Griessmann 1913)

Observation: Cell is about 3 µm long and somewhat triangular or rounded. There is a mouth protruding on the left ventral side of the cell. The cell has two flagella of unequal length. The acronematic anterior flagellum beats slowly and inserts apically. It is slightly longer than the cell length. The non-acronematic posterior flagellum is about 2.5 times the cell length, emerges from the ventral face of the cell and trails posteriorly. The cell glides slowly with the anterior flagellum in close contact with the substrate. One cell observed.

Remarks: The species was first assigned to *Bodo parvulus* Griessmann 1913, but Patterson *et al.* (1993) revealed ultrastructural features which are not compatible with a bodonid flagellate and placed it in the new genus *Caecitellus*. O'Kelly and Nerad (1998) reconstructed the kinetid architecture of this species and found a high similarity with the Bicosoecida. But unlike Bicosoecida, *Caecitellus* lacks flagellar hairs and due to this Al-Qassab *et al.* (2002) placed this taxa under a new group named Hamatores with pseudodendromonads, which also does not have flagellar hairs and has similar ultrastructural characters to *Caecitellus* (Al-Qassab *et al.* 2002). Recently, Hausmann *et al.* (2006) made a molecular and ultrastructural study and added two new species into this genus: *Caecitellus pseudoparvulus* and *Caecitellus paraparvulus*. According to Hausmann *et al.* (2006), these species including *C. parvulus* are distinguished primarily by the number

of microtubules in flagellar root 3 forming the cytoskeleton of the feeding basket (*C. parvulus*: 24, *C. pseudoparvulus*: 35, *C. paraparvulus*: 29). The microtubule numbers determine the size of the feeding basket, but may not be a good character for identifying morphospecies under a light microscope. Thus, in this study, we prefer to follow the previous works (Larsen and Patterson 1990, Lee and Patterson, 2000, Al-Qassab *et al.* 2002)' criterion for this morphospecies. This species is one of the most commonly encountered heterotrophic flagellates worldwide (Patterson and Lee 2000).

***Cafeteria minuta* (Ruinen 1938) Larsen *et* Patterson 1990 (Figs 1g, 2l)**

(= *Pseudobodo minuta* Ruinen 1938)

Observation: Cells are 4–4.5 µm long with a small ventral groove. The cells have two flagella emerging from the anterior end of the groove. The longer anterior flagellum is 2.2–2.5 times the cell length, beats with a sine-wave, and the posterior one is slightly longer than the cell. In swimming cells, the anterior flagellum is directed forward and the posterior one trails. May attach to the substrate by the tip of the posterior flagellum. Description based on observations of two cells.

Remarks: Our observations are in agreement with the observations of Larsen and Patterson (1990). This species resembles *Cafeteria roenbergensis*, but can be distinguished by the longer anterior flagellum relative to the cell and because the anterior flagellum of *C. roenbergensis* is curved over the body when attached (Larsen and Patterson 1990, Lee and Patterson 2000). This species has been found at marine sites in Australia, Belize, Brazil, India and Portugal (Larsen and Patterson 1990, Ruinen 1938, Tong *et al.* 1998, Vørs 1993b, Lee 2001).

***Cafeteria roenbergensis* Fenchel *et* Patterson 1988 (Figs 1h, 2g)**

Observation: Cells are D-shaped, 3–5 µm long, laterally compressed, and have a shallow groove on the ventral side of the cell. Two flagella of similar length emerge subapically and are slightly longer than the cell. In attached cells, the anterior flagellum is directed perpendicular to the ventral face of the cell and the posterior one is reflexed, passing over one face of the cell and then attaching to the substrate by the tip. The anterior flagellum is directed forwards and beats with a sine wave, and the posterior flagellum is directed backwards and trails when swimming. Move fast following a spiral path. Description based on observations of nine cells.

Remarks: Generally, our observations are consistent with the descriptions of Fenchel and Patterson (1988) and Larsen and Patterson (1990). This genus consists of four species: *C. roenbergensis* Fenchel *et* Patterson 1998, *C. ligulifera* Larsen *et* Patterson 1990, *C. marsupialis* Larsen *et* Patterson 1990, *C. minuta* (Ruinen 1938) Larsen *et* Patterson 1990. *Cafeteria roenbergensis* resembles *C. marsupialis* in general appearance and in having a short anterior flagellum, but *C. marsupialis* has a more conspicuous ventral groove and is larger. *Cafeteria roenbergensis* has a widespread distribution (Lee and Patterson 1998, 2000; Al-Qassab *et al.* 2002; Lee 2002b; Lee *et al.* 2003; Lee 2007a).

***Cyranomonas australis* Lee 2002 (Figs 1i, 2h)**

Observation: Cell 5.5–6 μm long, ovoid in outline, dorso-ventrally flattened and slightly flexible. Two non-acronematic and thickened flagella emerge from the right hand side of the cell. The tapering anterior flagellum is about 1.2 times the cell length and flickers forward. The posterior flagellum is about 1.5 times the cell length and trails behind the cell. The cells move slowly by gliding with the anterior flagellum. Description based on observations of four cells.

Remarks: Our observations are in agreement with the observations of Lee (2002). *Cyranomonas australis* resembles *Rhynchomonas nasuta* in gliding and beating behaviour of the anterior flagellum, but can be distinguished by the lack of the bulbous snout which is the characteristic of *R. nasuta* and by the trailing flagellum not being acronematic. This genus resembles *Amastigomonas* in general body shape, but *Amastigomonas* can produce pseudopodia ventrally and has a thin dorsal theca that also encloses the anterior flagellum basally or completely. Both flagella of the genus *Amastigomonas* may sometimes be difficult to see whereas the flagella of *Cyranomonas* are visible at all times. *Cyranomonas australis* resembles *Neoheteromita caudratti* Howe *et al.* 2009, but the genus *Neoheteromita* has a changeable body shape with an ameboid end. This species has been found from marine sites in Australia, Korea and UK (Tong 1994; Lee 2001, 2002).

***Developayella elegans* Tong 1995 (Figs 1j, 2i)**

Observation: Cells are oval and 4–6 μm long. The cells have two flagella emerging from a depression in the right anterior part of the cell. Both flagella are about the cell length. In attached cells the anterior flagellum is held in a curve and beats slowly up and down, and the posterior one beats rapidly with a shallow excursion. Move by swimming. Two cells found.

Remarks: Our observations are in agreement with the descriptions of Tong (1995) and Lee and Patterson (2000). When this species attaches to the substrate it can be easily distinguished from other small flagellates because of its flagellar beating pattern. It has been described from subtropical Australia, England and Korea with the cell length of 3.5–10 μm (Patterson and Simpson 1996; Tong 1995; Tong 1997a, b; Tong *et al.* 1998; Lee and Patterson 2000; Al-Qassab *et al.* 2002; Lee 2001, 2002).

***Dinema platysomum* (Skuja 1939) Lee *et* Patterson 2000 (Figs 1o, 2n)**

(= *Anisonema platysomum* Skuja 1939)

Observation: Cell is elliptical, about 24 μm long, flattened and flexible with a chisel-shaped ingestion apparatus and pellicular striations on ventral and dorsal faces of the cell. The ventral striations are more distinct than the dorsal ones. The two flagella are of unequal length. The anterior flagellum is slightly thickened, is about 1.5 times the cell length and sweeps from side to side. The posterior flagellum is thicker, is most strongly developed proximally, is about 2.8 times the cell length and trails. The flagellar pocket is located in the left side of the cell and the nucleus is located in the right. The cell moves by gliding and may jerk to change the direction. One cell observed.

Remarks: This species had been described under the name of *Anisonema platysomum* Skuja 1939, but was transferred to *Dinema* by Lee and Patterson (2000) because it is metabolic, and has an ingestion apparatus and thick pellicle. *Dinema inaequale* Larsen *et* Patterson 1990 is a junior synonym of *D. platysomum* (Lee and Patterson 2000). Our observation is in agreement with the observations of Larsen and Patterson (1990) and Lee and Patterson (2000). *Dinema platysomum* resembles some species of the genus *Anisonema* like *A. acinus* and *A. glaciale* in general appearance, but can be distinguished by the flexible body which is the most reliable character for distinguishing *Anisonema* and *Dinema*. It was found in marine sites in tropical Australia and Fiji and the cell length was reported to be 20 to 30 μm (Larsen and Patterson 1990, Ekebom *et al.* 1996, Lee and Patterson 2000, Lee 2001).

***Discocelis saleuta* Vørs 1988 (Figs 1k, 2j)**

Observation: Cells are 4–5 μm long, disc-shaped, flattened, anteriorly concave and posteriorly convex. Two flagella emerge from a depression on the anterior margin of the cell. The recurrent flagellum trails behind

the gliding cell and is 1.2–1.5 times the cell length, and the shorter flagellum is hard to see and probably beats actively and causes cell motion. Cells are with large granules. The cells glide smoothly in close contact with the substrate. Description based on observations of six cells.

Remarks: Generally, our observations are in agreement with the observations of Vørs (1988) and Larsen and Patterson (1990). This genus contains two species and *Discocelis saleuta* is distinguished from *D. punctata* Larsen et Patterson 1990 by the punctae around the cell periphery of *D. punctata*. Some cells in *D. saleuta* may lack the anterior flagellum (Vørs 1988, Larsen and Patterson 1990, Tong et al. 1998). This species has been found at marine sites in Australia, Brazil and Fiji, and the previously reported cell length is 3 to 6 µm (Larsen and Patterson 1990, Tong et al. 1998, Lee and Patterson 2000).

***Goniomonas amphinema* Larsen et Patterson 1990 (Figs 1l, 2k)**

Observations: Cells are 5–5.5 µm long, oblong and laterally flattened. Two flagella insert in an anterior lateral pocket; one directed anteriorly, one posteriorly. The cells have three delicate longitudinal ridges on both sides, which can be easily overlooked. The anterior row of ejectisomes is sometimes difficult to observe. Description based on the observations of two cells.

Remarks: The genus *Goniomonas* contains three species, *G. amphinema*, *G. pacifica* and *G. truncatum*. *Goniomonas amphinema* differs from *G. pacifica* and *G. truncatum* in having dissimilar flagella one of which curves to lie along the ventral side of the cell. This species was reported from marine sites in Australia, North Atlantic, Denmark, England, Fiji, Gulf of Finland, Panama and Korea and was reported to be 4 to 9 µm (Vørs 1992a, b; Larsen and Patterson 1990; Patterson et al. 1993; Tong et al. 1998; Lee and Patterson 2000; Lee 2001, 2002, 2006b; Al-Qassab et al. 2002).

***Goniomonas pacifica* Larsen et Patterson 1990 (Figs 1m, 2o)**

Observation: Cells are truncated with the posterior end rounded. The cells are 4–11 µm long with several distinct longitudinal ridges on both sides of the cell and with a row of ejectisomes near the anterior end of the cell. Two flagella of similar length emerge from a small anterior depression are shorter than the cell and are directed anteriorly, but diverge in different directions when swimming. Commonly observed.

Remarks: This species has been reported from marine sites in Australia, North Atlantic, Brazil, Denmark, England, Gulf of Finland, Hawaii, Panama and Korea (Larsen and Patterson 1990; Vørs 1992a, b; Patterson et al. 1993; Ekebom et al. 1996; Patterson and Simpson 1996; Tong 1997a; Tong et al. 1998; Lee and Patterson 2000; Lee 2002b, 2006b; Lee et al. 2003) and the previously reported length ranges of *G. pacifica* are 3 to 15 µm. This species is characterised by the two flagella being directed anteriorly but diverging in different directions when swimming. *Goniomonas truncatum* and *G. pacifica* are similar in cell shape and flagella orientation, but can be distinguished because *G. truncatum* has distinct striations. However, these striations are sometimes difficult to observe, so it may not be a good character. Hill (1991) suggested distinction using length: breadth ratio which is lower in *G. pacifica*.

***Heteronema exaratum* Larsen et Patterson 1990 (Figs 1q, 2p)**

Observation: Cell outline ovate, 10–20 µm long, dorso-ventrally flattened, and metabolic, but not vigorously so. The cells have a small ingestion organelle and pellicular striations following an S-helix on both faces of the cell. The dorsal striations are more strongly developed than the ventral ones. Two flagella of similar length are slightly longer than the cell. During movement the anterior flagellum points to the right, and the posterior flagellum to the left. The posterior flagellum has a knob at its base within the flagellar pocket and is thicker than the anterior flagellum. In immotile cells, the flagella coil up. The reservoir and nucleus are in the left side of the cell. The cells move by skidding. Description based on observations of six cells.

Remarks: This species is similar to *Heteronema ovale* Larsen et Patterson 1990 and *H. larseni* Lee et Patterson 2000. It can be distinguished from *H. ovale* by less vigorous squirming, the more weakly developed pellicular striations and the differences between dorsal and ventral striations and from *H. larseni* by its weaker pellicular striations and smaller size and by the lack of a posterior point. It has been reported from marine sites in subtropical and tropical Australia, Korea and Fiji with previously reported lengths from 8 to 20 µm (Larsen and Patterson 1990; Patterson and Simpson 1996; Lee and Patterson 2000; Lee 2002b, 2006a, 2008, 2012; Lee et al. 2003; Tikhonenkov 2006; Al-Yamani and Saburova 2010).

***Heteronema ovale* Kahl 1928 (Figs 1r, 2u–v)**

Observation: Cell is ovate, dorso-ventrally flattened, and normally about 20 µm long, but is metabolic and can be about 33 µm long when elongated. The pellicular striations follow an S-helix on the ventral and dorsal faces of the cell and may have associated refractile bodies. Two flagella are of almost equal length and are slightly longer than the cell. The posterior flagellum has a knob at its base and is thicker than the anterior one. The ingestion organelle has two rods. The reservoir and nucleus are located in the left side of the cell. The cell moves by skidding or by vigorous squirming in contact with substrate. Description based on observation of one cell.

Remarks: Our observation is generally in agreement with the observations of Lee and Patterson (2000). This species is similar to *Heteronema exaratum*, but can be distinguished by its more vigorous squirming movements. Furthermore *H. exaratum* has differences in its dorsal and ventral pellicular striations. These two species are not distinguished by size because there is considerable overlap (Lee and Patterson 2000). This species was reported from tropical and subtropical Australia, Fiji, Korea, Kuwait and White Sea with a length range of 15–40 µm (Kahl 1928; Ekebom *et al.* 1996; Lee and Patterson 2000; Al-Qassab *et al.* 2002; Lee 2002b, 2006a, 2012; Tikhonenkov 2006; Al-Yamani and Saburova 2010).

***Kathablepharis remigera* (Vørs 1992) Clay *et* Kugrens 1999 (Figs 1s, 2q)**

(= *Leucocryptos remigera* Vørs 1992)

Observation: Cells are oblong or cylindrical, 12–15 µm long, not flattened and with two rows of extrusomes located ventrally. Two flagella inserting subapically are thick and unequal in length, and may wrap around the body during swimming. The anterior flagellum is about 2 times the cell length and may coil up during resting, and the posterior one is about 2.5 times the cell length. The nucleus lies in the middle of the cell. The cells rotate while swimming. Description based on observations of three cells.

Remarks: *Kathablepharis* is similar to *Platytilomonas* in general appearance, but it may be distinguished because *Platytilomonas* is flattened. This species is reported from marine sites in Australia, Canada, Denmark, England, Gulf of Finland and Greenland, and the length was reported to be 7 to 25 µm under the name

Leucocryptos remigera (Vørs 1992a, b, c, 1993a; Vørs *et al.* 1995; Tong 1997b; Lee and Patterson 2000).

***Kiitoksia ystava* Vørs 1992 (Figs 1n, 4t)**

Observation: Cells are cap-shaped, slightly flattened, 2.5–3 µm long and about 2.5 µm wide. One flagellum emerges posteriorly from the posterior margin of the cell and is about 2.5 times the cell length. While gliding the cell vibrates and the flagellum trails behind. Description based on observations of four cells.

Remarks: Generally the observations here are in accordance with the original description of Vørs (1992a). This species is distinguished from the other species in this genus, *Kiitoksia kaloista* Tong *et al.* 1997 by the position of the flagellar insertion and by lacking a second flagellum. It shows some similarity to *Metromonas simplex*, but can be distinguished because *M. simplex* has two flagella and a side-to-side nodding behavior. It has been found at marine sites in Australia, Arctic Canada, Denmark, England and Gulf of Finland (Daugbjerg and Vørs 1992; Tong 1997; Tong *et al.* 1998; Vørs 1992a, b, 1993; Lee 2001; Lee *et al.* 2003).

***Massisteria marina* Larsen *et* Patterson 1990 (Figs 1u, 2r)**

Observation: Cells are 4–7 µm, normally adhere to the substrate and have a dorso-ventrally flattened irregular body. The cells have delicate pseudopodia with extrusomes, which extend radially from the cell. Two short curved flagella arise from the dorsal side of the cell and are relatively inactive. Description based on observations of four cells.

Remarks: Generally, our observations are in good agreement with the observations of Larsen and Patterson (1990) and Lee and Patterson (2000). Previously reported size ranges are 2–9.5 µm and this species has been reported from marine sites in Australia, Brazil, Denmark, Gulf of Finland, equatorial Pacific and Panama (Ekebom *et al.* 1996; Larsen and Patterson 1990; Patterson and Fenchel 1990; Tong 1997a; Tong *et al.* 1998; Vørs 1992 a, b; Vørs *et al.* 1995; Lee and Patterson 2000; Al-Qassab *et al.* 2002, Lee *et al.* 2003, Lee 2006a).

***Metromonas grandis* Larsen *et* Patterson 1990 (Figs 1v, 4d)**

Observation: Cell outline is leaf shaped. Cells are 5.5 to 9 µm long, and dorso-ventrally flattened. One side of the cell appears folded. The cells have two fla-

gella of unequal length. The longer flagellum is 1.2 to 1.5 times the length of the cell and trails behind the cell when gliding. The short inactive flagellum is less than 2 µm long, inserts to the right of the long flagellum, and is always present. The cells move with a nodding action – like a pendulum. Description based on observations of five cells.

Remarks: Generally, our observations are in good agreement with the observations of Larsen and Patterson (1990) and Lee and Patterson (2000). *Metromonas grandis* is similar to *M. simplex*, but differs in its slightly larger size and folded margin. This species is reported from marine sites in Australia, Brazil, Fiji, Hawaii and Korea and cell length reported was 5 to 12 µm (Larsen and Patterson 1990, Tong *et al.* 1998, Lee and Patterson 2000, Lee 2002b). Lee and Patterson (2000) reported three different cell shapes of *M. grandis*. Our cells are especially similar to the cells shown in Figures 24m and 26f of Lee and Patterson (2000). We believe that these three types should be separated to different species.

***Neobodo designis* (Skuja 1948) Vickerman 2004 (Figs 1w, 2t)**

(= *Bodo designis* Skuja 1948)

Observation: Kinetoplastid flagellate. Cell outline is slightly elliptical. Cells are 4 to 7 µm long with two flagella of unequal length emerging from a subapical pocket. The cells have no surface structures. The anterior flagellum is about 1.5 times the cell length and curves back over the rostrum. The posterior flagellum is acronematic, about 3 times the cell length and has a sinuous profile in swimming cells. The cells rotate around their longitudinal axes when swimming. Description based on observations of four cells.

Remarks: Generally, our observations are consistent with those of previous authors (Larsen and Patterson 1990, Lee and Patterson 2000). This species is characterised by the rotating behaviour of swimming cells, but *Bodo cygnus* reported by Patterson and Simpson (1996) and *B. platyrhynchus* Larsen *et al.* Patterson 1990 also have a slow rotating swimming movement (Lee and Patterson 2000). *Bodo cygnus* can be distinguished because it is bigger and has a spiral groove, and *B. platyrhynchus* is distinguished by its flattened anterior end. *Neobodo designis* has been found in marine sites worldwide and appears to be cosmopolitan.

***Neobodo saliens* (Larsen *et al.* Patterson 1990) Moreira *et al.* 2004 (Figs 1x, 2s)**

(= *Bodo saliens* Larsen *et al.* Patterson 1990)

Observation: Cells are usually elongately elliptical and somewhat inflexible, and are 8 to 9 µm long. Two flagella of unequal length emerge subapically from a shallow pocket. The anterior flagellum is slightly longer than the cell and is held forwards with a single anterior curve held perpendicular to the substrate. The posterior flagellum is acronematic, typically directed straight behind the cell and is about 2 times the cell length. The cells swim in rapid darts in straight lines. Description based on observations of four cells.

Remarks: *Neobodo saliens* is distinguished from other species of the genera *Neobodo*, *Parabodo* and *Bodo* by its rapid darting movement and the posterior flagellum that is directed in a straight line when swimming. This species is reported from marine sediments worldwide with sizes from 4 to 15 µm (Vørs 1992b; Tong *et al.* 1998; Lee and Patterson 1998, 2000; Al-Qassab *et al.* 2002; Lee 2002, 2006b; Lee *et al.* 2003).

***Notosolenus canellatus* Skuja 1948 (Figs 1t, 4e–f)**

Observation: Cell is pear-shaped, about 15 µm long, dorsally convex and ventrally flattened. The anterior end has a small collar and the posterior end is slightly rounded. Two flagella of unequal length emerge from the flagellar canal. The anterior flagellum is about the cell length and the posterior flagellum is about 0.7 times the cell length. The dorsal surface has three longitudinal grooves; one median groove and two lateral grooves. The ventral surface has a shallow longitudinal median groove. The flagellar pocket is located on the right side of the cell and the nucleus is on the left side. The cell moves by gliding. One cell found.

Remarks: Generally, our observations are in accord with the observations of Al-Qassab *et al.* (2002). This species resembles *N. pyriforme* Lee *et al.* Patterson 2000 and *N. lashue* Lee *et al.* Patterson 2000 in general appearance, but these species have only one dorsal groove. This species has been previously reported from marine sites in tropical Australia and the Danish Wadden Sea with cell lengths of 12–15 µm (Larsen 1987, Patterson and Simpson 1996, Al-Qassab *et al.* 2002).

***Percolomonas similis* Lee, Brandt, Vørs et Patterson 2003 (Figs 1y, 4h)**

Observation: Cells are oval in shape, 4–6 µm long, and laterally compressed. The cells have a groove extending ventrally in the anterior half of the body. Two flagella emerge from the head of the ventral groove. One long non-acronematic flagellum is about 2.5 times the cell length, is slightly thinner than the shorter flagellum and trails when moving. The short flagellum is slightly shorter than the cell length, usually lies in the groove and may beat fast in the groove. The cells move by skidding or gliding. Description based on observations of nine cells.

Remarks: Our observations are in agreement with the observations of Lee *et al.* (2003). The species of the genus *Percolomonas* are reported with four flagella except *P. denhami* Tong 1997 which has three flagella. This species is similar to *P. denhami* in cell shape and length, but can be distinguished by the number of flagella. It has been reported from several marine sites in Australia and in Korea under the name *Percolomonas* sp. with lengths of 5–7 µm (Lee 2001, 2002; Lee *et al.* 2003).

***Petalomonas marginalis* Larsen et Patterson 1990 (Figs 3a, 4m)**

Observation: Cells are 23–25 µm long, oblong but with a narrow anterior part. A small ingestion apparatus is visible subapically near the canal. The cells have a strongly ridged dorsal groove, which runs along the right lateral side of the cell. One flagellum emerges from the flagellar canal and is slightly longer than the cell. The reservoir is located on the right ventral side of the cell and the nucleus is in the middle or posterior part of the cell. The cells move by gliding. Description based on two cells.

Remarks: Generally, our observations are in good agreement with those of Larsen and Patterson (1990) and Lee (2006a). This species is easily distinguished from other species in the genus *Petalomonas* by the ridged groove and the visible ingestion apparatus. It has been previously reported from Fiji, the German Bight of the North Sea and Australia with cell length of 20–45 µm (Larsen and Patterson 1990, Hoppenrath 2000, Lee 2006a).

***Petalomonas minuta* Hollande 1942 (Figs 3b, 4g)**

Observation: Cells are 6–12 µm long, ovate in shape and flattened, with a deep longitudinal groove on

the dorsal face. The cells have one flagellum inserting into a reservoir in the right side of the cell and the flagellum is about 1.2 times the cell length. The nucleus is in the left side of the cell. The cells move by gliding. Two cells found.

Remarks: This species resembles *Petalomonas poosilla* Larsen and Patterson 1990 in cell length and flagellum length, but differs because of its deep dorsal groove. *Petalomonas minuta* was reported with cell length of 5.5 to 12 µm in marine sites worldwide (Larsen and Patterson 1990; Patterson *et al.* 1993; Lee and Patterson 1998, 2000; Al-Qassab *et al.* 2002; Lee 2002b, 2006, 2008, 2012; Lee *et al.* 2003). According to Lee and Patterson (2000), this species has several synonyms: *Petalomonas angusta* (Klebs) Lemmermann var. *pusilla* (Klebs) Lemmermann 1914, *Petalomonas mediocanellata* Stein 1878 var. *pusilla* Klebs 1892 and *Petalomonas minutula* Christen 1962.

***Petalomonas ornata* Skvortzow 1957 (Figs 3c, 4l)**

Observation: Cell is about 15 µm long and dorso-ventrally flattened. The cell is anteriorly narrow and posteriorly slightly pointed with hyaline margins. The cell has a shallow groove on the ventral side. One emergent flagellum is slightly longer than the cell and emerges from the reservoir in the right side of the cell. The nucleus is in the left side of the cell. The cell moves by gliding with the flagellum directed forwards. One cell found.

Remarks: Generally, our observation is in agreement with the observations of Lee (2006a). *Petalomonas ornata* differs from *P. minuta* and *P. poosilla* because of its general body shape and the shallow groove on the ventral side of the cell. This species was reported from Australia and Fiji (Larsen and Patterson 1990, Lee 2006a) with the length of 11–15 µm.

***Petalomonas poosilla* Larsen et Patterson 1990 (Figs 3d, 4k)**

(= *Petalomonas pusilla* Skuja 1948)

Observation: Cells are obovate to ellipsoidal, 5–6 µm long and flattened. The single emergent flagellum is shorter than the cell. The reservoir is in the right side of the cell and the nucleus is in the left side. The cells move by gliding. Description based on observations of five cells.

Remarks: This species has been widely reported from marine sites worldwide, with lengths of 4–12 µm (Lee and Patterson 1998, 2000; Lee *et al.* 2003; Lee

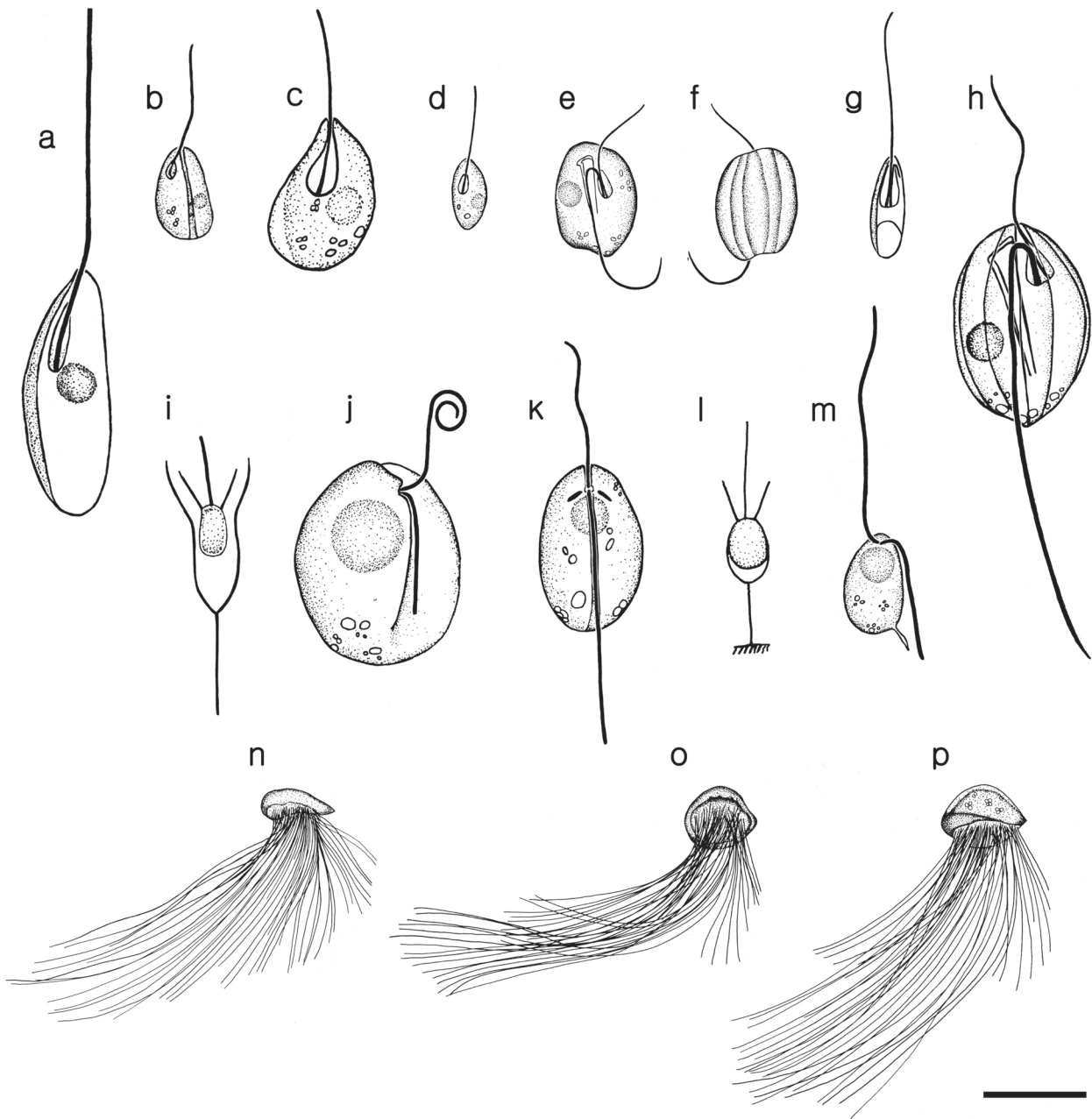
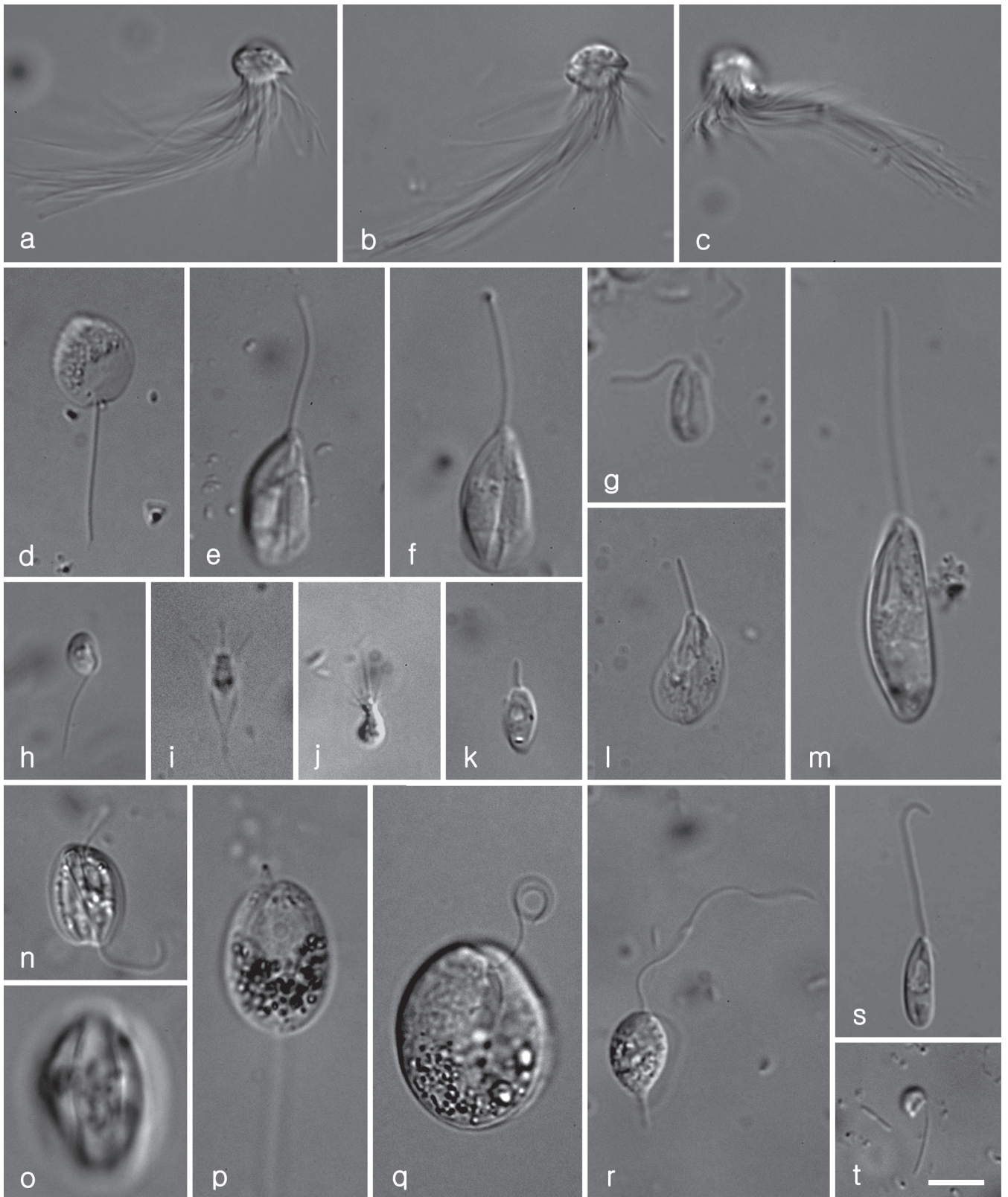


Fig. 3. a – *Petalomonas marginalis*; b – *Petalomonas minuta*; c – *Petalomonas ornata*; d – *Petalomonas poosilla*; e–f – *Ploeotia corrugata*; e – general appearance of the cell from ventral and (f) dorsal view showing the ridges; g – *Sphenomonas angusta*; h – *Ploeotia vitrea*; i – *Polyoecca dichotoma*; j – *Protaspis obliqua*; k – *Protaspis tegere*; l – *Salpingoeca marina*; m – *Pseudophyllomitus granulatus*; n–p – ‘Aegoni’, n – postero-lateral view of the cell showing the beak – like structure; o – posterior view of the cell showing the flagellar insertions; p – general view of the cell. Scale bar: 5 μ m for all figures.



Fig. 4. a–c – ‘Aegoni’, a – lateral view of the cell showing the beak – like structure; b – general view of the cell; c – posterior view of the cell showing the flagellar insertions and also extension of the surrounding plate caused by the posterior depression is visible; d – *Metromonas grandis*; e–f – *Notosolenus canellatus*; e – ventral view showing posterior flagellum behind the cell body; f – dorsal view of the cell, posterior flagellum in groove; g – *Petalomonas minuta*, dorsal face of the cell with the deep longitudinal groove; h – *Percolomonas similis*; i – *Polyoecca dichotoma*; j – *Salpingoeca marina*; k – *Petalomonas poosilla*; l – *Petalomonas ornata*; m – *Petalomonas marginalis*, in lateral view, note the margins of the strongly ridged dorsal groove; n – *Ploeotia corrugata*, dorsal view of the cell with seven ridges; o – *Ploeotia vitrea*, dorsal view of the cell with four double raised ridges; p – *Protaspis tegere* with nuclear caps around the cell; q – *Protaspis obliqua*, note anterior protrusion; r – *Pseudophyllomitus granulatus*; s – *Sphenomonas angusta* in lateral view, note the dash of dorsal groove; t – *Kiitoksia ystava*. All micrographs are DIC images. Scale bar: 5 μ m for all figures.



2006a, 2008, 2012). Lee and Patterson (2000) described two forms of *P. poosilla*: small cells and large cells differing in shape, size and visibility of ridges. Generally, our observations are in agreement with the small forms, but our cells appear to be different in the cell shape and the position of the flagellar reservoir. Further studies are required to establish if they are one species or if they are different species.

***Ploeotia corrugata* Larsen et Patterson 1990 (Figs 3e–f, 4n)**

Observation: Cell outline ovate to oblong, 11–15 μm long and slightly emarginated posteriorly with a hook-shaped ingestion organelle. The cells are dorsally convex and ventrally flattened with seven ridges on the dorsal side of the cell. The cells have a slight ridge down the middle of the ventral side against which the recurrent flagellum lies. Two flagella are of unequal length. The anterior flagellum is about the cell length and beats rapidly from side to side with an irregular wave motion when gliding. The posterior flagellum is about 1.5 times the cell length and tapers slightly towards the posterior end. The reservoir is on the left ventral side of the cell. The cells move by smooth gliding. Description based on observations of two cells.

Remarks: *Ploeotia corrugata* differs from other *Ploeotia* species because it has a combination of an indented posterior end and 7 corrugated ridges on dorsal face. Our cells are in agreement with Larsen and Patterson (1990) and also with Ekeboom *et al.* (1996) and Farmer and Triemer (1994), the latter under the name *Lentomonas applanatum*. *Lentomonas applanatum* (Preisig 1979) Farmer *et Triemer* (1994) and *P. corrugata* are quite similar because of the overlap of their size ranges and the number of the dorsal ridges, but these two species can not be synonymised because of the uncertainty about the protrusion of the ingestion organelle in *L. applanatum*. This species was reported from marine sites worldwide, and previously reported cell length ranges from 7 to 20 μm (Larsen and Patterson 1990; Patterson *et al.* 1993; Farmer and Triemer 1994; Ekeboom *et al.* 1996; Patterson and Simpson 1996; Tong *et al.* 1998; Lee *et al.* 2003; Lee 2006a, 2012; Tikho-nenkov *et al.* 2006).

***Ploeotia vitrea* Dujardin 1841 (Figs 3h, 4o)**

Observation: Cell is oval, about 20 μm long, and slightly flattened, with a well developed hook-shaped ingestion organelle. The anterior part of the cell is slightly blunt and the posterior part of the cell is point-

ed. This species has 10 longitudinal raised double ridges; 4 dorsally, 2 laterally, 4 ventrally. The ridges may be well developed and two mid-ventral ridges are close to each other. The anterior flagellum is about 0.7 times the cell length and beats freely from side to side, and the posterior flagellum is thick and twice the cell length. The nucleus is located in the right side of the cell and the reservoir is in the left side. Description based on record of one cell.

Remarks: The observation is in agreement with the Larsen and Patterson (1990). This species can be easily distinguished from other *Ploeotia* species by its ten raised double ridges. *Ploeotia vitrea* is a senior synonym of *Anisonema vitrea* (Dujardin 1841) Calkins 1901. It was reported from marine sites in Australia, Brazil, Fiji, Hawaii, Korea and USA, and the previously reported length range was 16–40 μm (Calkins 1901; Farmer and Triemer 1988; Larsen and Patterson 1990; Patterson and Simpson 1996; Lee and Patterson 2000; Al-Qassab *et al.* 2002; Lee 2002b, 2006a, 2008).

***Polyoeca dichotoma* Kent 1880 (Figs 3i, 4i)**

Observation: Cell is about 5 μm long and 2.5 μm wide, and located in a lorica which is about 15 μm long. The anterior part of the lorica has a broad opening and is about 3 times broader than the posterior part, and the lorica is pointed posteriorly. Several longitudinal costae are seen in the anterior part of the lorica. One flagellum is about the cell length. The cell attaches to the posterior end of the lorica by a thick stalk. Only one cell found.

Remarks: The cell observed here is assigned to *Polyoeca dichotoma* Kent 1880 because the observation is in agreement with those of Hara and Takahashi (1984). *Polyoeca dichotoma* is the only species in the genus. This species can be most readily distinguished from other species in Acanthoecidae by electron microscopy. *Polyoeca dichotoma* is very similar to *Acanthoeca spectabilis* Ellis 1929 in the length and general appearance of lorica, but according to Hara and Takahashi (1984) *P. dichotoma* can be distinguished by the whole length of the lorica including a long stalk. *Polyoeca dichotoma* is very similar to *Acanthoecopsis spiculifera* and due to this similarity *Acanthoecopsis spiculifera* Norris was synonymised with *Polyoeca dichotoma* Kent by Hara and Takahashi (1984). It was reported from marine habitats in Antarctica, Australia, Canada, England, France, Japan and USA (Wailes 1929, 1939; Norris 1965; Boucaud-Camou 1967; Thomsen 1977, 1992; Buck 1980, 1981; Hara and Takahashi 1984; Tong 1997a, c; Lee 2007b).

***Protaspis obliqua* Larsen et Patterson 1990 (Figs 3j, 4q)**

Observation: Cell outline is oval to roundish. Cells are 12–30 µm long and dorso-ventrally flattened. Cells are indented anteriorly and posteriorly where the margins of grooves meet. Anteriorly the right margin of the groove forms a protrusion and two flagella, unequal in length, emerge beneath this protrusion. The anterior flagellum is about 0.5 times the cell length and the posterior flagellum is 0.5–1.5 times the cell length. The nucleus is located subapically at the median line, is rounded and without nuclear caps. Description based on records of nine cells.

Remarks: Generally the description here is in accordance with the original description of Larsen and Patterson (1990). This species is easily distinguished from the other species of the genus by the protrusion located near the flagellar insertion. It has been reported from marine sites in tropical Australia, Fiji, England and Korea (Larsen and Patterson 1990; Tong 1997b; Lee and Patterson 2000; Lee 2001, 2002) and from a freshwater sediment in Tasmania (Lee *et al.* 2005).

***Protaspis tegere* Larsen et Patterson 1990 (Figs 3k, 4p)**

Observation: Cells are oblong or ovate, 12 to 19 µm long and slightly flattened. The cells have a longitudinal median ventral groove extending from the location of flagella insertion through to the posterior end of the cell. The cells have two flagella of unequal length; the anterior flagellum inserts subapically in the slight depression and is about the cell length. The posterior one inserts below the anterior flagellum and is 1.8–2.1 times the cell length. The nucleus is disc-shaped with anterior caps and is located anteriorly. Pseudopodia may be produced from the ventral groove. The cells move by gliding. Description based on records of nine cells.

Remarks: Our observations are in agreement with the observations of Larsen and Patterson (1990) and Lee and Patterson (2000). Cell length was reported to be 14 to 25 µm and this species is reported from marine sites in Australia, Fiji and Hawaii (Larsen and Patterson 1990, Ekebom *et al.* 1996, Tong *et al.* 1998, Lee and Patterson 2000, Lee 2001). *Protaspis tegere* may be a junior synonym of *Protaspis glans* because the only difference between these two species is the presence of nuclear caps and theses might have been overlooked.

***Pseudophyllomitus granulatus* (Larsen et Patterson 1990) Lee 2002 (Figs 3m, 4r)**

Observation: Cell is sack-shaped, flexible, 7–21 µm long and slightly flattened, being elliptical in cross section. Two flagella of unequal length emerge subapically. The nonacronematic anterior flagellum beats with a sine wave, is about 2.6 times the cell length and is directed to the front and slightly to the right during swimming. The posterior flagellum inserts to the left of the anterior flagellum, is about 1.3 times the cell length and trails behind the cell when swimming. Cytoplasm is extending at the posterior end. Refractile granules are visible beneath the cell surface. The roundish nucleus is located below the anterior pocket, near the centre of the cell. Description based on observation of one cell.

Remarks: Lee (2002a) redescribed *Phyllomitus undulans* Stein 1878, and this led to the establishment of a new genus for this organism *Pseudophyllomitus*. As mentioned in Lee (2002a) *Pseudophyllomitus* species are sac-shaped and flexible, and the two flagella are inserted subapically and do not adhere to each other. This genus contains four nominal species: *Pseudophyllomitus apiculatus* (Skuja 1948) Lee 2002, *Pseudophyllomitus granulatus* (Larsen et Patterson) Lee 2002, *Pseudophyllomitus salina* (Lackey 1940) Lee 2002, and *Pseudophyllomitus vesiculosus* (Larsen et Patterson 1990) Lee 2002. *Pseudophyllomitus granulatus* is similar to *P. salinus* in general appearance and cell length, but *P. salinus* has shorter flagella. This species is reported from marine sites in subtropical and tropical Australia, Brazil, Denmark, Hawaii and Korea (Larsen and Patterson 1990; Vørs 1992b; Lee and Patterson 2000; Lee 2001, 2002a).

***Salpingoeca marina* James-Clark 1867 (Figs 3l, 4j)**

Observation: Loricated choanoflagellate. The cell is about 5 µm long with a pedicel, which is 1.5 times the cell length. The thin lorica is ovoid with a slightly pointed posterior end, which is connected to the pedicel, and has a short neck at the anterior end. The cell fills out the posterior part of the lorica. The thickened flagellum is about 1.5 times the cell length and is surrounded by the pseudopodial tentacles. The lorica attaches to the substrate by the pedicel. One cell observed.

Remarks: Our observation here is assigned to *Salpingoeca* because it has a single theca but lack silicified costae, is sedentary and does not form colonies. *Salpingoeca marina* is very similar to *S. infusionum*, but is distinguished by the presence of a short neck at the

anterior part of a lorica (Kent 1880). As mentioned in Tong (1997c), however, a neck may be seen in *S. infusionum* after the cells are fixed or when the lorica contains a cyst. These two species can be distinguished by the stiffness of the lorica and because the lorica of *S. infusionum* is slightly wider anteriorly than that of *S. marina*. *Salpingoeca marina* is reported from Antarctica, North Atlantic, subtropical Australia, England, Denmark, Gulf of Finland, France, Germany and USA (James-Clark 1867; Griessmann 1913; Wailes 1929, 1939; Ruinen 1938; Vørs 1992a, b; Patterson *et al.* 1993; Tong 1997a, c; Tong *et al.* 1998).

Sphenomonas angusta Skuja 1956 (Figs 3g, 4s)

Observation: Cell is about 10 µm long, not flattened and with a dorsal groove. The cell is anteriorly truncated and posteriorly rounded. The cell body is slightly curved: the right margin of the cell is straighter than the left one. The cell has two flagella of unequal length; the anterior flagellum is about 1.5 times the cell length and the trailing posterior flagellum is about 0.2 times the cell length. One large refractile inclusion occupies the posterior part of the cell. Description based on observation of one cell.

Remarks: *Sphenomonas angusta* was first described by Skuja (1956) with cell length of 13–21 µm. He described a smooth cell, but his illustrations show a single groove. This genus consists of 14 nominal species (Christen 1959, Huber-Pestalozzi 1955, Playfair 1921, Skuja 1956, Schroeckh *et al.* 2003). Most of the species were reported from freshwater sites, but 3 species have been found in marine sites. *Sphenomonas angusta* is distinguished from other species of the genus by having one dorsal groove. This species is similar to *S. elongata*, but the reported cell length range of *S. elongata* is 30–70 µm. Generally *Sphenomonas* is similar to *Notosolenus*, but *Sphenomonas* is not flattened and with a hyaline inclusion which often largely fills the cell. This species is reported from Australia and Korea with the range of 10–14 µm cell length (Lee and Patterson 2000; Lee 2002b, 2008, 2012).

Unidentified organism

One cell was observed at one occasion. It was difficult to establish the identity of the cell due to not enough information, but its presence is recorded to establish its occurrence in a marine bottom sediment.

‘Aegoni’ (Figs 3n–p, 4a–c)

Observation: Cell is cap-shaped, like a jellyfish, about 5 µm long and 7 µm wide. Many flagella emerging from the posterior part of the cell are unequal in length. The shorter flagella with the varying lengths (mostly between 7–10 µm) are located on the lateral sides and surrounding the longer flagella beat actively, whereas the longer and numerous flagella in the middle are about 4 times the cell length, wave slightly and resemble a pony tail. The cell with a lateral protrusion at the one side of the cell close to posterior region. The protrusion can be seen as a separate beak – like structure from lateral view. In fact, it is an extension of the surrounding plate caused by the posterior depression where flagella emerge and the mouth is located – which is wider and/or larger on one lateral side. Bacteria that contact the flagella moved to the mouth by the flagellar movement. Description based on observation of one cell.

Remarks: The cell observed here is reported as an unidentified taxon because of not enough information. This species is similar to *Multicilia marina* Cienkowski 1881 in having many flagella, but can be easily distinguished by their movement patterns; ‘Aegoni’ swims, while *Multicilia* glides or rolls. *Multicilia marina* has been studied well by Mikrjukov and Mylnikov (1998). This species differs from *Stephanomonas locellus* (Fromentel) Kent 1880 because *S. locellus* has only one flagellum and many cilia around the body. Also *S. locellus* (32 µm) is bigger than the cell observed here. Further studies are needed to establish the identity of this organism.

DISCUSSION

Recently many studies of heterotrophic flagellates have been carried out to understand their diversity and geographical distribution (Ekebom *et al.* 1996; Lee and Patterson 1998, 2000; Patterson and Lee 2000; Al-Qassab *et al.* 2002, Lee 2002b; Lee *et al.* 2003; Lee 2006a, b, 2008, 2012). In the light of these studies, the finding is that most morpho-species of free-living heterotrophic flagellates have a cosmopolitan distribution. However, continued examination of previously poorly studied and/or unstudied sites is important to best test the idea of heterotrophic flagellates being cosmopolitan (Lee and Patterson 1998, Patterson and Lee 2000). In this context, Turkey has significance as an unstudied area to

build up the knowledge of the diversity and distribution of both marine and freshwater heterotrophic flagellates.

This survey is based on five sampling occasions. In this study we found 38 species from 30 genera of heterotrophic flagellates and one unidentified taxon. The records consist of one apusomonad, one cercomonad, two choanoflagellates, two cryptomonads, 12 euglenids, one heteroloboseid, one kathablepharid, three kinetoplastids, six stramenopiles, two thaumatomonads, and seven species of uncertain affinities. All of the species encountered in this study, except one unidentified taxon have been reported previously from other locations worldwide. Thereby with this study the model that flagellate species have a cosmopolitan distribution (Lee and Patterson 1998) is strengthened.

Acknowledgements. This study was accomplished by the project named “Determination of the Diversity of Freshwater Benthic Heterotrophic Flagellates in Gala and Çıldır Lakes” supported by the Scientific and Technological Research Council of Turkey and the laboratory works were done at Hacettepe University. Additionally this work was supported by the Kyungnam University Research fund to W. J. Lee. We are also grateful to Professor Ali Demirsoy (Hacettepe University) for making this work possible.

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Received on 27th March, 2012; revised on 1st June, 2012; accepted on 7th June, 2012