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Freshwater biodiversity of Guam. 1. Introduction, with new records of ciliates and a heliozoan

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Abstract—Inland waters are the most endangered ecosystems in the world because of complex threats and management problems, yet the freshwater microbial eukaryotes and microinvertebrates are generally not well known and from Guam are virtually unknown. Photo-documentation can provide useful information on such organisms. In this paper we document protists from mostly lentic inland waters of Guam and report twelve freshwater ciliates, especially peritrichs, which are the first records of ciliates from Guam or Micronesia. We also report a species of *Raphidiophrys* (Heliozoa). Undergraduate students can meaningfully contribute to knowledge of regional biodiversity through individual or class projects using photodocumentation.

Introduction

Biodiversity has become an important field of study since it was first recognized as a concept some 20 years ago. It includes the totality of heritable variation at all levels, including numbers of species, in an ecosystem or the world (Wilson 1997). Biodiversity encompasses our recognition of the "ecosystem services" provided by organisms, the interconnectedness of species, and the impact of human activities, including global warming, on ecosystems and biodiversity (Reaka-Kudla et al. 1997). Current interest in biodiversity has prompted global bioinformatics efforts to identify species through DNA "barcodes" (Hebert et al. 2002) and to make databases accessible through the Internet (Ratnasingham & Hebert 2007, Encyclopedia of Life 2008).

Biodiversity patterns are often contrasted between terrestrial ecosystems, with high endemism, and marine ecosystems, with low endemism except in the most remote archipelagoes (e.g., Hawai‘i), but patterns in Oceania suggest that this contrast may not be so clear as it seemed (Paulay & Meyer 2002). However, *freshwater* biodiversity has not yet raised a great deal of concern or study around the world in spite of a disproportionately large number of species, given the small global area covered by freshwaters, the great pressures on freshwater resources from burgeoning populations, and management issues that are more complex than those for terrestrial or marine ecosystems (Dudgeon et al. 2006). In particular, aquatic microbial biodiversity (both bacterial and eukaryotic) is often under-appreciated (Nee 2004), perhaps partly because of a prevailing view that microbial species are cosmopolitan and endemics are exceptional (Fenchel & Finlay 2004).

Identification of organisms is essential for monitoring anthropogenic changes in ecosystems and in managing biodiversity, and the first step is development of a baseline of species present. The focus in freshwater biomonitoring is often still on the vertebrates and macroinvertebrates (Rosenberg & Resh 1993), but protists in general, and ciliates in particular have been used for monitoring the health of aquatic ecosystems (Shen & Zhang 1990, Shen et al. 1995, Foissner & Berger 1996, Berger & Foissner 2003, Chen et al. 2005, Jiang 2005). Among the changes happening to many ecosystems are those resulting from invasive introduced species. Guam's inland aquatic ecosystems have been invaded by ampullariid snails (Smith 2003, and see Mochida 1991), toads and an increasing number of frogs (Wiles 2000), turtles (Leberer 2003), and fish (ISSG 2007), as well as several rooted plants (PIER 2007). Along with these visible aquatic species inevitably come unnoticed microinvertebrates and protists.

In Guam and other western Pacific islands, microinvertebrates and protists in any ecosystem have received scant attention in contrast to larger marine organisms (Paulay 2003a), terrestrial and wetland plants (Stone 1971, Stemmermann 1981, Raulerson & Rinehart 1991, 1992, Drew et al. 2005), fishes (Myers & Donaldson 2003), turtles (Leberer 2003) and crustaceans (Leberer & Cai 2003). Freshwater microinvertebrates and protists are relatively well-studied in North America (Thorp & Covich 2001, Wehr & Sheath 2003) and in parts of eastern Asia (Shen & Zhang 1990). Even in well-studied areas, however, the knowledge is "woefully incomplete" (Dudgeon et al. 2006, p. 165), "particularly among invertebrates and microbes, and especially in tropical latitudes." For Guam, there are no detailed studies of particular inland waters, only a handful of studies of taxonomic groups across different habitats—copepods (Watson & Belk 1975), cladocerans (Belk 1973), red algae (Bowden-Kerby 1985, Kumano & Bowden-Kerby 1986), and diatoms (Zolan 1981). Belk & Hotaling (1971) reported a small jellyfish from Fena Lake and mentioned a few microinvertebrates. Lobban et al. (1990) included some algae from Guam for comparison in a study of the freshwater flora of Yap.

The authors have conducted biodiversity research on Guam and in Micronesia for nearly 20 years (Gerrath & Lobban 1991, Lobban et al. 1990, 1995, 2002, Lobban & N'Yeurt 2006) and have been involved in science education for much of that time (Lobban & Schefter 1997, Schefter & Lobban 1997). With the acquisition of good photomicroscopy capacity in biology at UOG, and the incentive to improve microscopy training in the biology curriculum, we have begun involving students in exploration and documentation of freshwater microinvertebrates and protists. It became clear from our initial work with students that there were many new records to be found among these groups, even for the few taxa that had been studied before, and that students could contribute meaningfully to biodiversity research in this way and learn to do science through authentic discovery. For example, two cladocerans, so far identified only to genus (*Simocephalus* and *Alona*), are not even in the same families as any of the six species reported by Belk (1973). The larger red algae we have found (*Compsopogon*, *Compsopogonopsis*) are different from the ones that Bowden-Kerby (1985) reported from Guam.

While preservation and study of diverse phyla of microinvertebrates and protists by experts is not generally possible on Guam, we can now document many of these taxa with good photomicroscopy. With the assistance of taxonomic treatises and the generous help of experts examining our photographs, we have been able to make a start on the freshwater biodiversity list. The present report introduces the ongoing studies, describes some of the freshwater habitats of Guam, and presents new records of ciliates (mostly peritrichs) and a heliozoan. Ongoing records are initially posted on a biodiversity website at http://university.uog.edu/botany/474/fw_toc.htm. When there is sufficient interest, species records will be presented in *Micronesica* or other journals as appropriate. An accompanying paper documents the first freshwater bryozoan record for the region (Lobban et al. 2008).

Study sites

Wetlands are classified into categories depending on whether they are moving (lotic) or stationary (lentic) and on the size, depth, and vegetation characteristics (Polhemus et al. 1992 for tropical Pacific islands). Microbial ecology is significantly different in lotic and lentic environments (Sigee 2005). Lentic wetlands on Guam are mostly small marshy areas or ponding basins, with the exception of Fena Lake reservoir (Guam Bureau of Planning 1991, Taborosi in press). Some are seasonal (Guam's rainy season is approximately June through November), others have water year-round. The streams on Guam have very variable flow but rarely dry completely. Almost all are in the volcanic southern half of the island (Figure 1); some of these flow through limestone caps, acquiring carbonate loads that are redeposited as stromatolites. Figure 1 shows the locations of sites sampled to date by us and our students. Frequently visited or otherwise noteworthy sites are described below. Sampling so far has been biased toward lentic habitats but only one of these has been sampled extensively.

"Route 4 Marsh" (Figure 2) is a seasonal wetland near the Pago River, extending east from the edge of the highway, 13° 25' 34" N, 144° 46' 56" E. There is usually standing water from August to March. The marsh had considerable open water along the roadside after flooding in summer 2004; by early 2006 tall grasses (*Phragmites karka* (Retz.) Trin. ex Steud.) had filled in the open water but there was still standing water between the grass stems. The water surface was completely covered with duckweed (*Lemna aequinoctialis* Welwitsch), which formed a floating "canopy" above the mid-water and the bottom debris. By September 2007 there was no longer any duckweed among the *Phragmites* stems.

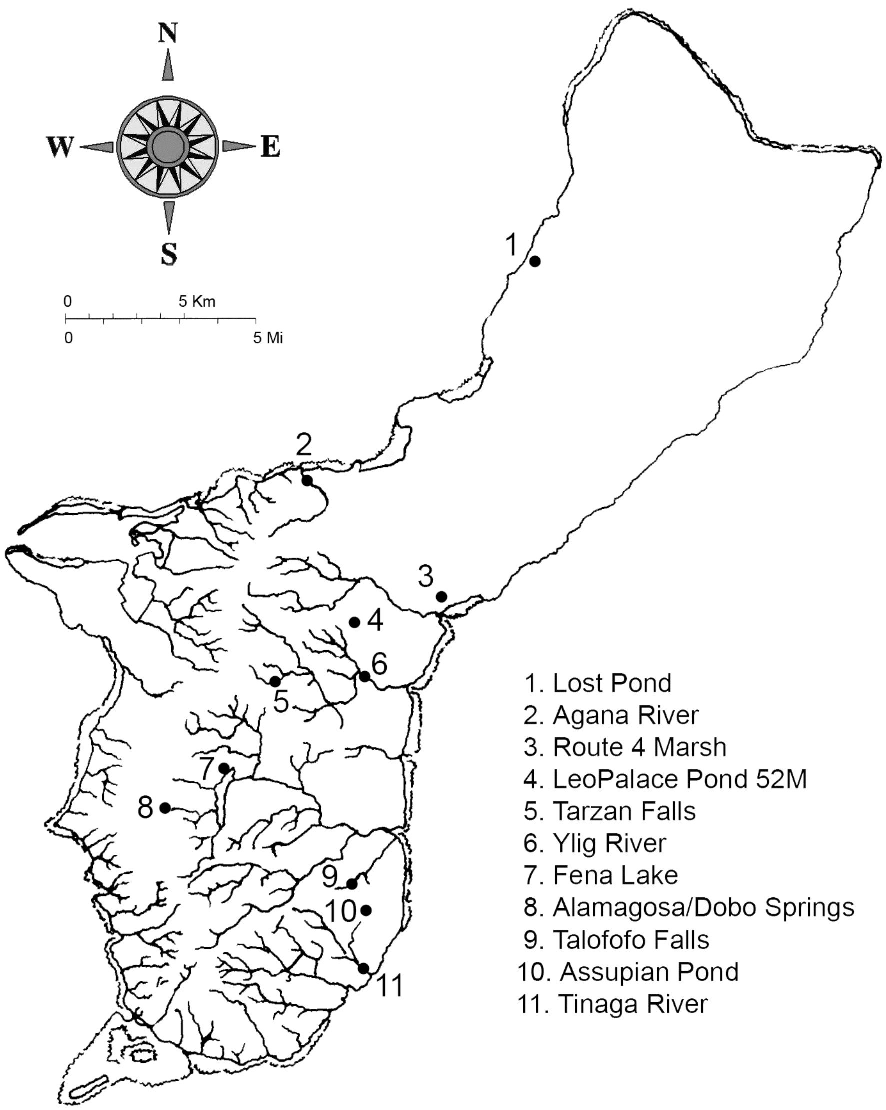


Figure 1. Location of study sites, listed north to south, also showing the freshwater surface flows. Adapted from a map drawn by Rick L. Castro after Tracey et al. 1964, *General Geology of Guam*.

Figures 2–4. Principal study sites. Fig. 2, Route 4 Marsh in October 2004. Fig. 3, LeoPalace Pond M52, September 2007. Fig. 4, Assupian Pond, Oct. 2004.

Small macroscopic animals commonly seen in the marsh included a green *Hydra,* at least two copepod species, the cladoceran *Simocephalus* sp., an introduced snail—*Physa* cf. *acuta*, and insect larvae; photographs of these are included on the web site. We sampled this marsh frequently from October 2004 to August 2007.

LeoPalace Pond 52M (Figure 3) is a small manmade and maintained wetland for drainage of the LeoPalace Resort golf course, 13° 24' 47" N, 144° 43' 58" E. The edges of the pond are planted with *Eleocharis ochrostachys* Steud. (Cyperaceae) and the middle has open water. The bottom is mucky; benthic microinvertebrates and protists collected so far have all been directly or indirectly attached to larger invertebrates (snails, shrimp) in two samples during April 2006. Several later samples in 2006 yielded no invertebrates and samples in 2007 yielded only apple snails, (*Pomacea canaliculata* (Lamarck, 1819)), without attached ciliates.

Assupian Pond (Figure 4) is a shallow seasonal wetland about the size of a football field in the Dandan area, 13° 18' 18" N, 144° 44' 54" E. The pond is largely filled with para grass (*Urochloa mutica* (Forssk.) T.Q. Nguyen = *Brachiaria mutica* (Forssk.) Stapf.; considered a threat to Pacific island ecosystems, PIER 2007) but there are some open spaces. There is an outcrop of limestone on the hill to the NE of it, which probably affects the pH; the soil here is otherwise acidic volcanic clay. The pond is notable for abundant *Chara*, *Oedogonium*, and unicellular green algae. Feral water buffalo sometimes wallow in the pond. It is a stable wetland, which we have sampled several times over the past 15 years.

Fena Lake is a reservoir in the Naval Magazine with several short streams feeding into it. One of the streams has two shady springs (Alamagosa and Dobo) as it flows over volcanic rock partially overlain by limestone. Access is very restricted but we have sampled here occasionally during the past 15 years.

Lost Pond, 13° 33' 21" N, 144° 49' 01" E is a sink hole (cenote) at the edge of the northern water lens, about 250 m inland from the ocean and surrounded by limestone forest. It is slightly brackish but is not an anchialine pool by the definition in Polhemus et al. (1992). The water is often green with microalgae and there are sometimes floating mats of the filamentous green alga *Pithophora*. Animals noticed include several fish species, tadpoles of *Bufo marinus*, water striders and abundant dragonflies. We have sampled this pond several times over the past 15 years.

We and our students have begun exploring streams (Figure 1), and have also sampled temporary puddles, catchment buckets, garden ponds, and other standing water. The current list of sites can be accessed at http://university.uog.edu/

botany/474/fw_toc.htm. Additional color photographs of all the organisms and study sites are posted on this web site.

Methods

Bucket samples containing mostly the surface *Lemna* mat, but also some bottom debris, were collected from Route 4 Marsh; samples of aquatic plants or animals were collected by hand from other sites. Sampling was done by CL unless otherwise noted. Subsamples were examined with Olympus CZ51 dissection microscopes. Small specimens were isolated and observed under Olympus CX41 compound microscopes with brightfield, phase, and darkfield illumination. Still and video images were made with Olympus 7070 digital cameras mounted on trinocular microscopes. A Nikon Eclipse 600 microscope was also used to provide differential interference contrast illumination. We are limited in our ability to document mobile organisms by the lack of flash capability or highly sensitive camera chips.

Initial identification of protists was done using keys and illustrations in Lynn & Small (2000). Additional references include Shen et al. (1995), Taylor & Sanders (2001), Berger & Foissner (2003), and web resources, especially Micro*scope (2006) and Protist Information Server (2008). Critical identification of ciliates requires specialized preservation and staining of cells and detailed analysis of ciliature, involving considerable work on the part of taxonomic experts as well as the collectors, and this has generally not been possible for our specimens. Most identifications presented below are thus not definitive, but in some cases specimens specimens alive or preserved in Bouin's solution (Foissner 1991) or ethanol were sent to the professional protistologists who assisted us.

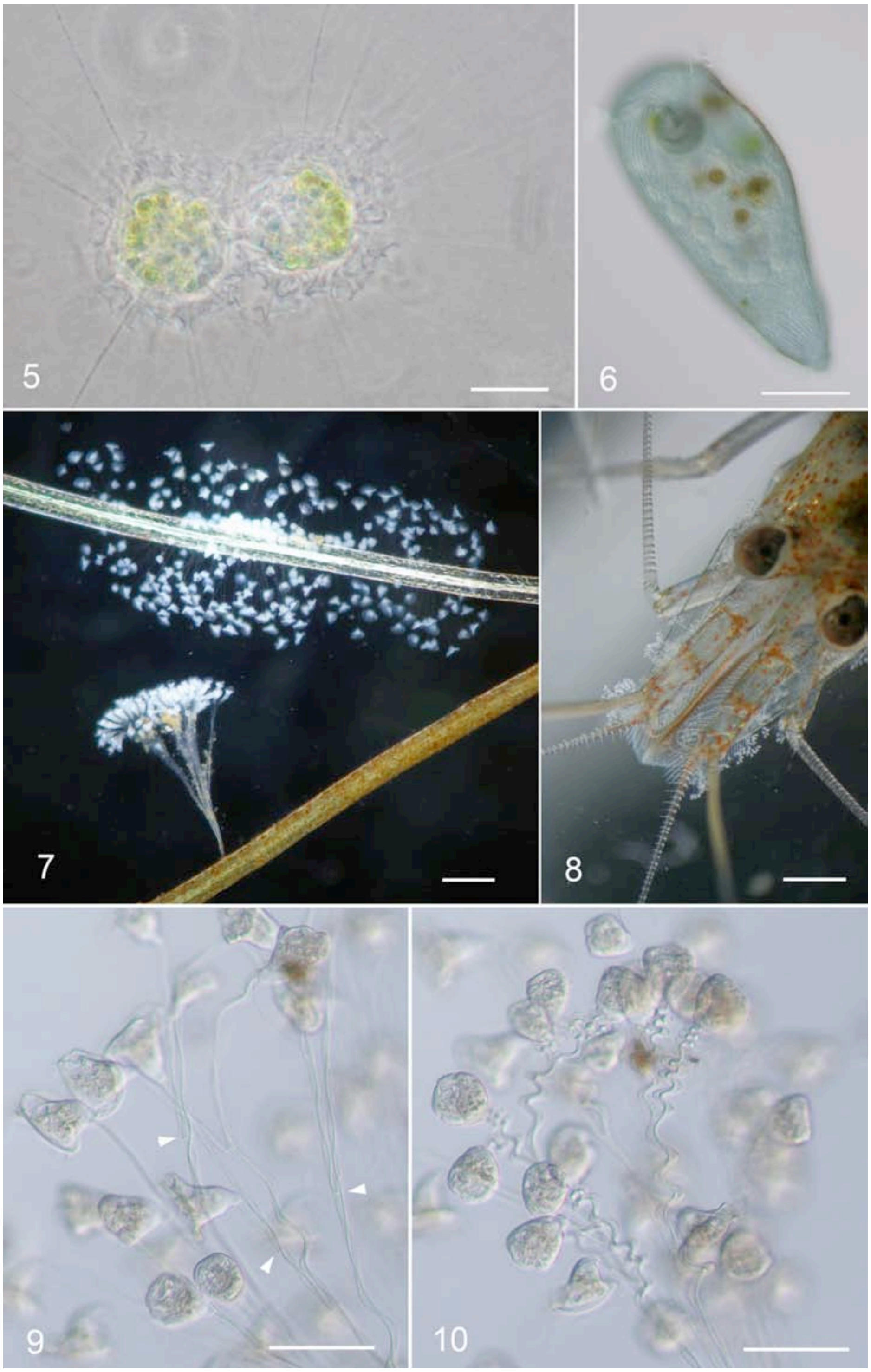
Results

The list presented systematically below (see Lynn & Small 2000, Adl et al. 2005) gives those that we have been able to photograph adequately for identification at least to genus. We saw many ciliates but most were too small or too fast to document. We also include the one heliozoan recorded to date. Many additional photographs are posted on the web site. All the following are new records for Guam and Micronesia and are the first freshwater ciliates documented from our region.

Eukaryota Insertae Sedis

CENTROHELIDA
Raphidiophryidae

Raphidiophrys cf. *elegans* Hertwig & Lesser, 1874 (Figure 5). This unusual organism was found once (two colonies) in Assupian Pond, 27 Oct. 2004. It has a periplast of siliceous scales and contains zoochlorellae. It may form small clusters of cells, as shown in the sample (Mikrjukov et al. 2000).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Phylum Ciliophora

CLASS HETEROTRICHEA

Order Heterotrichida

Stentoridae

Stentor coeruleus (Pallas, 1776) Ehrenberg, 1831 (Figure 6). This distinctive species was identified by CL on the basis of its size, the color of the pigment granules, and the moniliform nucleus, using the key in the monograph by Foissner & Wölfl (1994). It has been observed in low numbers in samples from Route 4 Marsh on several occasions, including 17 Oct. 2005 and 18 Dec. 2006. The paucity of observations may be due to our sampling bias toward lighted habitats, especially the surface duckweed canopy, whereas most strains of *S. coeruleus* require very dim light (Tartar 1961). Nevertheless, we documented a specimen that had been feeding on green euglenoids (Lobban et al. 2007, fig. 3c).

SUBCLASS PERITRICHIA

Order Sessilida

Vaginicolidae

Pyxicola carteri Kent, 1886 (= *P. nolandi* Finley & Bacon, 1965) (Figure 11). This species was encountered as an epiphyte on algal filaments in several collections; it was very common in a collection from LeoPalace Pond 52M, 19 Apr. 06, but elsewhere (Lost Pond, Ylig River, Tinaga River) was seen only in low numbers. It has a distinctive operculum. The stalked lorica may be clear but often becomes dark brown and opaque with age.

Single specimens of an unstalked genus, probably *Vaginicola* (Figure 12), have also been recorded on two occasions (Leo Palace Pond 52M, 19 Apr. 2006, and Tinaga River, 28 Apr. 2007).

Vorticellidae

Pseudovorticella sp. (Figures 7, 13–14). This genus was found fairly consistently in the Route 4 Marsh in 2005–07. This genus is distinguished from *Vorticella* by the presence of beads on the myoneme, visible in Figure 13. On one occasion a single colony with very short stalks was documented (Figure 14); this may be a different species or just a variant of the common one. We also found a *Pseudovorticella* once in Assupian Pond, 27 Aug. 2006.

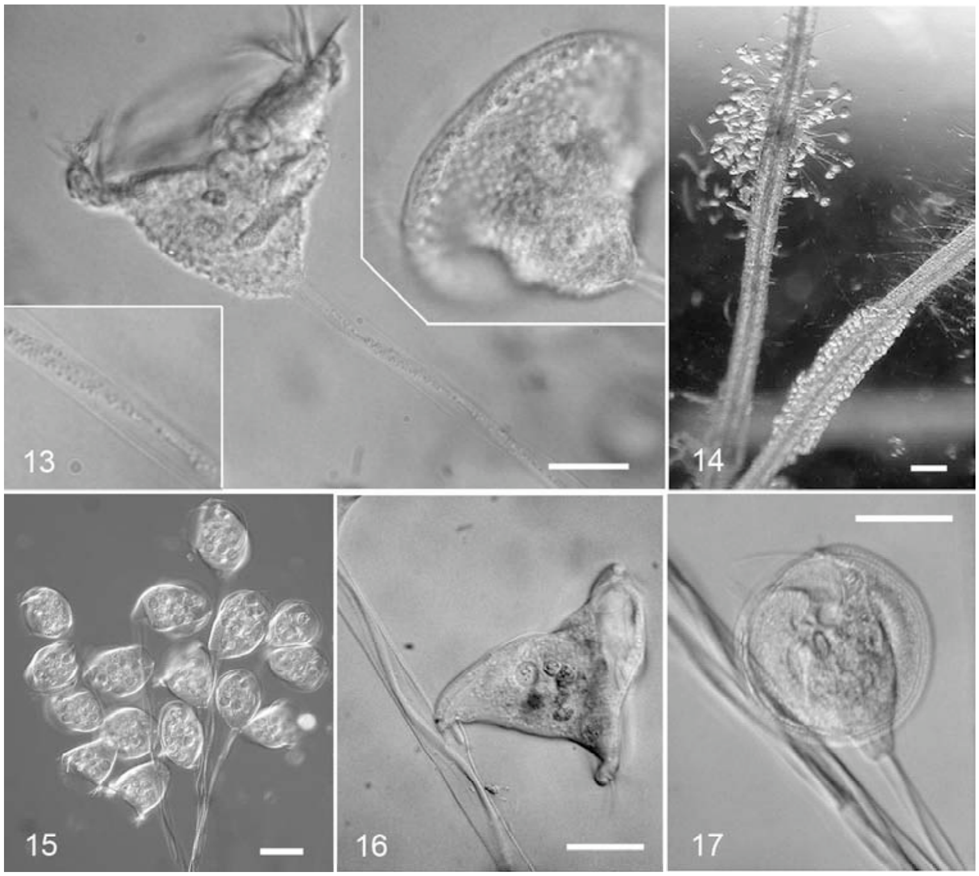
(*Facing page*) Figures 5–10. Sample photos of the organisms. Fig. 5, *Rhaphidiophrys* (phase contrast); Fig. 6, *Stentor coeruleus* showing moniliform (beaded) nucleus and characteristic color (DIC); Fig. 7. *Pseudovorticella* sp. (above) and *Epistylis plicatilis* on *Lemna* roots (dissection microscope); Fig. 8. *Zoothamnium* on *Atyoida* (dissection microscope); Figs. 9–10, *Carchesium polypinum,* 2007 collection showing initiation of separate myoneme at each branch point (arrows in Fig. 9) and characteristic coiling of stalks. DIC. Scale bars: 5 = 20 µm, 6, 9 and10 = 100 µm, 7 = 500 µm, 8 = 5 mm.

Figures 11–12. Sample photos of the Vaginicolidae. Fig. 11, *Pyxicola carteri*, showing operculum (arrowhead); Fig. 12, *Vaginicola* sp. Scale bars = 20 μm.

Carchesium polypinum (Linnaeus, 1758) Ehrenberg, 1830 (Figures 9–10, 15–17). One colony (Figure 15) epiphytic on *Cladophora* filaments was found by CL in a September 2006 collection by Marcello delos Reyes III from rocks in a pool of the Ylig River just above a small dam, 13° 23' 57" N, 144° 45' 14" E. Additional colonies from the same site, 28 August 2007 clearly showed the *Carchesium* characters (vs. *Zoothamnium*) of separate myonemes for each zoid and contraction by coiling (Figures 9–10, 16). Identity of this species was confirmed by Eleni Gentekaki (U. Guelph, personal communication, 1 Mar. 2008) from sequence analysis of specimens sent live to her.

Epistylidae

Several collections have included members of the Epistylidae, but none has been encountered consistently in repeated samples from the same location. *Epistylis* is now seen as polyphyletic (Utz & Eizirik, 2007, Williams & Clamp



Figures 13–17. Sample photos of the Vorticellidae. Fig. 13, *Pseudovorticella*: two cells showing shape and external surface of zoid and inset (lower right) enlargement of granules on the myoneme; Fig. 14, *Pseudovorticella* with very short stalks (on lower root), compared with usual type; Fig. 15–17, *Carchesium polypinum*: Fig. 15, 2006 collection ; Fig. 16, lateral view of zoid from 2007 collection showing initiation of new myoneme; Fig. 17, apical view. All DIC except 14. Scale bars: 13, 16 and 17 = 20 μm, 14 = 250 μm, 15 = ~50 μm

2007), but a revision of the genus has not been done yet. Stalks of *Epistylis* are noncontractile, in contrast to those of vorticellids and *Zoothamnium*.

Epistylis plicatilis Ehrenberg, 1838 (Figures 5, 18). This species was observed several times on *Physa* shells and plant debris in Route 4 Marsh (including 18 Oct. 2006, 2 Jan. 2007) and in LeoPalace Pond 52M. The zoids are the largest of the three species recorded and contract with characteristic folding of the base of the cell (Figure 18).

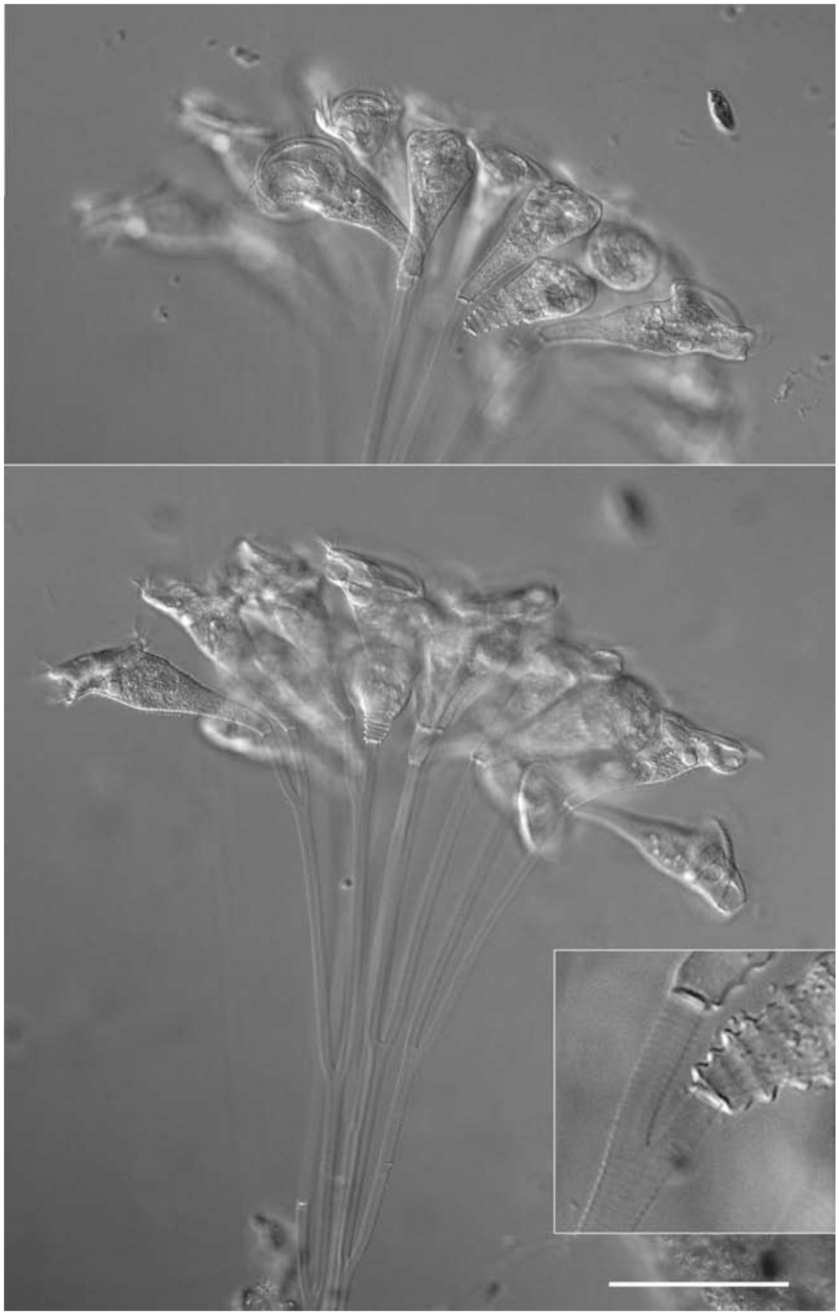


Figure 18. Sample photos of *Epistylis plicatilis*. Two views of the same colony; inset enlargement of upper photo showing striations on stalk and characteristic folding in contracted zoid. DIC. Scale bar: 100 μm.

Epistylis nympharum Engelmann, 1862 (Figures 19–20). This species was found only in September 2005 collections from Route 4 Marsh, where it was abundant on copepods and insect larvae. On those occasions copepods were very abundant. Preserved material and numerous still and video images were examined by Dr. W. Miao for the identification (personal communication 21 Mar. 2005).

Epistylis sp. #3 (Figure 21). These small epiphytic colonies, consisting of only one or two zooids, were photographed on *Cladophora* sp. that was in turn on the shells of the snail *Melanoides tuberculata* in LeoPalace Pond 52M, 19 Apr. 2006.

Zoothamniidae

Colonies that are probably *Zoothamnium* sp. were collected once on the atyid shrimp, *Atyoida pilipes* (Newport, 1847) from LeoPalace pond 52M, 19 Apr. 2006 (Figures 8, 22).

CLASS LITOSTOMATEA

SubClass Haptoria
Order Haptorida
Tracheliidae

Dileptus sp. (Figure 23). We encountered single individuals of this genus in several samples from Route 4 Marsh, including 16 Oct. 2006. It is a known predator on *Stentor* and other ciliates, and several heterotrichs have pigmented or colorless cortical granule contents that act as feeding deterrents against this species (reviewed in Lobban et al. 2007).

CLASS COLPODEA

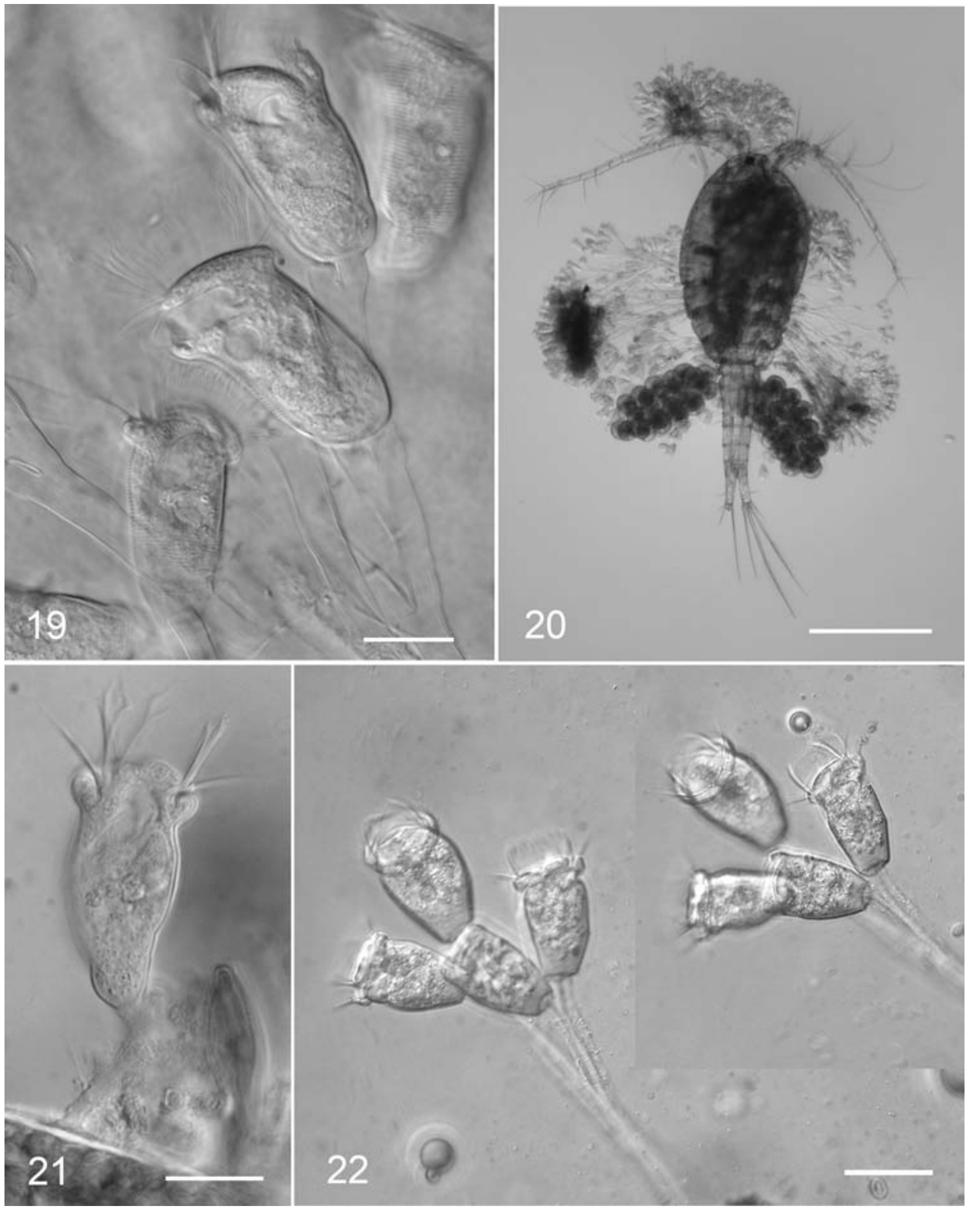
Order Bursariomorphida
Bursariidae

Bursaria sp. (Figure 24). We encountered a single very large cell recognizable as this distinctive genus in a sample from Route 4 Marsh. We documented it with video at low magnification but were unable to get high magnification views. One still from the video is shown in the illustration.

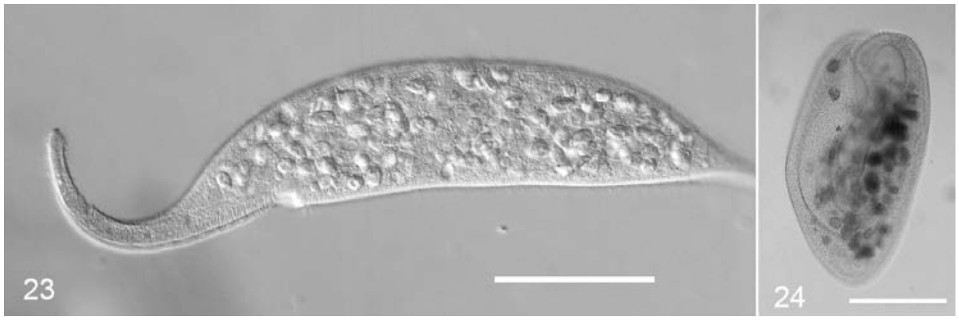
Discussion

PHOTODOCUMENTATION OF FRESHWATER BIODIVERSITY

Photodocumentation serves as a basis for comparison between habitats on Guam, and serves as an indication of where taxonomically interesting species might occur, in spite of the shortcomings inherent in photodocumentary taxonomy and the tentative identifications that result. Ideally, properly prepared voucher specimens should be kept for examination by experts. However, this is



Figures 19–22. Sample photos of Epistylidae and Zoothamniidae. Figs 19–20, *Epistylis nympharum* detail and habit on copepod; Fig. 21, *Epistylis* #3 on *Cladophora* sp.; Fig. 22, *Zoothamnium* sp. DIC except 20. Scale bars: 19 and 21 = 20 μm, 20 = 500 μm, 22 = 50 μm.



Figures 23–24. Fig. 23, *Dileptus* sp.; Fig. 24, *Bursaria* sp. DIC. Scale bars: 23 = 50 µm, 24 = 250 µm.

impractical for most groups because of the variety of specialized methods for preservation; several groups are difficult to preserve (rotifers) or must be specially dissected in order that experts could see the essential morphological characters (e.g., copepods). Identification of protists and microinvertebrates before fixation is encouraged (e.g., Wallace & Snell 2001); however, it is one thing for an expert to examine and photograph living specimens and quite another to identify taxa based on photographs taken by others. In some instances we were able to preserve material appropriately and send it to interested experts.

The potential for finding new or interesting taxa is fairly high because freshwater organisms have not been extensively studied in surrounding tropical areas. While most species in Guam have probably been transported in from other areas, e.g., on winds or on birds traveling along the east Asia–Australia flyways, Bowden-Kirby (1985) found apparent endemicity in the freshwater red algae of Guam, Palau, Pohnpei and Chuuk. Kumano & Bowden-Kirby (1986) described six new species from various islands. The bryozoan we report from Guam (Lobban et al. 2008) has been found only three times before—from North Carolina and Florida, USA and from New Zealand.

CILIATE FAUNA

The records here represent only a small sample of the ciliate species diversity in Guam's inland waters. Virtually all those listed are peritrichs, which are relatively large (several hundred micrometers long), often colonial, and generally non-motile, thus more amenable to capture and observation than small and/or highly mobile taxa. The habitats sampled were mostly small lentic water bodies.

Identification of taxa in regions that have not been studied in detail depends on reference to literature from other regions. For many groups of protists the main literature is from Europe but, as noted by Pillsbury & Slavik (2006) with reference to a North American diatom, this Euro-centric emphasis "often results in trying to fit North American taxa into the closest European description [and] … has the unfortunate outcome of erroneously attributing potential ecological information to the closest-appearing European counterpart while missing the environmental information these endemic taxa could provide" (p. 365). More broadly, the debate over whether eukaryotic microbes are "here and there or everywhere" (see Sharma et al. 2007) affects the present study in how much reliance can be put on comparing our specimens with species from North America and Europe. Differentiation into new species, and thereby the development of distinct local biodiversity, is prevented when dispersal of a species to an area is frequent, as it is for many marine animals in the Indo-West Pacific (Paulay & Meyer 2002). Some protistologists (e.g., Fenchel et al. 1997, Fenchel & Finlay 2004) have argued that the abundance and dispersal abilities of microorganisms (< 1 mm long) ensures that all species are everywhere, with appearance of taxa in samples dependent on environmental conditions. Other scientists (Boenigk et al. 2006, Foissner 2006, Martiny et al. 2006, Vyverman et al. 2007, among others) argue that dispersal is less than universal and there is some regional endemism in protistan taxa. To the extent that microbial eukaryotes are globally distributed, we can use literature from remote places to identify our taxa, but we thereby contribute to the appearance that the taxa are cosmopolitan. For instance, is our *Stentor coeruleus* really the same as that from Europe and North America? Ciliate species are defined in part by details of ciliature that can be seen only with special staining and painstaking analysis. At present, the alternative to proceeding as we have is to wait until suitably trained experts can devote time to detailed study of each species. However, as molecular databases are developed and methods, including DNA barcoding, become routine, it will become possible both for better identification of organisms and to address questions of regional versus global species distributions. Meanwhile, biodiversity documentation serves to identify distinctive regional species or the presence of taxa that are rare elsewhere, both of which might be useful to systematists. The islands of Oceania may be home to species that can help address the biogeography debate in protistology, just as Paulay & Meyer (2002) found them useful in examining terrestrial and marine biodiversity patterns.

Acknowledgements

The major impetus for these studies came from a pilot course in Science Communication, part of a grant from ED-MSEIP [P120A040092] in support of microscopy and science communication at UOG. The educational hypothesis in the project was that the unexplored diversity of microscopic life would excite student interest in biology, once they had the instruments to observe and document it. We thank the students in the pilot course for their enthusiasm for the project and their willingness to try out the new course materials and help us shape the curriculum, especially Esther Hermal, Rozalyn Pama and Keith Quiambao. We also thank the students in Plant Diversity, Fall 2006, who explored diversity of freshwater photosynthetic organisms. Funding for the Nikon E600 microscope was from a National Institute of General Medical

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These studies have been given impetus and greater accuracy by input from people with much more knowledge of freshwater organisms than us. In particular, our colleague in Biology at UOG, Dr. Lynn Raulerson, was involved in the microscopy grant and has been a mentor in exploring pond life. Experts in particular groups have also been vital in identifying organisms as far as possible on the basis of photographs; in the present instance Dr. Wei Miao (Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan), Dr. John Clamp (Central University, Durham, NC), Eleni Gentekaki (U. Guelph, Canada), and Dr. David J. Patterson (Marine Biological Laboratory, Woods Hole, MA). Nevertheless, the authors recognize the limitations in identifying species from photographs and take full responsibility for claiming these taxa as records for Guam. In addition, we thank Trina Leberer and Barry Smith for identifying the macroinvertebrate hosts of the ciliates and Lynn Raulerson for identifying the rooted macrophytes.

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