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Research Article

Ciliate diversity in a backyard fish farm from Zimatlán de Álvarez, Oaxaca Mexico: an island of aquatic microscopic biodiversity from a semi-urban area

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ABSTRACT. Ciliates are extremely versatile single-celled eukaryotes displaying an enormous functional diversity as key elements of food webs. In this study, we found the ciliates in an artisanal backyard Nile tilapia *Oreochromis niloticus* farm in Oaxaca, Mexico, to describe the diversity and species distribution. Twenty nominal taxa were recorded inhabiting the studied fish farm; only the species *Trichodina centrostrigeata* was found parasitizing the gills of the cultured Nile tilapia. Most ciliate species recorded here are indicators of α or β mesosaprobic waters, suggesting that bacteriophage taxa dominate ciliate composition. This study represents the first record of ciliate diversity from an aquaculture farm in Mexico.

Keywords: *Oreochromis niloticus*; Ciliophora; protozoans; biodiversity; anthropized environment; Nile tilapia farm

INTRODUCTION

Protozoans may be found in almost every aquatic habitat, conforming to natural communities that typically contain dozens of species (Patterson 2003). Among these, ciliates are a highly diverse clade of eukaryotic microorganisms and constitute a monophyletic group related to Apicomplexa and Dinoflagellata, among others, to conform the Alveolata clade (Lynn 2008, 2012, Pawlowski 2014, Adl et al. 2019). Ciliates are distributed worldwide and exhibit high species richness, with over 8000 described species (Lynn 2008) living in almost all habitats where water might accumulate. They display an enormous functional diversity as key elements of food webs and constitute the 'top' organisms in the microbial food web, feeding on bacteria, algae, other protists, and even some metazoans (Weisse 2017), and are, in their turn, being eaten by zooplankton, jellyfish and small fish, performing a role of transferring energy through aquatic food chains (Lynn 2012).

Even though ciliates are common single-celled organisms living in aquatic systems, studies on ciliates occurring in fish farms are scarce and focused on those species that parasitize the fish reared (e.g. Rintamäki et al. 1994, Bastos-Gomes et al. 2017, Jahangiri et al. 2021), or the interactions among bacteria and parasitic ciliates (Bastos-Gomes et al. 2019, Sufardin et al. 2021), omitting the actual diversity of ciliate species living in the ponds where fish are living. Since these species form part of the immediate environment where fish are growing, in this study, we recorded the ciliate species found in an artisanal backyard tilapia farm to describe their diversity, distribution, and relationships with the cultured Nile tilapia *Oreochromis niloticus*.

MATERIALS AND METHODS

Twenty-four water samples were collected from three sampling events from August to December 2020, from fishpond and other artificial enclosures at the tilapia farm "La Tilapia Zimateca," located at Zimatlán de

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Figure 1. Facilities of the backyard fish farm "Tilapia Zimateca" at Zimatlán de Álvarez, Oaxaca, Mexico. a) FTP1: fattening pond 1, b) S-BP: sedimentation-biofiltration pond, c) DNTP: denitritification pond, d) GRTP: growth pond, and FTP 3: fattening pond 3.

Álvarez (16º52'19.5"N, 96º47'03.122"W), Valles Centrales region, Oaxaca, Mexico. Facilities of this fish farm (Figs. 1-2) include seven ponds where samples were collected: three fattening ponds and one point pond with a capacity of 30,000 L; 6 m diameter and 1.5 m of maximum depth; one sedimentation-biofiltration pond (a smaller concrete-wall pond); one denitrification pond of polyethylene (capacity 1100 L; 1.1 m diameter, 1.4 m height), where water lily is used as biofilter; and one growth pond (capacity 1100 L; 1.1 m diameter, 1.4 m height) (Fig. 2). The water samples were collected in pre-sterilized glass bottles of 500 mL capacity, and transported to the Laboratorio de Biodiversidad, Escuela de Ciencias, Universidad Autónoma "Benito Juárez" de Oaxaca, Oaxaca, for examination immediately after collection. Additionally, 20 specimens of Nile tilapia (total length 20.3-25 cm) were retrieved from the fishponds to be analyzed for ectoparasitic ciliates; these ciliates were isolated on an air-dried smear. For parasitic ciliates, prevalence (i.e. the percentage of fish infected with at least one of the species of parasite) was calculated following Bush et al. (1997), and level of infestation (levels X: 1 to 5 individuals; XX: 5 to 20 individuals; and XXX: 20 to 50 individuals) was determined following Loubser et al. (1995).

After two days, glass containers with water samples were covered with gauze and road transported to the Laboratorio de Zoología Acuática, Facultad de Ciencias, Universidad Nacional Autónoma de México, Mexico City, then maintained for seven more days at room temperature (about 22ºC). Ciliates from these samples were transferred inside a drop of water onto a clean slide, where they remained functionally viable for a few minutes, allowing observation and capture of images. The samples were observed using bright field (Leica DM500) and phase-contrast microscopy (Carl Zeiss). Microphotographs and morphometric data were obtained using Leica DM500 photomicroscope equipment with the Leica ICC50 HD capture imaging system. Dry silver nitrate impregnation (Klein 1958) and supravital staining techniques to reveal cytological structures were used (Foissner 1991). Following recommendations by Patterson (2003), line drawings were done to direct the eye to important features of each ciliate taxon. Species identification follows Foissner et al. (1992, 1999), Patterson (2003), Fokin et al. (2004), Fan et al. (2014), and Zhisuai et al. (2019). The ciliate classification follows the proposal of Adl et al. (2019).

RESULTS

Twenty nominal taxa were recorded inhabiting the studied fish farm (Figs. 3-6); of these, only the species *Trichodina centrostrigeata* was found parasitizing the gills of the cultured tilapia (prevalence = 10%; level of

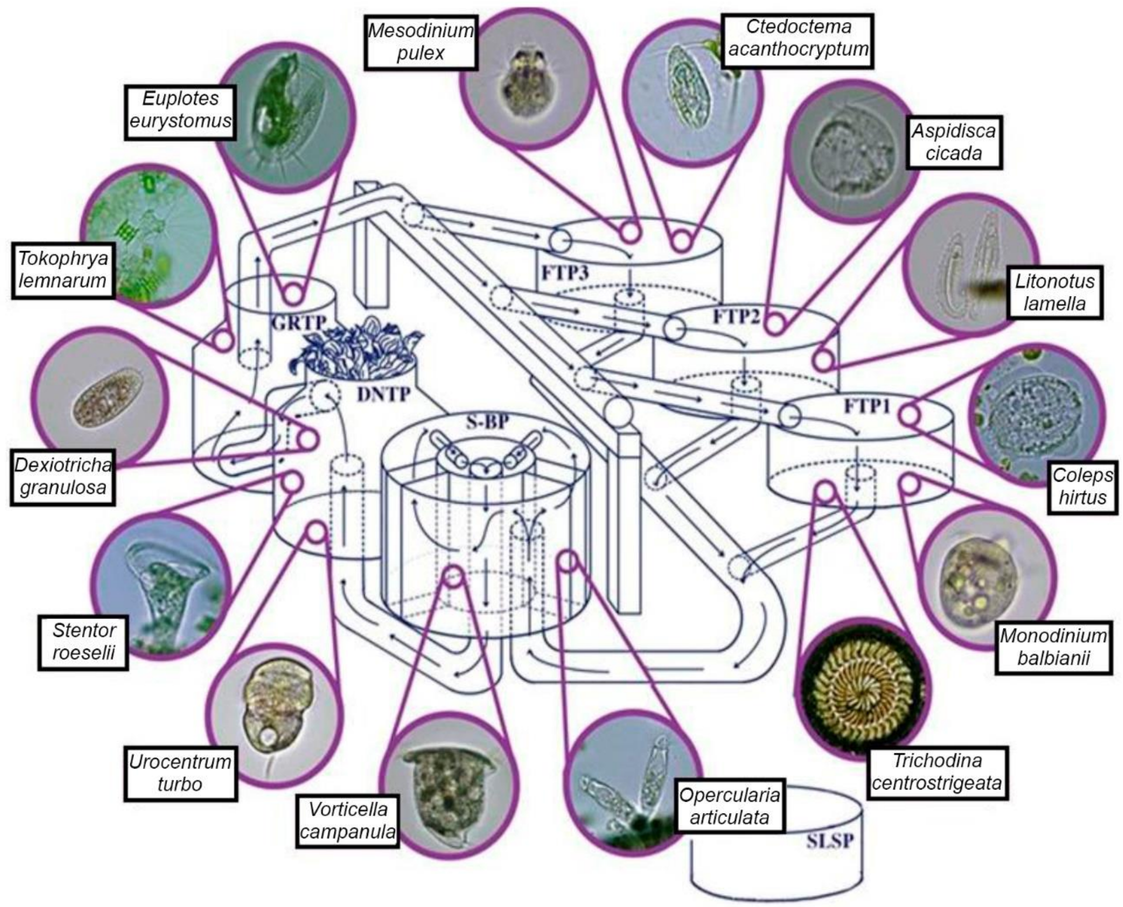

Figure 2. Diagram of the facilities of the fish farm "Tilapia Zimateca," showing some representative ciliate taxa living in each tank. FTP1: fattening pond 1, FTP2: fattening pond 2, FTP3: fattening pond 3, S-BP: sedimentation-biofiltration pond, DNTP: denitrification pond, GRTP: growth pond, SLSP: selling point pond. Arrows indicate the flux of water through the system.

infestation = X). The ciliate species recorded are listed in Table 1. The distribution of ciliate species per pond is presented in Table 2. The ciliate taxa *Aspidisca cicada*, *Coleps hirtus*, *Litonotus lamella*, and *Satrophilus* sp. were well-distributed in the fish facilities (6-7 ponds). In contrast, *Dexiotricha granulosa*, *Stylonychia* sp., and *Urocentron turbo* were restricted to the denitrification pond, and *Cyclidium* sp. and *Monodinium balbianii* were only found in the fattening pond 1. Seven ciliate species are recorded for the first time in the Mexican state of Oaxaca. Additionally, several morphotypes of suctorian ciliates were observed in very low densities, which prevented an accurate taxonomical determination, and for this reason, we excluded them from the taxa list. This study represents the first record of the ciliate diversity from the facilities of an aquaculture farm in Mexico, showing a relatively high diversity of single-celled aquatic taxa immersed in a semi-urban environment.

DISCUSSION

The current diversity of ciliates in Mexico exceeds 1000 species (Mayén-Estrada et al. 2020). However, these species have been irregularly recorded throughout the Mexican territory (Mayén-Estrada et al. 2014, Aguilar-Aguilar & Islas-Ortega 2015). As result, the diversity of these organisms in the state of Oaxaca has been severely understudied (Aladro-Lubel et al. 2006), even though recent works have started to report the first species (Durán-Ramírez et al. 2015, Lagunas-Calvo et al. 2016, Aristeo-Hernández 2017, Cruz-Jiménez 2017, Méndez-Sánchez 2017, Méndez-Sánchez et al. 2020). Results obtained in this work contribute to increasing the knowledge about protozoan species capable of living in an artificial aquatic environment in the middle of a semi-urban population. The ciliate species diversity recorded here suggests that the facilities of backyard fish farms immersed in semi-urban areas

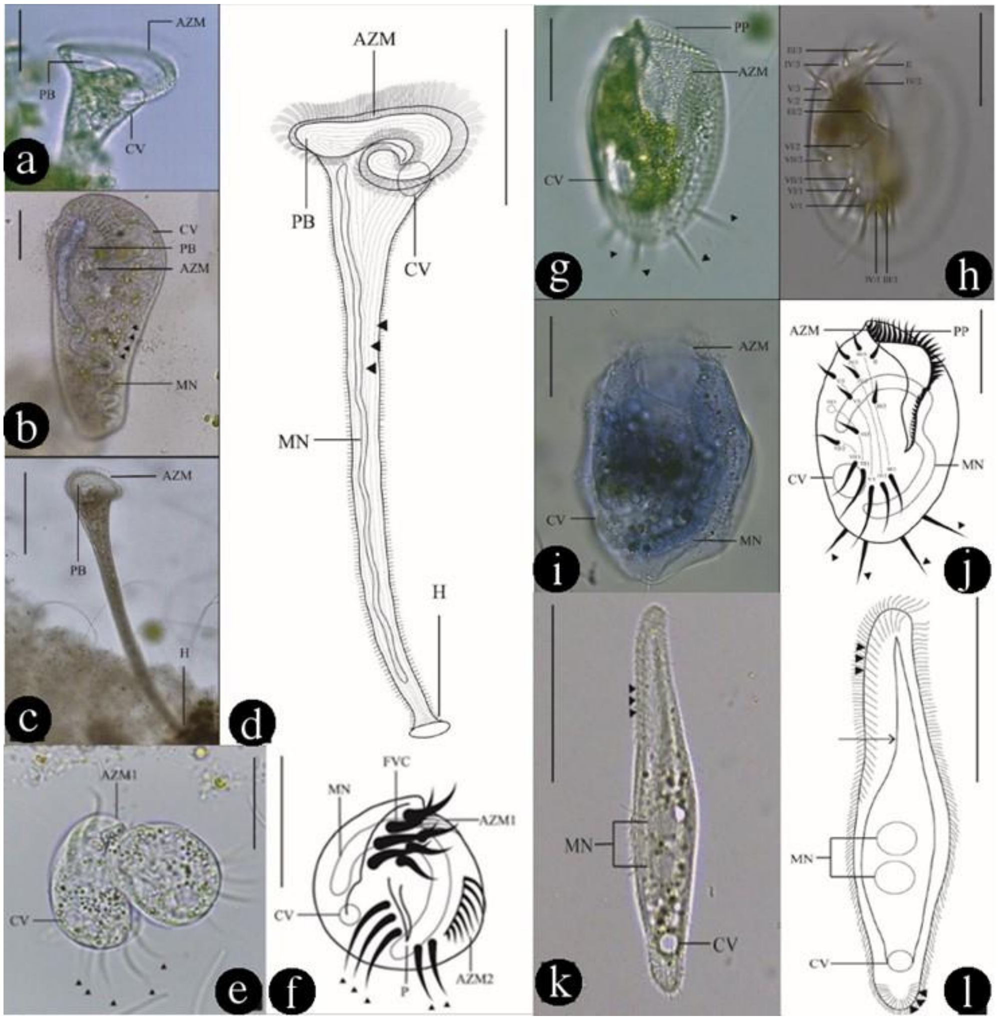

Figure 3. Some ciliate taxa recorded in the fish farm "Tilapia Zimateca", Oaxaca, Mexico. *Stentor roeselii*: a) oral region (*in vivo*), scale bar = 50 µm; b) stained specimen, scale bar = 50 µm; c) extended individual (*in vivo*), scale bar = 200 µm; d) schematic representation, scale bar = 200 µm. *Aspidisca cicada*: e) two individuals during conjugation, scale bar = 20 µm; f) schematic representation, scale bar = 20 µm. *Euplotes eurystomus*: g) ventral view (*in vivo*), scale bar = 50 µm; h) frontoventral (II, III/3-VI/3, and III/2-VI/2) and transversal (III/1-VII/1) cirri (*in vivo*), scale bar = 50 µm; i) stained specimen, scale bar = 50 µm; j) schematic representation, scale bar = 50 µm. *Litonotus amella*: k) specimen *in vivo*, scale bar = 50 µm; l) schematic representation, scale bar = 50 µm. AZM: adoral zone of membranelles, PB: peristomial field, CV: contractile vacuole, MN: macronucleus, H: holdfast, FVC: frontoventral cirri, P: projection, PP: peristomial collar, black triangles in (b, d) indicate some somatic kinetids, black triangles in (e-f) indicate transversal cirri, black triangles in (k-l) indicate some extrusomes, black triangles in (g, j) indicate caudal cirri, arrow in (l) indicates the pellicle line.

provide environmental conditions that enable the colonization and growth of several species, conforming small islands of biodiversity (Aguilar-Aguilar et al. 2023), where some organisms can thrive almost without human interference, despite inhabiting an anthropized environment (Montagnini et al. 2022), maintaining a community of microorganisms and small animals, which potentially interacting with the fish reared.

Most taxa recorded here have been extensively reported from Oaxaca (Aristeo-Hernández 2017, Méndez-Sánchez 2017, Méndez-Sánchez et al. 2020) and other localities in Mexico (Aladro-Lubel et al. 2006); however, the discontinuous efforts to record

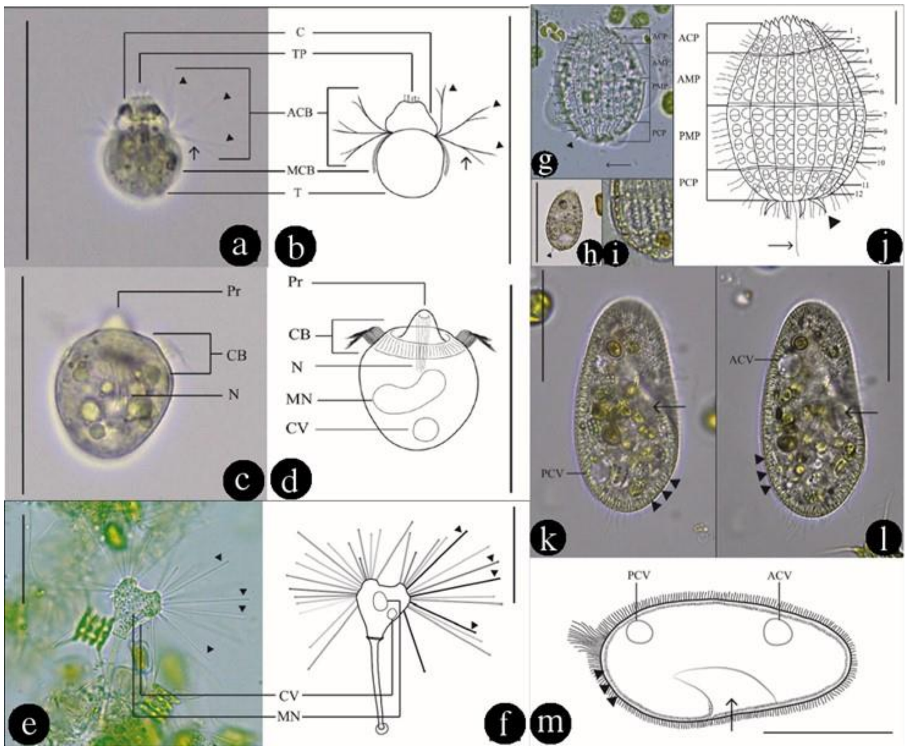

Figure 4. Some of the ciliate taxa recorded in the fish farm "Tilapia Zimateca", Oaxaca, Mexico. *Mesodinium pulex*: a) specimen *in vivo*, scale bar = 50 µm; b) schematic representation, scale bar = 50 µm. *Monodinium balbianii*: c) specimen *in vivo*, scale bar = 50 µm; d) schematic representation, scale bar = 50 µm. *Tokophrya lemnarum*: e) specimen *in vivo*, scale bar = 50 µm; f) schematic representation, scale bar = 50 µm. *Coleps hirtus*: g) stained specimen, scale bar = 20 µm; h) specimen *in vivo*, scale bar = 50 µm; i) detail of some windows; j) schematic representation, with numbered windows rows, scale bar = 20 µm. *Paramecium* sp. I: k-l) specimens *in vivo*, scale bar = 50 µm; m) schematic representation, scale bar = 50 µm. ACB: anterior band of cilia, MCB: middle band of cilia, C: conus, T: trunk, TP: tentacular projections, CV: contractile vacuole, MN: macronucleus, CB: ciliar band, N: nematodesmata, Pr: proboscis, ACP: anterior secondary tiers, AMP: anterior main tiers, PCP: posterior secondary tiers, PMP: posterior main tiers, ACV: anterior contractile vacuole, PCV: posterior contractile vacuole, black triangles in (a-b) indicate groups of cirri, black triangles in (e-f) indicate some tentacles, black triangles in (g-h, j) indicate posterior spines, black triangles in (k-m) indicate some extrusomes, the arrow in (a-b) indicates cirrus bifurcation, the arrow in (g, j) indicates the caudal cilium, the arrow in (k-m) indicates the oral opening.

protozoans in Mexico cause that some well-distributed ciliate taxa are instead reported as new records for some areas; thus, seven taxa listed in this study represent new records for the state of Oaxaca and other surrounding regions, and remarkably, the species *Ctedoctema acanthocryptum* and *Opercularia articulata* are being recorded for the second time in Mexico, since that the presence of *C. acanthocryptum* was reported by Madrazo-Garibay & López-Ochoterena (1982), whereas *O. articulata* was recently found as an epibiont of *Procambarus* (*Austrocambarus*) sp., from Lagos de Montebello, Chiapas, southeastern Mexico (Ramírez-Ballesteros et al. 2021).

During the study, we found the ectoparasitic species *T. centrostrigeata* associated with the gills of farmed Nile tilapia, exhibiting a relatively low prevalence (10%) on juvenile fishes. This parasite is considered an invasive species introduced to Mexico and other regions through the anthropogenic dispersal of cichlids worldwide (Valladão et al. 2016, Islas-Ortega et al. 2020), which have established effective populations after introduction (Islas-Ortega et al. 2022), being now recorded from diverse localities of northern, central, and southeastern Mexico (Aguilar-Aguilar & Islas-Ortega 2015, Lagunas-Calvo et al. 2016, Rodríguez-Santiago et al. 2019, Islas-Ortega et al. 2022). Ciliate

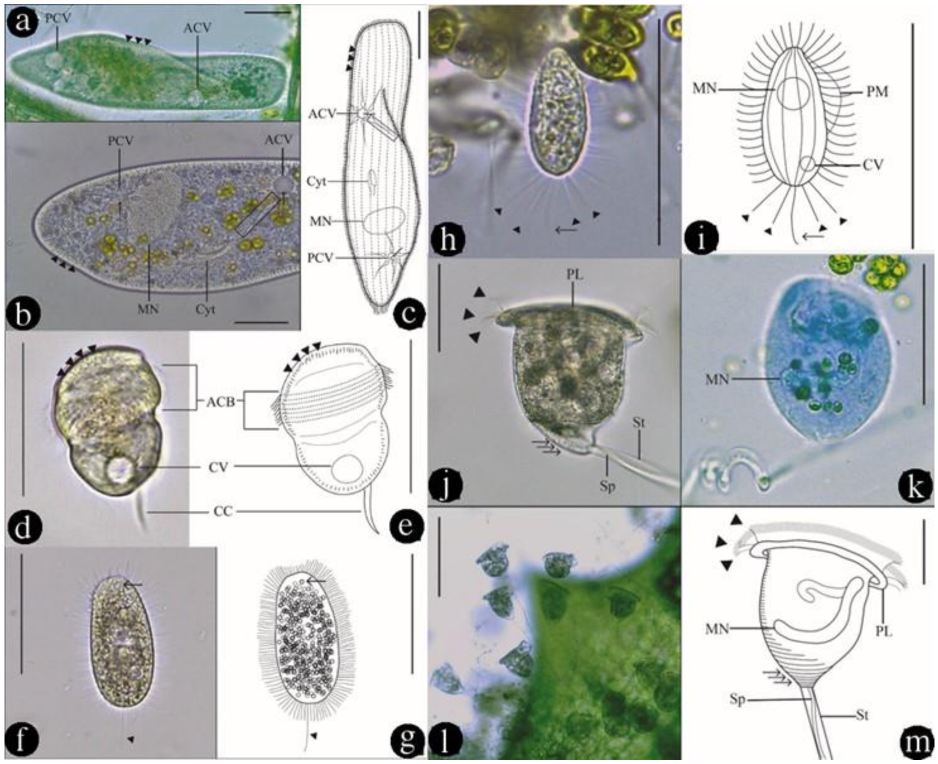

Figure 5. Some of the ciliate taxa recorded in the fish farm "Tilapia Zimateca", Oaxaca, Mexico. *Paramecium* sp. II: a) specimen *in vivo*, scale bar = 50 µm; b) posterior end of a stained individual, scale bar = 50 µm; c) schematic representation, scale bar = 50 µm. *Urocentrum turbo*: d) specimen *in vivo*, scale bar = 50 µm; e) schematic representation, scale bar = 50 µm. *Dexiotricha granulosa*: f) specimen *in vivo*, scale bar = 50 µm; g) schematic representation, scale bar = 50 µm. *Ctedoctema acanthocryptum*: h) specimen *in vivo*, scale bar = 50 µm; i) schematic representation, scale bar = 50 µm. *Vorticella campanula*: j) zooid and stalk (*in vivo*), scale bar = 50 µm; k) stained specimen, scale bar = 50 µm; l) colonial individuals (*in vivo*), scale bar = 200 µm; m) schematic representation, scale bar = 50 µm. MN: macronucleus, ACV: anterior contractile vacuole, PCV: posterior contractile vacuole, Cyt: cytostome, ACB: anterior band of cilia, CC: caudal cirrus, CV: contractile vacuole, PM: paraoral membrane, PL: peristome, Sp: spasmoneme, St: stalk, black triangles in (a-e) indicate some extrusomes, black triangle in (f-g) indicates the caudal cirrus, black triangles in (h-i) indicate large and rigid posterior cilia, black triangles in (j, m) indicate peristomial cilia, the arrow in (c) indicates the oral opening, the arrow in (f-g) indicates ring-like granule, arrow in (h-i) indicates the caudal cilium, arrows in (j, m) indicate some pellicular striae.

protozoans associated as facultative or obligate parasites with cultured fishes represent a potential risk for aquaculture activities. Ciliated protozoans can proliferate quickly, debilitating the host and, in the absence of an intervention, can lead to a significant loss of stock (Jahanari et al. 2021). Ciliate infections frequently facilitate the establishment of secondary microbial species linked to environmental and culture conditions (Islas-Ortega & Aguilar-Aguilar 2021, Jahangiri et al. 2021). The infestation with trichodinids, also known as "trichodiniasis," is associated with a chronicle or acute mortality during cage production (Valladão et al. 2016). For these reasons, some studies have tested the effectiveness of some treatments in farmed tilapia, which presented trichodiniasis with prevalence values from 30 to 43% (García-Magaña et al. 2019); in our case, the low value of prevalence, but especially the very low level of infection (X, less than five individuals per fish), does not allow us to consider the presence of *T. centrostrigeata* as a risk for the studied fish farm; however, long-term monitoring is necessary to support this viewpoint.

The presence of bacteria and algae and abiotic factors such as the concentration of organic matter modifying the water conditions promote a web of potential interactions (Fig. 7), explaining the occu-rrence of each ciliate taxa inside each pond. Most ciliate species recorded here are indicators of α or β mesosaprobic waters, and the remaining taxa can bear these abiotic conditions. Mesosaprobic waters could be

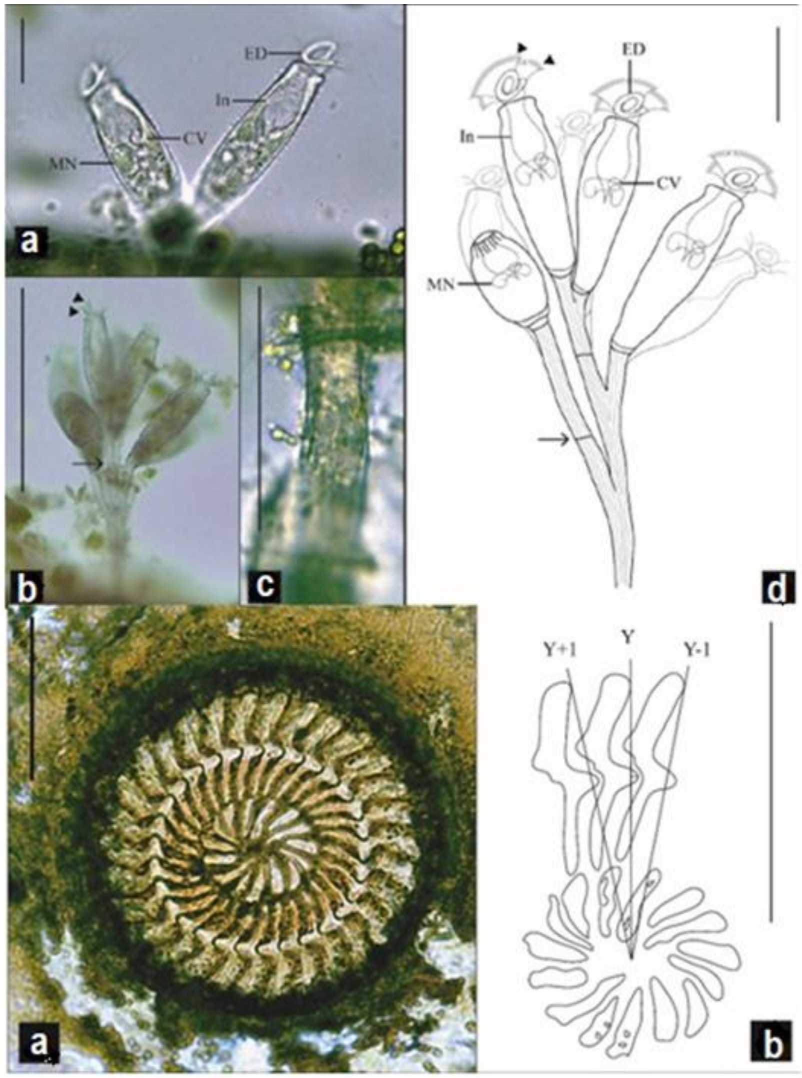

Figure 6. Some of the ciliate taxa recorded in the fish farm "Tilapia Zimateca", Oaxaca, Mexico. *Opercularia articulata*: a) zooids (*in vivo*), scale bar = 50 µm; b) colonial individuals (*in vivo*), scale bar = 50 µm; c) pellicular striae, scale bar = 200 µm; d) schematic representation, scale bar = 50 µm. *Trichodina centrostrigeata*: e) silver-impregnated adhesive disc, scale bar = 20 µm; f) denticle sketch, scale bar = 20 µm. MN: macronucleus, CV: contractile vacuole, in: infundibulum, ED: epistomial disk, arrow indicates one transversal stria, black triangles indicate peristomial cilia.

considered normal conditions present in fish farms because of the amounts of nutrients and organic matter derived from uneaten feed, fish feces, and metabolic excretion products (Varol 2019); even so, the water circulating through the fish farm is good enough to maintain communities of diverse microorganisms, including flag taxa such as *Coleps hirtus* and *Stentor roeselii*, which are intolerant to environments with a high concentration of nitrogen compounds such as ammonia and ammonium (Bick 1972), and for this reason have been considered as bioindicator species of good environmental conditions (Ymas-González et al. 2009, El-Serehy et al. 2014, Debastiani et al. 2016). These mesosaprobic conditions promote the growth of bacterial communities. As a result, the ciliate composition is dominated by bacteriophage taxa (Dias et al. 2008) and complemented with other omnivorous or algivores species (Fig. 4).

Most ponds harbored a similar relatively high richness (from 8 to 12 taxa). The sedimentation-biofiltration tank showed the highest species richness, and this diversity could be explained by the presence of fast-growing bacteria promoted by the biofilter film and the abundance of water lilies. As mentioned above, bacteria provide an abundant food source for many

Table 1. List of ciliate taxa recorded in this study. NRO: new local record (for the State of Oaxaca, Mexico); EPS: ectoparasitic species associated with cultured Nile tilapia.

Phylum Ciliophora Doflein 1901
- Class Heterotrichea Stein, 1859
  - Order Heterotrichida Stein, 1859
    - Family Stentoridae Carus, 1863
      - ***Stentor roeselii* Ehrenberg, 1835** (Fig. 3a-d)
- Class Spirotrichea Bütschli, 1889
  - Order Euplotida Small & Lynn, 1985
    - Family Aspidiscidae Ehrenberg, 1830
      - ***Aspidisca cicada* (Müller, 1786)**[NRO] (Fig. 3e-f)
    - Family Euplotidae Ehrenberg, 1838
      - ***Euplotes eurystomus* (Wrzesniowski, 1870)** (Fig. 3g-j)
  - Order Sporadotrichida Fauré-Fremiet, 1961
    - Family Halteriidae Claparède & Lachmann, 1858
      - **Halteriidae gen. sp. I**
    - Family Oxytrichidae Ehrenberg, 1830
      - ***Stylonychia* sp.**
- Class Litostomatea Small & Lynn, 1981
  - Order Pleurostomatida Schewiakoff, 1896
    - Family Litonotidae Kent, 1882
      - ***Litonotus lamella* (Müller, 1773)** [NRO] (Fig. 3k-l)
  - Order Cyclotrichiida Jankowski, 1980
    - Family Mesodiniidae Jankowski, 1980
      - ***Mesodinium pulex* (Claparède & Lachmann, 1859)** [NRO] (Fig. 4a-b)
  - Order Haptorida Corliss, 1974
    - Family Didiniidae Poche, 1913
      - ***Monodinium balbianii* Fabre-Domergue, 1888** [NRO] (Fig. 4c-d)
  - Order Endogenida Collin, 1912
    - Family Tokophryidae Jankowski in Small & Lynn, 1985
      - ***Tokophrya lemnarum* (Stein, 1859)** [NRO] (Fig. 4e-f)
- Class Prostomatea Schewiakoff, 1896
  - Order Prorodontida Corliss, 1974
    - Family Colepidae Ehrenberg, 1838
      - ***Coleps hirtus* (Müller, 1786)** (Fig. 4g-j)
- Class Oligohymenophorea de Puytorac et al., 1974
  - Order Peniculida Fauré-Fremiet in Corliss, 1956
    - Family Parameciidae Dujardin, 1840
      - ***Paramecium* sp. I** (Fig. 4k-m)
      - ***Paramecium* sp. II** (Fig. 5a-c)
  - Order Urocentrida Jankowski, 1980
    - Family Urocentridae Claparède & Lachmann, 1858
      - ***Urocentrum turbo* (Müller, 1786)** (Fig. 5d-e)
  - Order Philasterida Small, 1967
    - Family Cinetochilidae Perty, 1852
      - ***Sathrophilus* sp.**
    - Family Loxocephalidae Jankowski, 1964
  - Order Pleuronematida Fauré-Fremiet in Corliss, 1956

Continuation

***Dexiotricha granulosa* (Kent, 1881)** (Fig. 5f-g)
Family Ctedoctematidae Small & Lynn, 1985
***Ctedoctema acanthocryptum* Stokes, 1884** [NRO] (Fig. 5h-i)
Family Cyclidiidae Ehrenberg, 1838
***Cyclidium* sp.**
Order Sessilida Kahl, 1933
Family Vorticellidae Ehrenberg, 1838
***Vorticella campanula* Ehrenberg, 1831** (Fig. 5j-m)
Family Operculariidae Fauré-Fremiet in Corliss, 1979
***Opercularia articulata* Goldfuss, 1820** [NRO] (Fig. 6a-d)
Order Mobilida Kahl, 1933
Family Trichodinidae Claus, 1874
***Trichodina centrostrigeata* Basson, van As & Paperna, 1983**[EPS] (Fig. 6e-f)

Table 2. Distribution of ciliates by pond. FTP1: fattening pond 1, FTP2: fattening pond 2, FTP3: fattening pond 3, S-BP: sedimentation-biofiltration pond, DNTP: denitrification pond, GRTP: growth pond, SLSP: selling point pond.

Ciliate taxon	FTP1	FTP2	FTP3	S-BP	DNTP	GRTP	SLSP
Stentor roeselii				X	X		X
Aspidisca cicada	X	X	X	X	X	X	
Euplotes eurystomus				X	X	X	X
Halteriidae gen. sp. 1	X		X	X	X	X	X
Stylonychia sp.					X		
Litonotus lamella	X	X	X	X	X	X	X
Mesodinium pulex	X		X	X		X	
Monodinium balbianii	X						
Tokophrya lemnarum						X	X
Coleps hirtus	X	X	X	X	X	X	
Paramecium sp. I	X		X			X	
Paramecium sp. II				X	X		
Urocentrum turbo					X		
Sathrophilus sp.	X	X	X	X		X	X
Dexiotricha granulosa					X		
Ctedoctema acanthocryptum	X		X	X			
Cyclidium sp.	X						
Vorticella campanula	X		X	X	X		X
Opercularia articulata				X			X
Trichodina centrostrigeata	X		X				

ciliate taxa, so numerous individuals of diverse ciliate taxa can be easily collected. In opposition, the fattening pond 2 had the least number of ciliate taxa (four species); this could be because this pond is only filled at the end of the production period, around easter, and emptied at the sale's end. In contrast, the remaining ponds contain water throughout the year.

This contribution represents the first carried out in Mexico focused on the knowledge of ciliate biota inhabiting the facilities of a fish farm and provides valuable information about these organisms, frequently ignored in terms of biodiversity or biological conservation (López-Ochoterena 1993, Dunthorn et al. 2014). In this sense, this work contributes to filling a gap of knowledge about the biological diversity of the Mexican state of Oaxaca, which has been considered one of the most relevant components of the Mesoamerican "hotspot" of biodiversity (Margules & Sarkar 2009, Contreras-Medina & Aguilar-Aguilar 2013). Results presented herein were obtained from an artificial system of animal production inside a semi-

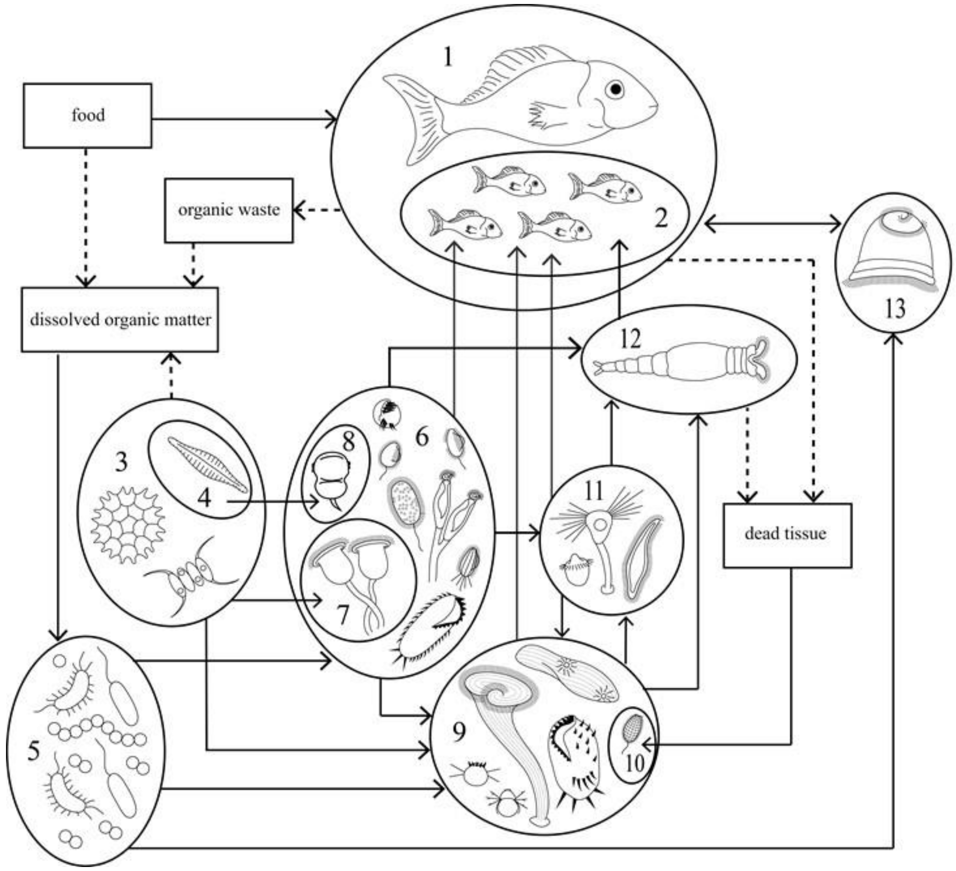

Figure 7. Interactions among ciliates and other organisms inhabiting the facilities of the fish farm "Tilapia Zimateca." Continue lines indicate food relationships, broken lines indicate organic matter flux and double-arrowed lines indicate symbiotic relationships. 1) Adult tilapia, 2) juvenile tilapia, 3) phytoplankton, 4) diatoms, 5) heterotrophic bacteria, 6) bacteriophage ciliates, including, 7) *Vorticella campanula* (phytoplanctophage), 8) *Urocentrum turbo* (diatom-eating species), 9) omnivorous ciliates, including 10) *Coleps hirtus* (histophagic species), 11) predatory ciliates, 12) metazooplankton, 13) trichodinid ciliates.

urban area, which implied the contribution of the local population to the generation of biological knowledge. This kind of synergy has been well documented in the state of Oaxaca (Galindo-Leal 2004, Margules & Sarkar 2009), where the contribution of organized civil society has been fundamental for the development of many projects to contribute to the well-being of the region (Galindo-Leal 2004). The current biodiversity framework of the state of Oaxaca is mainly based on well-studied taxa such as plants and animals. In this study, we provide novel information about a poorly known group of single-celled organisms, hoping they will soon be recognized as a part of the magnificent "Guelaguetza of the biodiversity". Guelaguetza is an annual multicultural festival devoted to celebrating the ethnic diversity of the State of Oaxaca, Mexico. Galindo-Leal (2004) coined the term "Guelaguetza de la Biodiversidad" to celebrate the high biological biodiversity of this region and the diverseness of researchers studying it.

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