

DIATOMS OF CALCAREOUS TROPICAL SPRINGS IN THE CENTRAL REGION OF MEXICO

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ABSTRACT — 57 species of diatoms (Bacillariophyceae) were found in four calcareous springs in the central region of México. 6 belong to Centrales and 51 belong to Pennales. Information for each species includes: general ecological characteristics, salinity, saprobity, pH, nutrients, temperature and known geographical distribution in México. With respect to temperature, 24 of 31 species reported in the literature coincided with our values (20-27° C, mesothermal or eutermal). 37 of 41 species with published pH data have been reported as alkaliphilous, alkalibiontic or indifferent to pH, corresponding to conditions in the Huasteca. With respect to salinity 23 of the 36 species are reported from low salinity habitats (oligohalobous or halophilous). Lastly, with respect saprobity, 38 species with reports in the literature has been found in habitats with low concentrations of organic matter (mesosaprobic, oligosaprobic, saproxenous and saprophobic). The importance of these characteristics to use the species as ecological indicators is discussed.

RÉSUMÉ — 57 espèces de diatomées (Bacillariophyceae) ont été identifiées dans des sources calcaires de la région centrale du Mexique. 6 de ces espèces appartiennent aux Centrales et 51 aux Pennales. Pour chaque espèce, l'information suivante est fournie : caractéristiques écologiques générales, salinité, saprobité, pH, nutriments, température et distribution géographique connue au Mexique. 24 des 31 espèces mentionnées dans la littérature l'avaient été comme méso- ou euthermales (températures du milieu concordant avec celles qui ont été mesurées dans cette étude : 20-27° C). 37 des 41 espèces pour lesquelles des données de pH du milieu avaient été publiées, avaient été citées comme alcaliphiles, alcalibiontes ou indifférentes au pH, ce qui correspond aux conditions observées au Huasteca. 23 des 36 espèces dont le comportement vis à vis de la salinité a été publié ont été rencontrées dans des habitats à faible salinité (oligohalobes ou halophiles). Enfin, 38 espèces ont été mentionnées dans la littérature comme provenant de milieux présentant de faibles teneurs en matière organique (mésosaprobies, oligosaprobies, saproxènes et saprophobes). L'importance de ces caractéristiques pour l'utilisation de ces espèces comme indicateurs écologiques est discutée. (Traduit par la Rédaction)

KEY-WORDS: Diatoms, freshwater, calcareous springs, Mexican tropics.

INTRODUCTION

Diatoms are one of the most diverse groups in lotic environments of the central region of México, and they are particularly evident in calcareous springs in the Huasteca in the State of San Luis Potosí. Aside from constant input of water, little chemical

variation, constant temperature and low concentrations of organic matter, these springs also have tropical temperatures. On the other hand, high concentrations of carbonates in the water make these springs quite unique biotopes. Current velocity, illumination and substrate type play an important role in the establishment of algal communities (Carmona & Montejano, 1993). Most worldwide studies in this habitat refer to thermal springs and only a few to cold or infiltration springs. The latter habitats have been described in Europe and the USA by Whitford (1956), Margalef (1977), Golubič (1967), Dary & Wayne (1968), Hynes (1970) and Round (1973; 1984). The goal of the present study is to compare the environmental conditions of the diatoms found in Huasteca with those of previous studies, and to better understand the range of ecological requirements of each species and evaluate its potential as an ecological indicator.

MATERIALS AND METHODS

Study sites are located in the low Panuco Basin, in an area called the Huasteca in the state of San Luis Potosí. This area is at the northern limit of the neotropical region between 101°20'-98°30' LW and 22°50'-21°10' LN, at an altitude between 60-500 m a.s.l. (INEGI, 1985). The prevalent climate is warm and humid with abundant summer rains (García, 1973). The predominant vegetation is tropical deciduous forest (Puig, 1991). The Huasteca is a geologically homogeneous region with predominantly calcareous substrate. As a consequence of its geological origin, there are numerous caves, springs and waterfalls with travertine as the main substrate. Water temperature varies between 20-27° C. The pH varies between 7 and 8. The springs we studied are Nacimiento El Salto, Choy, Huichihuyan and Puente de Dios (Fig. 1).

Samples were collected from 1984-1989 covering the rainy and dry seasons. Fragments of rock with visible algal growths were chipped off or the growths were collected with a spatula. The material was fixed in 4 % formaldehyde and deposited in the Herbarium of the Faculty Science, UNAM (FCME). Temperature, pH and conductivity were taken with a Jenway 3405 electrochemical analyzer. Alkalinity was measured using the phenolphthalein and methyl orange indicator method (Taras *et al.*, 1971) (Tab. 1).

Locality	Temperature (°C)	pH	Conductivity ($\mu\text{S cm}^{-1}$)	Alkalinity ($\text{mg l}^{-1} \text{CaCO}_3$)
Nacimiento El Salto	23-27	7-7.8	800-1320	472
Nacimiento del Choy	26-27	7-7.6	900-1128	460
Nacimiento de Huichihuyan	20-22	7-7.2	260-300	336
Nacimiento de Puente de Dios	25-26	7-8.0	900-1700	450

Table 1. Physical and chemical characteristics of study localities.

Frustules were cleaned following Rushforth, Kaczmarek & Johansen (1984), and mounted with Naphrax® resin. Simonsen's (1979) classification was used and Hustedt (1927-1930, 1930, 1931-1959); Sieminska (1964); Patrick & Reimer (1966, 1975); Germain (1981); Sarode & Kamat (1984); Schoeman & Archibald (1986); Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b), were used for species identification.

For each species the following information is given: range of dimensions and taxonomic comments when necessary; locality; ecological data; literature data on alkalinity: (pH), salinity (hs), saprobity (ss), nutrients (ns), current spectrum (cs), general habitat (gh), specific habitat (sh) and temperature (ts); distribution in México. Saprobity, salinity, alkalinity and temperature of our samples were compared following Lowe's (1974) proposed system (Tab. 2). Whitford (1956); Patrick & Reimer (1975); Sláděček (1973); Sláděček *et al.* (1981); Aboal (1989, 1989b); Round *et al.* (1990) and Krammer & Lange-Bertalot (*op. cit.*), were the main sources for environmental information.

RESULTS

Fifty seven species were identified for the four springs studied. 6 taxa belonged to Centrales and 51 to Pennales (35 species from El Salto, 11 species from Choy, 19 species from Huichihuayan and 20 species from Puente de Dios).

CENTRALES

Thalassiosiraceae Lebour 1930, *emend.* Hasle 1973

Cyclotella meneghiniana Kützinger 1844

Diameter 7-14.15 μm ; striae 8-9/10 μm smooth margins.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epiphytic. T = 25.5° C, pH = 7, C = 1300 $\mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous, alkalibiontic, indifferent; hs = oligohalobous: halophilous; ss = mesosaprobic; cs = indifferent; gh = river, gully, lake, pond, spring, salt marsh; sh = euplanctonic, periphytic: epilithic; ts = eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} .

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); Hidalgo (Huasca, San Miguel Regla, Ortega, 1984; Chang, 1989); Yucatán (Sánchez, 1985); Central México (Metcalf, 1985, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993); Morelos (Valadez, 1992); Puebla (Tehuacán, Cuesta, 1993).

Melosiraceae Kützinger 1844

Melosira lineata (Dillwyn) Agardh 1824

Diameter 11.2-16.3 μm ; height of cell 6.7-6.88 μm .

Localities: Huichihuayan, Choy.

Ecological data: Periphytic, unattached. T = 20-26° C, pH = 7-7.6, C = 300-800 $\mu\text{S cm}^{-1}$.

Literature data: hs = oligohalobous; gh = river, gully; sh = periphytic: attached.

Reports from México: San Luis Potosí (Carmona, 1993).

pH spectrum pH	Acidobiontic Acidophilous Neutral Alkaliphilous Alkalibiontic	Below 5.5 Below 7 Around 7 Over 7 Alkaline water
Nutrient spectrum (nutrient concentrations) ns	Eutrophic Mesotrophic Oligotrophic Dystrophic	High Moderate Low Rich in humic material
Halobion spectrum (salt concentrations, mg l ⁻¹) hs	Polyhalobous Euhalobous Mesohalobous alpha range beta range Oligohalobous halophilous indifferent halophobous Euryhalobous	Over 40,000 Marine forms 30,000 to 40,000 Brackish-water forms 500 to 30,000 10,000 to 30,000 500 to 10,000 Freshwater forms less than 500 Stimulated by small amounts Tolerates small amounts Does not tolerates small amounts Broad ranges
Saprobien spectrum (nitrogen heterotrophic) ns	Polysaprobic 72-90° (x = 81°) ^a Mesosaprobic alpha range 54-72° (x = 63°) beta range 36-54° (x = 45°) Oligosaprobic 18-36° (x = 27°) Saprophilic Saproxenous 0-18° (x = 9°) Saprophobic	Zone of degradation and putrefaction, oxygen absent Zone where oxidation of organic loads is proceeding Stronger pollution in form amino acids Weaker pollution in form ammonia compounds Zone of biodegradable compounds is complete Polluted waters but also in clean water habitats Clean waters habitats also in polluted ones Waters that have not been exposed to pollutants
Current spectrum cs	Limnobiontic Limnophilous Indifferent Rheophilous Rheobiontic	Only standing waters Standing water but may be found in running water Common in both flowing and standing waters Running water but may be found in standing water Only of running water
General habitat gh	Mar ine Estuarine Lake Pond River Spring and stream Acrophilous Other	Oceans and seas Estuaries and brackish water habitats Large inland bodies of standig waters Small bodies of standing water Large streams Small streams Non-submerged habitats Not listed above
Specific habitat sh	Euplanktonic Tychoplanktonic Periphytic epipelic epilithic epidendric epiphytic epizooic attached unattached	Suspended in the water Associated with periphytic or terrestrial habitats On substrate and submerged objects On mud On rock On wood On plants On animals Normally sessil Normally "free"
Temperature spectrum (T° C) ts	Euthermal Mesothermal Oligothermal Stenothermal Metothermal Eurythermal Undesignated	Warm-water, 30 Temperate-water, 15 to 30 Cold-water, 0 to 15 No greater than 5 5 to 15 15 or greater Not designated

Table 2. Ecological parameters (Lowe, 1974; Sláděček, 1973, 1981)
^a = Sláděček, 1973, 1981.

***Melosira undulata* (Ehrenberg) Kützing 1844**

Diameter 41.2-50 μm ; height of cell 30-32 μm , length line of puncta 18-22/10 μm .

Localities: Huichihuayan.

Ecological data: Periphytic, unattached. T = 21-21.5° C, pH = 7.

Literature data: gh = river.

Reports from México: San Luis Potosi (Carmona, 1993).

Hemidiscaceae* Hendey 1937, emend. Simonsen 1975**Actinocyclus normanii* (Gregory ex Greville) Hustedt 1957**

Diameter 127-135.5 μm ; density of striae 4/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. T = 25.5° C, pH = 7, C = 1300 $\mu\text{s cm}^{-1}$.

Literature data: hs = oligohalobous; ss = mesosaprobic; cs = rheophilous.

Reports from México: First report.

Eupodiscaceae* Kützing 1849**Pleurosira laevis* (Ehrenberg) Compère 1982**

Length 74-87.12 μm ; width 48.9-60 μm .

Localities: Nacimiento El Salto, Puente de Dios.

Ecological data: Periphytic, epiphytic. T = 25-25.5° C, pH = 7, C = 1300 $\mu\text{s cm}^{-1}$.

Literature data: pH = alkaliphilous, alkalibiontic, indifferent; hs = mesohalobus, oligohalobus; ss = mesosaprobic; cs = rheophilous; gh = river, spring, estuaries, tropics dams; sh = euplanktonic, periphytic; ts = eutermal, mesothermal. In brackish water forming large brownish masses. Conductivity 400-20,000 $\mu\text{s cm}^{-1}$. Total phosphates 0.02-0.83 mg l⁻¹. Brackish water.

Reports from México: Morelos (Valadez, 1992); Puebla (Tehuacán, Ibarra, 1992); San Luis Potosi (Carmona, 1993).

***Terpsinoe musica* Ehrenberg 1841 (Fig. 2, a)**

Length 100-130 μm ; breadth 43.5-52.5 μm in valvar view. Length 89.5-115 μm ; breadth 100-125 μm in girdle view.

Localities: Nacimiento El Salto, Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, epiphytic, epipellic, unattached. T = 20-27° C, pH = 7-8, C = 300-1500 $\mu\text{s cm}^{-1}$.

Literature data: cs = rheophilous; gh = river, spring, irrigation channel, natural wells, aerophilous; sh = euplanktonic, periphytic; ts = mesothermal. Low level of organic matter. Tropical distribution.

Reports from México: Hidalgo, Veracruz (Ortega, 1984); Yucatán (Sánchez, 1985); Puebla (Tehuacán, Avila, 1985; Cuesta, 1993); Morelos (Valadez, 1992); San Luis Potosi (Carmona, 1993); Oaxaca (Tavera, Elster & Marvan, 1994).

PENNALES

Fragilariaceae Hustedt 1930*Fragilaria biceps* (Kützinger) Lange-Bertalot 1991

Length 510-586 μm ; width 8.5-12.5 μm ; density of striae 6/10 μm in the center; 7/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: ss = mesosaprobic.

Reports from México: First report.

Fragilaria goulardii (Brébisson) Lange-Bertalot 1986

Length 73.5 μm ; width 9-11 μm ; density of striae 9/10 μm in the center, 10/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: no reports.

Reports from México: First report.

Fragilaria capucina var. *radians* (Kützinger) Desmazières 1825

Length 40.5 μm ; width 2.88 μm ; density of striae 15/10 μm .

Localities: Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25^\circ \text{C}$, $\text{pH} = 7$.

Literature data: pH = indifferent; ss = oligosaprobic, mesosaprobic; ns = mesotrophic, oligotrophic. Low conductivity.

Reports from México: San Luis Potosí (Carmona, 1993).

Fragilaria ulna (Nitzsch) Lange-Bertalot 1980

Length (113 μm) 210-311 μm (575 μm); width 5.4-9.5 μm (10.5 μm); density of striae 8-9/10 μm in the center and 8-9/10 μm at the poles.

Localities: Nacimiento El Salto, Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, epiphytic, epilithic. $T = 20-27^\circ \text{C}$, $\text{pH} = 7-8$, $C = 300-1500 \mu\text{S cm}^{-1}$.

Literature data: longer and wider than the reports of Patrick & Reimer (1975): 75-100 μm length, (50-350 μm) and 5-9 μm width; Germain (1981) reports up to 500 μm length. pH = alkaliphilous, indifferent; hs = oligohalobous, indifferent; euryhalobous; ss = mesosaprobic, oligosaprobic, saproxenous; ns = eutrophic; cs = indifferent; gh = river, spring, irrigation channel, lakes, ponds, fossil sediments, aerophilous; sh = periphytic: epilithic, epiphytic; ts = eutermal, mesothermal, oligothermal, eurythermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} .

Reports from México: State of México (Ixtlahuaca, Ehrenberg, 1870); State of México (Texcoco, Bradbury, 1971); Central México (Kusel-Fetzmann, 1973; Metcalfe, 1985, 1988); Valley of México (Flores-Granados, 1980; Chang, 1989); Guanajuato, Jalisco, Michoacán, Oaxaca, Hidalgo (Ortega, 1984); Oaxaca (Figueroa, 1984; Tavera & González-González, 1990); Yucatán (Sánchez, 1985); Puebla (Tehuacán, Avila, 1985,

1989; Navarro, 1988; Ibarra, 1992; Cuesta, 1993); Oaxaca (Tavera, Elster & Marvan, 1994); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993); Morelos (Valadez, 1992).

Eunotiaceae Kützing 1844

Eunotia praerupta var. *bidens* (Ehrenberg) Grunow 1843

Length 104.5-107 µm; width 13.75 µm; density of striae 14/10 µm. Length/width 10:1-12:1.

Localities: Choy.

Ecological data: Periphytic, unattached. T = 26-27° C, pH = 7-7.6, C = 800 µs cm⁻¹.

Literature data: pH = acidophilous, alkaliphilous; gh = aerophilous, fossil sediments, natural wells. sh = euplanktonic; ts = eutermal, mesothermal. Conductivity 400-20,000 µs cm⁻¹. Total phosphates 0.02-0.57 mg l⁻¹.

Reports from México: State of México (Ehrenberg, 1870); Texcoco (Bradbury, 1971); Central México (Metcalf, 1985, 1988); Yucatán (Sánchez, 1985); San Luis Potosí (Carmona, 1993).

Achnanthaceae Kützing 1844

Achnanthes inflata (Kützing) Grunow in Cleve & Grunow 1880 (Fig. 2, b, c)

Length 21-32 µm; width 8.6-10 µm; density of striae 10/10 µm; 10-12 puncta /10 µm.

Localities: Puente de Dios, Huichihuayan.

Ecological data: Periphytic, unattached. T = 20-26° C, pH = 7-7.8, C = 300 µs cm⁻¹.

Literature data: pH = alkaliphilous; hs = oligohalobous; ss = mesosaprobic; cs = limnophilous, rheophilous; gh = aerophilous, thick walls, waterfalls, streams, lakes, springs; sh = tychoplanktonic, periphytic; epiphytic; ts = eutermal. Low level of organic matter. Tropical species.

Reports from México: Puebla (Tehuacán, Avila, 1989; Cuesta, 1993); Morelos (Valadez, 1992); San Luis Potosí (Carmona, 1993); Oaxaca (Tavera, Elster & Marvan, 1994).

Cocconeis pediculus Ehrenberg 1838 (Fig. 2, d, e)

Length 22.56-25.3 µm; width 19.68-20 µm; density of striae 19/10 µm in the center and 19-20/10 µm near of margins.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epiphytic, epilithic, T = 25.5° C, pH = 7, C = 1300 µs cm⁻¹.

Literature data: pH = alkaliphilous; hs = oligohalobous: indifferent; ss = oligosaprobic, mesosaprobic, saproxenous; cs = rheophilous, indifferent; gh = river, spring, pond, aerophilous, reedbed; sh = periphytic; epiphytic, epilithic. Calcareous waters.

Reports from México: State of México (Ortega, 1984); Puebla (Tehuacán: Avila, 1989; Ibarra, 1992); Central México (Metcalf, 1985); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993).

***Cocconeis placentula* Ehrenberg 1838 var. *placentula* (Fig. 2, f)**

Length 25-29 μm ; width 11.56-20 μm ; density of striae 20-22/10 μm in the center, 18-20/10 μm near the margins and 19-20/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epiphytic. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: pH = indifferent, alkaliphilous; hs = oligohalobous, indifferent; euryhalobous; ss = mesosaprobic, saprophobic, saproxenous; cs = indifferent; gh = river, lakes, pond, spring, stream, irrigation channel, diatomaceous earth, estuaries, natural wells, gully; sh = euplanktonic, tychoplanktonic, periphytic, epiphytic, epilithic; ts = eutermal, mesothermal. Calcareous waters. Low level of organic matter.

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); Tlaxcala (Quintana, 1961); State of México (Texcoco, Bradbury, 1970, 1971); Central México (Kusel-Fetzmann, 1973); Guanajuato (Acámbaro, Ortega, 1984); Hidalgo, (Atonileo el Grande, Michoacán, Zinapécuaro, Ortega, 1984; Metcalfe, 1985, 1988); Yucatán (Sánchez, 1985); Puebla (Tehuacán, Novelo, 1985; Navarro, 1988; Laguna de Victoria, Mendoza-González, 1985); Oaxaca (Sierra de Juárez, Tavera & González-González, 1990); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993).

***Cocconeis placentula* var. *euglypta* (Ehrenberg 1854) Grunow 1884**

Length 15-18 μm ; width 10-13 μm ; density of striae 16-18/10 μm in the center; puncta 14/10 μm .

Localities: Nacimiento El Salto, Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, epiphytic. $T = 20-27^\circ \text{C}$, $\text{pH} = 7-7.6$, $C = 300-1500 \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous; hs = oligohalobous; halophilous; ss = mesosaprobic, oligosaprobic; cs = indifferent, rheophilous; gh = lakes, river, pond, aerophilous; streams, waterfalls, mud, river sediment, sulphurous spring; sh = euplanktonic, periphytic; epiphytic, epilithic; ts = eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} .

Reports from México: Michoacán (Ortega, 1984); Central México (Metcalfe, 1985, 1988); Oaxaca (Tavera & González-González, 1990; Tavera, Elster & Marvan, 1994); Puebla (Tehuacán: Ibarra, 1992); San Luis Potosí (Carmona, 1993).

***Cocconeis placentula* var. *lineata* (Ehrenberg 1843) Van Heurck 1885 (Fig. 2, g, h)**

Length 27-33 μm ; width 13.95-16 μm ; density of striae 18-19/10 μm in the center, 16-17/10 μm near the margins, and 19-20/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epiphytic, epilithic. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: Patrick & Reimer (1975) report a larger number of striae in the axial area (19-23/10 μm). pH = alkaliphilous; hs = oligohalobous; ss = oligosaprobic, mesosaprobic; cs = indifferent, rheophilous; gh = river; sh = periphytic, epiphytic; ts = eutermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} . High level of organic matter.

Reports from México: Central México (Ortega, 1984; Metcalfe, 1985, 1988); San Luis Potosí (Cantoral, 1993).

Naviculaceae Kützing 1844*Amphipleura lindheimeri* Grunow 1862

Length 117-155 μm ; width 22.5-25.5 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{s cm}^{-1}$.

Literature data: hs = oligohalobous; ss = mesosaprobic; cs = rheophilous.

Reports from México: Morelos (Valadez, 1992).

Amphipleura pellucida (Kützing) Kützing 1844 (Fig. 3, a)

Length 69.25-140 μm ; width 7-9 μm ; density of striae 37-40/10 μm .

Localities: Nacimiento El Salto, Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, unattached. $T = 20-27^\circ\text{C}$, $\text{pH} = 7-7.8$, $C = 300-1300\ \mu\text{s cm}^{-1}$.

Literature data: ss = oligosaprobic, saprophobic; cs = rheophilous; gh = river, pond; sh = periphytic. Frequently in brackish water.

Reports from México: Oaxaca (Navarro, 1988); San Luis Potosí (Cantoral 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993; Carmona, 1993).

Amphora copulata (Kützing) Schoeman & Archibald 1986 (Fig. 3, b)

Length 33-41.6 μm ; width 6.8-9 μm ; width of girdle view 5.8-20 μm ; density of striae 9-10/10 μm ; 10-11/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{s cm}^{-1}$.

Literature data: pH = alkaliphilous, alkalibiontic, indifferent; hs = oligohalobous, halophilous, indifferent, euryhalobous; gh = pond, stream; sh = periphytic. High conductivity.

Reports from México: this taxon is cited *A. ovalis* (Ehrenberg) Ehrenberg var. *libyca* (Ehrenberg) Cleve, for Hidalgo, Jalisco (Ortega, 1984).

Amphora ovalis (Kützing) Kützing 1844

Length 43.5-50 μm ; width 21.6-31.5 μm ; density of striae 8-10/10 μm .

Localities: Puente de Dios, Huichihuayan.

Ecological data: Periphytic, unattached. $T = 20-25^\circ\text{C}$, $\text{pH} = 7$, $C = 300\ \mu\text{s cm}^{-1}$.

Literature data: pH = alkaliphilous, alkalibiontic; hs = oligohalobous; ss = oligosaprobic, mesosaprobic; cs = rheophilous, indifferent; gh = river, pond, thick wall, fossil sediments, estuaries, springs, alpine lakes; sh = euplanktonic, tychoplanktonic, periphytic; ts = eutermal.

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); State of México (Texcoco, Bradbury, 1970, 1971); Hidalgo, Jalisco (Ortega, 1984); Central México (Metcalf, 1985, 1988); Yucatán (Sánchez, 1985); Oaxaca (Tavera & González-González, 1990); Morelos (Valadez, 1992); Puebla (Tehuacán, Cuesta, 1993); San Luis Potosí (Carmona, 1993).

Capartogramma crucicula (Grunow ex Cleve) Ross 1963 (Fig. 3, c)

Length 28.5-31 μm ; width 7.5-9.5 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^{\circ}\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: hs = mesohalobous; cs = rheobiontic, thermal waters; gh = river, lakes, spring thermal; ts = eutermal.

Reports from México: San Luis Potosí (Cantoral, 1990; Cantoral-Uriza & Montejano-Zurita, 1993).

Cymbella cymbiformis Agardh 1830 (Fig. 3, d)

Length 70-98.5 μm ; width 14.75-15.25 μm ; density of striae 8/10 μm in the center and 9/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^{\circ}\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: longer and wider than the reports of Patrick & Reimer (1975): 30-80 μm by 9-15 μm . Hustedt (1930), reports up to 100 μm length. $\text{pH} = \text{alkaliphilous}$, indifferent; hs = oligohalobous; ss = saprophobic; cs = rheophilous; gh = rivers, spring, lakes; sh = periphytic, epiphytic; ts = eutermal. Low level of organic matter.

Reports from México: Hidalgo (Mineral del Monte, Real del Monte, Ortega, 1984); Central México (Metcalf, 1985, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993).

Cymbella delicatula Kützing 1849

Length 17-47 μm ; width 3-7 μm ; density of dorsal striae 8-9/10 μm ; ventral striae 9/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epilithic, unattached. $T = 25.5^{\circ}\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: $\text{pH} = \text{acidophilous}$; ns = oligotrophic; gh = river, stream; sh = periphytic.

Reports from México: San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993); Puebla (Tehuacán, Ibarra, 1992).

Cymbella gracilis (Ehrenberg 1843) Kützing 1844

Length 18.81-46 μm ; width 4-9 μm ; density of dorsal striae 12-16/10 μm , and 8-18/10 μm at the poles, ventral valve with striae in central region 14/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epilithic, epiphytic. $T = 25.5^{\circ}\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: $\text{pH} = \text{alkaliphilous}$; ss = saproxenous; gh = river, acid peat bog, lakes; sh = euplanktonic, periphytic; ts = eutermal, mesothermal. Conductivity 400-5000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.57 mg l^{-1} .

Reports from México: San Luis Potosí (Cantoral, 1993).

Cymbella hustedtii Krasske 1923 (Fig. 3, e)

Length 24.48-25.7 μm ; width 8.1-9.9 μm ; density of striae 10-11/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^{\circ}\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: ns = oligotrophic.

Reports from México: First report.

***Cymbella mexicana* (Ehrenberg) Cleve 1894 (Fig. 3, f)**

Length 51.2-160 μm ; width 18.08-38.87 μm ; density of central striae 6-8/10 μm ; striae at the poles 9-10/10 μm ; puncta 11/10 μm .

Localities: Puente de Dios.

Ecological data: Periphytic, epiphytic. $T = 25^\circ\text{C}$, $\text{pH} = 7$.

Literature data: smaller than reported by Patrick & Reimer (1975); length 80-165 μm ; width 24-33 μm . $\text{pH} =$ alkaliphilous; $hs =$ oligohalobous, halophilous; $cs =$ rheophilous, rheobiontic; $gh =$ river, spring, diatomaceous earth; $sh =$ periphytic; $ts =$ mesothermal. Calcareous water.

Reports from México: Tlaxcala (Quintana, 1961); State of México (Texcoco, Bradbury, 1971; Ehrenberg, 1870); Guanajuato, Michoacán (Ortega, 1984); Hidalgo (Tulancingo, Ehrenberg, 1870; Ortega, 1984); Central México (Metcalf, 1985, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993; Carmona, 1993); Morelos (Valadez, 1992); Puebla (Tehuacán, Cuesta, 1993).

***Cymbella muelleri* Hustedt 1938**

Length 41 μm ; width 10.5 μm ; density of central striae 7/10 μm ; 6-7/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: $\text{pH} =$ alkaliphilous; $gh =$ streams; $ts =$ eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} . Calcareous water.

Reports from México: Central México (Metcalf, 1985, 1988); Puebla (Tehuacán, Ibarra, 1992).

***Cymbella silesiaca* Bleisch in Rabenhorst 1864**

Length 29.04-31 μm (80 μm); width 8-9.42 μm (20 μm); density of dorsal striae 7/10 μm ; ventral striae (11) 14-16/10 μm .

Localities: Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25^\circ\text{C}$, $\text{pH} = 7$.

Literature data: $\text{pH} =$ indifferent, alkaliphilous; $hs =$ oligohalobous; $ns =$ eutrophic, oligotrophic; $cs =$ rheophilous; $gh =$ spring, pond, river, aerophilous; $sh =$ periphytic, epilithic.

Reports from México: Central México (Metcalf, 1985, 1988); San Luis Potosí (Carmona, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993); Oaxaca (Tavera, Elster & Marvan, 1994).

***Cymbella tumida* (Brébisson) Van Heurck 1880 (Fig. 3, g)**

Length 65-70 μm ; width 17-18 μm ; density of striae 9-10/10 μm ; 11-12/10 μm at the poles. Puncta 16-20/10 μm .

Localities: Huichihuayan, Choy.

Ecological data: Periphytic, unattached. $T = 20-27^\circ\text{C}$, $\text{pH} = 7-7.6$, $C = 300-800\ \mu\text{S cm}^{-1}$.

Literature data: $\text{pH} =$ alkaliphilous, alkalibiontic; $hs =$ oligohalobous; halophilous; $ss =$ mesosaprobic, oligosaprobic, saproxenous; $cs =$ indifferent; $gh =$ rivers, lakes, spring, pond, aerophilous, edaphic; $sh =$ periphytic, epilithic, epiphytic; $ts =$ eutermal, mesothermal, metothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.29 mg l^{-1} . Low level of organic matter.

Reports from México: Central México (Kusel-Fetzmann, 1973; Metcalfe, 1985, 1988); Oaxaca (Tavera & González-González, 1990); Morelos (Valadez, 1992); San Luis Potosí (Carmona, 1993).

***Diploneis elliptica* (Kützing) Cleve 1891 (Fig. 3, h)**

Length 32.75-35.28 μm ; width 15.75-18.76 μm ; costae 9-11/10 μm , with a simple row of alveoli.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, epipelic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous, indifferent; hs = oligohalobous; ss = saproxenous; cs = limnophilous; gh = lakes, river, springs, pond, aerophilous; sh = euplanktonic, periphytic; ts = mesothermal, oligothermal, metothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.57 mg l^{-1} . Low level of organic matter.

Reports from México: State of México (Texcoco, Bradbury, 1971); Central México (Metcalfe, 1985, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993).

***Diploneis ovalis* (Hilse) Cleve 1891 (Fig. 4, a)**

Length 14-22.5 μm ; width 9-11.5 μm ; density of striae 9-10/10 μm in the center; 10-11/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous; hs = mesohalobous; cs = rheophilous; gh = aerophilous, spring, peat bog; sh = periphytic; epipelic, epilitic; ts = eutermal. Conductivity 3001-5000 $\mu\text{S cm}^{-1}$. Total phosphates 0.30-0.57 mg l^{-1} .

Record from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); Morelos (Valadez, 1992); Puebla (Tehuacán, Cuesta, 1993).

***Gomphonema angustum* Agardh 1831 (Fig. 4, b)**

Length 52.8-68.29 μm (87.76 μm); width 7.52-7.84 μm (12 μm); density of striae 9-10/10 μm in the center; 10-11/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous.

Reports from México: First report.

***Gomphonema gracile* Ehrenberg 1838**

Length 48.5-60 μm ; width 8.74-10 μm ; density of striae 11/10 μm in the center.

Localities: Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, epiphytic. $T = 20-27^\circ\text{C}$, $\text{pH} = 7-8$, $C = 300-800\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous, indifferent; hs = oligohalobous; halophilous; ss = mesosaprobic, oligosaprobic, saprophobic; ns = oligotrophic; cs = limnobiontic, limnophilous, rheophilous; gh = river, lagoons, waterfalls, natural wells, aerophilous; sh = euplanktonic, periphytic; epipelic, epiphytic; ts = eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.57 mg l^{-1} .

Reports from México: Hidalgo, Puebla, State of México (Ixtlahuaca, Ehrenberg, 1870); Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); State of México (Texcoco, Bradbury, 1971); Central México (Kusel-Fetzmann, 1973; Metcalfe, 1985, 1988); Coahuila, Guanajuato, Hidalgo, Jalisco, Michoacán (Ortega, 1984); San Luis Potosí (Carmona, 1993); Oaxaca (Tavera, Elster & Marvan, 1994).

Gomphonema grunowii Patrick 1975

Length 37.2-41.1 μm ; width 9.44-9.92 μm ; density of striae 16/10 μm in the center; 12-13/10 μm at the poles.

Localities: Choy.

Ecological data: Periphytic, epiphytic. $T = 26-27^\circ\text{C}$, $\text{pH} = 7-7.6$, $C = 800\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous; ts = mesothermal. Conductivity 400-3000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.29 mg l^{-1} .

Reports from México: Central México (Patrick & Reimer, 1975; Metcalfe, 1985, 1988); Hidalgo (Ortega, 1984); San Luis Potosí (Carmona, 1993).

Gomphonema pseudoaugur Lange-Bertalot 1979

Length 33.22-40.68 μm ; width 8.14-9.72 μm ; density of striae 7-8/10 μm in the center; 8/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{S cm}^{-1}$.

Literature data: ss = mesosaprobic; ns = eutrophic, mesotrophic.

Reports from México: First report.

Gomphonema truncatum Ehrenberg 1832 (Fig. 4, c)

Length 30-85 μm ; width 7-11 μm ; density of striae 8-11/10 μm in the center.

Localities: Puente de Dios, Huichihuayan.

Ecological data: Periphytic, unattached. $T = 20-25^\circ\text{C}$, $\text{pH} = 7-7.2$, $C = 300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkaliphilous; hs = mesohalobous; ss = mesosaprobic; cs = indifferent; ts = mesothermal.

Reports from México: Hidalgo (Ehrenberg, 1870); Hidalgo (Mineral del Monte, Ortega, 1984); Morelos (Valadez, 1992).

Gyrosigma acuminatum (Kützing) Rabenhorst 1853

Length 98.4-102 μm ; width 14-16.7 μm ; density of striae 16-18/10 μm transverse; 18-19/10 μm longitudinal.

Localities: Nacimiento El Salto, Huichihuayan.

Ecological data: Periphytic, epilithic, unattached. $T = 20-25.5^\circ\text{C}$, $\text{pH} = 7-7.2$, $C = 300-1300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkalibiontic; hs = oligohalobous; ss = mesosaprobic, oligosaprobic; ns = eutrophic; cs = rheophilous, indifferent; gh = river, spring, pond, irrigation channel, gully, reservoir; sh = periphytic, epiphytic. Calcareous water.

Reports from México: Puebla (Tehuacán, Novelo, 1985); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993; Carmona, 1993).

***Gyrosigma nodiferum* (Grunow) Reimer 1966 (Fig. 4, d)**

Length 80.8-82.17 μm ; width 13.5-14.72 μm ; density of striae 19-20/10 μm transverse; 22-23/10 μm longitudinal. Central area oblique, 6.4-7.79 μm length.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{s cm}^{-1}$.

Literature data: hs = oligohalobous; ss = mesosaprobic; gh = ponds.

Reports from México: San Luis Potosi (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993).

***Gyrosigma scalproides* (Rabenhorst) Cleve 1894**

Length 52.2 μm ; width 10.7 μm ; density of striae 20/10 μm transverse; 28-31/10 μm longitudinal.

Localities: Huichihuayan, Puente de Dios.

Ecological data: Periphytic, unattached. $T = 20-25^\circ\text{C}$, $\text{pH} = 7-7.2$, $C = 300\ \mu\text{s cm}^{-1}$.

Literature data: pH = alkalibiontic; hs = oligohalobous; halophilous; ss = oligosaprobic, mesosaprobic; cs = rheophilous, indifferent; ns = mesotrophic; gh = river, lakes, irrigation channel, gully, ponds, springs, aerophilous; sh = periphytic, epiphytic.

Reports from México: Central México (Metcalf, 1985, 1988); Oaxaca (Tavera, Elster & Marvan, 1994).

***Gyrosigma spenceri* (Quekett) Griffith & Henfrey 1856 (Fig. 4, e)**

Length 76-94.5 μm ; width 10.5-13.5 μm ; density of striae 18-20/10 μm transverse; 17-22/10 μm longitudinal.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{s cm}^{-1}$.

Literature data: pH = alkalibiontic; hs = mesohalobous, oligohalobous; ss = mesosaprobic; gh = river, fossil sediments.

Reports from México: Central México (Metcalf, 1985, 1988); State of México (Texcoco, Bradbury, 1971); Morelos (Valadez, 1992).

***Navicula charlatii* Peragallo 1921**

Length 28.8-30 μm ; width 10.35-11 μm ; density of striae 15-16/10 μm .

Localities: Huichihuayan.

Ecological data: Periphytic. $T = 21-22^\circ\text{C}$, $\text{pH} = 7$.

Literature data: pH = indifferent; gh = river; sh = periphytic.

Reports from México: Central México (Metcalf, 1985, 1988); San Luis Potosi (Carmona, 1993).

***Navicula pseudotuscula* Hustedt 1943**

Length 34 μm ; width 12 μm ; density of striae with punctae 15/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ\text{C}$, $\text{pH} = 7$, $C = 1300\ \mu\text{s cm}^{-1}$.

Literature data: pH = alkalibiontic; ss = oligosaprobic.

Reports from México: First report.

***Navicula radiosa* Kützing 1844**

Length (42.4 μm) 63.75-70 μm ; width (10 μm) 11.25-12 μm ; density of striae 9-12/10 μm in the center; 11/10 μm at the poles.

Localities: Nacimiento El Salto, Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25-25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{s cm}^{-1}$.

Literature data: pH = indifferent, alkaliphilous, alkalibiontic; hs = mesohalobous, oligohalobous; ss = mesosaprobic, oligosaprobic, saprophobic; cs = indifferent; gh = river, lakes, pond, alpine lakes, spring, thick wall, aerophilous; sh = euplanktonic, periphytic; epilithic; ts = mesothermal, oligothermal, eurythermal.

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956; Ortega, 1984); State of México (Texcoco, Bradbury, 1971); Central México (Metcalf, 1985, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993); Oaxaca (Tavera, Elster & Marvan, 1994).

***Navicula viridula* (Kützing) Ehrenberg 1838 var. *rostellata* (Kützing) Cleve 1895**

Length 42.75 μm ; width 9.2 μm ; density of striae 10/10 μm in the center.

Localities: Huichihuayan.

Ecological data: Periphytic, unattached. $T = 21^\circ \text{C}$, $\text{pH} = 7$.

Literature data: ss = mesosaprobic; sh = periphytic, epipellic.

Reports from México: Central México (Metcalf, 1985); San Luis Potosí (Carmona, 1993).

***Pinnularia mesolepta* (Ehrenberg 1843) W. Smith 1853 (Fig. 5, a)**

Length 48-54 μm ; width 10-11 μm ; density of striae 11-14/10 μm in the center; 12-13/10 μm at the poles.

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{s cm}^{-1}$.

Literature data: ss = oligosaprobic.

Reports from México: First report.

***Pinnularia viridis* (Nitzsch) Ehrenberg 1843 (Fig. 5, b)**

Length 80 μm ; width 26 μm ; density of striae 7/10 μm .

Localities: Nacimiento El Salto, Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25-25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{s cm}^{-1}$.

Literature data: pH = indifferent, alkaliphilous; hs = oligohalobous, indifferent, euryhalobous; ss = mesosaprobic; gh = pond, river; sh = periphytic; ts = eurythermal. Low-medium conductivity.

Reports from México: Hidalgo, State of México (Ixtlahuaca, Ehrenberg, 1870); Hidalgo (Ortega, 1984).

Epithemiaceae Grunow 1860

Epithemia adnata (Kützing) Brébisson 1838

Length 42.4 μm ; width 9.8 μm ; density of costae 3-4/10 μm ; costae 10-12/10 μm separating rows of alveoli 2-3.

Localities: Choy.

Ecological data: Periphytic, unattached. $T = 27^\circ \text{C}$, $\text{pH} = 7$.

Literature data: pH = alkaliphilous, alkalibiontic; hs = oligohalobous; ss = mesosaprobic, saproxenous; cs = indifferent; gh = river, lakes, spring, aerophilous, alpine lakes, thick wall; sh = euplanktonic, tycho planktonic, periphytic, epiphytic; ts = eutermal, mesothermal, eurythermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.57 mg l^{-1} .

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956; Quintana, 1961); State of México (Texcoco, Bradbury, 1971; Mendoza-González, 1985); Hidalgo (Ortega, 1984); Central México (Metcalf, 1985, 1988); Oaxaca (Tavera & González-González, 1990); San Luis Potosí (Carmona, 1993).

Rhopalodia gibba (Ehrenberg) O. Müller 1895 (Fig. 5, c)

Length (38.1 μm) 122.5-127.25 μm , width 23.75-24.96 μm ; with 6-7 rows of alveoli; density of striae 11-16/10 μm . Costae 6-8/10 μm with 2-3 alveoli.

Localities: Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25^\circ \text{C}$, $\text{pH} = 7$.

Literature data: pH = alkaliphilous, alkalibiontic; hs = oligohalobous; ss = mesosaprobic, oligosaprobic; ns = eutrophic; cs = rheophilous, indifferent; gh = river, spring, lakes, gully, fossil sediment, thick wall, aerophilous, pond, natural well of thermal water; sh = tycho planktonic, periphytic, epipellic, epiphytic; ts = eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} .

Reports from México: Michoacán (Pátzcuaro, Hutchinson, Patrick & Deevey, 1956); Tlaxcala (Quintana, 1961); State of México (Texcoco: Bradbury, 1971); Coahuila, Michoacán (Ortega, 1984); Puebla, Oaxaca and Veracruz (Avila, 1985, 1989; Tavera & González-González, 1990; Cuesta, 1993; Tavera, Elster & Marvan, 1994); Morelos (Valadéz, 1992); Central México (Kusel-Fetzmann, 1973; Mendoza-González, 1985; Metcalf, 1988); San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993; Carmona, 1993).

Bacillariaceae Ehrenberg 1831

Denticula valida (Pedicino) Grunow in Van Heurck 1881 (Fig. 5, d)

Length 15.39 μm ; width 4.68 μm ; density of striae 14-20/10 μm ; costae 4/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: cs = rheophilous; gh = river, spring thermal; ts = mesothermal.

Reports from México: Michoacán and Jalisco (Ortega, 1984); Puebla (Navarro, 1988); Oaxaca (Tavera & González-González, 1990); Morelos (Valadéz, 1992).

***Denticula tenuis* Kützing 1844 (Fig. 5, e)**

Length 15-17 μm ; width 3.9-4.5 μm ; density of striae 14-18/10 μm ; costae 5-6/10 μm .

Localities: Huichihuayan.

Ecological data: Periphytic, unattached. $T = 21^\circ\text{C}$, $\text{pH} = 7$.

Literature data: ss = oligosaprobic, saproxenous; cs = rheophilous; gh = river; ts = mesothermal. Calcareous water.

Reports from México: San Luis Potosí (Carmona, 1993).

***Nitzschia hantzschiana* Rabenhorst 1860**

Length 7.8-20 μm ; width 6-6.6 μm ; density of fibulae 6-7/10 μm , striae 13-14/10 μm . Fibulae occasionally quite thick, the two central ones more deviated.

Localities: Puente de Dios, Huichihuayan, Choy.

Ecological data: Periphytic, unattached. $T = 20-27^\circ\text{C}$, $\text{pH} = 7-8$, $C = 300-1500\ \mu\text{S cm}^{-1}$.

Literature data: pH = acidophilous, alkaliphilous; hs = oligohalobous; ss = mesosaprobic, oligosaprobic, saproxenous; cs = indifferent; gh = river, alpine lakes, thick wall, arid land; sh = periphytic; ts = eutermal, mesothermal, oligothermal, metothermal. Conductivity 400-5000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.57 mg l^{-1} .

Reports from México: Central México (Metcalf, 1985, 1988); State of México (Texcoco, Bradbury, 1971); Oaxaca (Tavera & González-González, 1990); Puebla (Tehuacán, Ibarra, 1992); San Luis Potosí (Carmona, 1993).

***Nitzschia sinuata* (Thwaites ex W. Smith) Grunow 1880**

Length 20.25-28 μm ; width 7.2-8.6 μm ; density of fibulae 6/10 μm , striae 18-23/10 μm . Costae 6/10 μm .

Localities: Huichihuayan.

Ecological data: Periphytic, epilithic, unattached. $T = 20-22^\circ\text{C}$, $\text{pH} = 7-7.2$, $C = 300\ \mu\text{S cm}^{-1}$.

Literature data: range of striae larger than reported by Germain (1981) 18-20/10 μm . pH = acidophilous, alkaliphilous; cs = indifferent; gh = river; sh = periphytic, epilithic (calcareous rocks). Waters rich in oxygen.

Reports from México: San Luis Potosí (Cantoral, 1990, 1993; Cantoral-Uriza & Montejano-Zurita, 1993; Carmona, 1993).

Surirellaceae* Kützing 1844**Campylodiscus hibernicus* Ehrenberg 1845**

Diameter of valve 79-88.8 μm ; fibules 20-22/100 μm .

Localities: Puente de Dios, Huichihuayan.

Ecological data: Periphytic, unattached. $T = 20-25^\circ\text{C}$, $\text{pH} = 7-7.2$, $C = 300\ \mu\text{S cm}^{-1}$.

Literature data: pH = alkalibiontic; hs = mesohalobous; ss = saproxenous; gh = river, pond; sh = periphytic.

Reports from México: San Luis Potosí (Carmona, 1993).

***Surirella constricta* W. Smith 1851**

Length 137.5 μm ; width 12.3 μm ; costae 20/100 μm .

Localities: Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25^\circ \text{C}$, $\text{pH} = 7$.

Literature data: pH = indifferent; hs = oligohalobous; cs = rheophilous; gh = river, aerophilous; sh = tycho planktonic; ts = oligothermal, stenothermal.

Reports from México: Central México (Metcalf, 1985, 1988); Puebla (Tehuacán, Avila, 1989); San Luis Potosí (Carmona, 1993).

***Surirella linearis* var. *helvetica* (Brun) Meister 1912**

Length 59 μm ; width 18.5 μm ; striae 23/10 μm ; density of alveoli 22/100 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: hs = oligohalobous; ss = mesosaprobic; gh = river. High conductivity. Litoral.

Reports from México: First report.

***Surirella ovalis* Brébisson 1838**

Length 147 μm ; width 21 μm ; density of alveoli 2/10 μm ; density of striae 19-20/10 μm .

Localities: Nacimiento El Salto.

Ecological data: Periphytic, unattached. $T = 25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: pH = indifferent, alkaliphilous; hs = mesohalobous, oligohalobous; ss = mesosaprobic, oligosaprobic; cs = indifferent; gh = river, spring, pond, gully, aerophilous, fossil sediments; sh = tycho planktonic, periphytic; ts = eutermal, mesothermal. Conductivity 400-20,000 $\mu\text{S cm}^{-1}$. Total phosphates 0.02-0.83 mg l^{-1} .

Reports from México: Central México (Metcalf, 1985, 1988); State of México (Texcoco, Bradbury, 1971); Oaxaca (Tavera & González-González, 1990); Puebla (Tehuacán, Avila, 1989; Ibarra, 1992).

***Surirella robusta* Ehrenberg 1841**

Length 174 μm ; width 76.95 μm ; costae 18-19/100 μm .

Localities: Nacimiento El Salto, Puente de Dios.

Ecological data: Periphytic, unattached. $T = 25-25.5^\circ \text{C}$, $\text{pH} = 7$, $C = 1300 \mu\text{S cm}^{-1}$.

Literature data: pH = indifferent; hs = oligohalobous; ss = mesosaprobic; gh = river, reservoir; sh = tycho planktonic, periphytic; ts = eutermal.

Reports from México: Central México (Metcalf, 1985, 1988); San Luis Potosí (Carmona, 1993).

There is a high coincidence between the values of environmental parameters of the diatoms found in the Huasteca and those reported in the literature (Tab. 3). With respect to temperature there are reports in the literature for 31 of the 57 species; of these, 24 coincided with our values ($20-27^\circ \text{C}$, mesothermal or eutermal). 7 of these have been reported as eutermal; the other 7 have a wide temperature range (eurythermal, oligothermal, mesothermal, metothermal to eutermal). 37 of 41 species with data on pH have been

Species	A	B	C	D
<i>Cyclotella meneghiniana</i>				1, 2
<i>Malavira lineata</i>				1
<i>Actinocyclus normanii</i>				1
<i>Pleurosigma laevis</i>		1, 2		
<i>Terpsinoe musica</i>		2		
<i>Eunotia praeurupta</i> var. <i>bideni</i>		1, 2		
<i>Achnanthes inflata</i>		1	1	1
<i>Cocconeis pediculus</i>	1		1	
<i>Cocconeis placentula</i> var. <i>placentula</i>	2, 3	1, 2		
<i>Cocconeis placentula</i> var. <i>egyptia</i>		1, 2	1	1, 2
<i>Cocconeis placentula</i> var. <i>lineata</i>	1	1	1	1
<i>Amphipleura lindheimeri</i>				1
<i>Amphipleura pellucida</i>	1, 3			
<i>Amphora ovalis</i>	1	1	1, 2	1
<i>Capartogramma crucicula</i>		1		
<i>Cymbella cymbiformis</i>	3	1		1
<i>Cymbella gracilis</i>	2	1, 2	1	
<i>Cymbella mexicana</i>		2	1	1, 2
<i>Cymbella silasticus</i>				1
<i>Cymbella muelleri</i>		1, 2	1	
<i>Cymbella tumida</i>			1, 2	1, 2
<i>Diploneis elliptica</i>	2			1
<i>Diploneis ovalis</i>		1	1	
<i>Fragilaria capricornis</i> var. <i>radians</i>	1			
<i>Gomphonema angustum</i>			1	
<i>Gomphonema gracile</i>		1, 2		1, 2
<i>Gomphonema grunowii</i>		2	1	
<i>Gomphonema truncatum</i>		2	1	
<i>Gyrogonia acuminatum</i>			2	1
<i>Gyrogonia nodiferum</i>				1
<i>Gyrogonia scalproides</i>	1		2	1, 2
<i>Gyrogonia spenceri</i>			2	
<i>Navicula pseudotriacula</i>			2	
<i>Pinnularia mesolepta</i>	1			
<i>Pinnularia viridis</i>		3		
<i>Epithemia adnata</i>		1, 2, 3	1, 2	1
<i>Rhopalodia gibba</i>		1, 2	1, 2	1
<i>Denticula valida</i>		2		
<i>Denticula tenuis</i>	1, 2	2		
<i>Nitzschia hantzschiana</i>	1, 2			
<i>Campylodiscus hibernicus</i>	2		2	
<i>Surirella constricta</i>				1
<i>Surirella linearis</i>				1
<i>Surirella ovalis</i>	1	1, 2		
<i>Surirella robusta</i>		1		1

Table 3. Values and parameters of the diatoms found in the central region of México and those reported in the literature. **A Saprobity:** 1 oligosaprobic, 2 saproxenous, 3 saprophobic. **B. Temperature:** 1 eutermal, 2 mesothermal, 3 eurythermal. **C pH:** 1. alkaliphilous, 2 alkalibiontic. **D Salinity:** 1 oligohalobous, 2 halophilous.

reported as alkaliphilous, alkalibiont or indifferent to pH, corresponding to what we find in the Huasteca. 20 are reported as preferring alkaline pH and the other 17 have wide pH tolerance; the remaining 4 species are considered acidophilous to alkaliphilous. With respect to salinity 23 of the 36 species with reports in the literature, are described for low salinity (oligohalobous or halophilous); the remaining 13 are considered mesohalobous, indifferent or euryhalobous. Finally, with respect to saprobity, 38 species with reports in the literature are described for low concentrations of organic matter (mesosaprobic, oligosaprobic, saproxenous and saprophobic). Of these, 8 are strict, oligosaprobic, saprophobic or saproxenous, for example *Amphipleura pellucida*, *Cymbella cymbiformis*, *C. gracilis*, *Diploneis elliptica*, *Navicula pseudotuscula*, *Pinnularia mesolepta*, *Denticula tenuis* and *Campylodiscus hibernicus*, and 30 have wider tolerance.

DISCUSSION

As a result of the comparison of environmental conditions between the species found in the springs studied, and those reported in the literature, we consider a group of 39 species as potential indicators of one or more of the parameters considered (Tab. III). Several have already been considered as ecological indicators by other authors. For example, *Amphipleura pellucida*, *Cocconeis pediculus*, *C. placentula*, *Cymbella mexicana*, *C. muelleri*, *Denticula elegans*, *Gomphonema truncatum*, *Gyrosigma acuminatum* and *Nitzschia sinuata* have been considered as indicators of high carbonate concentrations, while *Achnanthes inflata*, *Cocconeis placentula*, *Cymbella cymbiformis*, *C. tumida*, *Diploneis elliptica* and *Terpsinoe musica*, as indicators of low content of organic matter (Patrick & Reimer, 1966, 1975; Tavera, Elster & Marvan, 1994). Of the species reported as indicators of water with high conductivity *Amphora copulata*, *Cymbella muelleri*, *C. tumida*, *Diploneis ovalis*, *Pinnularia viridis*, and *Surirella linearis* var. *helvetica* are examples (Krammer & Lange-Bertalot, 1986, 1988). *Amphipleura pellucida*, *Cymbella cymbiformis* and *Rhopalodia gibba* have been reported for non contaminated waters (Aboal, 1989a, 1989b).

Terpsinoe musica is one of the most abundant species in the springs studied. In continental habitats, it is generally restricted to springs and to river sections where conditions are oligohalobous and oligosaprobic (Whitford, 1956; Luttenton *et al.*, 1986; Valadez-Cruz *et al.*, 1996). Nevertheless, it has also been reported for marine habitats, and though not abundantly, also for the Great Lakes (Wujek & Welling, 1981). Therefore it can be considered euryhalobous. It is not clear whether there are several morphologically convergent species or one species with a wide range of tolerance. We do not think the latter case is very probable because in freshwater it has been observed only in very restricted habitats. Culture studies would be required to solve this problem. For the remaining species more ecological studies are required to know the precise ranges of tolerance.

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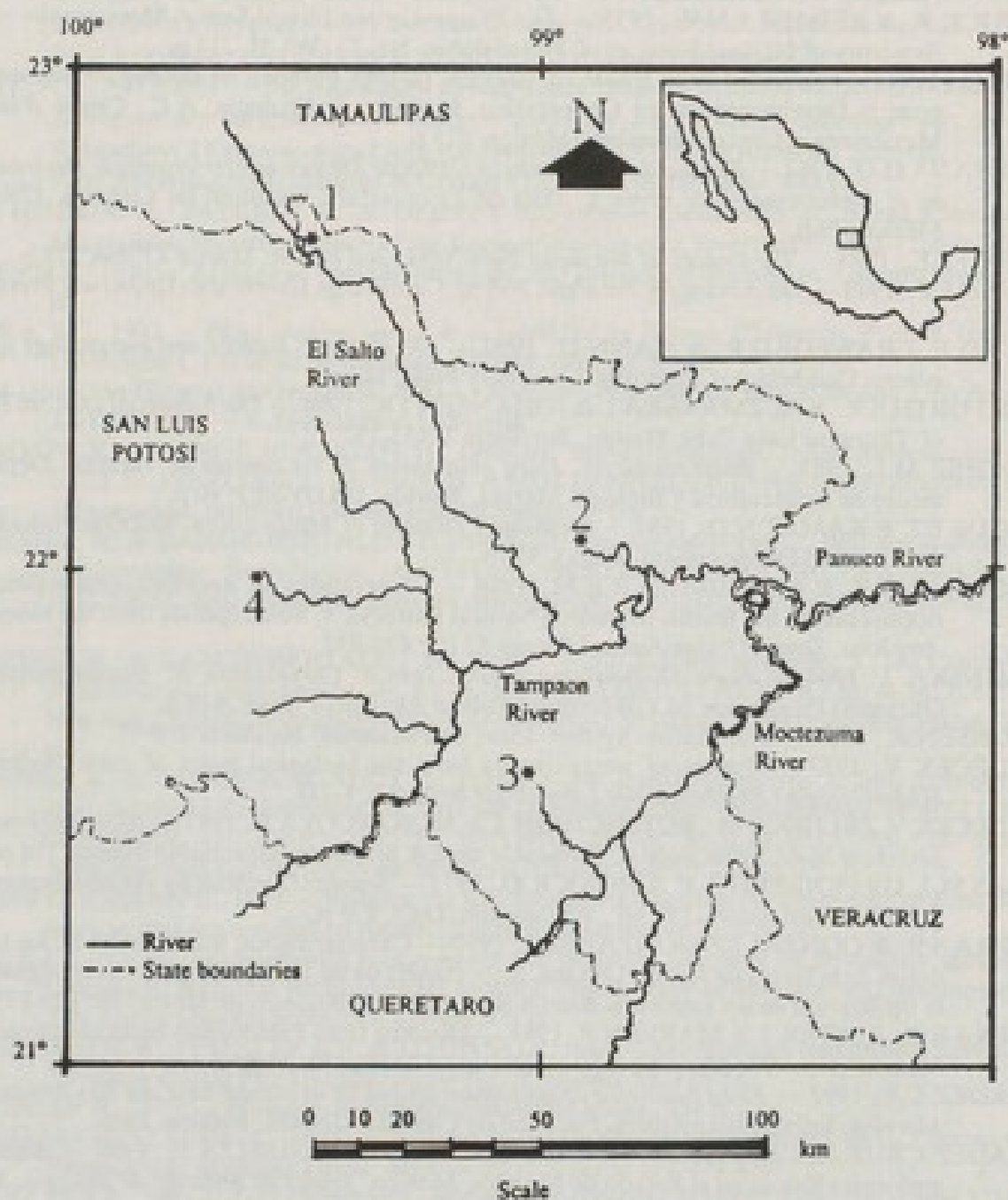


Fig. 1. Study localities. 1. Nacimiento El Salto. 2. Choy. 3. Huichihuayan. 4. Puente de Dios.

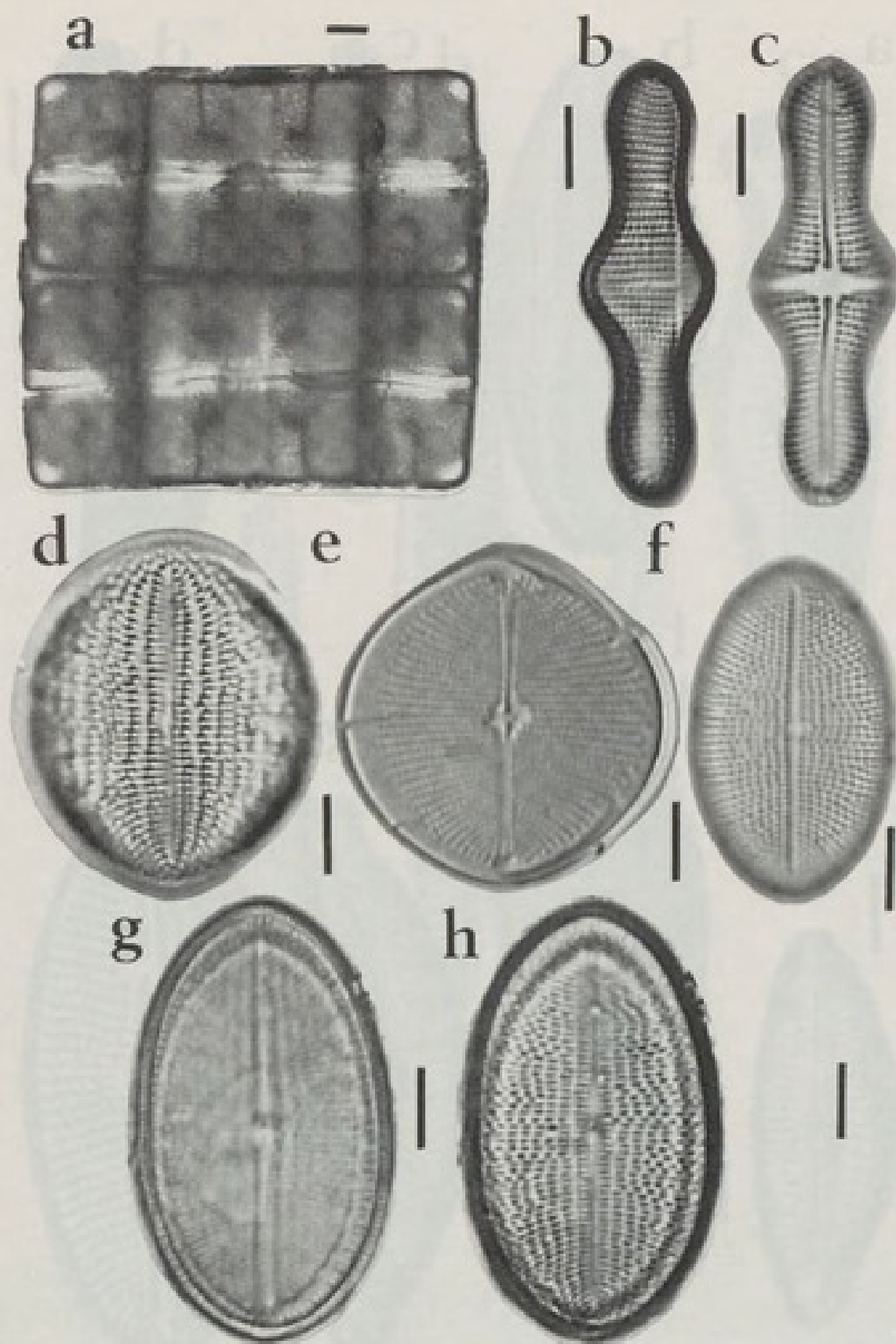


Fig. 2. a. *Terpsinoe musica*. b. *Achmanthes inflata* without raphe. c. *A. inflata* with raphe. d. *Cocconeis pediculus* without raphe. e. *Cocconeis pediculus* with raphe. f. *C. placentula*. g. *C. placentula* var. *lineata* with raphe. h. *C. placentula* var. *lineata* without raphe. Scale bar 10 μ m.

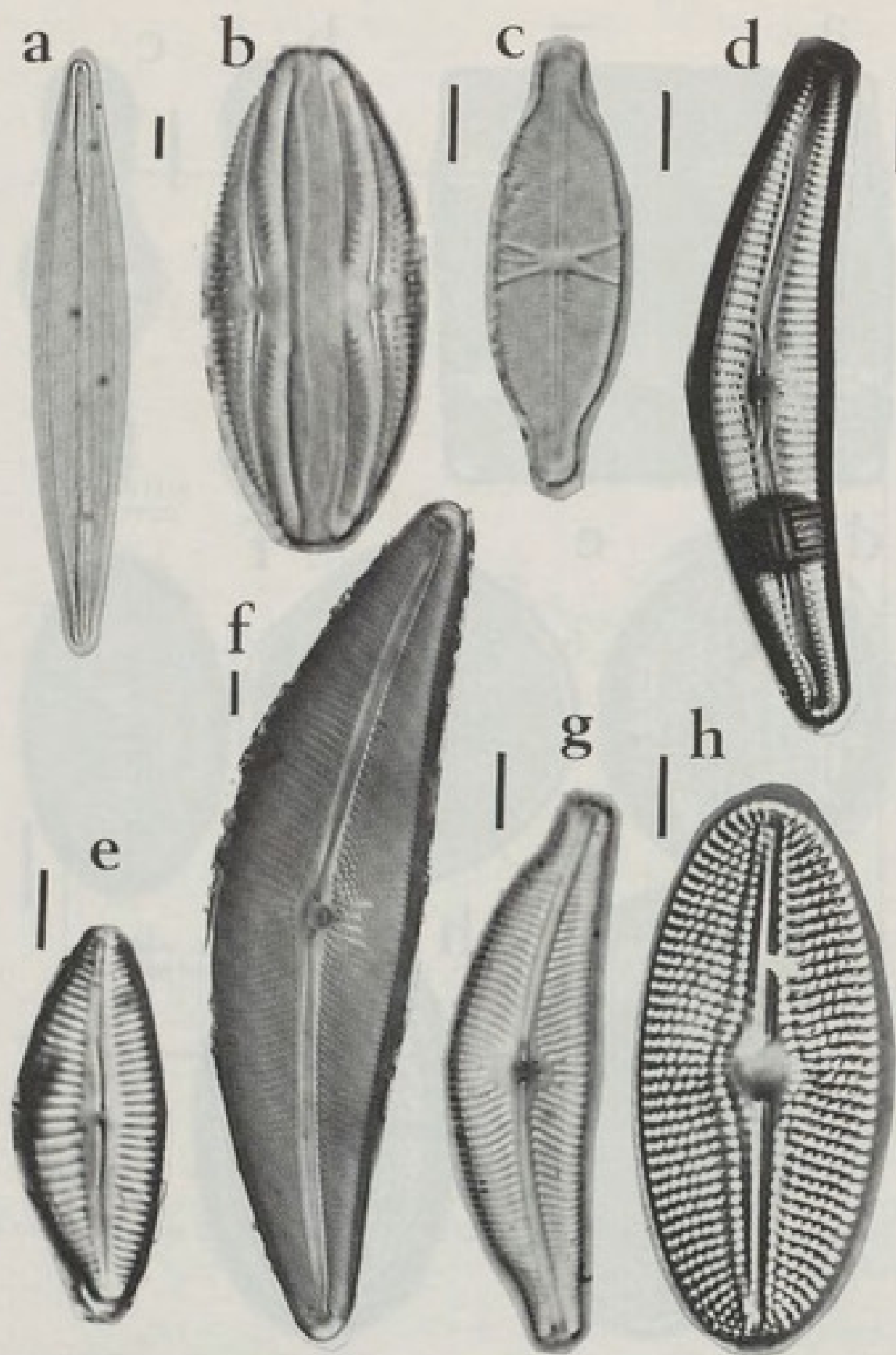


Fig. 3. a. *Amphipleura pellucida*. b. *Amphora copulata*. c. *Capartogramma crucicula*. d. *Cymbella cymbiformis*. e. *C. hustedtii*. f. *C. mexicana*. g. *C. tumida*. h. *Diploneis elliptica*. Scale bar 10 μm .

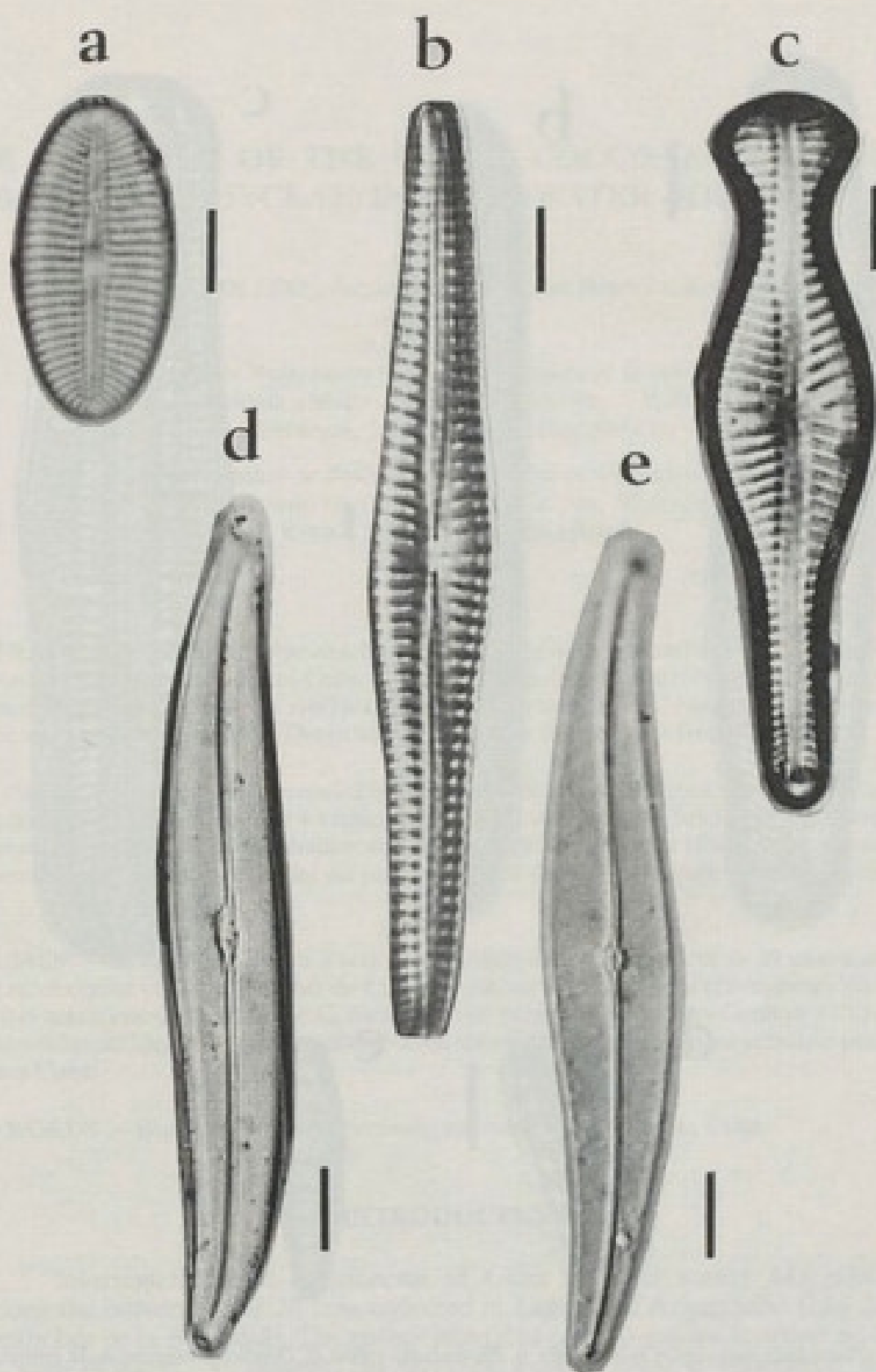


Fig. 4. a. *Diplonella ovalis*. b. *Gomphonema angustum*. c. *G. truncatum*. d. *Gyrosigma nodiferum*. e. *G. spenceri*. Scale bar 10 μ m.

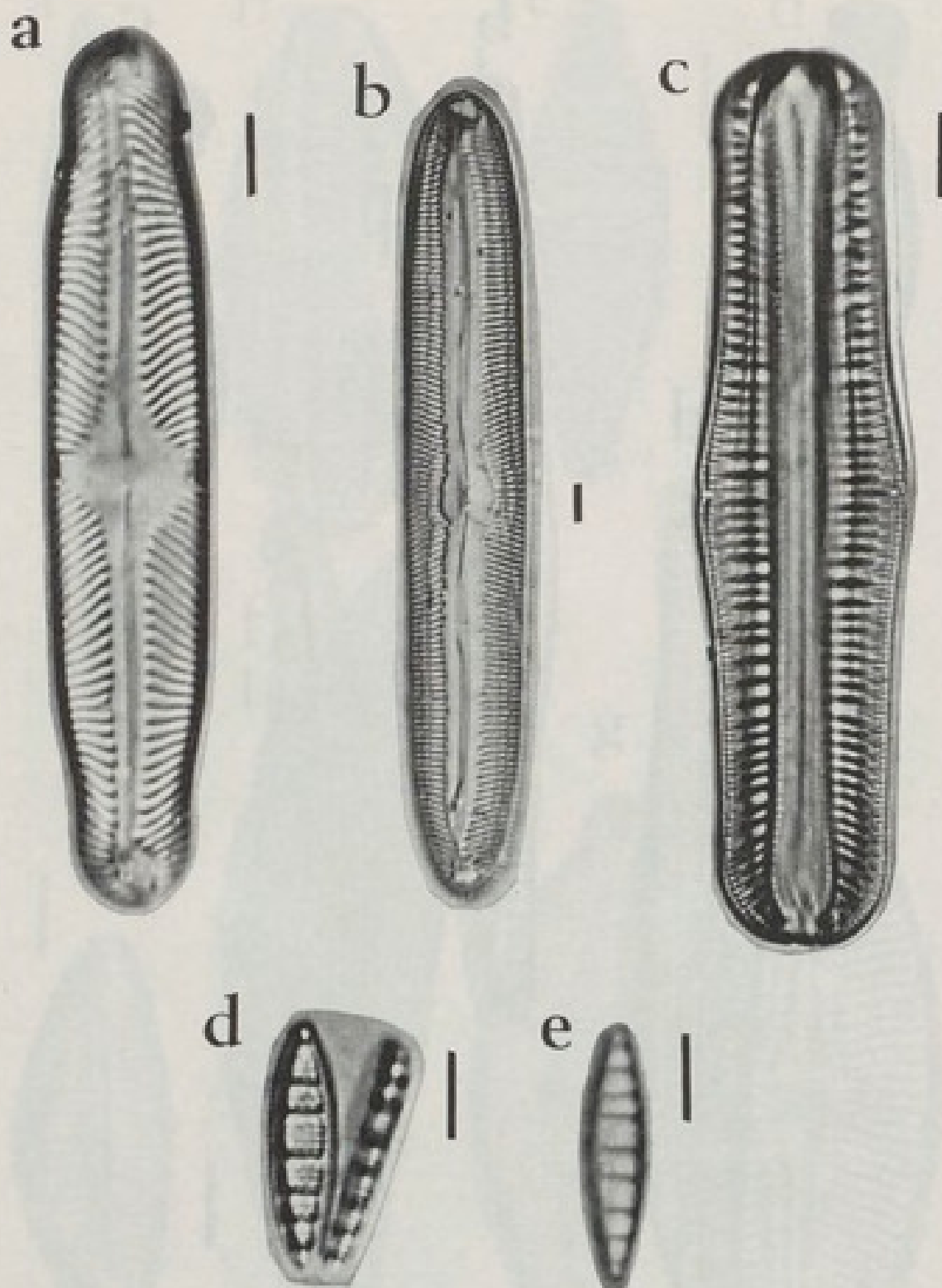


Fig. 5. a. *Pinnularia mesolepta*, b. *P. viridis*, c. *Rhopalodia gibba*, d. *Denticula elegans*, e. *D. tenuis*. Scale bar 10 μ m.



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