Great Basin Naturalist

Volume 46 | Number 4 Article 3

10-31-1986

Diatom flora of Cowboy Hot Spring, Mono County, California

Laura Ekins
Brigham Young University

Samuel R. Rushforth
Brigham Young University

DIATOM FLORA OF COWBOY HOT SPRING, MONO COUNTY, CALIFORNIA

Laura Ekins[1] and Samuel R. Rushforth[1]

ABSTRACT.—The diatom flora of Cowboy Hot Spring, Mono County, California, was studied. Two habitats, one at 37C and one at 41C, were examined. Fifty-six taxa were identified from our samples. These taxa were mostly broadly distributed forms, and no endemic species were encountered. The dominant taxon was *Nitzschia frustulum*, followed by *Achnanthes gibberula*, *Achnanthes exigua*, *Nitzschia hantzschiana*, and *Navicula cincta*.

Interest in natural thermal waters has increased substantially during the past few years. Early studies of these environments were generally concerned with Cyanophyta or the faunas of such habitats (Edwards 1868, Davis 1897, Tilden 1897, 1898). These authors often expressed surprise that organisms could exist in thermal environments and were interested in the upper temperature tolerance of thermophilic species.

Diatoms were not studied systematically until some time later (Lacsny 1912, Oestrup 1918, Strom 1921, Famin 1933, Springer 1930), when they were found to be common in hot springs. More extensive studies were begun in the 1940s (Negoro 1940, Emoto and Hirose 1940, Emoto and Yoneda 1941, Yoneda 1942a, 1942b) and have continued to the present time (Whitford 1956, Yoneda 1962, Thomas and Gonzalves 1965a, 1965b, 1966a-e, Biebl and Kusel-Fetzmann 1966, and others). Diatoms also have recently been studied in several western North American springs (Kaczmarska and Rushforth 1983, St. Clair and Rushforth 1977, Stockner 1967a, 1967b, 1968, Rushforth et al. 1986).

Cowboy Hot Spring of the Mono Basin thermal area of eastern California is one of many thermal springs in the Basin and Range Geological Province (Great Basin). This province occurs east of the Sierra Nevada Mountains, between the Snake River and the Mojave Desert, and extends across Nevada into western Utah.

The Great Basin is characterized by a thinning of the earth's crust, more than 200 north/south-oriented mountain ranges with associated valleys (Nelson 1981), an abundance of thermal springs, and a cold desert climate. These features appear to be a result of several geological phenomena, including the continued spreading of the American Plate through the center of the Great Basin, past subduction of the Pacific Plate under the American Plate (Miller 1983), and the uplift of the Sierra Nevada.

Thermal springs have been characterized as waters with a temperature 6–9C greater than the mean annual air temperature of the adjacent area (Tarbuck and Lutgens 1984). A more detailed classification of thermal springs is that of Elenkin (Kol 1932), where waters below 15C were termed hypothermal, between 15C and 30C as mesothermal, and above 30C as euthermal. Water temperature in thermal springs generally remains quite constant because the source water is continuously heated by tectonic events.

We have studied the diatom flora of Cowboy Hot Spring to compare the flora with that of other thermal waters of western North America. This euthermal spring is of particular interest since its temperature of 41C is near the upper temperature limit for eukaryotic organisms (Ruttner 1963). The present paper lists and illustrates all known diatom taxa in Cowboy Hot Spring.

SITE DESCRIPTION AND COLLECTIONS

Cowboy Hot Spring is at 37° 38.6′ N latitude and 118° 45.45′ W longitude in Mono County, California. A concrete tub has been built around the source water, which is 41C. A runoff stream from the source contains water at 37C 3 m from the tub. Water flow is 150

[1]Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602

l/min, and the total dissolved solids are 150 ppm (California Geol. Map 1980).

All sampling was done 26 August 1981. Samples were taken from both the concrete tub and the runoff stream. Composite samples were collected by scraping the sides of the concrete tub and obtaining visible algae and placing these collections into vials. Stones and submerged wood in the stream were scraped, and these scrapings, together with visible algae and small amounts of sediment, were placed into vials. Composite samples of this type were obtained to insure that as many taxa as possible would be collected, since the primary thrust of this study was a floristic survey. All samples were stored at air temperature and returned to our laboratory at Brigham Young University.

Methods

Diatoms were cleared with nitric acid following standard methods using boiling nitric acid (St.Clair and Rushforth 1977), and strewn mounts using Naphrax high resolution mounting medium were prepared. Slides were studied using Zeiss RA microscopes with Nomarski and bright field illumination. Photographs of each taxon were obtained using Nikon AFM photomicrographic equipment.

A minimum of 500 frustules was counted on each slide to calculate the relative density for each taxon in each sample. Species diversity of each sample was measured by calculating the Shannon-Weaver index (Shannon and Weaver 1963, Margalef 1958, Patten 1962).

Permanent diatom slides are in the collections at Brigham Young University.

Results and Discussion

Fifty-six diatom taxa in 20 genera were identified in samples from Cowboy Hot Spring. Most of the taxa encountered are cosmopolitan, eurythermal forms and none were endemics. Kaczmarska and Rushforth (1983) found 136 diatom taxa in Blue Lake Warm Spring, in the Great Basin, a somewhat cooler spring at 29C than Cowboy Hot Spring, which might account for much of the difference in species diversity between the two sites.

Twelve taxa in Cowboy Hot Spring had an average relative density above 1.0. *Nitzschia frustulum* (Kuetz.) Grun. was the most abundant, with an average density of 31%, followed by *Achnanthes gibberula* Grun. (10.3%), *Achnanthes exigua* Grun. (10.1%), *Nitzschia hantzschiana* Rabh. (9.3%), *Navicula cincta* Ralfs (8.6%), *Anomoeoneis sphaerophora* (Ehr.) Pftiz. (6.8%), *Nitzschia communis* Rabh. (4.1%), *Achnanthes exigua* var. 1 (3.1%), *Nitzschia valdecostata* Lange-Bert. and Simon. (2.2%), *Navicula cryptocephala* var. *veneta* (Kuetz.) Rabh. (1.6%), *Rhopalodia operculata* (C.A.Ag.) Hakan. (1.6%), and *Denticula elegans* Kuetz. (1.2%).

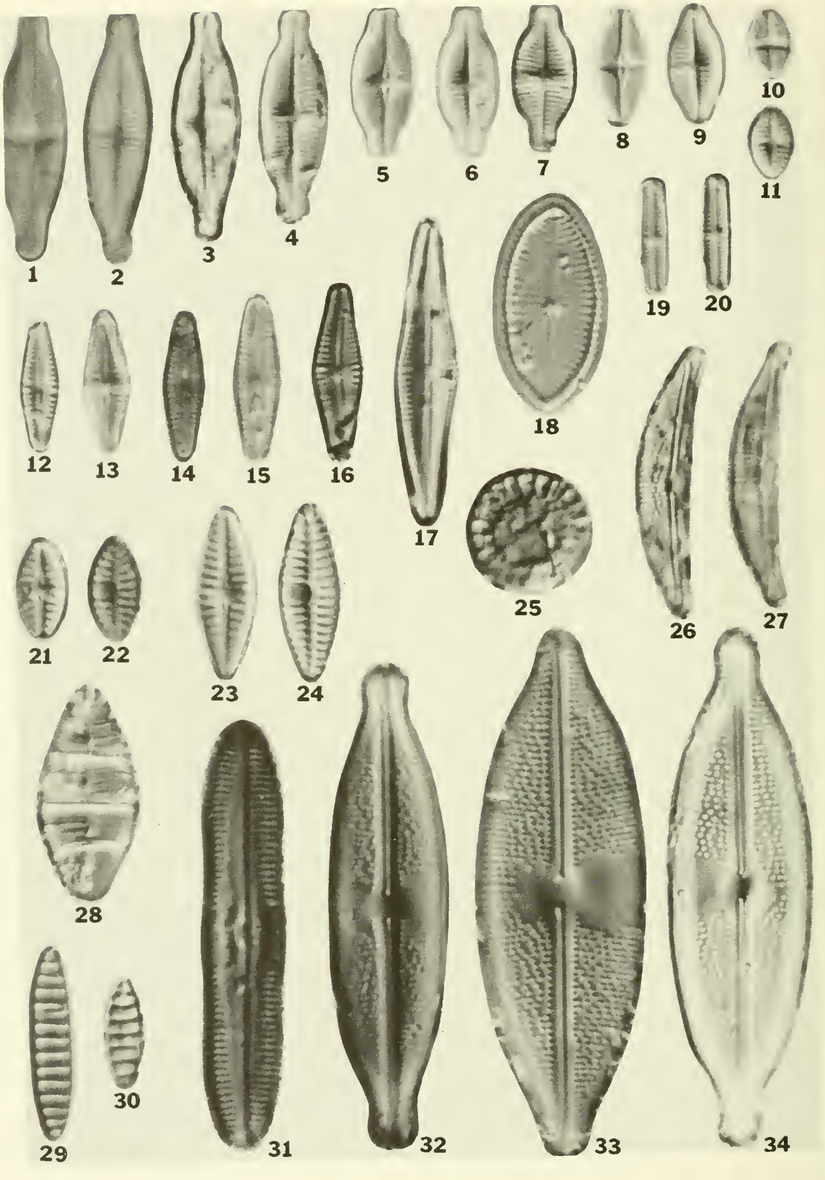
Kaczmarska and Rushforth (1983) found 17 taxa with importance values above 1.0 in Blue Lake Spring. Three of these also occurred in Cowboy Hot Spring, although none of them had average densities above 1.0%. Stockner (1967a) found 12 species common in waters above 35C in Yellowstone National Park. Eight of these taxa were also found in Cowboy Hot Spring. These included *Achnanthes gibberula* Grun., *Achnanthes lanceolata* Breb., *Amphora coffeaeformis* (Ag.) Kuetz., *Denticula elegans* Kuetz., *Gomphonema parvulum* Kuetz., *Navicula cincta* Ralfs, *Pinnularia microstauron* (Ehr.) Cl., and *Rhopalodia gibberula* (Ehr.) O.Muell.

None of the important taxa in Cowboy Hot Spring was confined to the stream or tub. However, several taxa did show a trend toward being restricted to one habitat or the other. Those reaching maximum development in the concrete tub were *Cocconeis placentula* var. *lineata* (Ehr.) V. H., *Denticula elegans* Kuetz., *Epithemia argus* (Ehr.) Kuetz., *Fragilaria construens* var. *venter* (Ehr.) Grun., and *Tabellaria quadrisepta* Knuds. Those with maximum development in the stream were *Achnanthes linearis* Grun., *Navicula confervacea* var. *peregrina* (W.Sm.) Grun., *Nitzschia microcephala* Grun., and *Pinnularia appendiculata* (Ag.) Cl. The Shannon-Weaver index value for the concrete tub was 3.67, and the stream value was 3.30.

A taxonomic section follows with a description of each taxon. A short discussion is included where appropriate.

Taxonomic Section

Achnanthes exigua Grun., Figs. 1–7. Valves 12.5–21.5 μm long by 5–6 μm wide; raphe valve striae 25–28 in 10 μm; rapheless valve striae 24–26 in 10 μm. This taxon oc-



Figs. 1–34. Diatom species: 1–7, *Achnanthes exigua*; 8–11, *Achnanthes exigua* var. 1; 12–17, *Achnanthes gibberula*; 18, *Cocconeis placentula* var. *lineata*; 19–20, *Achnanthes linearis*; 21–24, *Achnanthes lanceolata*; 25, *Cyclotella meneghiniana*; 26–27, *Amphora veneta*; 28, *Diatoma hiemale* var. *mesodon*; 29–30, *Denticula* cf. *parva*; 31, *Caloneis ventricosa* var. *truncatula*; 32–34, *Anomoeoneis sphaerophora*. All figures are 2000X.

curred at both sites but was most common in the stream, where it reached 14.0% relative density.

Achnanthes exigua var. 1, Figs. 8–11. Valves orbicular to elliptical with rounded to rostrate ends, 5–10 μm long by 3.5–5 μm wide; raphe valve with narrow, linear axial area and narrow, rectangular central area; rapheless valve with less distinct central area, often formed from one or two shortened striae; striae 22–24 in 10 μm on both valves. We considered several taxa for the placement of these specimens but were not satisfied with their fit. It seems probable that they belong with *A. exigua* except that valve shape differs somewhat and striae are slightly coarser. This taxon was present at about 3% relative density in samples from both collecting sites.

Achnanthes gibberula Grun., Figs. 12–17. Valves 5–26.5 μm long by 3–5.5 μm wide; striae 20–22 in 10 μm on both valves. Several of our specimens were shorter than ordinarily observed for this taxon. Even so, an unbroken series from very small to the largest specimens was observed. *A. gibberula* was abundant in the Cowboy Hot Tub system, with a relative density of 14.8% in the concrete tub and 5.8% relative density in the stream.

Achnanthes lanceolata Breb., Figs. 21–24. Valves 8–15 μm long by 4.5–5 μm wide; striae 13–14 in 10 μm on both valves. Several of our specimens were smaller than usual for this taxon. It was most abundant in the concrete tub at 1.6% relative density.

Achnanthes linearis Grun., Figs. 19–20. Valves 8.5–15.5 μm long by 2–3 μm wide; striae 24–28 in 10 μm on both valves. Several of our specimens were smaller than typically observed for the nominate variety. A continuous range in length was observed so that we did not place our smaller specimens in *A. linearis* f. *curta*. This taxon showed preference for the stream, where it had a relative density of 1.3%. Very few specimens were observed in samples from the concrete tub.

Amphora cf. *coffeaeformis* (Ag.) Kuetz., Fig. 119. Valve 15 μm long by 3 μm wide; striae indistinctly punctate, 24 in 10 μm. This *Amphora* corresponds to the description of *A. coffeaeformis* sensu Patrick and Reimer (1975). However, it does not fit the taxon as reinterpreted by Archibald and Schoeman (1984). We saw only a single valve of this *Amphora*, which is common in some marshes surrounding the Great Salt Lake of Utah (Felix and Rushforth 1979, Squires et al. in press).

Amphora veneta Kuetz., Figs. 26–27. Valves 15–29 μm long 3–5 μm wide; striae 21–24 at midvalve, becoming 28–32 at the ends. This *Amphora* was somewhat more common in the tub, where it reached 1% relative density.

Anomoeoneis sphaerophora (Ehr.) Pfitz., Figs. 32–34. Valves 36.5–45 μm long by 10–14 μm wide; striae 18–20 in 10 μm. This taxon was present at both localities at about 7% relative density.

Caloneis ventricosa var. *truncatula* (Grun.) Meist., Fig. 31. Valve 36 μm long by 7μm wide; striae 18 in 10 μm. A single valve of this taxon was observed during our study.

Cocconeis placentula var. *lineata* (Ehr.) V.H., Fig. 18. Valves 17.5–23 μm long by 9–12 μm wide; striae 16–21 in 10 μm. This taxon was rare in our study and was found only in the concrete tub.

Cyclotella atomus Hust., Figs. 117–118. Valves 4–5 μm in diameter; striae 16–20 in 10 μm. This taxon was collected infrequently from both habitats.

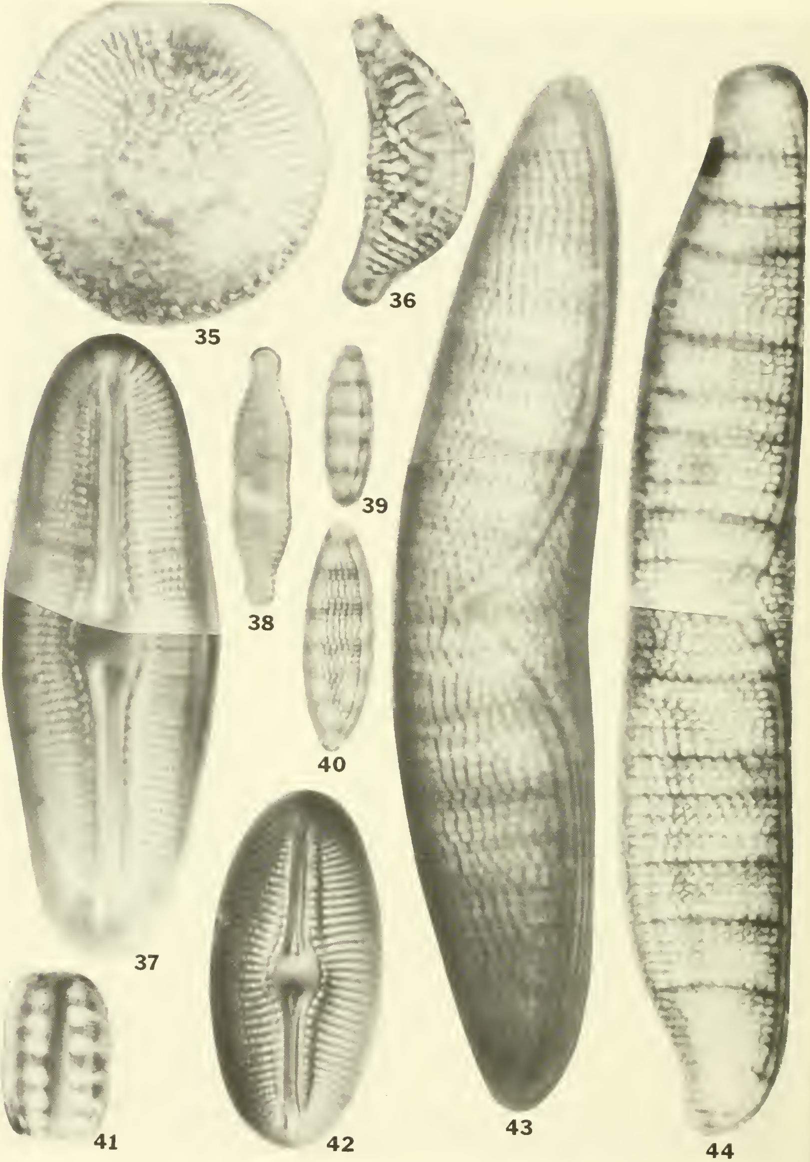
Cyclotella comta (Ehr.) Kuetz., Fig. 35. Valve 28 μm in diameter; striae 13–14 in 10 μm. A single valve of *C. comta* was observed.

Cyclotella meneghiniana Kuetz., Fig. 25. Valves 7.5–10 μm in diameter; striae 8–10 in 10 μm. Only two valves of this taxon were observed during our study.

Denticula elegans Kuetz., Figs. 39–41. Valves 10–31 μm long by 4–7 μm wide; costae 3–4 in 10 μm; striae 17–21 in 10 μm. *Denticula elegans* was less frequent in Cowboy Hot Tub than in many other thermal springs in western North America. It had a relative density of 2.4% in the concrete tub. It was present in the stream in lower numbers.

Denticula cf. *parva* Hust., Figs. 29–30. Valves 9–18.5 μm long by 3–3.5 μm wide; costae 6–10 in 10 μm; striae not resolved. We have seen this taxon in several spring systems throughout western North America. It was present in Cowboy Hot Spring in low numbers, always less than 1% relative density.

Diatoma hiemale var. *mesodon* (Ehr.) Grun., Fig. 28. Valve 17.5 μm long by 8.5 μm wide; costae 3 in 10 μm; striae 24 in 10 μm. Only a single valve of this taxon was observed.



Figs. 35–44. Diatom species: 35, *Cyclotella comta*; 36, *Epithemia sorex*; 37, *Diploneis oblongella*; 38, *Fragilaria construens* var. *binodis*; 39–41, *Denticula elegans*; 42, *Diploneis oblongella*; 43, *Epithemia argus*; 44, *Epithemia adnata* var. *porcellus*. All figures are 2000X.

Diploneis oblongella (Naeg. ex Kuetz.) Ross, Figs. 37, 42. Valves 31–52 μm long by 15–18 μm wide; striae 12–13 in 10 μm. Several valves were collected from both habitats during our study.

Epithemia adnata var. *porcellus* (Kuetz.) Patr., Fig. 44. Valve 90.5 μm long by 14 μm wide; costae 3 in 10 μm; striae 12 in 10 μm, 4–6 between costae. A single specimen of this taxon was observed.

Epithemia argus (Ehr.) Kuetz., Fig. 43. Valves 60–90 μm long by 12–16.5 μm wide; costae 2 in 10 μm; striae 10–11 in 10 μm, 4–6 between costae. This *Epithemia* was observed infrequently in samples from the concrete tub.

Epithemia sorex Kuetz., Fig. 36. Valve about 25 μm long by 9 μm wide; costae 12 in 10 μm; striae 2 between costae. Only a single frustule of this taxon was observed.

Fragilaria construens Grun., Fig. 45. Valves 10–15 μm long by 5.5 μm wide; striae 14 in 10 μm. Only two valves of this taxon were observed.

Fragilaria construens var. *binodis* (Ehr.) Grun., Fig. 38. Valve 22 μm long by 5 μm wide; striae 16 in 10 μm. A single valve of this taxon was observed during our study.

Fragilaria construens var. *venter* (Ehr.) Grun., Figs. 46–48. Valves 5.5–10 μm long by 4–4.5 μm wide; striae 12–16 in 10 μm. This taxon was quite rare in our study, always less than 1% relative density.

Fragilaria lapponica Grun., Fig. 53. Valve 32 μm long by 6 μm wide; striae 10–12 in 10 μm. A single valve of this taxon was observed.

Fragilaria pinnata var. *lancettula* (Schum.) Hust., Fig. 52. Valve 20 μm long by 6 μm wide; striae 10 in 10 μm. A single valve of this diatom was observed.

Fragilaria similis Krasske, Fig. 51. Valve 15 μm long by 5 μm wide; striae 10 in 10 μm. A single valve of *F. similis* was observed.

Gomphonema gracile Ehr., Figs. 58–60. Valves 24–32.5 μm long by 6.5–7.5 μm wide; striae 12–16 in 10 μm. It was present in low numbers in Cowboy Hot Spring, always less than 1% relative density.

Gomphonema parvulum Kuetz., Figs. 49–50. Valves 16–17.5 μm long by 4.5–5 μm wide; striae 14 in 10 μm. Two frustules of this *Gomphonema* were observed during our study.

Navicula confervacea (Kuetz.) Grun., Figs. 73–74. Valves 18–26 μm long by 7–8 μm wide; striae 19–24 in 10 μm. This taxon was present in samples from both sites in low numbers, always less than 1% relative density.

Navicula confervacea var. *peregrina* (W. Sm.) Grun., Figs. 69–71. Valves 6–13 μm long by 3.5–4 μm wide; striae 24 in 10 μm. Specimens of this variety were somewhat smaller than generally observed. It was present at about the same density as the nominate in samples from both sites.

Navicula cincta (Ehr.) Ralfs, Figs. 54–57. Valves 14–24.5 μm long by 4–5.5 μm wide; striae 14–16 in 10 μm. Our specimens of this taxon differ from the typical by being smaller with somewhat coarser striae. This diatom was present in rather high numbers, reaching 11.0% relative density in the thermal stream.

Navicula cryptocephala var. *veneta* (Kuetz.) Rabh., Figs. 65–68. Valves 18–26 μm long by 5.5–6.5 μm wide; striae 14–16 in 10 μm. This *Navicula* was present in the concrete pool at 2.2% relative density and 1% relative density in the thermal stream.

Navicula halophila (Grun.) Cl., Figs. 63–64. Valves 34–53 μm long by 10–12.5 μm wide; striae 16–20 in 10 μm. This *Navicula* was more common in the stream, where it reached nearly 2% relative density.

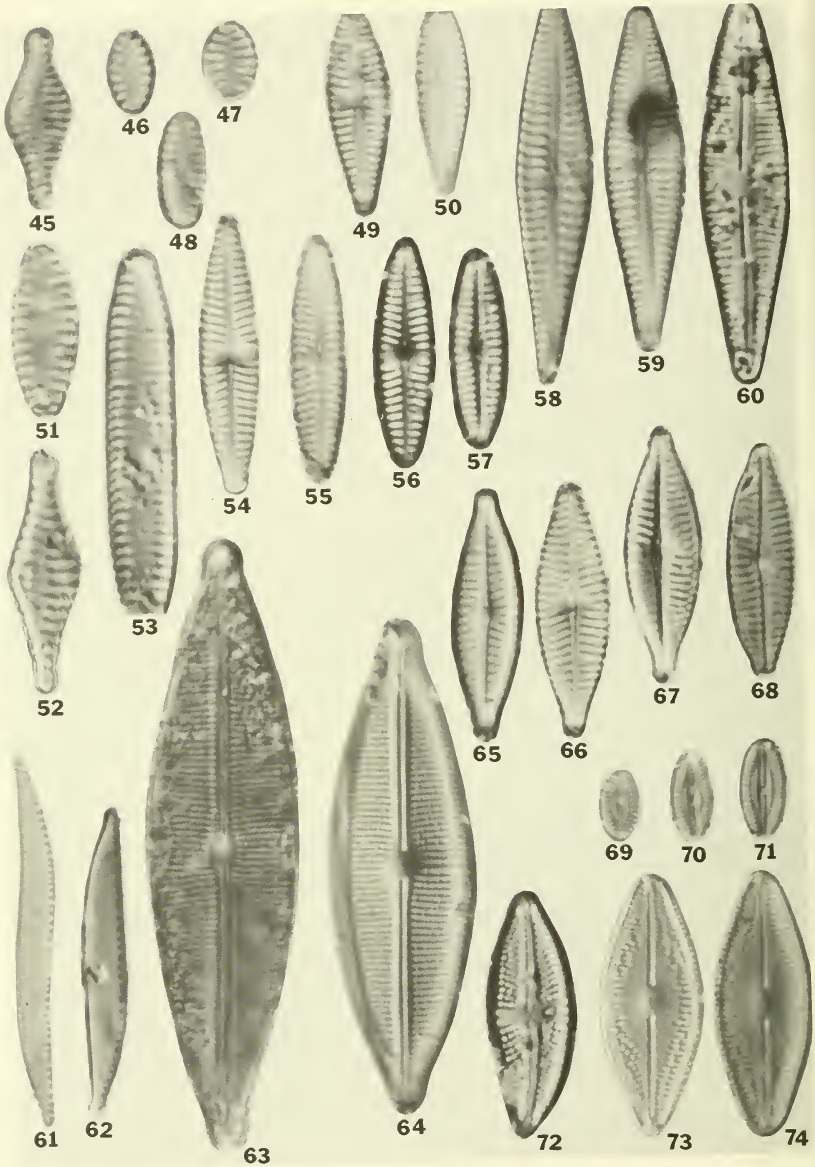
Navicula mutica Kuetz., Fig. 72. Valve 21 μm long by 7.5 μm wide; striae 18 in 10 μm. A single valve of this taxon was observed.

Nitzschia clausii Hantz., Figs. 61–62. Valves 25.5–36.5 μm long by 3–4.5 μm wide; striae not resolved; fibulae 13–16 in 10 μm. Fibulae of our specimens were somewhat finer than previously reported for this taxon. It was present at less than 1% relative density in both sampling localities.

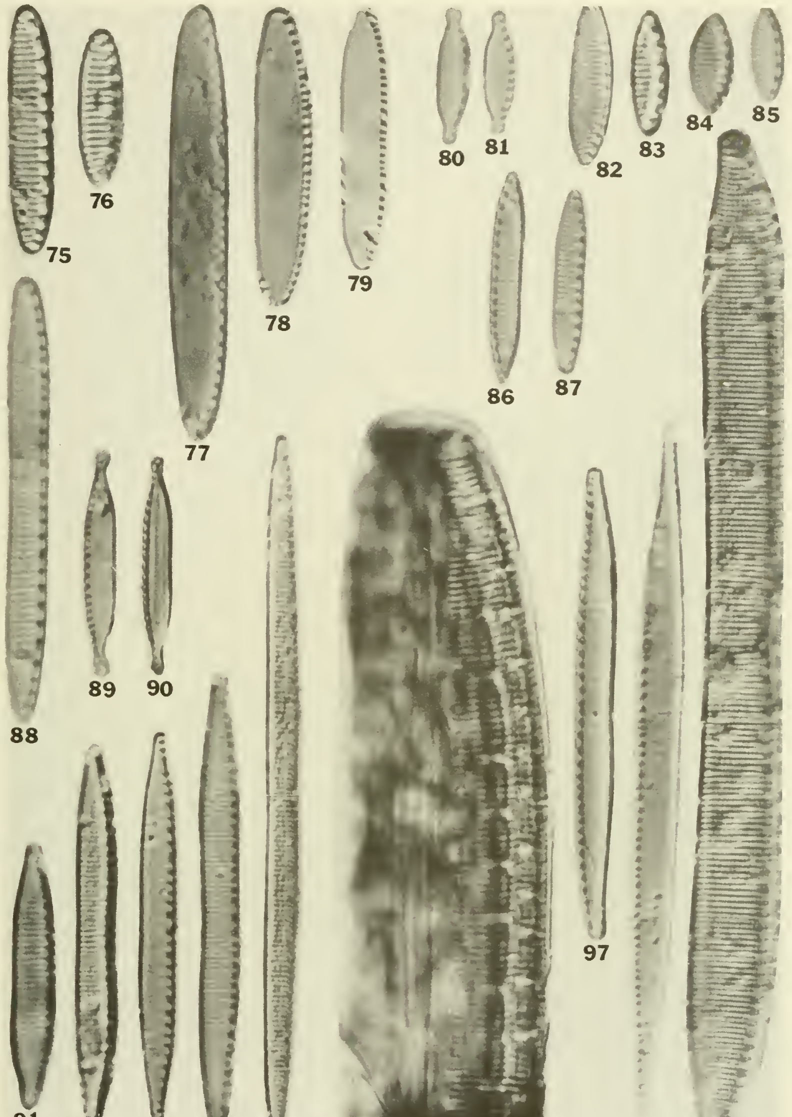
Nitzschia communis Rabh., Figs. 77–79. Valves 20–38.5 μm long by 4–5 μm wide; striae approximately 32–36 in 10 μm, often unresolved; fibulae 10–16 in 10 μm. It was present at 4% relative density in both the concrete tub and the spring stream.

Nitzschia frustulum (Kuetz.) Grun., Figs. 82–85. Valves 8–22 μm long by 3–4 μm wide; striae 21–22 in 10 μm; fibulae 10–12 in 10 μm. This *Nitzschia* was one of the most common diatoms in our study. It occurred at 32% relative density in the concrete tub and as high as 30% relative density in the runoff stream.

Nitzschia frustulum var. *subsalina* Grun., Figs. 89–90. Valves 13–20 μm long by 2.5–3



Figs. 45–74. Diatom species: 45, *Fragilaria construens*; 46–48, *Fragilaria construens* var. *venter*; 49–50, *Gomphonema parvuium*; 51, *Fragilaria similis*; 52, *Fragilaria pinnata* var. *lancettula*; 53, *Fragilaria lapponica*; 54–57, *Navicula cincta*; 58–60, *Gomphonema gracile*; 61–62, *Nitzschia clausii*; 63–64, *Navicula halophila*; 65–68, *Navicula cryptocephala* var. *veneta*; 69–71, *Navicula confervacea* var. *peregrina*; 72, *Navicula mutica*; 73–74, *Navicula confervacea*. All figures are 2000X.



Figs. 75–99. Diatom species: 75–76, *Nitzschia valdecostata*; 77–79, *Nitzschia communis*; 80–81, *Nitzschia micro-ephala;* 82–85, *Nitzschia frustulum*; 86–87, *Nitzschia hantzschiana*; 88, *Nitzschia valdecostata*; 89–90, *Nitzschia rustulum* var. *subsalina;* 91–95, *Nitzschia hantzschiana*; 96, *Nitzschia* species; 97–98, *Nitzschia gracilis*; 99, *Nitzschia ieufleriana*. All figures are 2000X.

μm wide; striae 32 in 10 μm; fibulae 14–15 in 10 μm. Several valves of this taxon were observed in both the concrete tub and the thermal stream.

Nitzschia gracilis Hantz., Figs. 97–98. Valves 40.5–62.5 μm long by 3–3.5 μm wide; striae 32–33 in 10 μm, often unresolved; fibulae 11–14 in 10 μm. This taxon was present in samples from both collecting sites at a relative density of less than 1%.

Nitzschia hantzschiana Rabh., Figs. 86–87, 91–95. Valves 10.5–60 μm long by 2–3.5 μm wide; striae 22–24 in 10 μm; fibulae 10–13 in 10 μm. Our collections of this taxon contain specimens that are both shorter and longer than generally reported. However, a good size gradient was observed. This taxon occurred between 9% and 10% relative density in both the concrete tub and the stream.

Nitzschia heufleriana Grun., Fig. 99. Valve 85 μm long by 7 μm wide; striae 20 in 10 μm; fibulae 10 in 10 μm. We saw a single specimen of this *Nitzschia* that had ends less capitate than usual.

Nitzschia microcephala Grun., Figs. 80–81. Valves 8.5–11.5 μm long by 2.5–3 μm wide; striae unresolved; fibulae 10–14 in 10 μm. This taxon reached 1% relative density in the thermal stream but was absent in the concrete tub.

Nitzschia valdecostata Lange-Bert. and Simon., Figs. 75–76, 88. Valves 13–37.5 μm long by 3.5–4.5 μm wide; striae 16–18 in 10 μm; fibulae 7–9 in 10 μm. We used the epithet *N. valdecostata* rather than *N. valdestriata* since our specimens appeared to lack a nodulus. Petersen (1930) has also collected this taxon (as *N. valdestriata*) from thermal waters. This *Nitzschia* occurred in the concrete tub at about 2% relative density and about 3% relative density in the stream.

Nitzschia species, Figs. 96, 114. Valves linear, greater than 100 μm long by 8 μm wide; striae 17–20 in 10 μm; fibulae 3 in 10 μm. This *Nitzschia* has been seen in several California thermal springs but has never been abundant in any of our samples. At Cowboy Hot Spring it was present in both the concrete tub and the spring stream in low numbers.

Pinnularia appendiculata (Ag.) Cl., Figs. 102–104. Valves 18.5–25 μm long by 4.5–6 μm wide; striae 20–22 in 10 μm. Some specimens demonstrated more strongly radiate striae near midvalve (Figs. 103–104) than others. However, it appeared that this feature intergraded in the population. This taxon was more common in the stream but occurred at less than 1% relative density.

Pinnularia intermedia (Lagerst.) Cl., Figs. 107–109. Valves 11.5–17 μm long by 3–3.5 μm wide; striae 10–12 in 10 μm. Our specimens were shorter than usual for this taxon. Some of our specimens were similar to *P. obscura* since they had up to 12 striae in 10 μm. This diatom was rare in our samples.

Pinnularia microstauron (Ehr.) Cl., Figs. 111–113. Valves 24–52 μm long by 7–13 μm wide; striae 10–12 in 10 μm. Some of our specimens are very similar to *P. brebissonii*. However, since they seemed to be at one end of a morphological gradient from the more common and more typical *P. microstauron* specimens, we opted to use the latter specific name. This taxon was not particularly common, although a number of frustules were collected.

Pinnularia stauroptera var. *recta* (May.) Cleve-Euler, Fig. 110. Valve 43 μm long by 7.5 μm wide; striae 9 in 10 μm. Hustedt (1930) used *Pinnularia gibba* var. *linearis* for specimens similar to ours. A single specimen of this taxon was observed in a sample from the thermal stream.

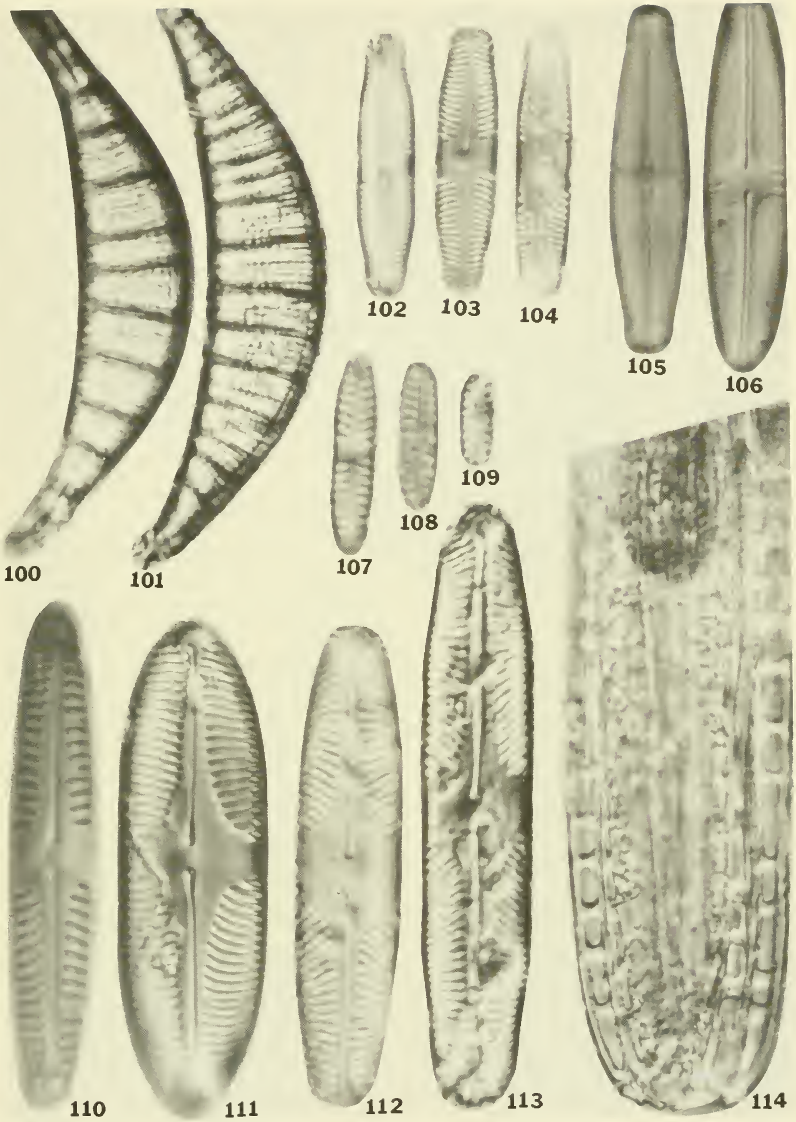
Rhopalodia gibberula (Ehr.) O. Muell., Fig. 115. Valve 80–127.5 μm long by 12–12.5 μm wide; striae 18 in 10 μm; costae 3–5 in 10 μm. It was rare in the concrete tub.

Rhopalodia operculata (C. A. Ag.) Hakansson, Fig. 100–101, 120. Valves 25–49 μm long; 6–12 μm wide; striae 18–20 in 10 μm; costae 3–6 in 10 μm. This taxon occurred in samples from the concrete tub at 2% relative density and was somewhat rarer in the stream.

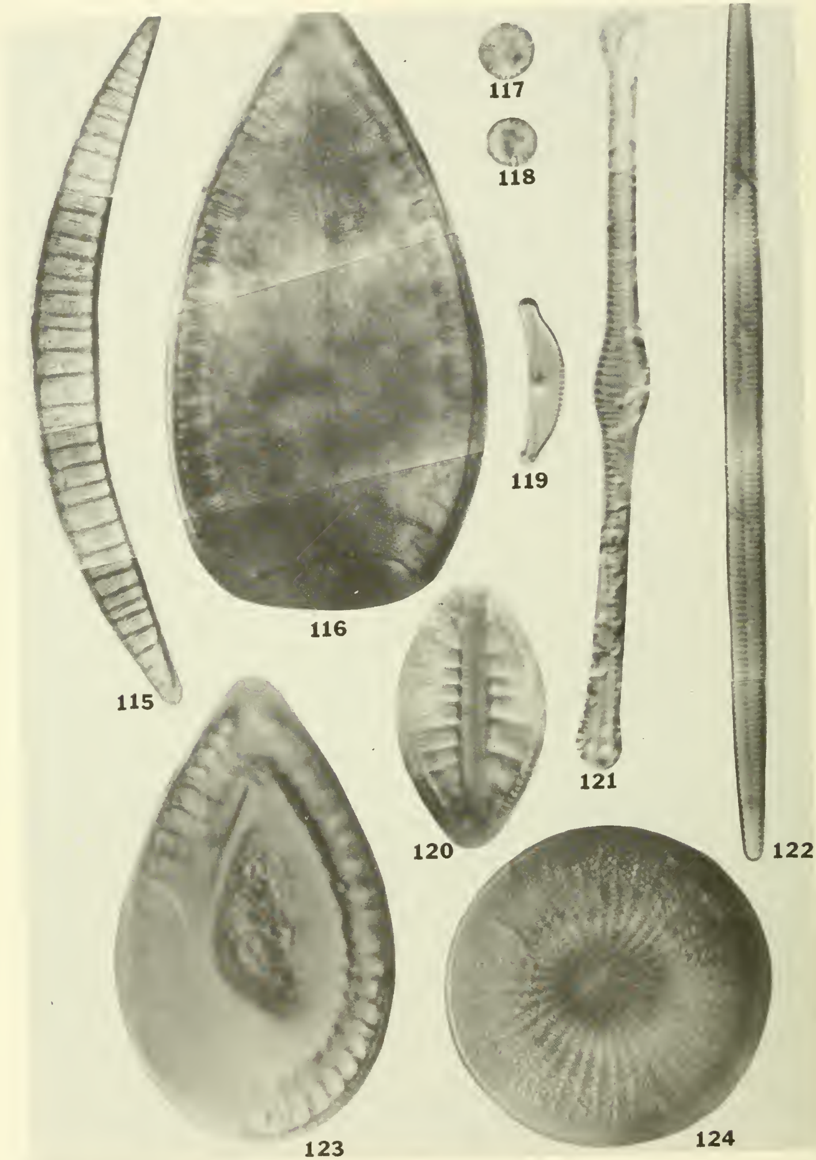
Stauroneis wislouchii Poretz. et Anisimowa, Figs. 105–106. Valves 22–34 μm long by 5–8 μm wide; striae 22–26 in 10 μm. This taxon was present in samples from both collecting localities at about 0.5% relative density.

Stephanodiscus carconensis var. *pusilla* Grun., Fig. 124. Valves 26–28 μm in diameter; large striae 4 in 10 μm, composed of distinct rows of punctae; rows of punctae 17–18 in 10 μm. Only two valves of this taxon were found in our samples.

Surirella ovalis Breb., Fig. 116. Valve 113 μm long by 53 mm wide; striae 14 in 10 μm;



Figs. 100–114. Diatom species: 100–101, *Rhopalodia operculata*; 102–104, *Pinnularia appendiculata;* 105–106, Stauroneis wislouchii; 107–109, *Pinnularia intermedia*; 110, *Pinnularia stauroptera* var. *recta;* 111–113, *Pinnularia microstauron*; 114, *Nitzschia* species. All figures are 2000X.



Figs. 115–124. Diatom species: 115, *Rhopalodia gibberula*; 116, *Surirella ovalis*; 117–118, *Cyclotella atomus;* 119, *Amphora* cf. *coffeaeformis;* 120, *Rhopalodia operculata*; 121, *Tabellaria quadrisepta*; 122, *Synedra ulna;* 123, *Surirella ovalis* var. *brightwellii*; 124, *Stephanodiscus carconensis* var. *pusilla*. Figures 115, 116 and 122 are 1000X. All others are 2000X.

wing canals 3 in 10 μm. Only a single specimen of this taxon was observed in our samples.

Surirella ovalis var. *brightwellii* (W. Sm.) Cl., Fig. 123. Valves 39 μm long by 21–23 μm wide; striae 19–20 in 10 μm; wing canals 5–6 in 10 μm. Only two specimens of this taxon were observed in our samples.

Synedra ulna (Nitz.) Ehr., Fig. 122. Valve 115 μm long by 6.5 μm wide; striae 10 in 10 μm. This taxon occurred as a single specimen from the concrete tub.

Tabellaria quadrisepta Knuds., Fig. 121. Valves 37–65 μm long by 6 μm wide at mid-valve; striae 15–16 in 10 μm. Only three frustules of this taxon were observed in our samples.

Literature Cited

Archibald, R. E. M., and F. R. Schoeman. 1984. *Amphora coffeaefromis* (Agardh) Kuetzing: a revision of the species under light and electron microscopy. South African Jour. Bot. 3: 83–102.

Biebl, R., and Kusel-Fetzmann. 1966. Beobachtungen ueber das Vorkommen von Algen an Thermalstandorten auf Island. Osterreich. Bot. Zeitschr. 113: 408–423.

California Geologic Map Series. 1980. Map 4. Geothermal Resources of California. Nat. Geophys. and Solar-Terrestrial Data Center, Nat. Ocean. and Atmos. Admin.

Davis, D. M. 1897. The vegetation of the hot springs of Yellowstone Park. Science 4(134): 145–157.

Edwards, M. E. 1868. On the occurrence of living forms in the hot waters of California. Amer. Jour. Sci. and Arts 2(65): 239–241.

Emoto, Y., and H. Hirose. 1940. Studien ueber die Thermalflora von Japan (III). Thermale Bacterien und Algen aus den themalen Quellen von Hakone (2). Shokobutsu Kenkyn Zasshi 16: 405–420.

Emoto, Y., and Y. Yoneda. 1941. Bacteria and algae of the thermal springs in Simane Prefecture (1). Shokobutsu Kenkyn Zasshi 17: 654–715.

Famin, M. A. 1933. Action de la temperature sur les vegetaux. Part 4: les vegetaux vivant dans les eaux naturellement a temperatures elevees. Rev. Generale Bot. 45: 574–595, 655–682.

Felix, E. A., and S. R. Rushforth. 1979. The algal flora of the Great Salt Lake, Utah, USA. Nova Hedwigia 31(12): 163–195.

Hustedt, F. 1930. Die Kieselalagen Deutschlands, Osterreichs und der Schweiz mit Berucksichtigung der ubrigen Lander Europas sowie der angrenzenden Meeresgebiete. Vol. 7 in L. Rabenhorst, Kryptogamen-flora von Deutschland, Osterreich und der Schweiz. Akad. Verlagsgesell., Leipzig. Reprint 1971, Johnson Reprint Corp., London.

Kaczmarska, I., and S. R. Rushforth. 1983. The diatom flora of Blue Lake Warm Spring, Utah, USA Biblio. Diatomologica 2(1): 1–123.

Kol, E. 1932. Thermalvegetation von Hajduszoboszolo in Ungarn. Pt. 4, Algen. Archiv Protistenk. 76: 309–324.

Lacsny, I. L. 1912. Beitraege zur algen Flora der Thermalwasser bei Nadyvard. Botanikai Kozlemenyek 11(5–6): 167–185.

Margalef, R. 1958. "Trophic" typology versus biotic typology, as exemplified in the regional limnology of northern Spain. Verh. intern. Ver. Limno. 13: 339–349.

Miller, R. 1983. Continents in Collision. Time Life Books, Alexandria, Virginia. 176 pp.

Negoro, K. 1940. The diatom flora of the Nasu Hot Spring (preliminary report). Bot. Mag. 54(638): 63–65.

Nelson, C. A. 1981. Basin and range province. Pages 203–216 *in* W. G. Ernst, The geotectonic development of California. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Oestrup, E. 1918 (1920). Fresh-water diatoms of Iceland. Pages 1–90 *in* Rosenvinge and Warming, Botany of Iceland, vol. 2, 1(5): 1–96. Arbeider Botaniske Have Kobenhavn.

Patrick, R., and C. Reimer. 1975. The diatoms of the United States exclusive of Alaska and Hawaii. Mon. Acad. Nat. Sci. Philadelphia 13, vol. 2, pt. 1. 213 pp.

Patten, B. C. 1962. Species diversity in net phytoplankton of Raritan Bay. J. Marine Res. 20: 57–75.

Petersen, J. B. 1930. Algae from O. Olufsens second Danish Pamir Expedition 1898–1899. Dansk Botanisk Arkiv 6 No. 6, Copenhagen.

Rushforth, S. R., L. E. Squires, and J. E. Johansen. 1986. Three new records for diatoms from the Great Basin, USA. Great Basin Nat. 46(3): 398–403.

Ruttner, R. 1963. Fundamentals of limnology. University of Toronto Press. Toronto, Ontario, Canada. 295 pp.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana. 117 pp.

Springer, E. 1930. Bacillariales aus den Thermen und der Umgebung von Karlsbad. Archiv Protistenkunde 71: 502–542.

Squires, L. E., S. R. Rushforth, and C. C. Newberry. The diatom flora of newly inundated land at the south end of the Great Salt Lake, Utah, USA. Great Basin Nat. In press.

St. Clair, L. L., and S. R. Rushforth. 1977. The diatom flora of the Goshen Warm Spring ponds and wet meadows, Goshen, Utah, USA. Nova Hedwigia 28: 353–425.

Stockner, J. G. 1967a. Observations of thermophilic algal communities in Mount Rainier and Yellowstone National Parks. Limnol. Oceanogr. 12(1): 13–17.

______. 1967b. The ecology of the Ohanoapecosh Hot Springs, Mt. Rainier National Park, Washington. Unpublished dissertation, University of Washington, Seattle. 232 pp.

______. 1968. The ecology of a diatom community in a thermal stream. Brit. Phycol. Bull. 3(3): 501–514.

Strom, K. M. 1921. Some algae from hot springs in Spitzbergen. Botaniska Notiser 1921: 17–21.

Tarbuck, E. J., and F. K. Lutgens. 1984. The earth: an introduction to physical geology. Charles E. Merrill Pub. Co., Columbus, Ohio. 594 pp.

THOMAS, J., AND E. A. GONZALVES. 1965a. Thermal algae of western India, I. Algae of the hot springs at Akloi and Ganeshpnri. Hydrobiologia 25: 330–340.

_____. 1965b. Thermal algae of western India, II Algae of the hot springs at Palli. Hydrobiologia 25: 340–351.

_____. 1966a. Thermal algae of western India, III. Algae of the hot springs at Sav. Hydrobiologia 26: 21–28.

_____. 1966b. Thermal algae of western India, IV. Algae of the host springs at Aravali, Tooral and Rajewadi. Hydrobiologia 26: 29–40.

_____. 1966c. Thermal algae of western India, V. Algae of the hot springs at Tuwa. Hydrobiologia 26: 41–54.

_____. 1966d. Thermal algae of western India, VI. Algae of the hot springs at Unai, Lasundra and Unapdeo. Hydrobiologia 26: 55–65.

_____. 1966e. Thermal algae of western India, VII. Algae of the hot springs at Ragapur. Hydrobiologia 26: 66–71.

TILDEN, J. E. 1897. On some algal stalactites of Yellowstone National Park. Bot. Gazette 24: 144–199.

_____. 1898. Observations on some west American thermal algae. Bot. Gazette 25: 89–105.

WHITFORD, L. A. 1956. The communities of algae in the springs and spring systems of Florida. Ecology 37(3): 432–442.

YONEDA, Y. 1942a. Bacteria and algae of hot springs in Gihu Prefecture. Shokobutsu Bunrui Chiri 11: 83–100.

_____. 1942b. Bacteria and algae of hot springs in Wakayama Prefecture. Shokobutsu Bunrui Chiri 11: 194–210.

_____. 1962. Study of the thermal algae of Hokkaido. Shokobutsu Bunrui Chiri 20: 308–313.