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## FRESHWATER ALGAE OF THE CENTRAL DEATH VALLEY DESERT<sup>1, 2</sup>

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### ABSTRACT

The Central Death Valley desert was investigated at seasonal intervals between 1959 and 1961 to determine the algae indigenous to its freshwater ponds and streams. Myxophyceae, Chlorophyceae, and Bacillariophyceae were represented by substantial populations throughout the year. Blue-green algae were especially predominant under the thermophilic conditions. Thirty-two previously unrecorded species were also found in the survey.

Deserts are not often considered suitable habitats for an algal flora. Because of the severe environmental conditions of Death Valley National Monument, California, therefore, it would seem almost impossible to find very many, if any, algae, especially those indigenous to an aquatic habitat. However, in March, 1959, I found a substantial bloom of algae, macroscopically identified as belonging

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to the Zygnemataceae, growing in a swampy area near Eagle Borax Mine (fig. 1). This initial discovery stimulated further trips to that and other areas and the eventual amassment of a representative algal collection.

Until July, 1962, when Durrel reported on the algae, no concentrated attempt was made to survey Death Valley specifically for these plants. Although the flowering plants of the Monument have been studied and classified since Merriam's initial expedition (U.S.D.A., 1893), little attention was paid to the aquatic flora of the freshwater ponds and streams located throughout the Monument. These ponds and streams, though sparse, are not unusual in any desert environment, even that of Death Valley.

This survey is an attempt to identify the algae from select ponds and streams in the Central part of the valley. The algae were collected over a three year period, and all four seasons of the year are represented. The approach is to identify and list species found growing naturally in the ponds and streams as well as algae from



FIGURE 1. Eagle Borax Mine. From 282 ft below sea level, the valley floor rises to 11,049 ft above sea level at the summit of Telescope Peak in the Panamint Mountains.

these areas cultured in the laboratory. Ecological notes are added as essential to a survey of this kind.

I made all collections upon which this study is based except for the summer 1962 collections made by Mr. William C. Bullard and his staff of the National Park Service.

It is recognized that a study of this length is no way represents a complete list of the algae of Death Valley. But it is hoped that this report will contribute somewhat to a knowledge of some of the algae to be found in this unique locale, and that it will stimulate further studies of this nature in this and in other desert regions.

I wish to acknowledge those who encouraged and assisted me in this study. Special thanks are given to Mr. William C. Bullard, Chief Park Naturalist of Death Valley National Monument and to his staff for their assistance in collecting material and for allowing me the use of their facilities. I also wish to thank Dr. Clarence E. Taft, my advisor, for his help in identification and verification of

species. To members of my family who occasionally accompanied me on my trips and aided me in collecting and photographing the area, I also wish to express my appreciation.

#### HISTORY

Bounded by the Panamint Mountain Range on the west and the Amargosa Range on the east, Death Valley stretches approximately 140 miles in a north-westerly-southeasterly direction and ranges in width from 4 to 16 miles. The valley itself is a part of a group of depressions known collectively by geologists as the Great Basin and by biologists as the Mojave Desert. It lies in the area east of the Sierra Nevada in Eastern California and Western Nevada. The valley is unique, however, in that it possesses the lowest point in the Western Hemisphere, this land being 282 ft below sea level in the vicinity of Badwater. From this depth, the two mountain ranges rise to heights between 5,000 and 11,000 ft.

Geologic eras from Archeozoic to Cenozoic are represented by rocks and fossils within the confines of Death Valley. The forces which carved Death Valley,



FIGURE 2. Travertine Pond. This pond is fed from ground water from nearby Travertine Stream, which enters from the southeast sector (foreground) and flows out at the opposite end. It is bordered on the east by athel trees, and its shore has an abundant growth of grasses and *Scirpus*.

moreover, are still active, and even today changes in size of sand dunes, the effects of rainfall and temperature extremes, fresh fault scarps, as well as the possibility of recent volcanic activity often alter the familiar landscape.

Death Valley, as it is known today, evolved during the Pleistocene Epoch of the last or Cenozoic Era. A lake about 90 miles long, 6 to 11 miles wide, and 600 ft deep at its maximum covered the valley floor. It was fed from the overflow of nearby Lakes Panamint and Mojave as well as by increased rainfall and melting mountain snows. This lake was called Lake Manly in honor of William Lewis Manly, a member of the Bennet-Arcane Party of Fortyniners who helped lead the wagon train to safety from the valley.

As the climate became more arid, the lake water evaporated. All that remains today is the familiar basin with its saltpillars, as in Devil's Golf Course and Manly

Terrace, with its evidence of previous wave action. Several small streams and ponds are scattered through the valley, many of them containing salt water and three species of a fish, a minnow of the Genus *Cyprinodon*, which survived from the ancient lake.

So recent geologically and of such short duration was Lake Manly that evidence of human habitation during the end of the Pleistocene has been established. Crude, water-worn tools, which were perhaps useful in hunting the mammoths and camels then abundant in that area, have been found on Manly Terrace. If it is accepted that man was in existence at that period, Death Valley is then one of the earliest-inhabited lands in North America.

Until the arrival of the white man, Death Valley was inhabited by the Panamint Indians, a branch of the Shoshone Indian Nation. Their name for the valley was "Tomesha," meaning "ground afire." Today there are few remaining Indians in the Death Valley area, although their artifacts may be found throughout the Monument.

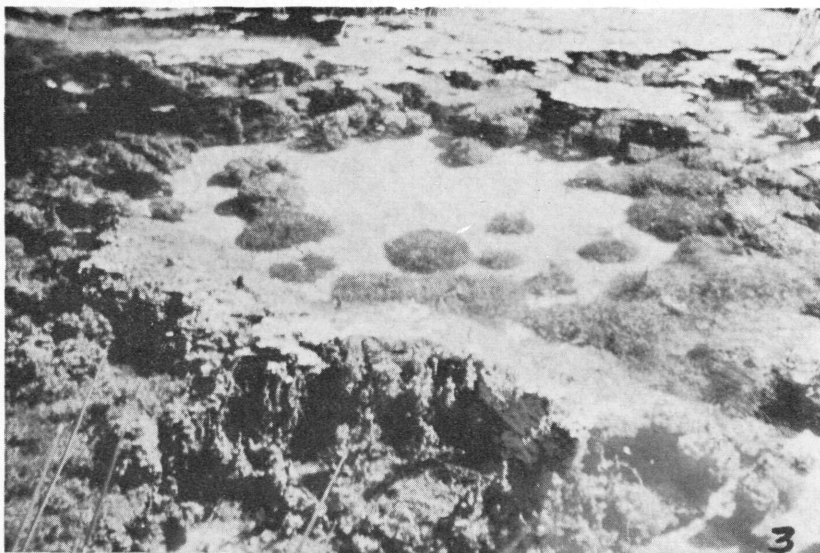


FIGURE 3. Travertine Pond. Clumps of *Chara* growing on mud ledges toward the center of the pond can be viewed through the clearness of the pond water. Mats of blue-greens float upon the pond surface, and where there is turbulence, these algae often become attached to and grow upon the *Chara*.

The first contact with Death Valley by white men was probably in 1844 when John Fremont and his party camped near the south end (U.S.D.I., 1958). It was not until 1849, however, that Death Valley became known in any significant sense. A wagon train, seeking a shorter route to the California goldfields, entered the valley in 1849 on Christmas Day. The emigrants were so discouraged when they saw the forbidding salt flats and the towering mountains that they separated into seven groups, each trying to find a way out for itself. The Jayhawker Party, one of the groups, escaped through the Panamints by way of a canyon later called Jayhawker Canyon. Another group, the Bennett-Arcane Party, sent Manly and John Rogers (for whom northern Lake Rogers was named) to scout for an escape route. This party, after much hardship, was finally led to safety across the salt flats.

Despite the forbidding aspect of the valley, only one recorded death has been

located for the 1849 wagon train. It is also of interest to note that many of the forty-niners later returned to Death Valley to search for precious metals within its boundaries. Small mining towns were built, such as Skidoo, Greenwater, and Chloride City, but these were soon abandoned.

In 1856, Death Valley was surveyed for the first time by the General Land Service, and by 1860 many of the present names were given to locations in the valley by the Darwin French and S. G. George prospecting parties. Prospecting and boundary fixing continued through the 1860's, and in 1870 "Bellerin" Tex Bennett started Furnace Creek Ranch, located 182 ft below sea level.

Although borax was first discovered in the valley in 1873, the industry did not really begin until 1880 when Aaron Winters sold the borax he found at Furnace Creek for \$20,000. The Harmony Borax Works began producing borax in huge quantities, transporting it out of the valley by means of gigantic high-wheeled wagons pulled by a 20-mule team. A Frenchman named I. Daunet with his Eagle Borax Works, located about 20 miles south of Furnace Creek, surpassed the Harmony Borax Works in production in 1882 with about 260,000 lbs of borax

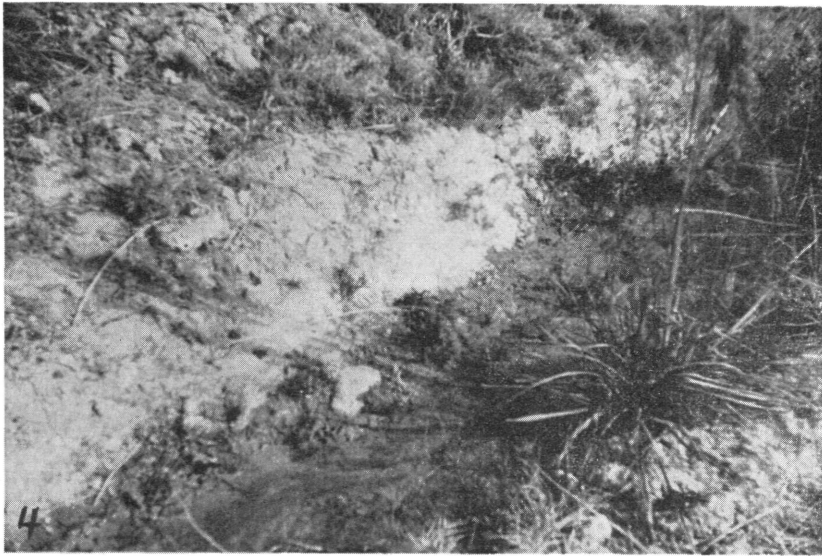


FIGURE 4. Travertine Stream. The water in this stream is ground water which has its origin well off Rt. 190 to the east. At this point, the stream is slightly greater than one ft wide, although at a higher point and near the source, it may reach a width of three ft. Zygnemataceae may be seen streaming in the water in the picture's foreground.

refined. Although in 1907 the Tonopah and Tidewater Railroad was built to carry the mineral, it was soon deserted when richer deposits were found outside the valley. There are still, however, many private companies with land interests within the valley which freight borax and other minerals out by means of trucks instead of the 20-mule team.

In 1891, the first attempt was made to study the area biologically when Dr. C. Hart Merriam and other experts in their respective areas of study set out by horseback and on foot to investigate the flora and fauna of the deserts of California, Arizona, Nevada, and Utah. During this exploration, F. V. Coville and F. Funston collected a few specimens of algae; however, it is not ascertained as to whether they were collected in the valley itself or in its environs. Drouet (1943) refers to their collections in his studies of California and Nevada desert algae.

Furnace Creek Inn, near Furnace Creek Ranch and Monument Headquarters, was built in 1926 and by 1927 tourist traffic to Death Valley had begun on a toll road built from Darwin. Because of increasing interest in the area, President Herbert Hoover established Death Valley National Monument in 1933. After President Franklin D. Roosevelt added a small portion of Nevada to the Monument, it comprised a total of 2,000,000 acres, the second largest area under the jurisdiction of the National Park Service of the Department of the Interior in continental United States.

#### ECOLOGY

Death Valley is an austere and uninviting name for a land area which, because of its variations in altitudes from below sea level to mountains of 11,000 ft above sea level, supports a wide variety of plants and animals.

The winter months, from October to May generally, are pleasant with higher humidity and lower temperatures. The summer months, especially July and August, are notorious for their extremes in seasonal temperatures and almost complete absence of atmospheric moisture. Contrary to the usual opinion, the summer nights in the valley are also hot, often with but a few degrees difference between daytime and nighttime temperatures. The highest temperature recorded in the Western Hemisphere was at Furnace Creek Ranch on July 10, 1913, when the thermometer reached 134 F in the shade (Clements, 1959). The world's highest recorded temperature is from the Lybian Desert, where in September, 1922, the thermometer registered 136 F. Relative humidity in Death Valley is usually around 1 per cent in the summer and may reach 66 per cent or more during the winter.

The mean annual rainfall in the valley is reported at around two inches. Although most rain falls in the winter, an occasional summer cloudburst may produce a flash flood, a destructive phenomenon often responsible for losses of plants and animals.

Except for the salt flats where only salt-tolerant plants survive, the sandy soil of Death Valley is not much different from that of any other desert, and with proper irrigation is quite fruitful. Furnace Creek Ranch supports an excellent grove of date palms, irrigated from streams in Furnace Creek Wash.

A variety of animals are found within the monument boundaries. The valley itself is inhabited by more species than would ordinarily be imagined. Few snakes live on the valley floor because of the extremely high soil temperatures, around 190 F during the summer months (Durrel, 1962), and those that do usually coil beneath mesquite bushes during the heat of the day. Lizards are more abundant and may be encountered even during the day scurrying over rocks and under bushes. Over 200 different kinds of birds have been reported from Death Valley, although many of these are migratory. The bird most often seen by visitors is the Black Raven. Insects are also very common, and some of the ponds are inhabited by the fish *Cyprinodon*.

Twenty-six species of mammals are known for the valley itself including many rodents such as antelope ground squirrel, kangaroo rats, jack rabbits, and pack rats. Larger mammals include the kit fox and the coyote. In the mountains, wild burros and bighorn sheep may also be seen.

A total of more than 600 species of flowering plants have been identified throughout Death Valley Monument, although just a few plants seem to dominate. The most widespread and characteristic Mojave Desert plant is the creosote bush, *Larrea divaricata*, a large, dark-stemmed, dark-green-leaved plant which often occurs in almost pure stands. Sometimes associated with it is the burro-bush, *Franseria dumosa*.

At higher elevations, near sand dunes, or near water is found the deep-rooted mesquite, which may reach tree heights and often occurs in forest-like stands.



The honey mesquite, *Prosopis juliflora*, and the Screwbean, *Prosopis pubescens*, are both found throughout the valley. Often associated with the mesquite is the introduced Australian Athel tree, *Tamarix articulata*, (also known as a species of *Casuarina*) an evergreen with gray-green foliage bearing a marked resemblance to the genus *Pinus*.

A large group of herbaceous plants make up the Death Valley picture, and scarcely a month passes without some plant flowering, although the usual time for this is in the early spring. The rarer plants, Pickleweed, *Allenrolfea occidentalis*; Inflated Stem, *Eriogonum inflatum*; Desert Holly, *Atriplex hymenolytra*; Wet-Leaf, *Boerhaavia annulata*; Death Valley Euphorbia, *Euphorbia vallismortae*; Five-Spot, *Malvastrum rotundifolium*; the Desert Bearpoppy, *Arctomecon Merriami*, and the Death Valley Sage, *Salvia funerea* are striking when seen. There are also 14 species of cacti in Death Valley, of which the most unusual is the cotton-top *Echinocactus polycephalus*.



FIGURE 5. Furnace Creek Wash. From Travertine Stream and Pond, the water flows in a cement trough, as pictured, into the Furnace Creek Ranch area. The trough runs parallel to Rt. 190.

Near the streams and ponds are large stands of grasses and sedges, the latter being primarily of the genus *Scirpus*. The Naiad *Najas marina* grows in the ponds with *Chara*.

Thus botanically, the flora encountered is largely influenced by the local environment or microclimate rather than by the climate of Death Valley as a whole. Often the entire valley is ablaze with the gold of the poppy fields, the yellow of the desert sunflowers, and the white of the primroses, and though this spectacle is not an enduring one, it nevertheless is illustrative of the abundance and variety of life to be found in such a forbidding atmosphere.

Streams and ponds in the Death Valley area differ in salt content, pH, and temperature (U.S.D.I., 1960). Although the average water temperature of Travertine Pond and Stream during the winter months is between 80 and 85 F, it may rise to as high as 120 F or more during the summer months. A comparison between Travertine Spring and Badwater illustrates that the latter has a far greater amount of dissolved solids (21,300 to 635), 86 per cent sodium (in sodium

chloride), and more boron (344.0 ppm to 1.0 ppm). The pH usually averages, in all streams and ponds, between 7.5 and 7.9, although occasionally a slightly acidic condition is found.

#### METHODS

Samples of algae were collected at the following sites: Badwater Pond, about 15 miles south of Furnace Creek; Eagle Borax Mine well and swampy area, about 20 miles south of Furnace Creek; Travertine Pond, three miles east of Furnace Creek on Rt. 190; Travertine Streams, three miles east of Furnace Creek on Rt. 190; irrigation ditches, Furnace Creek Ranch date groves; and Museum pond, Furnace Creek Ranch (map, fig. 6).

Collections from all sites except the Eagle Borax Mine (fig. 1) were made November 10 and 11, 1960; February 11 and 12, 1961; March 27, 1961, and July 23, 26, and 27, 1962.

Algae were collected from mud along the edges of the ponds and streams, scraped from rocks, taken from grasses and other plants which were partially collected from floating mats of algae, and sampled from a plankton net placed near areas of rapid water flow.

The field collections were immediately preserved in Transeau's Medium (6 parts water, 3 parts ethyl alcohol, 1 part formalin) and placed in polyethylene containers.

In addition to the algae preserved, several collections of living specimens were made November 11, 1960, and February 11, 1961, at Travertine Pond and Travertine Stream (figs. 2-5). These were maintained in 125-ml erlenmeyer flasks which were cotton-plugged. The flasks were kept in an east-facing window, and the water level was held at the 50-ml level by periodic additions of water from Travertine Stream. On May 5, 1961, the algae in these flasks were also preserved in Transeau's Medium.

Soil samples collected near Travertine Pond and Travertine Stream November 11, 1960, were dried and later placed in petri plates and moistened with distilled water. Scrapings from Travertine rock from Travertine Stream collected the same date were also placed in erlenmeyer flasks and maintained in water from the stream and later with distilled water. Resultant algae from both cultures were further subcultured in the following nutrient solution, derived from a basic complete nutrient supplemented by salts and minerals in proportion comparable to those listed in water reports of the U.S. Geological Survey (U.S.D.I., 1960).

KNO <sub>3</sub>		2 ml*
Ca(NO <sub>3</sub> ) <sub>2</sub>		3 ml
KH <sub>2</sub> PO <sub>4</sub>		2 ml
MgSO <sub>4</sub> ·7H <sub>2</sub> O		2 ml
EDTA		1 ml
metabolic elements		1 ml
	H <sub>3</sub> BO <sub>4</sub>	2.5 g
	MnCl <sub>2</sub> ·4H <sub>2</sub> O	1.5 g
	ZnCl <sub>2</sub>	0.10 g
	CuCl <sub>2</sub> ·2H <sub>2</sub> O	0.05 g
	MoO <sub>3</sub>	0.05 g
	H <sub>2</sub> O	1.01 g
NH <sub>2</sub> CO		0.10 g/l
Sr(NO <sub>3</sub> ) <sub>2</sub>		0.01 g/l
Na <sub>2</sub> CO <sub>3</sub>		0.10 g/l

\*1 Molar Solution of each nutrient.

Small sections of the original algal cultures were placed in 50 ml of the nutrient solution in 125-ml erlenmeyer flasks and plugged with cotton. All equipment including the nutrient solution had previously been sterilized by autoclaving at 15



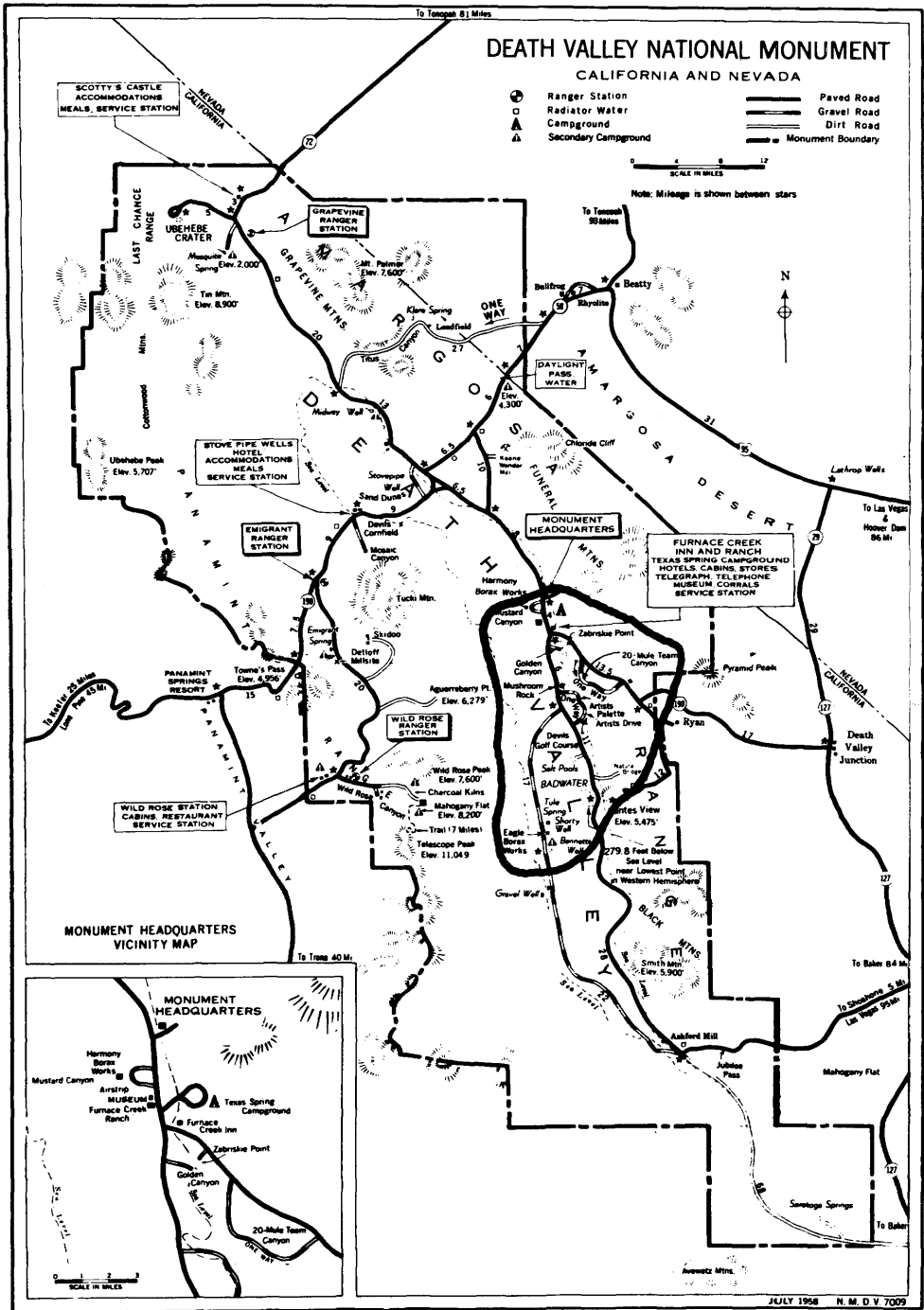


FIGURE 6. Map of Death Valley National Monument. Reprinted with permission of the National Park Service. Area investigated outlined with heavy black line.

lb pressure for 20 min. The flasks were labeled and set in a constant temperature room in which temperatures were maintained at 80 F during the day and 65 F at night. Photoperiod was timed at 12 hr light and 12 hr darkness.

Within one week of the initiation of the cultures, the flasks were almost filled with blue-green algae. This bloom then became static in growth until subcultured again. No attempt was made to isolate algae in pure or unialgal cultures, although they did, in general, become almost unialgal eventually.

Both preserved and cultured algae were examined microscopically and identified with appropriate keys. Because of the lack of reproductive structures, insufficient numbers, or inadequate keys, a few algae could not be identified to species.

Photographs of the areas where collections were made were taken February 11, 1961, and March 27, 1961.

## RESULTS

Microscopic examination of freshly-collected material as well as that cultured in the laboratory resulted in the following identified algae.

### *Myxophyceae*

#### Chroococcales:

##### Chroococcaceae:

*Anacystis montana* (Lightf.) Dr. & Daily. Cultures from Travertine Pond, May 5, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, growing in mud, March 27, 1961; Travertine Pond, March 27, 1961; culture from travertine rock collected November 10, 1960.

*Anacystis thermalis* (Menegh.) Dr. & Daily. West side of Badwater Pond, floating near edge, November 10, 1960; cultures from Travertine Stream, May 5, 1961; cultures from Travertine Pond, May 5, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, surface sample, March 27, 1961; pond behind old museum, Furnace Creek Ranch, March 27, 1961; Travertine Pond, March 27, 1961, July 23, 1962; culture from soil collected at Travertine Pond November 10, 1960; Travertine Stream above road, July 26, 1962; Museum Pond, Furnace Creek Ranch, July 23, 1962.

*Agmenellum quadruplicatum* (Menegh.) Br eb. Irrigation ditch east of date palms on Furnace Creek Ranch, growing on mud, March 27, 1961; Museum Pond, Furnace Creek Ranch, March 27, 1961; Travertine Pond, March 27, 1961.

*Coccochloris stagnina* Spreng. Cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961.

*Gomphosphaeria aponina* K utz. West side of Badwater Pond, floating near edge, July 23, 1962, November 10, 1960; cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961.

*Gomphosphaeria lacustris* Chod. Cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961.

##### Entophysalidaceae:

*Johannesbaptista pellucida* (Dickie) Taylor & Drouet. This alga was found growing prolifically in Travertine Pond during all seasons when collections were made. It was tentatively identified as *Heterohormogonium schizodichotomum* J. J. Copeland (fig. 7, C). However, the alga, though examined extensively, evidenced no branching of any kind. This is one of Copeland's diagnostic characters. Later studies of the alga refer it to the genus *Johannesbaptista*, most recently described by Desikachary (1959).

#### Chamaesiphonales:

##### Pleurocapsaceae:

*Myxosarcina amethystina* J. J. Copeland (fig. 7, A). Colonies of up to 60 cuboidal to globose cells surrounded by a firm gelatinous sheath. Reproduction is by division of cellular contents into a great number of endospores. This species was found growing abundantly in culture on sand collected from the bank of Travertine Pond, November 11, 1960.

## Oscillatoriales:

## Rivulariaceae:

*Amphithrix janthina* (Mont.) Bornet & Flahault. Cultures from Travertine Stream, May 5, 1961.

*Calothrix parietina* (Näg.) Thur. Travertine Stream in fast-flowing water, February 11, 1961; cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961, July 23, 1962.

*Gloeotrichia natans* (Hedro.) Robenh. Travertine Pond, March 27, 1961.

*Rivularia haematites* (D.C.) Ag. Travertine Stream, scraped from rocks along edge, November 11, 1960; cultures from soil collected at Travertine Pond, November 10, 1960.

## Nostocaceae:

*Aulosira implexa* Bornet & Flahault. Travertine Pond, November 11, 1960.

*Nostoc ellipsosporum* (Demmas.) Rabenh. Culture from soil collected near Travertine Stream, November 10, 1960. This same species has recently been recorded for the Sonoran Desert in Arizona by Cameron (1962).

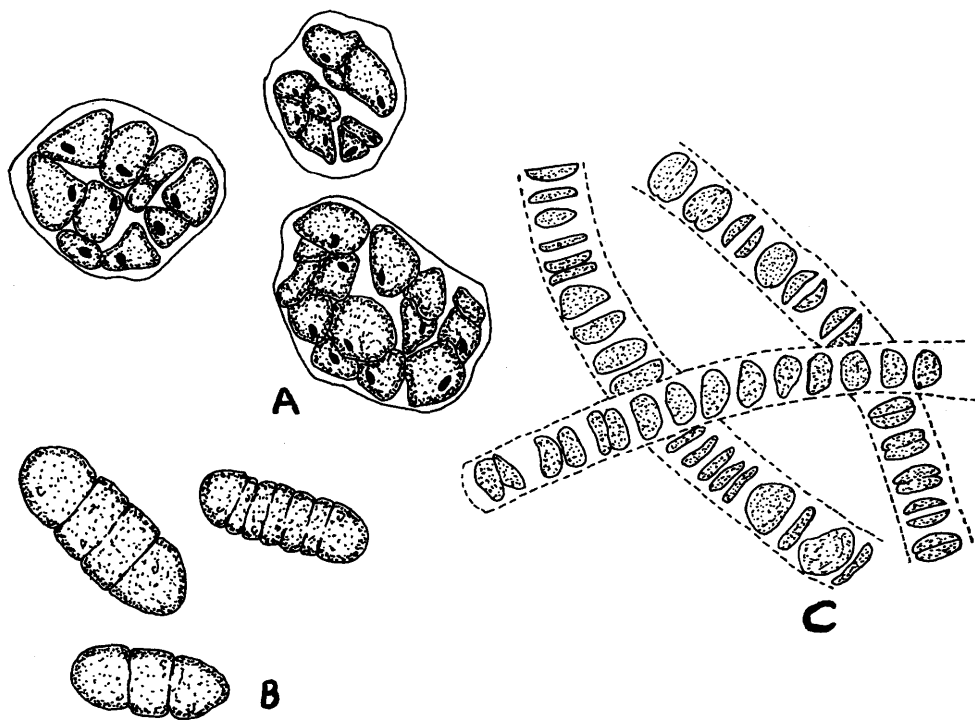


FIGURE 7. A, *Myxosarcina amethystina* J. J. Copeland, 950 $\times$ ;  
B, *Borzia trilocularis* Cohn, 440 $\times$ ;  
C, *Johannesbaptista pellucida* (Dickie) Taylor & Drouet, 440 $\times$ .

## Oscillatoriaceae:

*Borzia trilocularis* Cohn. (fig. 7, B). Irrigation ditch east of date palms on Furnace Creek Ranch, growing on mud, March 27, 1961; Travertine Stream above Rt. 190, July 26, 1962; Travertine Pond, July 23, 1962. *Borzia* is hormogonial in structure with hemispherical terminal cells. It is a rarely found alga.

*Lyngbya aestuarii* (Mert.) Liebm. Travertine Stream, scraped from rocks along edge of stream, November 11, 1960; cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961; irrigation ditch at Furnace Creek Ranch, July 23, 1962.

*Lynghya Taylorii* Dr. & Strickl. Cultures from Travertine Pond, May 5, 1961; Travertine Pond, March 27, 1961, July 23, 1962.

*Microcoleus vaginatus* (Vauch.) Gom. Travertine Stream below road, from mud, July 23, 1962; irrigation ditch at Furnace Creek Ranch, from mud, July 23, 1962; Museum Pond at Furnace Creek Ranch, July 23, 1962.

*Oscillatoria chalybea* Mert. (after Gom.) Travertine Stream, below road, July 23, 1962.

*Oscillatoria chlorina* (Kütz.) Gom. Travertine Pond, March 27, 1961.

*Oscillatoria cortiana* (Menegh.) Gom. Travertine Pond, March 27, 1961; irrigation ditch at Furnace Creek Ranch, July 23, 1962.

*Oscillatoria formosa* Bory. Travertine Pond, November 11, 1960, March 27, 1961; cultures from Travertine Pond, May 5, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, growing on mud, March 27, 1961; Museum Pond, Furnace Creek Ranch, March 27, 1961.

*Oscillatoria limosa* (Roth.) Ag. Travertine Stream, growing on mud near edge of stream, November 11, 1960; Travertine Pond, floating on surface, November 11, 1960, March 27, 1961; Travertine Pond, growing on moist mud south of pond at edge of desert, February 11, 1961; cultures from Travertine Pond, May 5, 1961.

*Oscillatoria ornata* (Kütz.) Gom. Travertine Pond, associated with *Chara*, February 11, 1961; Eagle Borax Mine, growing on surface of water in well, February 12, 1961; Eagle Borax Mine, in swampy area west of water pan, February 12, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, growing on mud, March 27, 1961; Travertine Pond, March 27, 1961.

*Oscillatoria tenuis* Ag. Travertine Pond, plankton sample near outflow, February 11, 1961.

*Phormidium autumnale* (Ag.) Gom. Travertine Pond, March 27, 1961.

*Phormidium corium* (Ag.) Gom. Travertine Pond, March 27, 1961; culture from soil collected at Travertine Pond, November 10, 1960.

*Phormidium Groesbeckianum* Dr. Travertine Pond, November 11, 1960, March 27, 1961; cultures from travertine rock collected November 10, 1960.

*Phormidium laminosum* (Ag.) Gom. Cultures from Travertine Pond, May 5, 1961; Travertine Pond, floating on surface, February 11, 1961, November 11, 1960, March 27, 1961, July 23, 1962; Travertine Stream, growing on submersed rocks and grasses in fast-flowing water, February 11, 1961, July 26, 1962; Travertine Pond, associated with *Chara*, February 11, 1961; Travertine Pond, plankton sample near outflow, February 11, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, March 27, 1961; Museum Pond, Furnace Creek Ranch, March 27, 1961, July 23, 1962; cultures from soil collected at Travertine Pond, November 10, 1960.

*Phormidium luridum* (Kütz.) Gom. Travertine Pond, November 11, 1960; cultures of algae from Travertine Pond, May 5, 1961.

*Phormidium papyraceum* (Ag.) Gom. Travertine Stream, growing on mud along the edge, November 11, 1960; cultures from Travertine Stream, May 5, 1961.

*Phormidium Retzii* (Ag.) Gom. Travertine Pond, November 11, 1960, February 11, 1961, March 27, 1961; cultures from Travertine Pond, May 5, 1961; Travertine Stream, February 11, 1961, July 23, 1962; Badwater Pond, July 23, 1962; Museum Pond, Furnace Creek Ranch, July 23, 1962; cultures from travertine rock collected November 10, 1960; cultures from soil collected at Travertine Pond, November 10, 1960.

*Phormidium subfuscum* Kütz. Travertine Pond, March 27, 1961.

*Phormidium tenue* (Menegh.) Gom. Cultures from Travertine Stream, May 5, 1961; Travertine Pond, floating on surface, November 11, 1960; cultures from Travertine Pond, May 5, 1961; Travertine Stream, July 23, 1962; Travertine Pond, July 23, 1962; irrigation ditch at Furnace Creek Ranch, July 23, 1962; Museum Pond at Furnace Creek Ranch, July 23, 1962.

*Phormidium Treleasei* Gom. Travertine Pond, March 27, 1961.

*Schizothrix friesii* (Ag.) Gom. Travertine Stream, July 23, 1962.

#### *Euglenophyceae*

#### Euglenales:

#### Euglenaceae:

*Euglena acus* Ehr. Travertine Pond, November 11, 1960.

*Euglena polymorpha* Dang. Travertine Pond, November 11, 1960, March 27, 1961; irrigation ditch east of date palms on Furnace Creek Ranch, March 27, 1961; Museum Pond, Furnace Creek Ranch, March 27, 1961.

*Cryptoglena pigra* Ehr. Culture from soil collected at Travertine Pond, November 10, 1960.

#### *Chlorophyceae*

##### Ulotrichales:

###### Ulotrichaceae:

*Ulothrix aequalis* Kütz. Irrigation ditch east of date palms at Furnace Creek Ranch, March 27, 1961.

##### Oedogoniales:

*Oedogonium* sp. Filaments were noted in collections made November, 1960, February, 1961, March, 1961, and July, 1962 at Travertine Pond, Travertine Stream, Museum Pond, and irrigation ditches. Specific identification was not possible because the algae were in a vegetative state. One oogonium was observed in the February 11, 1961 sampling from Travertine Stream, but this was not sufficient for further identification, and subsequent searchings yielded no other reproductive structures.

##### Chlorococcales:

###### Chlorococcaceae:

*Chlorococcum humicola* (Näg.) Rabenh. Cultures from Travertine Stream, May 5, 1961; cultures from Travertine Pond, May 5, 1961; Travertine Pond, July 23, 1962; culture from travertine rock collected November 10, 1960; culture from soil collected at Travertine Pond, November 10, 1960.

###### Oocystaceae:

*Chlorella vulgaris* Beijerinck. Culture from soil collected at Travertine Pond, November 10, 1960.

##### Zygnematales:

###### Zygnemataceae:

*Mougeotia genuflexa* (Dillw.) C. A. Agardh. Travertine Pond, March 27, 1961. *Mougeotia* was also observed from Travertine Pond and Travertine Stream in the November and February collections, but the material on these dates was vegetative.

*Spirogyra* sp. At least four different species of *Spirogyra* were noted from the Furnace Creek Wash area in samples collected November, 1960, February, 1961, March, 1961, and July, 1962. Aplanospores were found with filaments collected from an irrigation ditch at Furnace Creek Ranch on March 27, 1961, but no evidence of sexual reproduction was ever found. Macroscopic observations of algae at the Eagle Borax Mine in March, 1959, also indicated that at times a flora of Zygnemataceae may be found there.

*Zygnema* sp. Associated with *Spirogyra* and *Mougeotia*, in the Furnace Creek Wash area, specimens were collected November, 1960, February, 1961, and March, 1961. No reproduction was observed, although a slight swelling was seen on some of the filaments collected February 11, 1961.

###### Desmidiaceae:

*Cosmarium rectangulare* var. *hexagonum* Elfv. Travertine Pond, November 11, 1960, February 11, 1961, March 27, 1961; Travertine Stream, February 11, 1961; irrigation ditch east of date palms at Furnace Creek Ranch, March 27, 1961; Museum Pond, Furnace Creek Ranch, March 27, 1961, July 23, 1962.

##### Charales:

###### Characeae:

*Chara* sp. Large clumps of this genus were observed growing on the mud bottom of Travertine Pond during all collecting seasons (fig. 3). No reproductive structures were noted.

#### *Bacillariophyceae*

In addition to the algae already listed, an extensive diatom flora was studied. Because of

the difficulties encountered in classifying this unique group to species, only the genera are listed in this paper:

<i>Navicula</i>	<i>Cymbella</i>
<i>Synedra</i>	<i>Surirella</i>
<i>Epithemia</i>	<i>Acnanthes</i>
<i>Cocconeis</i>	<i>Gomphonema</i>
<i>Nitzschia</i>	<i>Cyclotella</i>
<i>Fragillaria</i>	<i>Biddulphia</i>

All preserved specimens as well as living cultures are at present at the Department of Botany and Plant Pathology, The Ohio State University, Columbus, Ohio, in my possession.

#### DISCUSSION

In March, 1959, members of the Zygnemataceae were observed growing profusely in an extensive swampy area at the Eagle Borax Mine. This site, located about 20 miles south of Furnace Creek, consisted of a deserted kiln and water pan. Athel trees and mesquite formed a dense thicket about three miles long in the center of the desert. Horses were observed living in the area, and the soil near the water pan and under the trees was often quite black, contrasting markedly with the sandy, salted soil of the surrounding desert.

Because it seemed unusual to find algae growing in such an unlikely place as Death Valley, and although the algae at that time could not be identified to species, it was felt that further investigations be incurred to determine the algal flora of the valley.

Death Valley National Monument covers such a wide area that a work of this scope could take years of constant collecting; however, preliminary investigations could easily be undertaken by sampling select streams and ponds during specific months of the year. Although the complete flora would not be identified, a study of the algae present during those specific times correlated with the general ecology of the area could present a pattern which would be useful in later studies.

Death Valley was revisited in November, 1960, and again in February, March, 1961, and in July, 1962 (these latter collections were made by the rangers in the Monument). In addition to algal samples, the flowering vegetation was also collected and environmental conditions noted. The results of these trips and culture work of the algae have already been mentioned.

Although in general Death Valley, as is true of many desert areas, is regarded as having alkaline ponds which are highly toxic to animals, water surveys do not always confirm this hypothesis. Travertine Pond and Streams are not especially alkaline (pH 7.9), and even Badwater is only pH 7.5. Various mineral salts may be dissolved or suspended in the waters, but for the most part these merely impart a rather bad taste to the water.

The ponds and streams of Death Valley are rich in an unexpected flora and fauna. Aquatic insects and snails, and even occasionally fish, are found abundantly, and the basis of their food chain must necessarily be a smaller form of life, usually algae.

Algae have existed in Death Valley for millions of years as evidenced by fossils found in limestone beds. Deposits of diatomaceous earth have also been discovered in the Pliocene rocks near Furnace Creek (Jaeger, 1957). However, it has been only recently that any major interest in the algae living in the ponds, streams, on soil, or on rock has developed. Many of the algae which exist in the salt ponds in the valley will not be covered in this paper.

That many of the algae are relicts of the ancient Lake Manly is evident when one studies the diatoms. *Biddulphia*, generally considered a marine or estuary genus, is one of the more prolific forms in freshwater Travertine Pond. It is possible that it survived the ecological changes and became adapted, probably



through mutations, to existence in a new environment. The diatoms are an unusual group of algae, and their study is complicated by the difficulty involved in specific identifications, but they are also beneficial in that they are anachronisms of sorts which aid in piecing together the geological history of certain land regions.

It is believed that there is a similiarity and correlation between algae in American deserts with algae in other deserts of the world because of similar environmental conditions. Elazari-Volcani (1940) did preliminary work on the so-called sterile Dead Sea and found, in addition to bacteria, living blue-green and green algae growing profusely on bottom mud samples. A rich desposit of fossil diatoms was also studied.

Studies in Egyptian deserts have yielded large numbers of different species of which the majority were desmids (El-Mayal, 1932, 1936). At the present time, Dr. I. Friedman of the Hebrew University, Jerusalem, is working on algae of the Negev Desert (personal correspondence) and has found blue-greens similar to those identified from Death Valley.

A few samples from selected sites in Arnhem Land in Northern Australia resulted in a collection of algae similar to those found in Egypt, i.e., a large variety of desmids in addition to greens and blue-greens. As only five samples were studied, only a general idea of the algal flora of that area is known, but the results are of some significance (Scott and Prescott, 1958).

Three investigations of the algae of Death Valley, including the present work, have been made since 1943, and the results have been tabulated in the following check lists. The lists are arranged by author and date of the investigations.

Drouet in 1943 collected Myxophyceae in the desert areas of Western Nevada and Eastern California. He also studied other collectors' samples, of which several came from Death Valley. His work resulted in the following Death Valley blue-greens, site of collection, collector, and date:

*Gloeocapsa violacea* Kütz. First spring south of Triangle spring, Grinnell, October, 1933.

*Chroococcus rufescens* (Kütz.) Näg. Culture from: Badwater, Holman & Bonar, April, 1933; cold alkaline stream, Gnome's Workshop, Groesbeck, Jan., 1951; Nevares Spring, Munz, April, 1937.

*Chroococcus turgidus* (Kütz.) Näg. First spring south of Triangle spring, Grinnell, October, 1933; in tepid spring, Furnace Creek Wash, Groesbeck, Jan., 1941; cold alkaline spring, Gnome's Workshop, Groesbeck, October, 1940.

*Gomphosphaeria aponina* Kütz. Alkaline pool, Badwater, Holman & Bonar, April, 1933; Groesbeck, Feb., Oct., 1940, Jan., 1941.

*Haplosiphon pumilus* (Kütz.) Kirchn. Sides of wood flume about 1 mile east of Furnace Creek Inn, Groesbeck, Feb., 1940.

*Amphithrix janthina* (Mont.) B & F. On *Ruppia* in a salt pool, Groesbeck, October, 1940.

*Dichothrix inyoensis* Drouet. In a very shallow pool in a salt playa on the floor of Death Valley, 35.7 miles south of Furnace Creek on the east highway, Groesbeck, Feb., 1940.

*Dichothrix gypsumhila* (Kütz.) B & F. Inyo County, Death Valley, Parish.

*Aulosira implexa* B & F. In a warm spring up Furnace Creek Wash about 1 mile from the hotel, Grinnell, October, 1933.

*Scytonema figuratum* Ag. Ex B & F. Nevares spring near Cow Creek, Munz, April, 1937.

*Schizothrix coriacea* (Kütz.) Gom. In flume in Furnace Creek Wash, Groesbeck, Jan., 1941.

*Schizothrix lardacea* (Ces.) Gom. First spring south of Triangle spring, Grinnell, October, 1933.

*Hydrocoleum Groesbeckianum* Drouet. Bottom of a brine-pool, salt playa on floor of Death Valley 35.7 miles south of Furnace Creek on east highway, Groesbeck, Feb., 1940.

*Plectonema nostocorum* Born. Ex Gom. Culture from Badwater, Death Valley, Holman and Bonar, April, 1933; stream about ½ mile east of Furnace Creek Inn, Groesbeck, Feb., 1940.

*Plectonema Wollei* Farl. ex Gom. In Furnace Creek, Parish, May, 1905. October, 1933.

*Phormidium tenue* (Menegh.) Gom. On the standpipe at Furnace Creek Ranch, Grinnell,

October, 1933.

*Phormidium uncinatum* (Ag.) Gom. On plant stems, pool in stream flowing from Monument headquarters to the playa in the bottom of Death Valley, Groesbeck, Feb., 1940.

*Oscillatoria tenuis* Ag. ex Gom. Near Borax Lake, Wilkenson, June, 1910; with *Phormidium uncinatum* on plant stems, pool in stream flowing from Monument headquarters to a playa in the bottom of Death Valley, Groesbeck, Feb., 1940.

*Oscillatoria chalybea* Mert (after Gom.) In a tepid spring in Furnace Creek Wash, Death Valley, Groesbeck, Jan., 1941.

Durrell (1962) working with the U.S. Geological Survey, published on Death Valley algae in which he investigated primarily the soil and crust-forming algae at various sites in the valley. He reported the following:

*Chlorophyta:*

*Chlorococcum humicola* (Näg.) Rabenh.  
*Chlorella vulgaris* Beijerinck  
*Protococcus viridis* Agardh.  
*Rhizoclonium hieroglyphicum* (C. A. Ag.)  
 Kütz.

*Phormidium angustissimum* W. & G. S. West  
*Phormidium Retzii* (Ag.) Gom.  
*Phormidium subcapitatum* Boye P.  
*Phormidium ambiguum* Gom.  
*Phormidium dimorpha* Lemm.  
*Phormidium foveolarum* (Mont.) Gom.  
*Lynghya thermalis* Roth.  
*Microcoleus vaginatus* (Vauch.) Gom.  
*Anabaena variabilis* Kütz.  
*Nostoc commune* Vauch.  
*Nostoc muscorum* Agardh.  
*Tolyptothrix distorta* Kütz.  
*Calothrix Castellii* Fremy  
*Coccolithis stagnale* Sprengel.

*Cyanophyta:*

*Anacystis montana* (Lightf.) Drouet and  
 Daily  
*Gomphosphaeria apoina* Kütz.  
*Chamaesiphon incrustans* Grunow  
*Oscillatoria Agardhii* Gom.  
*Phormidium tenue* (Menegh.) Gom.

The results of this investigation have added 32 species of algae to the number of those already recorded. These are:

*Anacystis thermalis* (Menegh.) Dr. & Daily  
*Agmenellum quadruplicatum* (Menegh.) Bréb.  
*Gomphosphaeria lacustris* Chod.  
*Myxosarcina amethylstina* J. J. Copeland  
*Johannesbaptista pellucida* (Dickie) Taylor &  
 Drouet  
*Calothrix parietina* (Näg.) Thur.  
*Gleotrichia natans* (Hedro.) Robenh.  
*Rivularia haematites* (D.C.) Ag.  
*Nostoc ellipsosporum* (Demmas.) Rabenh.  
*Borzia trilocularis* Cohn.  
*Lynghya aestuarii* (Mert.) Liebm.  
*Lynghya Taylorii* Dr. & Strickl.  
*Oscillatoria chlorina* (Kütz.) Gom.  
*Oscillatoria cortinana* (Menegh.) Gom.  
*Oscillatoria formosa* Bory.  
*Oscillatoria limosa* (Roth) Ag.

*Oscillatoria ornata* (Kütz.) Gom.  
*Phormidium autumnale* (Ag.) Gom.  
*Phormidium corium* (Ag.) Gom.  
*Phormidium Groesbeckianum* Dr.  
*Phormidium laminosum* (Ag.) Gom.  
*Phormidium luridum* (Kütz.) Gom.  
*Phormidium papyraceum* (Ag.) Gom.  
*Phormidium subfuscum* Kütz.  
*Phormidium Treleasei* Gom.  
*Schizothrix friesii* (Ag.) Gom.  
*Euglena acus* Ehr.  
*Euglena polymorpha* Dang.  
*Cryptoglena pigra* Ehr.  
*Ulothrix aequalis* Kütz.  
*Mougeotia genuflexa* (Dillw.) Agardh.  
*Cosmarium rectangulare* var. *hexagonum* Elfv.

In addition to these species, *Zygnema*, *Spirogyra*, *Oedogonium*, and *Chara* were found growing abundantly during most seasons. Diatoms were also studied, and 12 genera of these are listed under results.

Perhaps the most important factor controlling algal growth in Death Valley is temperature. The winter months are not especially severe, but summer, especially July and August often finds the thermometer soaring into the 120's and 130's Fahrenheit. Water temperatures may rise as high as 120 F and remain at this level for weeks or even months. That any living thing could endure in this situation does not seem plausible.

Nevertheless, as Copeland (1936) revealed in his work with Yellowstone Thermal Myxophyceae, algae can and do grow prolifically in tepid waters. The results of the Death Valley survey confirm that the greatest number of algae found growing throughout the year in these ponds and streams belonged to the Myxophyceae, and more especially to the Oscillatoriaceae. *Phormidium* and *Oscillatoria* are represented by the largest number of species, and it is probable that some were overlooked.

The Myxophyceae are also known to inhabit waters which tend to be slightly alkaline. Many of the genera form travertine deposits, and the concentration of carbonates in the streams and ponds in addition to the presence of travertine-forming blue-greens explains these thick deposits adequately. Although many of the blue-greens are soil inhabitants, these were not studied as intensively as were those closely associated with the ponds and streams.

The Myxophyceae are not an easy group to identify specifically. Drouet (1956, 1957) revised the classification of the coccoid Myxophyceae, and in his key eliminated many of the filamentous species. Because this key is acknowledged as being the most recent, it was used as the basis of the identifications in this paper. Often only fragments of trichomes or filaments were found; therefore, not all the blue-greens were identified, but on a whole, this group was classified more completely than any other. The class also composed the largest concentration of algae found in Death Valley.

The difficulty in identification of the Chlorophyceae lay in the absence of reproductive structures. With the exception of *Mougeotia genuflexa*, no reproductive features were found. Smith (1950, 1955) observes, though, that "Zygnemataceae and Oedogoniaceae often occur in abundance in gently flowering portions of streams, but rarely in a fruiting condition." The culturing of these forms may lead to their eventual identifications.

The only culture work which was done was with soil algae and travertine-forming algae. The work was quite successful, but again the dominant forms were Myxophyceae.

Death Valley has several freshwater ponds and streams, especially in its northern extremes, which, as far as is known, have not been studied. It would be interesting to collect in and observe these new areas as well as return to the ones already sampled and to continue this work continuously over several years. Because of the ecological conditions of the valley, the Myxophyceae, especially thermophilic ones, would probably still comprise the majority of species. But the work would certainly be beneficial to further our understanding of the biology of seemingly barren desert regions.

#### SUMMARY

Collections of algae growing in select ponds and streams in Death Valley were begun November, 1960, and concluded July, 1962. Algae were also cultured in the laboratory.

Identifications to species were made of both those forms collected in the field as well as of those cultured in the controlled environment room. This was done as accurately as possible, but because of the absence of certain necessary structures, many algae could not be classified. In this survey, 36 Myxophyceae, 3 Euglenophyceae, and 4 Chlorophyceae were identified to species, 32 species being previously unrecorded. In addition, there were several species of *Zygnema*, *Mougeotia*, *Spirogyra*, *Oedogonium*, and *Chara* which could not be so identified.

Death Valley still presents a challenge to anyone interested in studying the algal flora within its boundaries. This study is by no means complete. It is hoped that with further work and with the contribution of this paper, its completion may be achieved.

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