The algal flora of the East Gallatin River as a contribution to the Algae of Montana
by Veda Jacobs

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Botany
Montana State University

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section of the East Gallatin Elver and its tributaries in the vicinity of Bozeman, Montana was studied in an effort to determine the species of algae present and to determine the effect of Bozeman sewage on algal growth. From systematic collections made during July and August. Cladophora, Spirogyra, and Oscillatoria were found to be the dominant genera in the East Gallatin River. Bridger Creek, and Rocky Creek, while . Nostoc, Monostroma, and Bhisoclonium were the dominant forms in Bear Creek. Oscillatoria, Stigeoclonium, Mougeotia, and Spirogyra noticeably increased in quantity of individuals as the season advanced, while Cladophora, Rhizoclonium, and Vaucheria showed no appreciable increase. Twenty-five genera including twenty-nine species and two varieties were identified eight additional species were tentatively identified, and four unknown species were described but not named. A key based on vegetative characteristics was made by which the algae in the area studied could he identified to genus. The conclusion that the Boseman sewage did not grossly pollute the East Gallatin River was based on two determinations: (1) that although the number of individual algae was decreased® the number of species was scarcely affected in the immediate area of the sewage outlet, and (2) that the notmal algal picture was resumed one and one-half miles downstream from the sewage outlet. -

THE ALGAL FLORA OF THE EAST GALLATIN RIVER
AS A CONTRIBUTION
TO THE ALGAE OF MONTANA

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VEDA JACOBS

A THESIS

Submitted to the Graduate Faculty

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ABSTRACT

A section of the East Gallatin River and its tributaries in the vicinity of Bozeman, Montana was studied in an effort to determine the species of algae present and to determine the effect of Bozeman sewage on algal growth. From systematic collections made during July and August, Cladophora, Spirogyra, and Oscillatoria were found to be the dominant genera in the East Gallatin River, Bridger Creek, and Rocky Creek, while Nostoc, Monostroma, and Rhizoclonium were the dominant forms in Bear Creek. Oscillatoria, Stigeoclonium, Mougeotia, and Spirogyra noticeably increased in quantity of individuals as the season advanced, while Cladophora, Rhizoclonium, and Vaucheria showed no appreciable increase. Twenty-five genera including twenty-nine species and two varieties were identified, eight additional species were tentatively identified, and four unknown species were described but not named. A key based on vegetative characteristics was made by which the algae in the area studied could be identified to genus. The conclusion that the Bozeman sewage did not grossly pollute the East Gallatin River was based on two determinations: (1) that although the number of individual algae was decreased, the number of species was scarcely affected in the immediate area of the sewage outlet, and (2) that the normal algal picture was resumed one and one-half miles downstream from the sewage outlet.

INTRODUCTION

Since at the present time very little study has been made of the algal flora of Montana from a taxonomic standpoint, there is a vast field open for determinative and comparative work. That we have a wealth of algal forms which are in common with many parts of the world is expected. That we have species remaining to be discovered, described and published is very probable. A systematic survey has never been made, although isolated collections of algae are reported by several collectors. This paper is a very meager beginning of an investigation of the species of algae found in our state. It is hoped that when a study of the algae of Montana is undertaken that this report of the algae of the East Gallatin River and its tributaries will be a helpful contribution to the all-inclusive work, an aid to a greater study. This paper is merely a preliminary report; the list of species is by no means complete. Seasonal scarcity of many species is caused by the comparatively short length of time the field work was carried on. The East Gallatin River would furnish additional species if studied at different seasons of the year.

In the following pages will be given an account of the species of algae found and identified. The study is predominantly that of Chlorophyceae, with Myxophyceae being represented by three genera. One genus each of Heterokontae and Rhodophyceae are listed. Bacillarieae are not classified because of the lack of time for investigation.

The author is grateful to Dean F. B. Cotner of Montana State College for suggesting this study and for his valuable assistance during its progress.

MATERIALS AND METHODS

The East Gallatin River is formed by the junction of Bear Creek with Rocky Creek. During the summer when a large percent of the waters of Bear Creek are taken out for irrigation at Mt. Ellis Academy, Rocky Creek is the main tributary of the river. No noticeable change in appearance occurs after the waters of Rocky Creek are joined by Bear Creek. Small Kelly Creek joins these combined waters one mile farther west, while Bridger and Bozeman Creeks add their flow to make the river north of Bozeman much larger. The East Gallatin is not a turbulent one; its shallow waters flow quietly with occasional deeper pools or contrasting rippling stretches.

The area selected for study included the stretch of river from its point of formation four miles east of Bozeman to a bridge three and six tenths miles northwest of the city. Ten collecting stations were established at intervals on the river. These were determined by their accessibility and by their positions near points which were expected to influence the algal picture. These stations were visited at frequent intervals, each one at least twice per week during an eight-week period. Others, as stations B, D, E, and G (see map, p. 71), being very rich in many species, were studied an average of four times a week. During certain periods daily collections were made at these points. Collections were not confined to the ten main stations. The map shows additional collecting areas. As the work progressed, Bear Creek became increasingly interesting as a source of material and much time was spent collecting specimens from it.

Specimens were studied in the laboratory and preserved in Transeau's solution[1] suggested by Tiffany (1938). Water samples from nine stations (see Chart I) were analysed for carbonate and bicarbonate content by use of the Alkalinity Method (Ellis, 1948) while pH values of the water samples were determined by means of the Beckman Glass Electrode pH Meter.

Identification of genera was made by consulting Smith (1933). Further identification of Chlorophyceae, Rhodophyceae, and Heterokontae to species was done with the aid of Wolle (1887), De Toni (1889), and Wood (1972). Tilden (1910) and Wolle were the authorities for Myxophyceae species.

Drawings of undetermined genera were made with the aid of a camera lucida and are included with this report.

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[1]Transeau's solution: water, 6 parts; 95% alcohol, 3 parts; 40% formalin, 1 part; a little copper sulfate.

VEGETATIVE KEY TO THE GENERA OF FRESH WATER ALGAE OF THE EAST GALLATIN RIVER

A. Cells grass green or yellowish green
    Cells spherical or oval   page
      Cells free-swimming; solitary..............Chlamydomonas(20)
      Cells united in colonies
        Colony in gelatinous matrix................Tetraspora(21)
        Colony not gelatinous
          Cells extremely variable in size.......Chlorococcum(35)
          Cells not conspicuously different
              in size..........................Protococcus(28)
    Cells rectangular, elongate or lunate
      Cells solitary
        Cells rigid, lunate; no eye spot...........Closterium(44)
        Cells not rigid, changing shape
            easily; red eye spot....................Euglena(46)
      Cells in colonies
        Cells not seriately united in
            filaments
          Thallus a hollow tube.................Enteromorpha(33)
          Thallus a bright green sheet............Monostroma(34)
        Cells seriately arranged in branched
            or unbranched filaments
          Filaments branched
            Filaments without cross walls..........Vaucheria(36)
            Filaments with cross walls
              Macroscopic colony a firm jelly,
                  green, size of pea or cherry...Chaetophora(27)
              Macroscopic colony not a
                  firm jelly
                Branch ends broadly rounded,
                    cell membrane thick...........Cladophora(29)
                Branch ends pointed, cell
                    membrane thin
                  Branches in lateral clusters;
                      stem cells much more
                      broad than branch cells...Draparnaldia(27)
                  Branches not in lateral
                      clusters; stem and
                      branch cells approx-
                      imately same width.......Stigeoclonium(26)
          Filaments unbranched
            Filaments without transverse walls.....Vaucheria(36)
            Filaments with transverse walls
              Walls of some cells with
                  transverse striations...........Oedogonium(32)
              Walls of cells with no trans-
                  verse striations

Chloroplast or chloroplasts axial
Chloroplasts irregularly lobed, two to a cell............Zygnema(39)
Chloroplast an axial ribbon......Mougeotia(38)
Chloroplast or chloroplasts parietal
Chloroplast a spiral ribbon......Spirogyra(40)
Chloroplast not a spiral ribbon
Chloroplast girdle-shaped encircling most of cell..........................Ulothrix(24)
Chloroplast entirely encircling cell
Cell wall not composed of H-pieces...........Rhizoclonium(31)
Cell wall composed of interlocked H-pieces
Cells barrel-shaped, 10.5 mic. wide; walls of stout H-pieces................Tribonema(18)
Cells cylindrical, 17.5 mic. wide; walls of delicate H-pieces...............Microspora(25)

A'. Cells not grass green or yellowish green
Cells solitary......................................Diatoms
Cells united in filaments
Filaments unbranched
Filaments of spherical cells; heterocysts present......................Nostoc(14)
Filaments of rectangular cells; no heterocysts present
Cell pigment blue-green; not contained in chromatophores......Oscillatoria(11)
Cell pigment golden brown; contained in chromatophores...............Diatoms
Filaments branched
Filaments brown; cells multiseriate; branching irregular...................Stigonema(15)
Filaments bluish-green or olive; cells uniseriate; branches in dense clusters...............Batrachospermum(17)

DESCRIPTION AND CLASSIFICATION OF SPECIES

The confusion which arises when identification to species is attempted is often frustrating to the worker. The differences of opinion among authorities is extremely discouraging. Hazen (1902) gives Microspora as an example, saying that Rabenhorst, Kuetzing and others describe its diameter as 7.5-10 mic.; Cook and Wolle increase it to 14-17 or 18 mic.; while De Toni combines these making the diameter 10-18 mic. The East Gallatin specimens were uniformly 17.5 mic. Hazen says much confusion has resulted in the incorrect determination of specimens in forcing a given form into a certain species, i.e., stretching a specific diagnosis so as to include specimens varying in what is believed to be unimportant details to avoid burdening literature with new species. He adds: "The evil results of De Toni's wholesale grouping of species of ill-defined character may be seen in the very unreliable determinations of species by certain American writers who seem to have pinned their faith to his work."

Collins (1928) supplemented his book with two papers in which he listed so many substitutions, insertions, cancellations and additions that Tiffany's remarks seemed most appropriate. Tiffany reflected that scientists must organize and reorganize, classify and reclassify, correlate and recorrelate factual and inferential material.

Hazen deplores the use of cell measurements to separate species and says its use has been resorted to in a much greater degree than he had expected. Collins emphasizes this in his discussion of Spirogyra when he says dimensions of filaments are too uncertain to have much weight except when associated uniformly with other characteristics. In the books of Hazen, Collins, Croasdale (1935) and Setchell-Gardner (1903) can be found decisions that previously identified species were not correct. Criticism of others' work Hazen calls essential in causing improvement. Some species in this paper likewise will come in for later critical questioning. Thus classifying and reclassification has its place in the advancement of science.

MYXOPHYCEAE

This class includes the organisms commonly known as the blue-green algae. All species of this category contain the blue pigment phycocyanin in addition to chlorophyll and carotinoids. This group of plants also differs from other algae in that the pigments are distributed throughout the entire peripheral part of the cell without the presence of definite chromatophores. The nuclear material is not enclosed within a nuclear membrane.

HORMOGONALES

This order includes those plants in which the organization of the thallus is multicellular and filamentous. The filaments or trichomes may break into few-celled segments or hormogones.

OSCILLATORIACEAE

The filaments (trichomes) of this family are always uniseriate, unbranched, and except for apical and immediately adjacent cells, are of the same diameter throughout.

OSCILLATORIA

This genus was, according to Tilden, described by Vaucher in 1803. It includes species with free somewhat motile cylindrical trichomes without a sheath or rarely enclosed in a thin mucous sheath.

Oscillatoria chlorina Kuetzing.

Trichomes 3 mic. wide, not constricted at joints, apex very slightly curved; cytoplasm almost colorless, filled with blackish granules; transverse walls pellucid; filaments constantly moving slowly and steadily through the water.

Tilden and Croasdale both mention the plant mass of yellow-green. This feature was not observed in this study as specimens found were not in pure colonies but were mixed with *O. tenuis* Ag. at stations E, G, and V.

For illustrations see Tilden (1910) plate 4, figure 22; Wood (1872) plate 1, figure 1.

Oscillatoria cruenta Grunow.

Very similar in appearance in color and other characteristics to O. natans Kuetz. with the following differences: filaments slightly narrower, 6 mic. wide with articulations about 4 mic.; filaments looped, coiled or curved instead of straight; apex smoothly convex.

Found associated with Tetraspora gelatinosa (Vauch.) Desv. being observed microscopically when samples of T. gelatinosa were being studied. This Oscillatoria species was never observed by itself but only in the gelatinous mass of the T. gelatinosa colonies. Wolle mentions this relationship and notes a purplish tint which was not noted here. The color of the gelatinous mass was yellow-green.

For illustrations see Wolle (1887) plate CCVI, figure 5, and plate CCVII, figures 4-7.

Oscillatoria limosa Agardh.

Trichomes straight, not constricted at joints, cells 14-17.5 mic. wide, 3-7 mic. long; apex of trichome curved convexly; transverse walls paralleled by rows of dots which are cyanophycin granules; cells more brownish than the usual blue-green color of other species.

Found only sparingly in early part of summer mixed with O. tenuis. A pure stand found in August under the bridge at station G was a dark brown colony rising from the mud, standing approximately 3 cm high. This is the largest Oscillatoria species found in the area studied.

For illustrations see Tilden (1910) plate 4, figure 6; West (1916) page 42, figure 29a.

Oscillatoria natans Kuetzing.

Trichomes straight or curved, cells 7 mic. wide, 7 mic. long; cells blue-green; apex of many trichomes definitely tapering to a knob, but other trichomes with exactly the same appearance and measurements otherwise, have a convex apex. Found very commonly at all stations appearing in bluish-green to blackish masses coating rocks rather than mud.

For illustration see Wolle (1887) plate CCVI, figure 19.

Oscillatoria tenuis Agardh.

Trichomes straight or slightly curved; cells 3.5 mic. wide, not quite so long as broad; apex of trichome convex, not tapering; cells light blue-green, contents finely granular, almost homogeneous. Pure stands varying from bright to dark green were very common at all stations in the river on mud at shore, or on muddy bottom of river where water was 2 or 3 feet deep and flowing slowly.

For illustration see Tilden (1910) plate 4, figures 17-18.

NOSTOCACEAE

Filaments of this family regularly form heterocysts. The filaments are unbranched and uniseriate and are always surrounded by a homogeneous sheath. Akinetes are a frequent occurrence in all genera.

NOSTOC

The gelatinous thallus surrounding the intertwined trichomes of this genus is of firm consistency. It may be solid or hollow, often reaching a diameter of several inches. Trichomes possess intercalary heterocysts.

Nostoc comminutum Kuetzing.

Thallus approximately 0.3 cm - 2 cm in diameter, usually 1 cm, gelatinous, hollow, yellowish-brown, sometimes tinged with green; gelatin very soft, thin, easily torn; trichomes only fairly densely entangled; cells 4 mic. in diameter, spherical, often depressed spherical and closely connected; heterocysts spherical, 6 mic. in diameter, intercalary. Plant mass attached to rocks in Bear Creek, station R.

Nostoc parmilioides Kuetzing.

Colonies disk-shaped, quite hard, up to 1 cm in diameter; brownish out of water, but dark blue-grey irridescent under water; attached to stones with thallus standing usually perpendicular to article of attachment; trichomes very densely packed and interwoven; spherical cells 4 mic. wide, heterocysts 6 mic. spherical, intercalary. Found only in upper Bear Creek, very numerous just below Cooper Reservoir, gradually giving way to

N. verrucosum (Linn.) Vauch. down stream and not appearing after about 3 miles down stream from Cooper Reservoir.

For illustration see Tilden (1910) plate 8, figure 20.

Nostoc verrucosum (Linnaeus) Vaucher.

Thalli of varying sizes 5 mm in diameter to 8 cm x 3 cm; small thalli dark brown, firm, solid; larger ones hollow, more easily torn, with tinge of green; trichomes densely packed, cells 3.5 mic. in diameter, a bit subspherical, closely connected; heterocysts intercalary, spherical, 7 mic. in diameter. Very common in Bear Creek and Meadow Creek, station V. No colonies noted in the East Gallatin River.

For illustrations see Tilden (1910) plate 8, figures 11-16.

STIGONEMATACEAE

Trichomes of this family exhibit true branching which is not shown by any other family in the Hormogonales. Heterocysts are formed by all genera.

STIGONEMA

The main axes of trichomes of this genus are multiseriate, Branches may be either multiseriate or uniseriate. The sheaths around the trichomes are of firm texture and if colored, are yellowish to brown or black.

Stigonema informe Kuetzing.

Filaments brownish, somewhat mucous; small filaments 1 mm wide, 2-10 cm long, unbranched or with very short fuzz-like branches; older filaments with many branches giving feathery appearance; branches 30-40 mic. wide, cells 10-14 mic. in diameter, spherical; trichomes of several rows of cells both in main filaments and in branchlets. Found only in Bear Creek and New World Gulch Creek, stations P and Q.

For illustrations see Wood (1872) plate 8, figure 4; Tilden (1910) plate 15, figure 21.

RHODOPHYCEAE

All organisms of this class contain the red pigment, phycoerythrin, in addition to chlorophyll and the carotinoids. Phycocyanin is sometimes present also. These pigments are localized in plastids. The reserve food is stored in the form of "floridean starch". Motile reproductive cells are lacking. Sexual reproduction is practically universal in this class, and is never isogamous. Red algae played a great part in geologic ages in the building up of rocks and reefs, a process which is still going on in tropic seas today.

NEMALIONALES

Members of this order are all fresh water organisms. Alternation of generations occurs, with the plants being haploid. Growth of the thallus is always terminal from apical cells. In the sexual reproduction the carpogones (female organs) have conspicuous trichogynes (long slender structures through which male nuclei pass).

BATRACHOSPERMACEAE

Organisms of this family are characterized by a distinct main axis from which much smaller lateral branches are borne in whorls. Carpogones and antherids are produced by mature plants only, with juvenile plants forming monospores.

BATRACHOSPERMUM (batracho, frog; spermum, seed)

Members of this genus are fairly common in fresh water of temperate regions, favoring cool shaded areas and swiftly running streams. The thallus is freely branched and gelatinous in texture with a bluish or olive color. Specimens obtained from deeper water are more red in color due to a difference in the intensity of light which reaches them.

Batrachospermum moniliforme Roth.

Soft thick gelatinous thallus of branched, bead-like threads, blue-grey or olive in color; main filaments of large axial cells 350 mic. wide, with whorls of densely-branched lateral ramuli appearing at intervals; branches moniliform, cells 7 mic. wide, 17.5-20 mic. long; some branch ends setigerous. Found in Bear Creek, station Q at only one spot, attached to rocks in middle of stream.

For illustration see Chapman (1941) page 220, figure 144.

HETEROKONTAE

Organisms of this class have a greater proportion of carotin and xanthophyll than chlorophyll. Reserve foods are stored as fats. Motile cells have two flagella of unequal length. Cell walls are frequently of two overlapping halves and are composed chiefly of a pectic substance with cellulose only occasionally present. Sexual reproduction is found in only a few forms. This class is called Xanthophyceae by many algologists.

HETEROTRICHALES

All of the filamentous organisms of the Heterokontae are grouped in this order. It contains two families.

TRIBONEMATACEAE

Of the two families of the Heterotrichales, this one includes all plants with unbranched filaments.

TRIBONEMA (tribo, thin; nema, thread)

Species of this genus are frequently confused with those of Microspora of the Chlorophyceae. They both are unbranched filaments, both form H-pieces, and have a similar general appearance. A test for the presence of starch will easily distinguish them.

Tribonema bombycinum (Agardh) Derbes and Solier.

Long unbranched filaments 10.5 mic. in diameter; cells barrel-shaped, 14, 18, or 21 mic. long; chromatophores small.

several to a cell. When filaments break, the cell walls pull apart in the middle leaving H-shaped pieces, very characteristic of this genus. Found only at station S below Cooper Reservoir, mixed with species of Vaucheria.

According to Collins T. bombycinum is a very common spring plant which would tend to explain why filaments were found only at the high elevation of upper Bear Creek in August.

For illustrations see West (1916) page 412, figure 263; Hazen (1902) plate 25, figures 1-3.

CHLOROPHYCEAE

This class includes the organisms commonly known as the green algae. Plastids called chloroplasts contain four pigments: chlorophyll a, chlorophyll b, carotin, and xanthophyll which occur in essentially the same proportions as in higher plants. One or more pyrenoids are usually found in each chloroplast. Food is stored principally as starch. Cellulose is present in the cell wall. Motile stages have flagella at the anterior end, and all flagella are of equal length. Reproduction is both asexual and sexual with a wide range of types. The green algae are very variable in form and are widespread, occurring in all types of habitat.

VOLVOCALES

This order includes those green algae that have flagellated vegetative cells which are actively motile during their vegetative phase. Cells may be solitary or united in colonies of definite shape. Asexual reproduction occurs by the formation of motile zoospores or motile autocolonies. Sexual reproduction varies from isogamy to oögamy.

CHLAMYDOMONADACEAE

This family includes all unicellular Volvocales with a definite wall except those with a wall composed of two overlapping halves or those with numerous contractile vacuoles.

CHLAMYDOMONAS (chlamydo, cloak; monas, single)

This genus includes species characteristically possessing two flagella which are inserted close together, a single cup-shaped chloroplast, an eyespot, two contractile vacuoles, and one nucleus. Asexual reproduction is by the formation of 2, 4, or 8 zoospores freed by the gelatinization of the mother cell wall. A palmella stage results when the cell wall fails to gelatinize. Sexual reproduction is by the fusion of isogametes.

Chlamydomonas sp. Eherenberg.

Ovate, granular, very active solitary motile cells in a hyaline thin membrane; cells 14 x 10 mic. Occasionally seen with diatoms and Spirogyra species all along the river. A pool just south of the bridge at station G was colored lime-green with large amounts of Chlamydomonas cells.

Pascher monographed the genus in German in 1927 so species prior to this are of little value (Smith). No description that fitted specimens obtained here could be found in literature consulted.

For illustrations see Collins (1928) plate II, figure 13; Smith (1933) page 316, figure 208.

TETRASPORALES

This order contains those green algae whose vegetative cells are immobile but which may return directly to a flagellated condition. A few members are unicellular but the majority have cells united in gelatinous colonies. Cells are uninucleate and have one chloroplast. Members of the Tetrasporales are closely allied to members of the Volvocales and many authorities do not recognize Tetrasporales as a separate order.

TETRASPORACEAE

Members of this family all have two or more pseudocilia at the anterior end of vegetative cells. The cells are united in gelatinous colonies of varying shape, and have their anterior poles toward the edge of the colony so the pseudocilia extend to or beyond the envelop boundary.

TETRASPORA (<u>tetra</u>, four; <u>spora</u>, spores)

Members of this genus form green macroscopic colonies which are attached at first but which may later become free floating. There is a tendency for the cells to be in groups of two or four, embedded in the matrix which is always homogeneous in structure. Colonies increase in size by vegetative cell division. Vegetative cells may produce biflagellate zoospores which escape and start new colonies. Sexual reproduction is by the fusion of biflagellate isogametes.

Tetraspora bullosa (Roth) Agardh.

Thallus dark green, sac- or bladder-like, definitely granular, approximately $2\frac{1}{2}$ cm long; cells 8-12 mic. in diameter, spherical, very crowded, mostly in groups of four but having divided on more than one plane. Occasionally found attached to stones in gently running water, Bear Creek stations O and Q, and East Gallatin River station E.

For Illustration see Wolle (1887) plate CLXV, figures 1-6.

Tetraspora gelatinosa (Vaucher) Desvaux.

Colonies of firm gelatin, not hollow, color tan to very pale green, 2 mm to 2 cm in diameter; cells 7 mic., spherical or slightly oval, occasionally larger, 10 or 14 mic., all bright green, rather scattered, not densely packed. Diatoms and O. cruenta are frequently present in the colonies. Quite prevalent in both East Gallatin River and tributaries tending to disappear as August advanced. Collins says lack of uniformity in cell size is marked in this species.

Tetraspora lubrica (Roth) Agardh.

Light green, very delicate, thin tubular thallus varying 1-6 inches in length, sometimes splitting; cells spherical to slightly angular, 8-10 mic., not too crowded, groups of four easily seen. Found in very quiet but not stagnant water, anchored to creek bottom, standing erect or streaming with the slow current. Found at Bear Creek station M; East Gallatin River stations E, G, and J; Bridger Creek at its junction with East Gallatin River at station C.

For illustration see Wolle (1887) plate CLXV, figure 9.

Tetraspora lubrica (Roth) Agardh, Var. lacunosa Chauvin.

Colonies 1-6 inches long, bright dark green; gelatinous matrix perforated with large lacunae; attached basally to rocks; cells 7-9 mic., spherical, quite densely packed, becoming fewer toward edges of colonies; some cells showing cup-shaped chloroplasts, others solid green. Found at stations E and G, appearing the first week in August.

For illustration see Wolle (1887) plate CLXV, figure 10.

ULOTRICHALES

This order includes those green algae which are filamentous and form biflagellate or quadriflagellate zoospores. The most primitive of the Ulotrichales are unbranched filaments; others are branched or are in sheets. Smith believes this order to be a direct evolutionary line from the Tetrasporales.

ULOTRICHACEAE

This family includes those filaments which are uniseriate and unbranched. The cells are uninucleate with a girdle-shaped chloroplast partially encircling the cell.

ULOTHRIX (ulo, shaggy; thrix, hair)

This genus includes species with unbranched filaments equipped with holdfasts. The cells are shorter than broad and have one chloroplast with one or more pyrenoids. All cells except the holdfast are capable of division and reproduction. Asexual reproduction is by quadriflagellate zoospores which attach themselves to objects and grow into filaments. In sexual reproduction biflagellate isogametes fuse to form zygospores which germinate after a period of rest.

Ulothrix zonata (Weber and Mohr) Kuetzing.

Unbranched filaments with girdle-shaped chloroplasts encircling more than half the cell; filaments attached, bright green, 21-35 mic. wide, cells half as long as broad, thin cell membrane. A trace of filaments found attached to submerged rock station O, a bit more 100 yards below sewage outlet, station D, and a few strands mixed with Cladophora species at station C.

Smith reports U. zonata appearing in early spring, disappearing during the summer, and reappearing in the fall. Croasdale and Hazen agree with this.

For illustrations see Wolle (1887) plate CXVII, figures 1-3; Hazen (1902) plate 20, figures 1-4.

MICROSPORACEAE

This family contains only one genus, Microspora. Cells of the unbranched filaments have walls in two overlapping halves held in place by a delicate membrane. When filaments break, H-shaped pieces are formed. The chloroplast is parietal. Asexual reproduction is by biflagellate zoospores that are liberated by the breaking of the filaments into H-pieces. Aplanospores are common. Sexual reproduction is as yet not fully confirmed.

MICROSPORA (micro, small; spora, seed)

Since the Microsporaceae contains only the one genus, all statements in the preceding paragraph apply here also.

Microspora floccosa (Vaucher) Thuret.

Short unbranched filaments with parietal chloroplasts; cells cylindrical, 17.5 mic. wide, 21-24 mic. long with very thin walls. Found on twigs at station B in quiet shallow water on north edge of river 100 yards above bridge.

This genus has cell walls which pull apart in the middle leaving H-shaped pieces as does also Tribonema bombycinum. M. floccosa is easily distinguished from the latter, however: cells lack barrel shape, have thinner walls and different dimensions. At one time both genera were placed together as Conferva but Lagerheim finally properly defined both genera by their chromatophores and assimilation products (Hazen).

CHAETOPHORACEAE

The filaments of this family are branched, usually with a prostrate portion and an erect portion. Branch ends usually are attenuated. The cells are uninucleate and have a single laminate parietal chloroplast.

STIGEOCLONIUM (stigeo, sharp pointed; clonium, branch)

This genus includes species with a cushionlike prostrate portion and rather sparingly branched erect filaments enclosed in a watery gelatinous sheath. Branch ends terminate in colorless hairs. Asexual reproduction is by means of quadriflagellate zoospores usually formed singly with a cell. Sexual reproduction is by the fusion of biflagellate isogametes. The presence of a palmella stage is common.

Stigeoclonium nanum (Dillwyn) Kuetzing.

Filaments 3 mm long, alternately branched into fairly short branches tapering to short pointed end cells; branch cells 6-7.5 mic. wide, approximately as long as broad; main filament cells 8-10 mic. wide, 7-12-14 mic. long, longer lengths going with greater widths. S. nanum appears as very beautiful intensely bright green coatings on rocks in running water. Found only in main river especially at stations E and G and at D above sewage; traces in poor condition at station C.

For illustration see Wolle (1887) plate XCVI, figure 10.

CHAETOPHORA (chaeto, hair; phora, bearing)

This genus was described by Schrank in 1789. It includes species with very tough spherical or elongate macroscopic thalli. Asexual and sexual reproduction methods are the same as those given for Stigeoclonium.

Chaetophora elegans (Roth) Agardh.

Globose, more often tuberculose, firm jelly-like colonies, pale to deep green, size of pea; cells of main filaments 10.5-14 mic. wide, 3-5 times longer, branches 7 mic. wide; fascicles of branches lax, apical cells short pointed, occasionally setiferous. Found in Bear Creek station Q and in Meadow Creek station V.

C. elegans and C. tuberculosa are hard to separate according to Wolle. Hazen doubts the existance of the latter species believing Wolle's C. tuberculosa to be only a growth form of C. elegans.

For illustrations see Hazen (1902) plate 37, figures 1-3; Wolle (1887) plate CIII, figures 12-15.

DRAPARNALDIA (after J. P. R. Draparnaud)

The plants of this genus have a greatly reduced or absent prostrate system. The main branches of the erect system are much larger than the side branches which grow out in tufts from the main filaments. Quadriflagellate zoospores are formed in the branch cells in asexual reproduction. Sexual reproduction is by quadriflagellate isogametes which become amoeboid before fusion occurs.

Draparnaldia plumosa (Vaucher) Agardh.

Pale green plant body of long primary filaments and short fasciculate lateral branches which are somewhat lanceolate in outline; cells of primary filaments almost as long as broad, not swollen in the middle, 45 mic. wide, 30-35 mic. long; cells of branches 10 mic. wide; fascicles of branches densely packed. Only a few filaments found in Bear Creek, station M; section of filament 2 cm long found at station B.

For illustration see Wolle (1887) plate XCII, figure 1.

PROTOCOCCACEAE

The simplicity of members of this family is due to their being reduced rather than primitive forms. Cells usually contain single parietal chloroplasts with pyrenoids generally lacking.

PROTOCOCCUS (proto, first; coccus, berry)

The cells of this alga occur singly or in small groups. Each cell has a nucleus and a single chloroplast. The only known method of reproduction is by cell division. Protococcus is one of the most common algae in the world. The adaptation to an aerial habitat is permitted by the great capacity of cells for absorbing water from moist air.

Protococcus viridis Agardh.

Not gelatinous; cells spherical, 10.5 mic. in diameter, mostly in groups of two; chloroplast practically fills the cell; no pyrenoid. Found on twigs on ground at water's edge 100 yards below sewage outlet, station D.

For illustration see Smith (1933) page 408, figure 277.

CLADOPHORACEAE

Genera of this family have multinucleate cells united in branched or unbranched, usually sessile filaments. Cell walls have three zones: chitin, pectin, and cellulose. Whether or not this family is to be classified in a suborder of the Ulotrichales or should remain in the order Siphonocladiales or should be placed in a separate order, the Cladophorales, is dependent on whatever authority is preferred.

CLADOPHORA (clado, branch; phora, bearing)

Members of this genus are widely distributed, being found in both fresh and salt waters. Filaments are branched and septate with cells having elongate reticulate chloroplasts containing numerous pyrenoids. Epiphytic algae commonly cover Cladophora filaments since the chitinous cell wall zone is external to the pectic zone. Asexual reproduction is by means of quadriflagellate zoospores. Sexual reproduction is by the fusion of biflagellate isogametes. Both zoospores and gametes are formed by the division of vegetative cells.

Cladophora glomerata (Linnaeus) Kuetzing.

Filaments much branched, coarse; cells about four times longer than broad, thick cell membrane; branches are lateral outgrowths from upper ends of cells; stem cells 60-70-87 mic. wide, branch cells 42 mic. wide; walls externally very smooth. Dominant alga in East Gallatin River where it is attached to nearly every rock; not so common in Bear Creek. Bright green color usually obscurred by trash coating.

For illustration see Wolle (1887) plate CX, figure 1.

Cladophora glomerata (Linn) Kg. Var ?.

Main filaments 70 mic. wide, cells 2½ times longer; branches 35 mic. wide; very branched, feathery, and delicate, not covered with debris. These filaments fit the description for C. glomerata in dimensions and other characters but the feathery appearance caused by so many branches gives quite a different macroscopic appearance. Found at stations F, O, and V.

Cladophora sp.

Main filaments very coarse, very sparingly branched; cells 140 mic. wide, 2½-4 times longer; branch cells 56-70-87 mic. wide. Found at station D attached to rocks, mostly bright green and free from trash in contrast to other species in the same situation.

RHIZOCLONIUM (rhizo, root; clonium, branch)

The uniseriate filaments of this group are simple or possess short septate or nonseptate colorless rhizoidal branches. Growth of filaments is intercalary. The number of nuclei, as in species of Cladophora, depends upon the size of the cell. Reproduction is by means of biflagellate zoospores and from the accidental breaking of filaments.

Rhizoclonium sp. Kuetzing.

Filaments 28 mic. wide, long, unbranched, not constricted between cells, with occasional short colorless one-celled lateral processes; cells thin walled, 2-4 times longer than wide, containing parietal chloroplasts with several pyrenoids. Found frequently in Bear Creek and Kelly Creek. East Gallatin River stations K, G, and B produced specimens sparingly, but Rhizoclonium is not at all prevalent in the East Gallatin River. This species could be a variety of R. hieroglyphicum.

For illustration see Tiffany (1928) plate XIII, figures 4-5.

OEDOGONIALES

Plants in this order resemble certain members of the Ulotrichales, but because of the annular splitting of the cell wall in cell division, and the whorl of flagella on zoospores and antherozoids, they are put in a separate order. The cells are uninucleate with a laminate parietal chloroplast, seriately united in branched or unbranched filaments. Sexual reproduction is always by oogamy.

OEDOGONIACEAE

There is but one family in the order. All statements in the preceding paragraph apply here.

OEDOGONIUM (oedo, swelling; gonium, vessel)

The plants in this genus consist of unbranched filaments attached to a basal holdfast when young. Transverse striations occur at the distal ends of some cells. The chloroplast is reticulate and with numerous pyrenoids. Zoospores with a ring of flagella at one end are produced singly in the vegetative cells. Gametes are produced in special cells. The motile male gametes are much smaller than the non-motile female gametes. Both heterothallic and homothallic species are known. Species of this genus serve as an excellent example of highly developed sexual reproduction in a so-called "lower" plant.

Oedogonium sp. Link.

Long unbranched filaments 40 mic. wide, cells 60-63-66 mic. long; chloroplasts of several longitudinal bands, many pyrenoids; some cells possessing several transverse lines at distal end. Species can not be separated from each other unless the plant is in fruiting condition (Smith). Size of the vegetative filaments make O. princeps Kuetz. and O. capillare Kuetz. as possibilities. Found in late August, station G.

ULVALES

This order includes plants with cell division on two or three planes. This results in either a flat sheet or hollow tube one cell thick if division is on two planes, or a solid cylinder if on three. Thalli are usually sessile and attached. All genera form zoospores, and sexual reproduction is by the fusion of biflagellate isogametes.

ULVACEAE

This family includes those plants in which cell division is on two planes, resulting in either an expanded sheet or a hollow cylinder.

ENTEROMORPHA (entero, entrail; morpha, form)

The plants in this genus commence life as uniseriate filaments but soon develop into hollow tubes one cell thick. Both salt water and fresh water species are known. Cells are packed closely together and are often angular due to mutual compression. Species have an alternation of asexual diploid plants and sexual haploid plants.

Enteromorpha intestinalis (Linnaeus) Link.

Tubular thallus sometimes pale green, sometimes dark green either attached at basal portion or entangled with other filamentous algae; 1 inch to 1 foot or more in length; usually the diameter of a pencil, kinked, with walls 1 cell thick; cells 4-7 mic. in diameter, 3-5-6 angular. Found at stations B, E, and G., and in Bridger Creek one-half mile before it joins the East Gallatin River at station C. Wolle's cell dimensions of 12-20 mic. are much larger than those specimens found here.

For illustration see Smith (1933) page 454, figure 306.

MONOSTROMA (mono, single; stroma, layer)

The plants of this genus according to Chapman (1941) differ sharply from those in the preceding genus with the diploid generation represented only by the enlarged zygote. The macroscopic plants are haploid here. Because of this he classifies this genus in a separate family, the Monostromaceae.

Monostroma bullosa (Roth) Wittrock.

Sheet-like thallus dark bright green one cell thick except at basal point of attachment; thalli varying from 0.5 cm x 2 cm to 4 cm x 8 cm; cells packed in groups of four, oval, 3.5 x 7 mic., with chloroplasts appearing completely filling each cell. Found at station V and Bear Creek stations being especially abundant at stations O, P and Q, becoming less frequent and finally disappearing toward the headwaters.

CHLOROCOCCALES

Solitary cells are prominent in this order. They also may be united in nonfilamentous colonies. The great diversity of shape and size of cells has resulted in the occurrence of many genera. The cells do not divide vegetatively, and division of the protoplast occurs only in connection with reproduction.

CHLOROCOCCACEAE

This family contains the unicellular members of the Chlorococcales. The plants may be either aerial or aquatic.

CHLOROCOCCUM (chloro, green; coccum, berry)

Species of this genus are primitive members of the order, being small and of simple form. Cells contain one chloroplast, one pyrenoid, and one nucleus. The uninucleate condition becomes multinucleate before zoospore formation occurs. Many algae once believed to belong here are now known to be phases in the life cycles of other genera.

Chlorococcum humicolum (Naegeli) Rabenhorst.

Cells varying much in size, 3-7 mic. in diameter, spherical; thin hyaline membrane; non motile; chloroplast parietal. Found growing on soggy bush stump about 100 yards downstream from sewage entrance, station D. This is the only *Chlorococcum* species that is subaerial, and the cells are much smaller than those of the aquatic species *C. infusionum* (Schrank) Menegh. which are uniformly 10-15 mic. in diameter.

For illustration see Smith (1933) page 468, figure 311.

SIPHONALES

Vegetative filaments of this order do not have cross walls. This coenocytic condition is accompanied by a single central vacuole running the length of the filaments. The layer of cytoplasm next to the cell wall contains numerous chloroplasts and many nuclei. Zoospore formation is rare, while in sexual reproduction there is a marked difference in the size of the gametes. The majority of the members of this order are tropical.

VAUCHERIACEAE

This family is separated from the other Siphonales by the fact that oogamy occurs here with the sex organs usually found on the same thallus. The two genera are both found in temperate regions. Some authorities believe that the genus Vaucheria should be removed to the Heterokontae since its members form oil and have more than the normal amount of xanthophyll in the chloroplasts. The fact that its species can produce starch under conditions of constant illumination is the main reason the genus Vaucheria still remains in the Chlorophyceae.

VAUCHERIA

The plants in this genus are filamentous, inarticulate, irregularly and sparingly branched, forming more or less dense tufted or felty masses usually attached by colorless rhizoids. Cell walls are comparatively thin, chloroplasts numerous, small and without pyrenoids; nuclei many, minute. Asexual reproduction is by means of large ciliate zoospores also in some species by aplanospores or akinetes. Sexual reproduction is by oogonia and antheridia of variable shape and position.

Sterile plants are quite indeterminable (Collins).

Specific differences are based entirely upon the structure of mature sex organs (Smith).

Three different types of Vaucheria were found during the study. Since the plants were not in fruiting condition, classification to species could not be made.

Vaucheria sp. DeCandolle.

Unsegmented filaments 45 mic. wide, rhizoids very frequent. Very common as short filaments densely interwoven to form a dark green layer on moist soil all along the river.

Vaucheria sp.

Aquatic, in dense turfy mats attached to stones or submerged twigs; filaments 52-60-70 mic. wide, sparingly branched. Found at most river stations, with great masses of this species occurring in the clear cold waters of Bear Creek, New World Gulch Creek, and in a cold irrigation ditch which emptied into the river at station B.

Vaucheria sp.

Aquatic, filaments 35-42 mic. wide, sparingly branched; chloroplasts less numerous than in other species; filaments smaller and lacking the mat-like turfy appearance of the type just described; light green in color, extending quite uniformly 1 cm from place of attachment on rocks in flowing water. Found at station U.

ZYGNEMATALES

This order is called Conjugales by most authorities. The method of reproduction differs sharply from that shown by plants in all other orders. Flagellated reproductive cells are unknown and in their place we find amoeboid gametes. Cells are either solitary or attached in unbranched filaments.

ZYGNEMATACEAE

Cells in this family are united end to end in unbranched filaments and contain three types of chloroplasts: spirally arranged ribbon-like chloroplasts, axial laminate chloroplasts, or stellate chloroplasts. The filaments are usually slippery and free floating. During conjugation the cell contents do not escape from the enclosing wall.

MOUGEOTIA (after J. B. Mougeot)

The filaments of the different species contain cells with axial laminate chloroplasts. These orient themselves according to the light intensity. Scalariform conjugation is characteristic in this genus with the gametes uniting in the conjugation tube.

Mougeotia genuflexa (Dillwyn) Agardh.

Cells cylindrical, 25-28 mic. wide, $2\frac{1}{2}$-5 times longer; thin walled; chloroplasts are axial plates with conspicuous pyrenoids; filaments unbranched, drab yellow to yellow-green, tending to break into individual cells when taken for study.

In some cells the chloroplasts have the appearance of a thin line down the center, others are turned to show platelike structure of chloroplasts. Station V in late August was especially rich in this species in colonies which mushroomed up from bottom of quiet pools in mucous association. The three groups observed were 4 inches, 1 foot, and 2 feet in diameter. Mixed with these plant masses were several species of Spirogyra although not in large quantities.

ZYGNEMA (zyg. yoke; nema, thread)

Members of this genus have filaments whose cells contain two axial stellate chloroplasts each with a pyrenoid, the nucleus lying between them at the center of the cell. When cell division occurs, each daughter cell receives one of the chloroplasts which then divides.

Zygnema anomalum (Hassall) Kuetzing, Var. crassum, Wolle.

Filaments unbranched, 42-45 mic. wide without a sheath, 60 mic. wide with sheath; cells $1\frac{1}{2}$-$2\frac{1}{2}$ times longer; two axial stellate chloroplasts in each cell with nucleus between. Filaments were seen once mixed with Spirogyra adnata Kuetz. at station G, refound after a microscopic search of many samples of Spirogyra from the same area. There may be much more Zygnema in the East Gallatin River, but search of much Spirogyra failed to find it.

For illustration see Wolle (1887) plate CXLIV, figure 9.

SPIROGYRA (<u>spiro</u>, coil; <u>gyra</u>, curved)

This genus has many species of world-wide distribution. Specific distinctions not always clear, based on character of dissepiments, the number and breadth of the chromatophores, size and form of spore, character of median membrane, inflation of fertile cell, and too often dimensions of filaments; this last being too uncertain to have much weight except when associated uniformly with other characters. Size and shape of spore of more importance, but a change of position in the cell may give a totally different aspect to the spore when seen under the microscope. (Collins).

Stokes (1893) produced a vegetative key to species of <u>Spirogyra</u> described by Wolle but Smith and Wolle both agree with Collins that fruiting material is necessary for absolute species identification. Since <u>Spirogyra</u> species fruit in the spring, no reproductive bodies were observed in this study. A careful comparison of vegetative characteristics of the plants has been made and eight species listed.

<u>Spirogyra adnata</u> Kuetzing.

Vegetative cells in unbranched filaments, 45 mic. wide, usually 1-1½ times as long as broad; 2 chloroplasts making 2½-3 turns; cell ends not replicate. Easily distinguished from <u>S. dubia</u> Kuetz. although both are same diameter. <u>S. adnata</u> cells appear almost solid green, while <u>S. dubia</u> cells with narrower chloroplasts and greater cell length show much clear space.

For illustration see Wolle (1887) plate CXXV, figure 3.

<u>Spirogyra dubia</u> Kuetzing.

Vegetative cells in unbranched filaments 42-45 mic. wide, cells 2-2½ times longer than broad; ends not replicate; two narrow chloroplasts, each making 1½-2 turns; size of chloroplast causing much clear space in cell. Present everywhere in quiet edges of the East Gallatin River mixed with <u>S. adnata</u> which is more plentiful. All spirogyra filaments are slick to the touch.

For illustration see Wolle (1887) plate CXXXV, figure 11.

<u>Spirogyra Grevilleana</u> (Hassall) Kuetzing.

Unbranched filaments 28-32 mic. wide, cells 5-6 times longer than broad; cell ends replicate; chloroplast broad, single, making 4 or 6 turns, less often 7 or 8 turns. Found at station V mixed with <u>Mougeotia genuflexa</u>, also in masses of <u>Spirogyra</u> which were predominantly <u>S. adnata</u>.

For illustrations see Wolle (1887) plate CXXXII, figures 12 and 13.

<u>Spirogyra inflata</u> (Vaucher) Rabenhorst.

Unbranched filaments 14-17 mic. wide, varying greatly in length being 3-10 times longer than broad; cell ends replicate; chloroplast fairly broad, single, making 4 or 5 turns. Found at station V occurring infrequently in association with Mougeotia genuflexa.

For illustrations see Wolle (1887) plate CXXXII, figures 6 and 7.

Spirogyra longata (Vaucher) Kuetzing.

Unbranched filaments 28-35 mic. wide, cells 4-10 times longer than broad; cell ends not replicate; chloroplast single, very narrow, making 3 turns, cell contents mostly clear. Found in Bear Creek above station R at creek edge in marshy ground. Backwater here appeared quite stagnant.

For illustrations see Wolle (1887) plate CXXXV, figures 9 and 10.

Spirogyra quinina (Agardh) Kuetzing.

Unbranched filaments dark green, very slippery; cells 35-42 mic. wide, usually about as long as broad, though occasionally 6 times longer; ends not replicate; chloroplast single, making 1½-2 turns. Found at station J mixed with species of Cladophora in small shallow pool, also at station V occurring infrequently.

For illustrations see Wolle (1887) plate CXXXIV, figures 14-17.

Spirogyra tenuessima (Hassall) Kuetzing.

Unbranched filaments 12-14 mic. wide, cells 12 times longer; cell ends replicate; chloroplast single, very narrow, laxly turning 3 times. Found at station V occurring infrequently in association with Mougeotia genuflexa . Wolle says the diameter is 9-12 mic. but that it varies considerably in size even more than measurements indicate. Collins calls it our smallest species.

For illustrations see Wolle (1887) plate CXXXII, figures 1-3.

Spirogyra Weberi Kuetzing.

Unbranched filaments 28 mic. wide, cells 7-11 times longer; chloroplast single, very narrow and lax, making 2½-4 turns; cells almost colorless; laxness of chloroplast so marked in many cases that chloroplast makes 2 loops, then strings out, barely curving. Found at station V occurring infrequently in association with Mougeotia genuflexa.

For illustration see Wolle (1887) plate CXXXII, figure 11.

DESMIDEACEAE

This family includes species in which cells are usually solitary. Pores and transverse segments occur in the cell wall. Many beautiful and diverse shapes are found in this group. Some desmids are very similar to members of the Zygnemataceae, showing a close relationship between the two families.

CLOSTERIUM (enclosed space)

Cells of this genus do not have a median constriction. Two curved chloroplasts are present, one in each semicell. Cells are curved, often being strongly arc shaped. The granules present in the vacuoles at the apices are of gypsum but their value has not been determined. A cell divides by a transverse constriction at its center, each semicell then producing another half. In sexual reproduction the conjugating gametes are not protected by a cell wall.

Closterium lanceolatum Kuetzing.

Single cells, elongated, filled with bright green contents except for small area of clear cytoplasm at each end; cells gradually tapering to blunt ends, semi-lanceolate, 42-45 mic. wide, 8-10 times longer; upper surface convex but only fairly so, i. e., not strongly curved; lower surface only slightly curved, almost straight; chlorophyll granules often in longitudinal series. Seen with C. moniliferum Ehr., Oscillatoria species and diatoms along muddy edges of river. Floating dirt patches were an excellent source of this alga.

For illustrations see Chapman (1941) page 106, figure 72e; Fritsch (1935) page 343, figure 108a.

Closterium Leibeinii Kuetzing.

Single cells, luneately curved, strongly convex dorsally, almost as much ventrally, with very slight ventral central inflation; ends more acute than those of C. moniliferum; diameter 38.5-42 mic. with length 6 times the width; no central row of pyrenoids, but chloroplasts uniformly granular with 4 or 5 longitudinal ridges; large clear space at each end of cell with about 10 "dancing granules" clearly seen in fresh specimens. Found with diatoms at water's edge, stations U and V.

For illustration see West (1916) page 365, figure 229b.

Closterium moniliferum Eherenberg.

Single cells, elongated, luneately curved, bright green; cells 35-45 mic. wide, 6-8 times longer; ends rounded, with area of clear cytoplasm; large chlorophyll granules in single longitudinal series down center of cell; upper margin convex, lower concave with slight central inflation. Found with diatoms along muddy river edges, also with Rhizoclonium filaments in Bear Creek, station R.

EUGLENOPHYCEAE

Organisms in this class have the same pigmentation as the organisms in the Chlorophyceae but they store food as paramylum, a carbohydrate. Most organisms are motile due to one or two flagella at the anterior end of the cell. Cell shape may be either rigid or flexible. Whether these organisms should be included among the algae is not settled. Many algologists ignore them when writing books on algae.

EUGLENALES

This is the only order in the class and is divided into four families.

EUGLENACEAE

Most of the members of this family contain chloroplasts, and all members whether chloroplasts are present or not, possess an eyespot. A glandular swelling occurs in the flagella a short distance from where they are inserted in a reservoir in the gullet. Sexual reproduction does not occur in this family.

EUGLENA

Members of this genus possess chloroplasts and are uniflagellate. Cells are usually spindle-shaped with the posterior end more or less pointed. Two contractile vacuoles are present, located near the reservoir of the gullet. Division of cells is usually longitudinal and begins at the anterior end. Species of this genus are very common in waters that are rich in organic matter.

Euglena sp. Ehrenberg.

Solitary cells, elongated, motile, changing shape very easily and often; posterior end pointed into a tail-like projection; red eyespot at anterior end, green chloroplasts filling most of the remainder of organism; length 70-77 mic., width 8-10 mic. Found at edge of river at station D below sewage, also station V in association with species of *Vaucheria*, *Oscillatoria*, and *Chlamydomonas*.

Smith reports twenty-one species in this country but Wolle mentions only *E. viridis*. Wolle's measurements of 40-62 mic. are a great contrast to De Toni's 12-13 mic. for the same species. Not enough species descriptions could be found to allow complete classification. A drawing, plate I, figure 1, accompanies this report.

UNKNOWN GENERA

1. Colonies spherical, some 84 mic., others 63 mic. in diameter; cells densely packed, mutually compressed and hard to distinguish individually; colony surrounded by colorless layer 3 mic. thick, some colonies observed as hollow spheres. Later microscopic examination revealed spherical clear spaces up to 10 mic. in some colonies which were not noted in first examination. Colonies rotated constantly, some clock-wise and others counter-clockwise. The specimens were found mixed with species of *Oscillatoria* at station E just north of the bridge below the stockyards. They could be members of the Volvocales. The fact that the cells were packed so closely tends to rule out *Volvox*. There were far too many cells per colony to be classified as *Eudorina* or *Pandorina*. See drawings plate I, figures 2a and 2b.

2. Cells oval, 7 mic. wide, 14 mic. long with stalks almost as long as the cell; occurring in colonies but occasionally singly, varying from 14 to 25 cells per colony, arranged with stalks converging on a central point leaving cells free to wave gently in the water. Cells were not all on one plane. Colony width varied according to number of cells present, being 50 mic. more or less. Cells were slightly more yellowish than Chlamydomonas cells appearing in the same microscopic field. Cells could be related to Stylosphaeridium stipitatum (Bachm.) Geitler and Gimesi or to Characium or Characiopsis species. These were given as epiphytic forms which does not seem to be true of this alga. See drawing, plate II, figure 1.

3. This unknown genus appeared at all stations in the river all through the period of study. It appeared as pin-point dots of green on rocks giving them a very definite light green color. Not gelatinous. Microscopic view was always very unsatisfactory since these bits of green could not be teased out into thin sections. Edges showed one or two celled projections, 8 mic. wide. It may be a palmella stage of some alga in the river. It was very common all summer, and although study was made at least twice a week, identification could get no further. The attempts to grow it in the laboratory were futile as the knobs grew no bigger.

4. A tubular thallus, sometimes split, of a very tough matrix; tan with occasional green traces of color; not over 10 cm long, and 2-5-8 mm in diameter; groups of germinating green cells usually 5 mic., occasionally 8 mic. in diameter, some appearing as two cells together, others as a green cell growing from a colorless cell. Found in Dean Gulch Creek by station R. These could be the start of a filamentous form. Laboratory attempts at growth were not successful. Cells turned yellow after one week. See drawing, plate II, figure 2.

CHART I

RESULTS OF ALKALINITY TESTS

STATION	pH	CARBONATE	BICARBONATE
B	6.8	none	204 ppm
D	7.6	12 ppm	180 ppm
E	7.8	14 ppm	181 ppm
G	7.5	24 ppm	178 ppm
J	7.4	22 ppm	165 ppm
L	7.8	20 ppm	162 ppm
O	7.2	6 ppm	171 ppm
P	7.2	4 ppm	209 ppm
Q	7.5	6 ppm	160 ppm

CHART II

DISTRIBUTION OF GENERA

GENUS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
Oscillatoria	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
Nostoc				x				x						X	X		X	X	X		x	X
Stigonema																X	X					
Batrachospermum																	X					
Tribonema																			X			
Chlamydomonas				x			X															X
Tetraspora	X	X			X	X	X			X	X	X	X		x		X	X			X	
Ulothrix		x	x	x	x		x															x
Microspora		X																				
Stigeoclonium	X	X	x	X	X																	
Chaetophora																	X	X				X
Draparnaldia		x											X									
Protococcus				X																		
Cladophora	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X
Rhizoclonium														X	X		X	X		X		
Oedogonium							X															
Enteromorpha		X			X		X															
Monostroma												x	X	X	X	X	X	X				X
Chlorococcum				X																		
Vaucheria, aquatic		X				X	X						X	X	X	X	X	X	X	X	X	X
Vaucheria, soil	X	X		X	x		X			X	X		X									
Mougeotia							x					X										X
Zygnema							X															
Spirogyra	X	X		X	X		X	X	X	X		X			X			X		X		X
Closterium	X	X		x			X		X			x	X									X
Euglena				X																		X
Unknown I					X																	
Unknown II							X															
Unknown III	X	X		X	X		X	X	X	X	X	x										
Unknown IV																		X				
Diatoms	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X			X	X

X-present in conspicuous amounts
x-present occasionally in traces

LOCATION OF STATIONS

Station A

This is 3.6 miles from the intersection of Seventh Ave. and Main St. in Bozeman. Travel north on Highway 10 from Seventh and Main for 2.6 miles; turn right, off highway, go 0.7 mile; again turn right, go 0.3 mile to bridge which is on the Springhill road.

Station B

Travel north on Highway 10 from intersection of Seventh Ave. and Main St. 1.4 miles to Nikles' Corner which is just beyond the viaduct over the freight tracks. Turn east, go 0.4 mile which is just beyond another railroad crossing. Turn north, go one mile to bridge.

Station C

Contact Bridger Creek one-half mile north of Cereal Mill, follow creek through barnyards and fields until it joins the East Gallatin River.

Station D

Turn east at Nikles' Corner, go 0.7 mile and turn north. Go 0.2 mile toward city dump. Park car by wire gate, proceed on foot 50 yards to junction of sewage with river.

Station E

This is 0.9 mile east of Nikles' Corner. It is also 0.2 mile east of the junction of North Rouse Ave. with the road from Nikles' Corner. At this station the river curves to the road, fence is easily surmounted. The station covers area from this point east to the bridge below the auction stock-yards.

Station F

A few hundred yards south of the Cereal Mill on the old Bridger Canyon Road.

Station G

0.4 mile south of Cereal Mill, across railroad spur tracks. Stop by bridge. This is also 0.4 mile east of the Northern Pacific depot tracks, on the old Bridger Canyon Road.

Station H

Leave car at station G, hike south along railroad spur track about one-half mile to railroad trestle. Slide down embankment to the river.

Station I

1.2 miles east of Bozeman on Highway 10 counting mileage from the junction of East Main St. and Buttonwood Ave. (the old cemetery road). Turn north to railroad tracks, walk west along tracks to the curve of the river. Be prepared for large thistle and nettle patch between tracks and station I.

Station J

2.3 miles east of Bozeman on Highway 10. Turn north, cross railroad tracks, continue north 0.2 mile to bridge.

Station K

Turn north across railroad track at same point as for station J. Turn east immediately after crossing tracks, go 0.7 mile on dirt road to bridge. By continuing eastward, Kelly Creek can be followed.

Station L

This station, the junction of Rocky and Bear Creeks, is a few hundred yards north of station M. Dense underbrush must be skirted, preferably to the east, in order to reach it from station M.

Station M

3.6 miles east of junction of Main St. and Buttonwood Ave. Bear Creek flows under the highway at this point. A large commercial sign here says Bozeman 4 miles.

Station N

Leave Highway 10 4.6 miles east of Bozeman, go south on Mount Ellis Road. Follow Bozeman Ski Club signs 2.3 miles from Highway 10.

Station O

Continue on Bear Creek Road 1.2 miles past station N.

Station P

In area where logging trail crosses New World Gulch Creek 0.2 mile above station O.

Station Q

On Bear Creek Road 0.3 mile above station O.

Station R

Although the automobile road continues past station Q for approximately one mile it becomes increasingly bad for travel. Station R is on a foot trail approximately $1\frac{1}{2}$ miles above station Q.

Station S

At the outlet of Cooper Reservoir. Trails to this point are inadequately marked and confusing.

Station T

See instructions for station K. Continue beyond station K for 1.5 miles.

Station U

Turn off Highway 10 at Chestnut on Trail Creek Road. Go one-half mile from the highway. The road parallels the creek for some distance at this point.

Station V

Three-fourths of a mile beyond station U, Meadow Creek flows under a simple plank bridge and crosses the road.

DISCUSSION

Chart II is a summary of stations in relation to genera found. The flora of station S at Cooper Reservoir was viewed macroscopically and must be considered incomplete. Only one trip was made to this point after a four-hour survey hike to the headwaters of Bear Creek. Monostroma bullosa, which reached its maximum quantity in the region of stations O, P, and Q, had by station R, thinned out just to traces, and had disappeared entirely one mile farther upstream. At station R observation was first made of Nostoc parmiliodes which became increasingly abundant toward the headwaters. Station R was visited three times, it also being accessible only to the hiker.

While stations O, P and Q received frequent visitations, station N received incomplete study, being remarkable chiefly for the excellent specimens of Nostoc verrucosum it afforded.

Kelly Creek was found to be rich in species of Vaucheria and Rhizoclonium with Spirogyra species appearing in August. Only a few trips were made to station T, since Kelly Creek contributed only a trickle of water to the main river.

From the chart it can be acertained that Cladophora, Spirogyra, and Oscillatoria were the dominant genera in the East Gallatin River. The eight weeks period showed no appreciable changes in the quantity of Cladophora species which, usually trash-covered, grew attached to most rocks at all stations in the main river. _Oscillatoria_ species increased in quantity as the season progressed, favoring silt and rocks in quiet waters for colony growth. _Spirogyra_ species after being noted as scarce at the early part of the study, increased rapidly in the pools and along quiet edges until in August many of these places were choked with great masses of filaments. Chapman places two seasonal peaks for _Spirogyra_: one spring and one autumn, the latter phase being due to the germination of a percentage of the spring zygospores.

Although Bacillarieae species were not included, the presence of diatoms were a factor that could not be overlooked. Like _Oscillatoria_, the diatoms favored quiet silted areas where they occurred in great quantities, coloring the mud a yellow-brown. According to Conger (1941) diatoms are valuable because sluggish water would rapidly become stagnant and incapable of sustaining animal life without the diatoms and their underestimated function of reoxygenation.

A study was made to determine the effect of the Bozeman sewage on algal growth. Sewage polluted waters influence the algal picture in proportion to the degree of contamination. Lackey (1941) in studying the effect of sewage on plankton of the Scioto (Ohio) River lists _Oscillatoria_ species along with _Euglena viridis_, _Paramecium_ and _Vorticella_ as organisms thriving best in polluted water.

In a report of the Sangamon River in Illinois, Eddy (1932) makes the statement that this small stream, grossly polluted, supported little aquatic life. The installation of a sewage disposal plant altered the condition of the stream so it now supports an abundance of clean-water plankton, he added. In the polluted middle section of the Lippe River in Europe according to Budde (1932) algae were very scarce, but a rich algal flora was present in the lower part which was well-supplied with oxygen. These observations are reinforced by Brinley (1943) who in studying the Indiana White River writes that algae and oxygen almost disappear immediately below a major source of pollution while biological oxygen demand is high. In his study he points out the tremendous growth of algae that appears fifty miles downstream from the pollution source accompanied by high oxygen concentration and low biological demand. In another study Brinley (1942) explains this increase in plankton growth by saying that raw sewage is detrimental to plankton and fish life but farther downstream where sewage has been reduced to available plant food materials, there is a marked increase in plankton and fish. He farther states in another work (1943) areas that are toxic below sewer outlets extend downstream for variable distances until the sewage is decomposed by bacteria, and when sewage has received proper secondary treatment the degradation zone does not exist and the entire stream is benefitted biologically by the available plant foods introduced.

At station D in a fifty-yard section of the river directly above the point of sewage entrance there was the usual algal picture. The stream itself varied ankle- to knee-deep, flowing rapidly in the shallower areas and with sediment substrate in the quieter regions. Trash-covered filaments of Cladophora glomerata shared rock space with the bluish-grey patches of Oscillatoria natans and diatoms. The silted edges of the stream were brownish-yellow with heavy diatom concentration. Later in the summer Stigeoclonium nanum appeared on the rocks while Spirogyra dubia and S. adnata became abundant near the bank.

The sewage caused a grey opaqueness in the water for some seventy-five yards downstream. At the water's edge here, microscopic study revealed species of Euglena, occasional species of Chlamydomonas, fragments of Oscillatoria natans and O. tenuis, short filaments of Ulothrix zonata and Vaucheria species, and traces of Nostoc species on moist soil. Dirty short filaments of Cladophora glomerata in poor condition were removed from a rock in the stream.

On August 5, the presence of Spirogyra adnata was noted in a shallow pool approximately 120 yards downstream from the sewage entrance. This alga increased to a heavy growth in subsequent observations. The scarcity of forms was expected but the presence of Cladophora and Spirogyra species such a short distance below the point of contamination would indicate the pollution as not too severe. Stigeoclonium nanum in poor condition was observed at station C, one-half mile below station D. The water here was still turbid.

The river between stations C and B was followed and checked with the fact established that Oscillatoria natans, O. tenuis and diatoms were the dominant forms in the river, Cladophora glomerata appearing only rarely. At station B, approximately 100 yards upstream from the bridge the river suddenly widened becoming shallow, the heavy silt bottom of the past mile disappeared except along the shore, and Cladophora glomerata once more became the dominant species. Station A, one and one-half miles downstream, was found to have much the same algal picture as station B.

In an attempt to understand why Monostroma bullosa appeared with such abundance in Bear Creek and not in the East Gallatin River, water samples were tested for pH and carbonate and bicarbonate alkalinity. Results are tabulated in Chart I. Carbonate values varied from 0 to 24 parts per million, and the bicarbonate values from 160 to 209 parts per million. Ellis says carbonates and bicarbonates in natural waters range from 0 to 250 parts per million.

Water temperature of Bear Creek and East Gallatin stations was determined. It was found that Bear Creek was colder by five to eight degrees than the East Gallatin. On August 4, river readings varying between 20.8° C. and 23.4° C. averaged 21.3° while the Bear Creek average was 15° C. On August 15, Bear Creek temperatures were 11.2° C. to 12.2° C. and the river average was 18° C. Setchell and Gardner (1903) in referring to coast marine waters say the temperature of the surface waters are of extreme interest because they are the principal factors concerned in limiting distributions and bringing about the existance of general geographical regions of distribution. Although they were studying coastal waters from Alaska to lower California there might be a similar relationship in fresh water environment.

SUMMARY AND CONCLUSIONS

During the eight weeks of study, twenty-five genera, including twenty-nine species and two varieties were identified, eight species were tentatively identified, and four unknown genera were described. A key based on vegetative characteristics was made, constructed? by which all algae found in the area studied could be identified to genus. Species of Vaucheria and Oedogonium cannot be identified beyond genus without the observation of the fruiting bodies, while spores of Spirogyra species must be present for positive identification. Many specimens have been preserved in Transeau's solution which was found to be an excellent preservative for filamentous forms.

Bear Creek differed in appearance from the East Gallatin River more than did the tributaries Rocky Creek and Bridger Creek. Bear Creek had cooler water, less sediment, and greater turbulence than the other streams. Its dominant species, Nostoc, Monostroma, and Rhizoclonium differed from those of the other three streams. The latter supported large quantities of Cladophora glomerata, and several Oscillatoria and Spirogyra species.

It appears that the main effect of the Bozeman sewage on the algal flora of the East Gallatin River was that of decreasing the number of individuals rather than the number of species. The presence of small amounts of green forms--Cladophora glomerata, Spirogyra adnata, Chlamydomonas species and species of Vaucheria--within a hundred yards of the sewage outlet, and a complete resumption of the normal algal picture at station B, one and one-half miles downstream, lends itself to the conclusion that the East Gallatin River is not grossly polluted by the Bozeman sewage. Although large quantities of species of Oscillatoria appeared downstream from the sewage outlet, they also thrived in equally large numbers above that point.

The following conclusions were reached by the writer:

1. The classification of species in this paper is a start toward the complete all-season record of the algal flora of the East Gallatin River and its tributaries. It is hoped that additional work will complete the list of algal species in our area.

2. The East Gallatin River is not grossly polluted by the Bozeman sewage.

3. Bear Creek supported a different group of dominant species from the main river and other tributaries with these factors adding in the cause: cooler water, less sediment.

4. Carbonate concentration in the streams varied from 0-24 parts per million, bicarbonate concentration ranged from 160-209 parts per million, and the pH value ranged from 6.8-7.8.

5. Water temperature should be thoroughly investigated if supplementary studies are made.

6. _Oscillatoria_, _Stigeoclonium_, _Mougeotia_, _Spirogyra_, and diatoms increased in quantity of individuals as the season advanced.

7. _Cladophora_, _Rhizoclonium_, and _Vaucheria_ showed no appreciable increase in quantity as the season advanced.

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EXPLANATION OF PLATES AND MAP

PLATE I

Figure 1: *Euglena* sp., x 440.

Figure 2a: Unknown genus #1, x 100.

Figure 2b: Unknown genus #1, x 440.

PLATE II

Figure 1: Unknown genus #2, x 440.

Figure 2: Unknown genus #4, x 440.

MAP

Scale: 3/4 inch = 1 mile.

Collecting stations marked in red.

PLATE I

figure 1

figure 2a

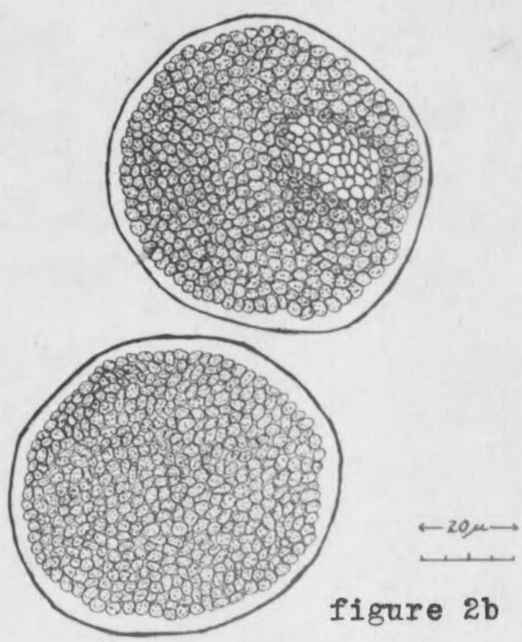
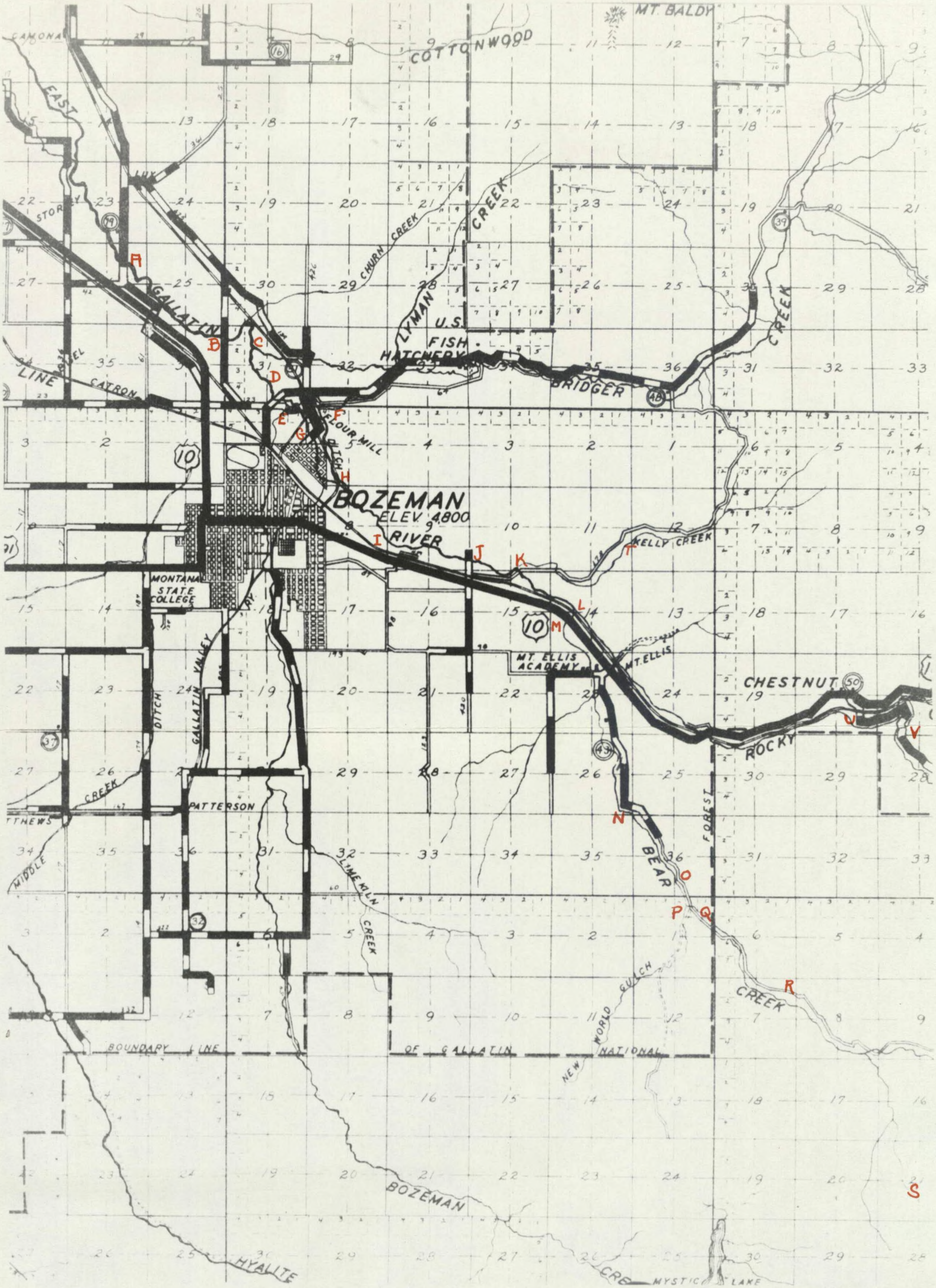


figure 2b

PLATE II

figure 1

figure 2


MT. BALDY
COTTONWOOD
EAST
LUX
STORY
GALLATIN
CHURN CREEK
LYMAN CREEK
U.S. FISH HATCHERY
BRIDGER
CREEK
LINE
CATRON
FLOUR MILL
DITCH
BOZEMAN
ELEV 4800
RIVER
KELLY CREEK
MONTANA STATE COLLEGE
GALLATIN VALLEY
MT. ELLIS ACADEMY
MT. ELLIS
CHESTNUT
ROCKY
BEAR
FOREST
DITCH
PATTERSON
MIDDLE CREEK
LIME KILN CREEK
NEW WORLD GULCH
CREEK
BOUNDARY LINE OF GALLATIN NATIONAL
BOZEMAN
HYALITE
CRE
MYSTIC LAKE
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