AN ABSTRACT OF THE THESIS OF

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(Name) (Degree)

in BOTANY presented on July 23, 1968
(Major) (Date)

Title: BENTHIC ALGAL COMMUNITIES OF THE METOLIUS RIVER

Abstract approved: Redacted for Privacy
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Samples of benthic algae were collected from the Metolius River of central Oregon at two-week intervals between April 15, 1967 and March 9, 1968. Species of filamentous algae and diatoms present were recorded for every sampling station on each sampling date. Permanent mounts of diatom frustules were prepared.

This sampling revealed a community dominated by species of *Cladophora*, *Achnanthes*, and *Spirogyra* to be present throughout much of the study area on a year-round basis. Although seasonal distributions were evident for some species, the majority of species were perennial. In view of the fact that the physical and chemical characteristics of the Metolius River remained constant over the year, such seasonal periodicity as was observed may be attributed to changes in available solar radiation.

The described community was distributed throughout the study area with the exception of the headwaters and the sampling station immediately downstream. Species of diatoms were dominant at these

two sites, with filamentous forms not well established. Species of filamentous algae were found regularly at downstream sampling sites where current velocity was somewhat reduced.

This Cladophora - Achnanthes - Spirogyra community was similar in species composition to other previously described Cladophora communities, and appears to be characteristic of a cold mountain stream which is free of organic pollution.

Benthic Algal Communities of the Metolius River

by

Barbara Jane Powell Sherman

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

June 1969

APPROVED:

Redacted for Privacy

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Date thesis is presented July 23, 1968

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ACKNOWLEDGEMENTS

I should like to express my sincere appreciation to my major professor, Doctor H. K. Phinney, for his assistance and encouragement during the course of this study and assistance in the preparation of this thesis. Thanks are also due Doctor C. David McIntire for his advice and help with diatom taxonomy.

I wish, also, to thank Doctor Frank H. Smith for his constructive criticisms of this manuscript.

To my husband, Robert, for his assistance in the field, help in the presentation of data, encouragement and patience, I shall always be grateful.

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BENTHIC ALGAL COMMUNITIES OF THE METOLIUS RIVER

INTRODUCTION

The ecology of algae has been approached in a variety of ways, each designed to shed light on the responses of these plants to their environment. Algal ecology assumes increasing importance as problems arise regarding the pollution of water supplies vital to man. Responses of algae to such pollution may, for instance, take the form of "blooms," rendering water supplies unfit for use.

The ecology of algae is complicated in natural situations by the instability of an environment in which many variables are operating at any one time. This is particularly the case when dealing with lotic environments. The Metolius River, arising on the east slope of the Cascade Mountain Range in central Oregon, is unique for a stream of its size in that it is essentially free of much of the variability common to other rivers. For this reason, the Metolius River was selected for the study of the effect of environmental factors upon the composition of natural communities and the distribution of algal species in a lotic situation.

REVIEW OF LITERATURE

In comparing fresh water habitats from the standpoint of streams versus lakes and ponds, Odum (1959) described the stream habitat as more open than that of the lake or pond, and more subject to environmental influences. This is frequently the case when variations in meteorological conditions bring about changes in current velocity, clarity of water, and temperature in streams. Perhaps it is for this reason that lotic habitats have received relatively little study in the United States compared with the effort directed toward the study of bodies of standing water.

There have been numerous studies of the flora of European streams, including the work of Butcher (1932, 1944) and Budde (1942). Studies of streams in the western United States include the work of McConnell and Sigler (1959) on the Logan River of Utah and the study by Pennak (1943) of Boulder Creek in the Rocky Mountains of Colorado.

Although the study carried out by Pennak concerned primarily the zooplankton of Boulder Creek, a portion of the study was devoted to a description of phytoplankton. Boulder Creek was described as a small, cascading mountain stream which was subject to change as a result of precipitation in the surrounding mountains. These changes consisted of variations in clarity of water, chemical characteristics and rate of flow. Although the streambed was at no time completely dry, the flow was greatly diminished during periods of reduced precipitation. The Logan River was likewise described by McConnell and Sigler as a rapidly flowing stream in which conditions tended to vary markedly with changes in precipitation patterns. In this case, attempts were made to assess the productivity of the stream through quantitative estimates of chlorophyll. Benthic algae mentioned as making up part of the standing crop of the Logan River included *Cladophora glomerata* (L.) Kütz. and *Vaucheria*.

The observation has been made that swiftly flowing streams do not develop a true plankton but, rather, such forms as may be found free-floating are benthic forms which have become dislodged from their normal habitat (Butcher, 1932; Pennak, 1943; Blum, 1957b). As pointed out by Whitford (1960b) studies which have been directed toward the algae of streams have centered mainly around the planktonic forms.

The current of a swiftly flowing stream necessarily imposes restrictions upon the types of organisms which may survive under these conditions. The benthic algae of such streams are forms which are capable of adhering to the substrate by means of some sort of holdfast, and encrusting forms may also be evident (Fritsch, 1929). The benthic communities of streams have been described by Blum (1957b) as frequently dominated by species of *Cladophora* which possesses a well developed holdfast structure. A growth habit which does not offer resistance to flowing water is also advantageous. This situation limits the diversity of species which may inhabit a stream, particularly a rapidly flowing stream such as those frequently encountered in mountainous areas.

Not only does the movement of flowing water exert a limiting influence upon species in terms of ability to remain attached to the substrate, but the effect of flowing water may be a physiological one as well. Measurements of respiratory rates of a fresh water alga carried out by Whitford and Schumaker (1961) have shown respiration rates to be higher in moving than in standing water. This difference may result from the constant renewal of the water surrounding attached algae.

Whitford (1960a) also pointed out that some species seem to be particularly characteristic of moving water, and are capable of their most favorable growth in this situation. Studies of benthic forms developing under the influence of two different current velocities have shown a higher rate of productivity at the higher current velocity (McIntire, 1966). It would thus appear that some forms benefit from an active current in terms of increased rates of growth and metabolism.

A variety of methods have been devised for the study of benthic algae in the naturally occurring communities of streams and rivers. Several types of methods were described by Cooke (1956) including the use of submerged glass slides as artificial substrates. Glass slides were employed by Butcher (1946) and by Patrick (1950) as well as Deever (1962) and Reese (1966). Slides to be used for this purpose were mounted in racks and suspended in the water for varying lengths of time. The use of plexiglass plates in a similar manner was described by Grzenda and Brehmer (1960). In addition, the use of concrete cylinders as artificial substrates has been described by Waters (1961). After a designated period of time, such artificial substrates were removed, and the species which had colonized the surface identified. The accumulated biomass may be determined. Quantitative measurement of cumulative growth may be made by methods involving pigment analysis, dry weight measurements, or the counting of individual organisms occupying a unit of area (Douglas, 1958; Kobayasi, 1961). Periodic inspection of such substrates provides insight into the pattern of colonization of bare surfaces, making it possible to determine whether or not a form of succession takes place as well as the length of time necessary for a stable community to become established.

Methods of "ranking" species of algae in natural waters in terms of their abundance include that of Jones (1951) in which macroscopic forms were classified as abundant, common, rare, and very rare. Estimates of cover were described by Sládečková (1962) in which the importance of a species was designated on a six-point scale dependent upon the amount of surface area actually covered by growth of the species in question. Microscopic forms were ranked by Brook (1955) from abundant to rare on the basis of the number of cells observed in a given number of microscope fields.

The line transect method of sampling attached forms was described by Blum (1957a) in studies of the Saline River of Michigan. In this case, sampling was carried out in a direct line across a shallow river, with samples being removed or identified in situ at specified locations across the streambed. Also, samples of benthic algae may be removed from rocks taken from the streambed itself. Quantitative measurements may be made of the numbers of organisms removed from a specifically measured surface area (Butcher, 1946).

Measurements of the chlorophyll extracted from the organisms found on naturally occurring substrates may also be used as a measure of the biomass present (Grzenda and Brehmer, 1960). Such measurements are, of course, most meaningful in situations where growth is relatively uniform and are not particularly meaningful in cases in which plants are scattered or exhibit a mosaic pattern.

Among the characteristics of natural streams which are usually subject to rapid change from time to time is the rate of flow. Douglas (1958) pointed out the effect of changes in current velocity upon the composition of benthic communities. In fact, it has been stated by Margalef (1960) that variations in current velocity may be more important than variation in temperature in influencing the composition of the flora of streams.

The environmental factor of temperature may, of course, exert an influence upon the plants found in flowing waters. It was noted by Pearsall (1923) that some have concluded that diatom periodicity is due to fluctuations in temperature. However, Pearsall has shown maximum development of Melosira to be correlated with flooding, possibly due to the influence of dissolved substances added to the water during such periods.

Hargraves and Wood (1967) have described what appears to be the effect of changes in water temperature upon the benthic algae of a river. However, certain elements of the flora, namely the diatoms, remained fairly constant throughout the year in spite of these temperature fluctuations. Whitford (1960b) has also noted that some species of fresh water algae appear to be sensitive to temperature changes. In this case, however, diatoms were included among those forms which may show sensitivity to temperature changes. It was emphasized that the relationship between the effect of temperature and the effect of variation in solar radiation has not been adequately investigated.

In addition to the study of streams themselves, the springs which give rise to streams have been studied from an ecological point of view. Prominent among studies of the ecology of springs is the work of Odum (1957) dealing with the Silver Springs of Florida. He has demonstrated that the spring habitat is remarkably stable and produces a situation comparable to that encountered in the laboratory where environmental factors may be carefully controlled. In the case of Silver Springs, photoperiod was the only environmental factor which fluctuated over the course of time. Such is no doubt the case in a great many, if not most, spring habitats.

Springs have been used in studies of community metabolism by Teal (1957) who noted that the flora of a spring is usually comprised of relatively few species. The community of benthic algae found in springs was classified by Whitford (1956) as perennial, due, again, to the constance of environmental factors.

The delineation of associations of terrestrial plant species into what are termed communities has long been a practice of some terrestrial ecologists. Less information is available regarding the existence of definable communities of aquatic plants, particularly cryptogamic forms. Problems involved in the analysis of aquatic plant communities have been described by Shelford and Eddy (1929). The question was raised as to whether aquatic plant communities will reach a steady state under uniform environmental conditions. The authors advanced the idea that permanent stream communities do indeed exist and are as classifiable as terrestrial plant communities.

More recently, types of algal communities characteristic of flowing waters have been described by Blum (1960). Included in this discussion is a listing of species which are described as rheophilic, together with environmental conditions under which each of these species tends to be found. In addition, means of classifying algal communities were described.

DESCRIPTION OF STUDY AREA

The Metolius River

The Metolius River arises at 915 m elevation as a large spring flowing from the base of Black Butte in Jefferson County, Oregon, Twp. 13S, Range 9E, Section 22, NE quarter and flows in a north-northeasterly direction for approximately 35 km, terminating in Lake Billy Chinook (Figure 1). For the purposes of this study, investigation was limited to the upper 13 km of the Metolius River (Figure 2).

The soils in the area are of volcanic origin and are characteristically gravely and highly pervious, with a low organic content. The streambed itself consists of rocks and boulders of varying sizes with no silting generally evident. Occasional deposits of sand are found at the edge of the water in areas of reduced current velocity.

The dominant tree species in the area immediately adjacent to the portion of the river under consideration is ponderosa pine. This type of open forest with little growth of shrubs along the stream bank results in very little shading of the surface of the water.

The Metolius River and many of the tributary streams are largely spring fed, resulting in a relatively constant discharge over the course of the year. This is evident in Figure 3 in which data from a gauging station on the upper Rogue River of southwestern Oregon is

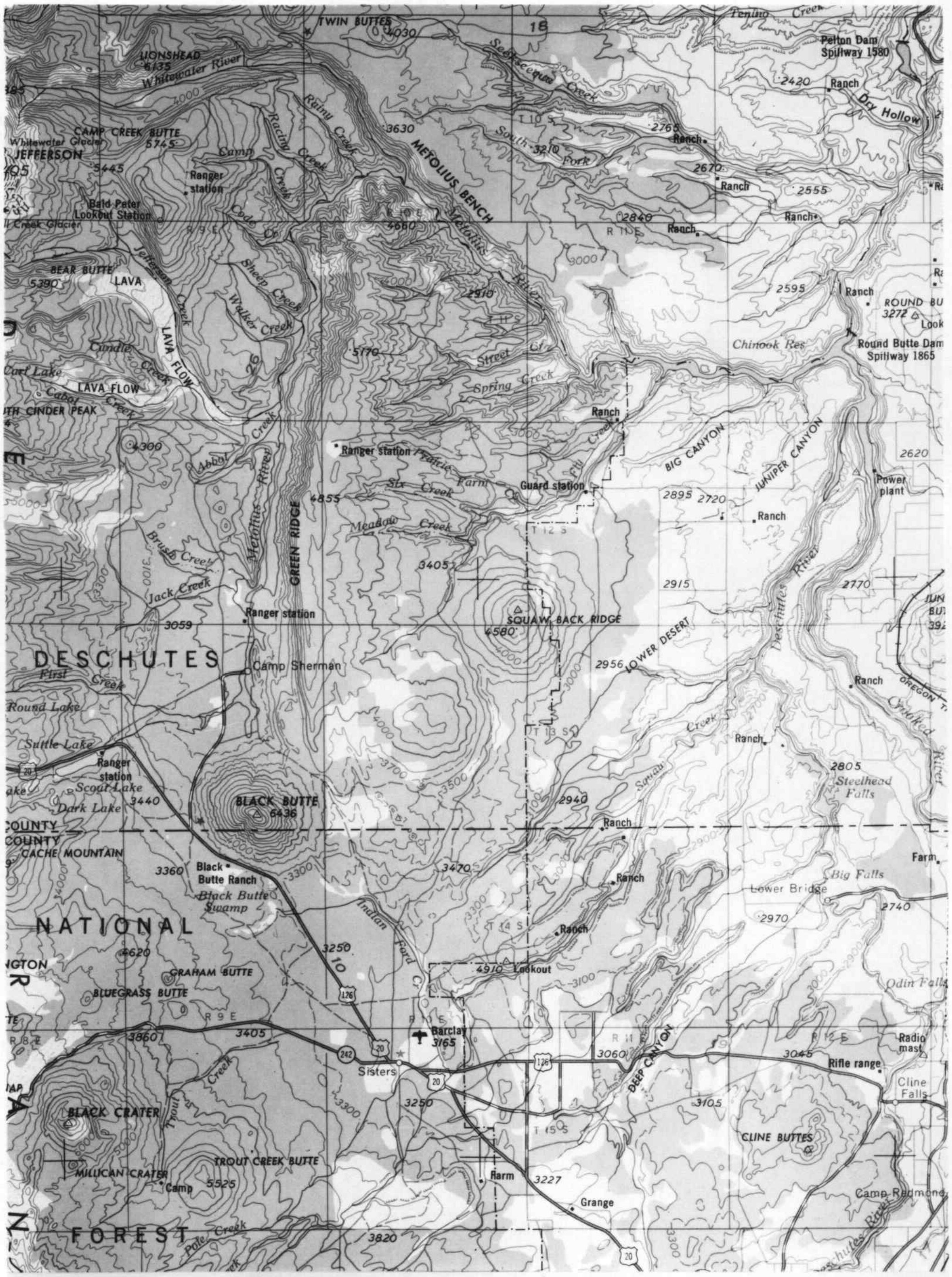


Figure 1. Map of portion of Bend Quadrangle, Oregon (U. S. Geological Survey Map. 1955).

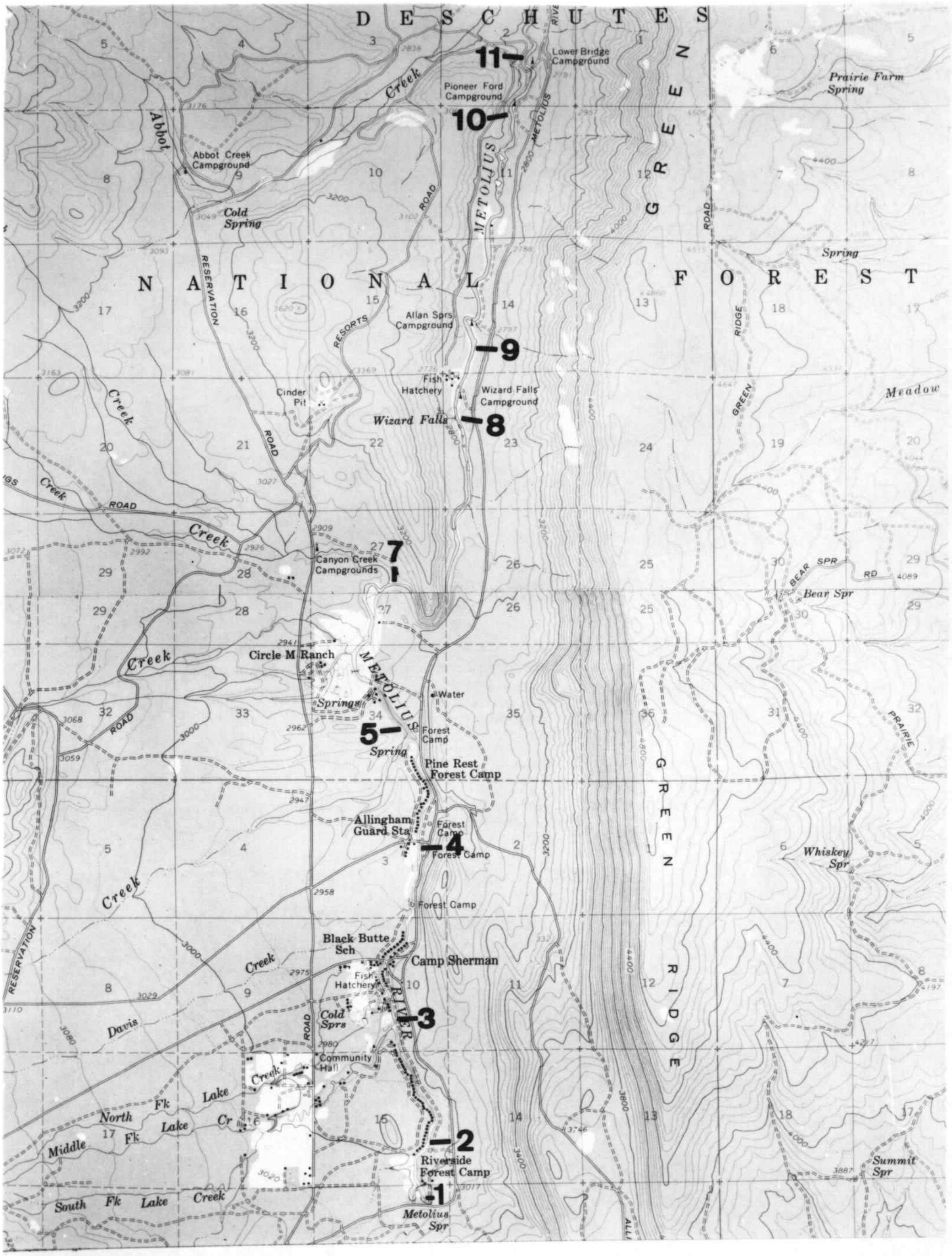


Figure 2. Topographic map of study area showing location of sampling stations (U. S. Geological Survey Map, Whitewater River Quadrangle, Oregon. 1961).

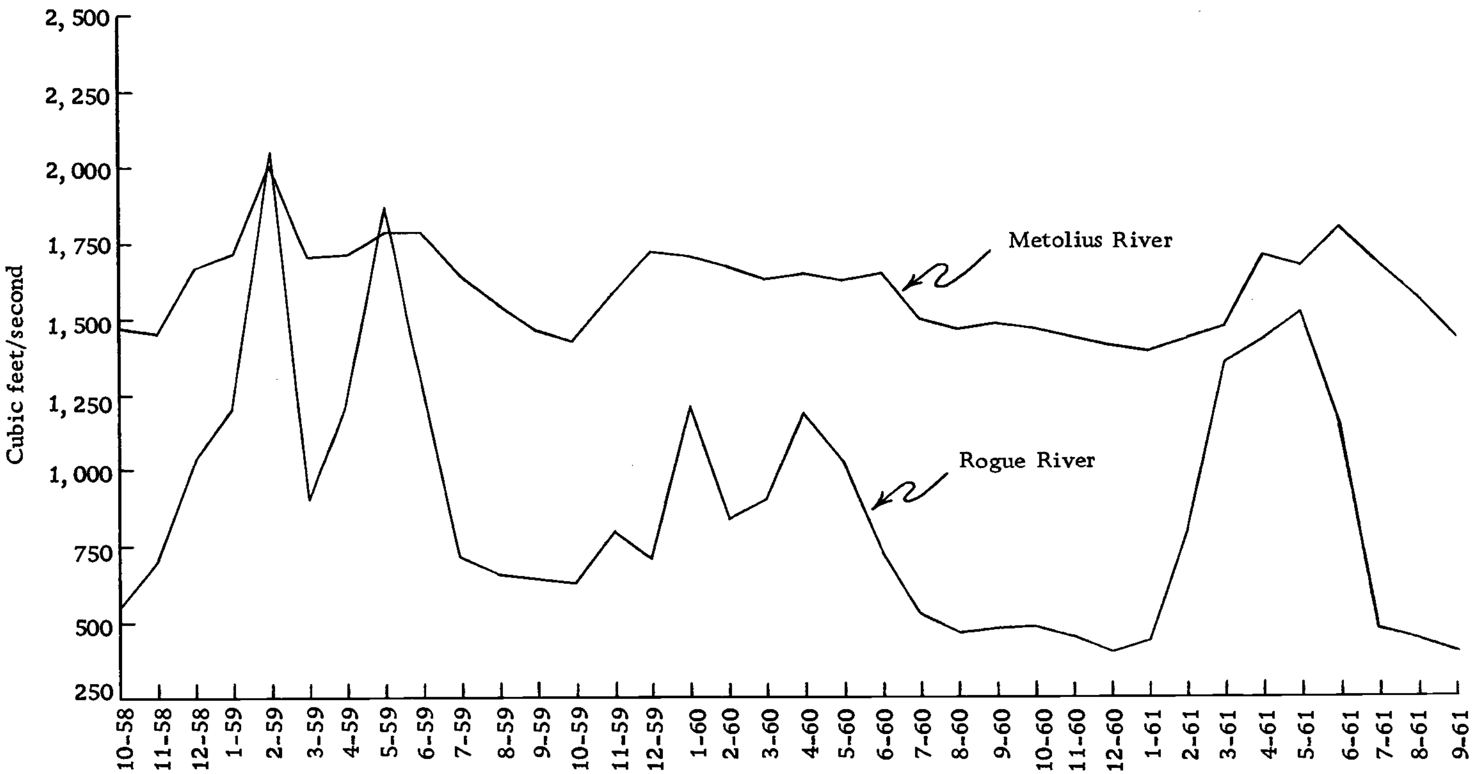


Figure 3. Comparison of the discharges of the Metolius and Rogue Rivers over a three year period.

included for purposes of comparison with data from a gauging station on the lower Metolius (Hendricks, 1963).

The Rogue River, like the Metolius, is free of impoundments and diversions above the location of the gauging station. The Rogue exhibits a much greater variation in discharge. The portion of the Metolius River included in the study area is even less subject to variation in volume than is the lower portion of the river which includes the gauging station, as a series of tributaries empty into the river below the study area and influence the volume of discharge. Despite this fact, the constant flow of the Metolius River is readily apparent.

Early records of the discharge of springs and tributaries of the Metolius River have been summarized by Meinzer (1927). Apparently, few measurements have been made in more recent years other than those at the lower reaches of the channel near the mouth of the river. However, in view of the small amount of water diverted for purposes such as irrigation and relatively little disturbance in the area that would cause radical changes in surface or ground water patterns, early records are most probably completely applicable at the present time.

The discharge of Black Butte Springs (Metolius Springs) was recorded as 122 second feet (3.4 m^3/second) on November 24, 1925. The flow is augmented within the first three miles by the discharge of Lake Creek and Spring Creek. During the years 1911 and 1912, the flow recorded at a gauging station maintained at Allingham Ranger Station averaged 376 second feet (10.5 m^3/second).

Jack Creek, entering the river approximately 3 km below Allingham Ranger Station, was described as having a flow of about 30 second feet (.8 m^3/second). Canyon Creek, entering just below Jack Creek had a flow of never less than 30 second feet (.8 m^3/second). It is also largely spring fed.

In 1912, additional large springs downstream from the mouth of Jack Creek were recorded as having a discharge of 128 second feet (3.6 m^3/second). The Metolius River, at a point 4.8 km downstream from the mouth of Canyon Creek, had a flow of 1,040 second feet (29.1 m^3/second) on March 26, 1912 and 1,100 second feet (30.8 m^3/second) on June 22, 1915. Measurements obtained from a gauging station at a point below all tributary streams indicated a flow never less than 1,300 second feet (36.4 m^3/second).

The situation described differs radically from that frequently encountered in mountain streams in which spring freshets are followed by a period of greatly reduced flow in the late summer and autumn months. The low level of precipitation in the area results, also, in little variation in the clarity of water, since there is little or no surface runoff during the year. According to data obtained from the Sisters Ranger Station, average annual precipitation is approximately 44 cm. Much of this occurs as snow in the months of November through March, with occasional thunderstorms contributing small amounts of rain during the summer.

The segment of the Metolius River between the headwaters and the mouth of Lake Creek exhibits very little turbulence. Depths generally do not exceed 40 cm. The riverbed measures approximately 30 m wide throughout most of this segment. Downstream from the mouth of Lake Creek, frequent areas of deeper, more turbulent water are found where the channel is markedly narrowed. These areas are interspersed with areas of less turbulent, shallower water flowing over a broad, flat stream bed. This sort of situation exists throughout the study area, with turbulent conditions particularly pronounced in the vicinity of Gorge Forest Camp and the Wizard Falls Trout Hatchery.

The temperature of the Metolius River varies only slightly during the year (Figure 4). This is characteristic of streams which are largely spring fed and is in sharp contrast with most streams which show a definite seasonal fluctuation in water temperature. This situation is somewhat unique, also, in that water temperature tends to decrease slightly downstream from the headwaters rather than increasing. This reduction results from the presence of springs along the course of the river.

Data obtained from chemical analyses performed by the Oregon

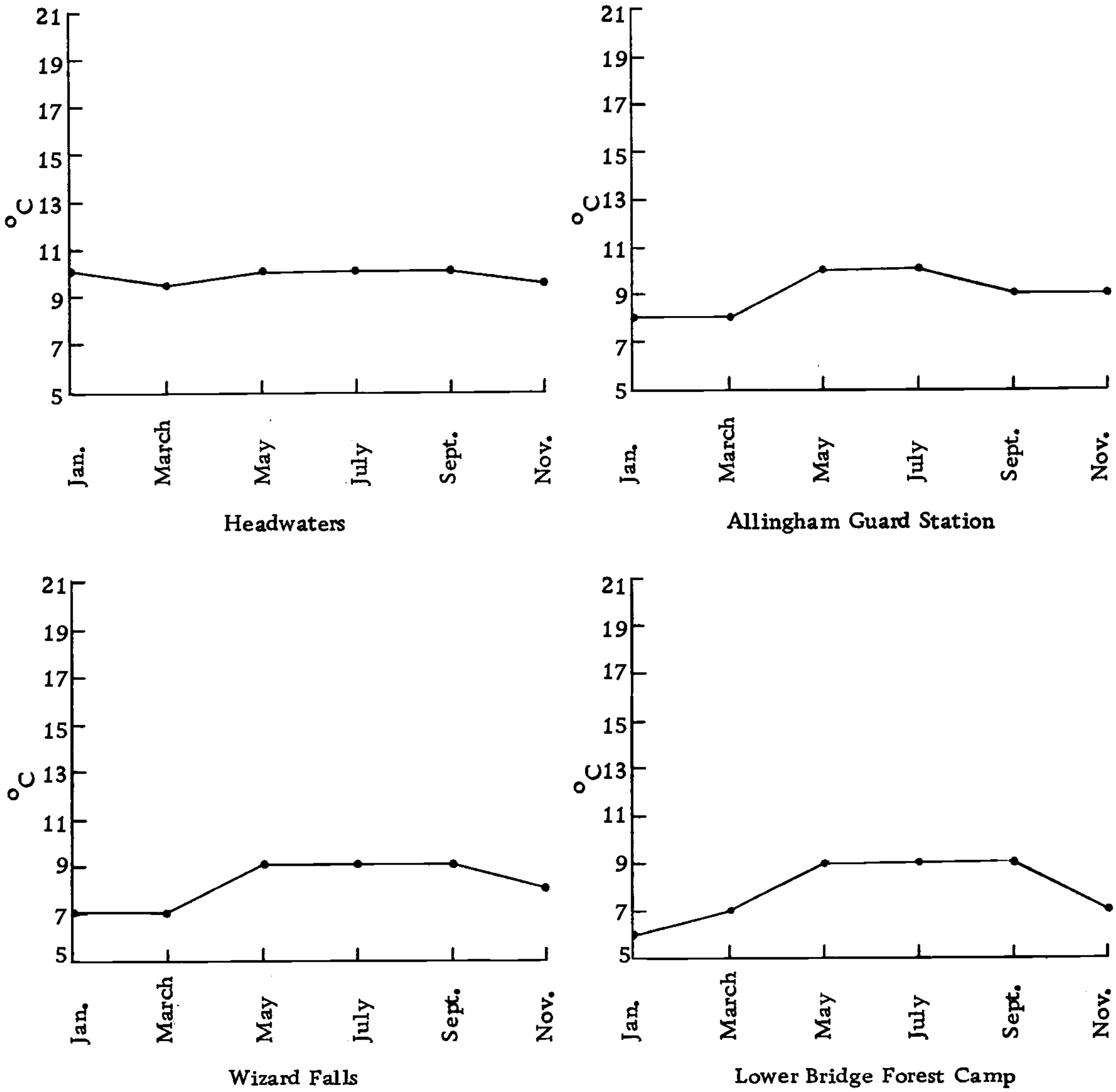


Figure 4. Temperature recorded at selected sites on the Metolius River during 1967 and 1968.

State Sanitary Authority are presented in Table 1. Samples were taken at the headwaters and at a point approximately 1.5 km downstream from Bridge 99, 12 km north of Camp Sherman. The Metolius River is a slightly alkaline stream, the pH falling well within the normal limits for natural surface waters. Dissolved oxygen is uniformly high, with a low BOD. The level of nitrate nitrogen is also low. The levels of dissolved oxygen, BOD and nitrate fall within the levels defined by Patrick (1950) as normal for an unpolluted stream. Little seasonal periodicity in levels of chemical constituents is observed nor is there a pronounced difference in quality between the water flowing from the spring and in the lower portion of the study area.

The segment of the Metolius River between Metolius Springs and Gorge Forest Camp includes several Forest Service campgrounds and summer home developments as well as private resorts. Use of these recreational facilities is quite heavy during the summer months. A small number of homes along the river are in use during the entire year. The location and density of summer homes, forest camps and resorts may be seen in Figure 2.

Sampling Stations

Following a period of reconnaissance during the summer of 1966, ten sampling stations were established at intervals along the Metolius River from Metolius Springs (Black Butte Springs) to Lower

Table 1. Results of analyses of water samples taken from the Metolius River. Analyses performed by the Oregon State Sanitary Authority.

		pH	DO	NO_3-N mg/L	NH_3-N mg/L	$SO_4^=$ mg/L	$PO_4^{\equiv}$ mg/L	Cl^- mg/L	BOD
Head-waters	9-8-65	-	-	-	-	-	-	-	-
	5-3-66	-	-	-	-	-	-	-	-
	7-12-66	7.3	9.2	<.01	.260	.60	.230	1.90	0.1
	10-4-66	7.8	10.7	.040	.023	3.80	.150	1.60	0.9
	4-25-67	7.3	9.4	<.01	.130	1.00	.210	2.80	0.0
	8-22-67	7.1	8.9	.02	.030	7.00	.110	2.90	0.4
Below Sheep Creek	9-8-65	7.3	11.1	.160	.810	1.50	.110	2.60	-
	5-3-66	7.4	10.1	.040	.140	10.00	.210	1.30	1.5
	7-12-66	7.3	10.2	.050	.210	.60	.180	1.80	0.1
	10-4-66	7.4	11.0	<.020	.090	2.80	.210	1.40	0.8
	4-25-67	7.3	10.9	<.010	.200	1.00	.180	1.90	0.2
	8-22-67	7.1	10.2	.010	.030	8.20	.060	2.33	0.5

Bridge Forest Camp, a point approximately 14 km downstream from Metolius Springs (Figure 2). With the exception of stations 7 and 10, which were inaccessible during the winter because of snowfall, samples of benthic algae were collected from each station at approximately two-week intervals between April 15, 1967 and March 9, 1968. Sampling stations were selected on the basis of accessibility and the degree to which conditions allowed a representative sample to be obtained. These sampling stations are pictured in Figures 5 through 12.

A sixth sampling station, not indicated in Figure 2, was established during preliminary investigation. It was necessary, however, to curtail collecting at this site due to difficulty of access and very few samples were obtained.

Station 1 was established at Metolius Springs. Samples collected at this point included aquatic vascular plants for the identification of epiphytes and small rocks for the study of microscopic forms. Unlike the remaining sampling stations, growth of trees and shrubs surrounding the spring provides shade throughout the year.

Station 2, just downstream from Riverside Forest Camp, includes a segment of quite shallow water where it was possible to sample the entire width of the river. As at sampling stations further downstream, the shading here is minimal as an open forest surrounds the stream which has an approximately 30 m wide streambed.

Figure 5. Photograph of sampling station 1.

Figure 6. Photograph of sampling station 2.

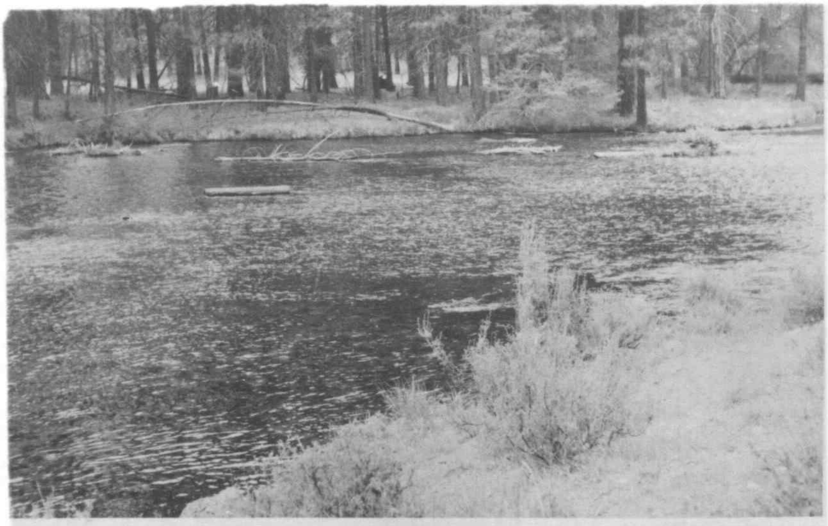


Figure 7. Photograph of sampling station 3.

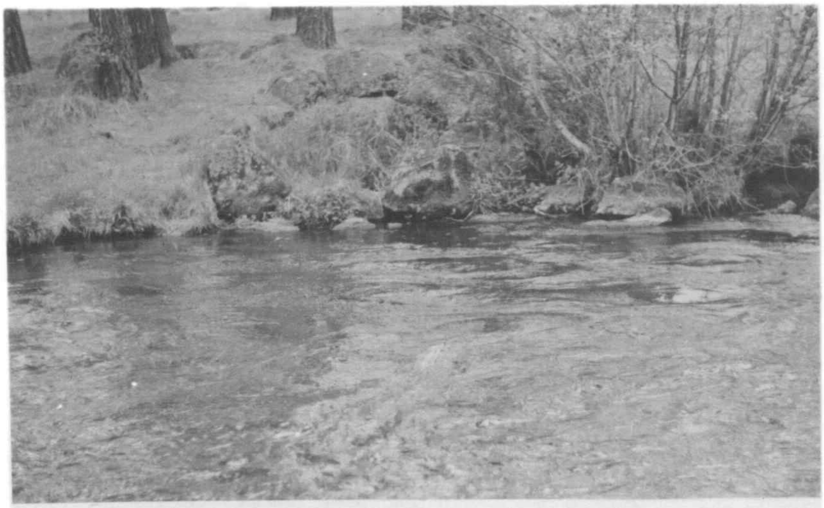


Figure 8. Photograph of sampling station 4.

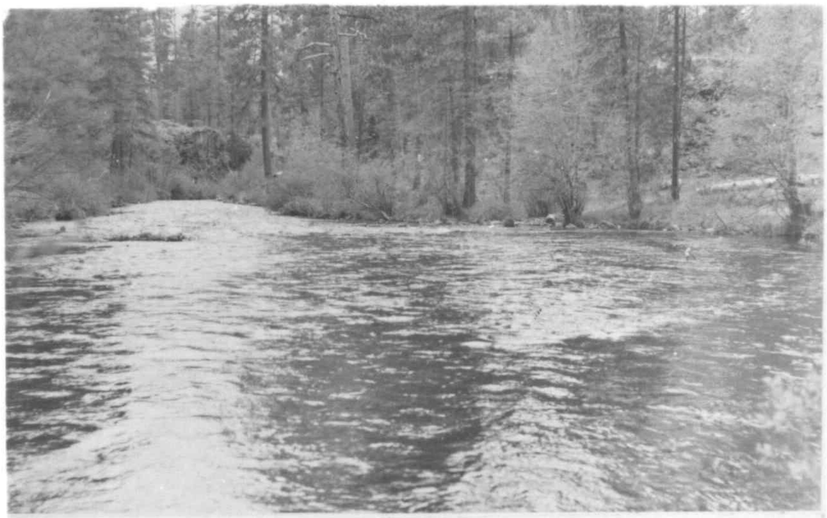


Figure 9. Photograph of sampling station 5

Figure 10. Photograph of sampling station 8.

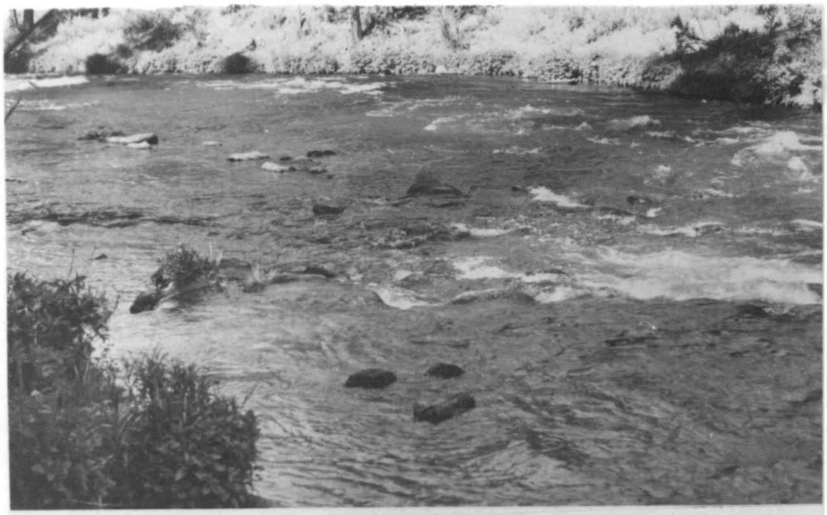


Figure 11. Photograph of sampling station 9.

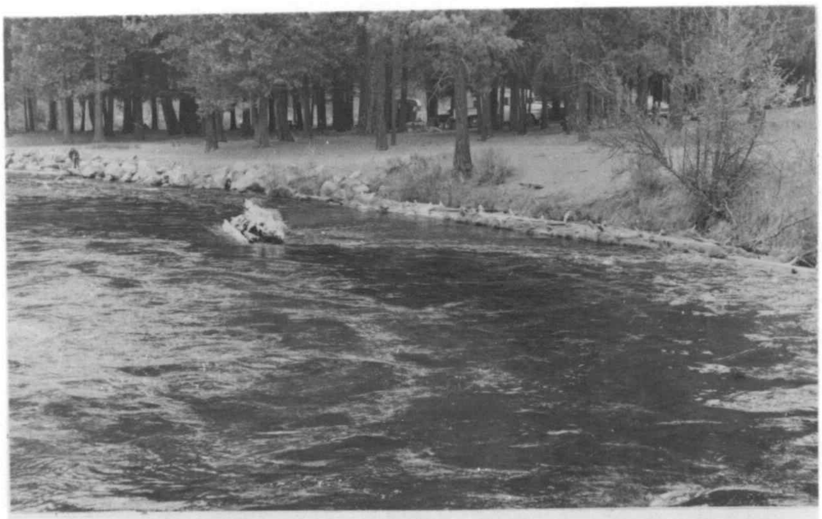


Figure 12. Photograph of sampling station 11.

Sampling station 3, approximately 10 m downstream from the mouth of Lake Creek, is also an area of shallow water with a channel measuring approximately 30 m in width. The streambed is composed of small, smooth rocks and some larger rocks which project above the surface. The entire width of the river may be waded at this point.

Sampling station 4, at Allingham Guard Station, includes portions of the streambed covered by shallow water where collections may be made fairly easily. Nearer the center of the stream, however, the shallow portion is abruptly interrupted by a channel estimated to be approximately 3 meters deep. No attempt was made to collect from these deeper waters. This situation is not uncommon in several places along the course of the upper 14 km of the Metolius River. In many cases, visual observation lead to the conclusion that there was little or no plant growth on the rocks in these deeper areas, probably as a result of high current velocity.

Sampling station 5, at the lower end of Gorge Forest Camp, includes a stream segment which is shallow along both banks, with deep and turbulent water in the center third of the width. The substrate here is primarily large, flat rocks. Immediately downstream from the sampling station, the river channel becomes narrow and the water very turbulent.

Sampling station 8 was established at Wizard Falls approximately .4 km upstream from the Wizard Falls Trout Hatchery. As at station 4, shallow water near the edges of the streambed allowed fairly effective sampling, but much deeper, turbulent water precluded sampling for the entire width. Much of the streambed at this point is composed of smooth, flat rock. Sampling station 9, located 1 km downstream from station 8 is essentially similar.

Sampling station 11, located at Lower Bridge Forest Camp, includes an area of deep, swift water, and sampling was of necessity confined to the rocks along either edge of the river.

Stations 7 and 10 were accessible only during the summer and autumn months. In the case of both these sampling stations, current velocity limited sampling to the rocks near the edge of the streambed.

Measurements of current velocity were taken at each sampling station (Figure 13). These measurements are an average of readings obtained on two separate occasions, as current velocities on the two dates were nearly identical.

These current velocity measurements are not intended to be representative for the river as a whole at any one point, but only for the portion of the riverbed actually sampled. For this reason, the current velocity at stations 2 and 3, where sampling was carried out for the entire width of the river, appears greater than that at sampling stations further downstream where sampling was limited to rocks near the edge of the streambed. In these downstream areas current velocity was quite low relative to that nearer the center of the stream.

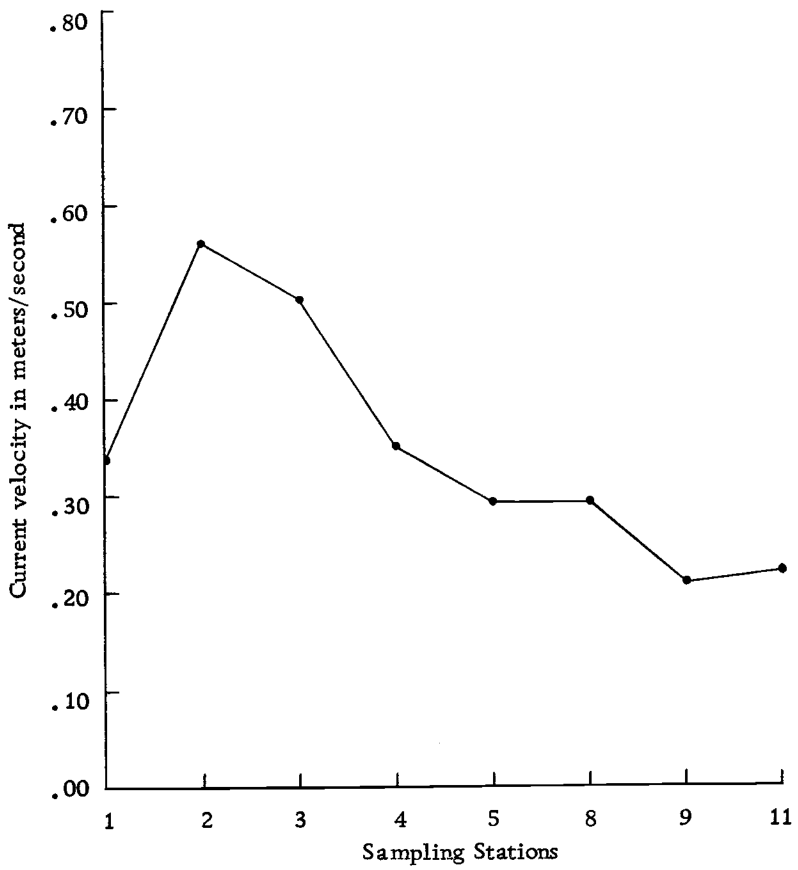


Figure 13. Current velocity in meters per second, recorded at eight sampling stations on the Metolius River.

MATERIALS AND METHODS

Collection of Samples and Identification of Filamentous Forms

Samples of benthic algae were collected from randomly selected areas of the streambed in the accessible portions of the river at each sampling station at approximately two-week intervals between April 15, 1967 and March 9, 1968. Where possible, small rocks were removed in order that attached diatoms could be effectively removed for identification. Between six and ten samples were collected each time from each sampling station. Every sample was later examined microscopically, and the species of flamentous algae present recorded. Samples of each of the filamentous species collected were preserved as herbarium specimens by drying.

No attempt was made to obtain quantitative data concerning the amount of growth present because of the mosaic pattern of growth. Tufts of filamentous algae and macroscopically evident growths of diatoms were scattered over the surface of the rocks, with some rocks appearing entirely devoid of cover. Only in the upper reaches of the river was any sort of uniform cover of the substrate observed and then only in portions of the river bed. It was felt that under these circumstances, any attempt to obtain a quantitative estimate of growth would fail to be fully representative of the actual situation.

Preparation of Diatom Mounts

Permanent microscopic mounts of diatom material were prepared for each sampling station for each collecting date. In order to facilitate identification, diatom frustules were freed of organic matter using a combination of hydrogen peroxide and potassium dichromate.

Attached diatoms were removed from small rocks with a stiff brush and suspended in approximately 15 ml of water. To this suspension were added small portions of filamentous material from each sample to insure inclusion of epiphytic diatoms. In this manner, an attempt was made to prepare a sample of diatom material representative of a given sampling station.

Approximately 3 ml of 30% hydrogen peroxide was added to the suspension of diatom material and the sample allowed to remain at room temperature for 48 hours. During this time, oxidation of organic material occurred. A few crystals of potassium dichromate were then added to the suspension. Following clearing of the suspension, 30 ml of distilled water was added and the suspension left at room temperature for a minimum of three hours. At this time, a sediment of frustules was evident. The supernatant fluid was discarded and 40 ml of distilled water added to the precipitate, with mixing, to assure thorough washing of the frustules. After three hours, the supernatant fluid was again removed, and the cleaned frustules suspended in a quantity of distilled water sufficient to give a concentration suitable for mounting.

A small amount of diatom material was spread evenly on a clean cover glass and allowed to air dry. The cover glass was heated for five minutes at high temperature using an electric hotplate and mounted on a glass slide in a small amount of Hyrax mounting medium. The slide was heated gently to dispel the benzene solvent. Pressure was applied to the coverglass to assure as thin a mount as possible.

Slides of diatom material were examined microscopically by observing fields randomly selected across the slide and the species identification recorded for the first 100 frustules observed. Identification of diatom species was based on Heusted (1930), Patrick and Reimer (1966), and Sovereign (1958) with the assistance of Dr. C. David McIntire of the Department of Botany and Plant Pathology, Oregon State University.

Only those species of diatoms constituting at least 5% of the 100 cells identified on any one slide are included in the discussion to facilitate comparisons between sampling dates and sampling stations. It was felt that limitations imposed by the physical character of the river itself and the patterns of algal distribution in the river resulted in sampling methods which were not sufficiently sensitive to distinguish between species which made up less than 5% of the cells identified and those absent from any one slide.

Measurement of Current Velocity

Current velocity measurements were made with a Gurley pygmy current meter. Measurements were made as near as possible to the rocks from which samples were normally taken.

Analysis of Community Composition

An analysis of community structure was conducted as outlined by McConnaughey (1966). This method of analysis is a modification of that described by Fager (1957). A coefficient of association was determined for every pair of species collected on any given date according to the formula:

$$\frac{(a + b)c}{ab} - 1$$

where a was equal to the number of occurrences of one species on that date; b equal to the number of occurrences of the other species; and c the number of times the two species occurred together (at the same sampling site) on the date under consideration. Coefficients of association were arranged in a trellis diagram. Possible coefficients of association range from +1 where each occurrence of one species was accompanied by the other, to -1 where the two species did not occur together on the date under consideration.

When coefficients of association had been determined for every possible pair of species on a given date, species were grouped into communities, each member showing a positive grouping coefficient with every other species in the community (the core community). Following McConnaughey's suggestion, species that showed a positive grouping coefficient with half or more of the species in this core series were included in the community, resulting in nearly every species collected on any one date being included in a single group or community. In general, there was little or no tendency for the species which were not included in this major community to be positively associated with one another in any particular pattern. Instead, these species usually had negative coefficients of association with one another.

Ordination of Sampling Dates

In order to clarify the absence of seasonal variation in community composition in a quantitative fashion, sampling dates were compared by means of the dissimilarity index as described by Bray and Curtis (1957). The objective of the calculation of a dissimilarity index is the ordination of that which is to be compared (in this case dates) in such a manner that similarity and dissimilarity between sampling dates is readily apparent. The dissimilarity index was determined according to the formula:

$$c = 1 - \frac{2w}{a + b}$$

where w was the number of species common to both the sampling dates under consideration, and a and b were equal to the total number of species collected on each of the two dates being compared. In this manner, dissimilarity values were computed for every possible pair of sampling dates and the coefficients arranged in a matrix.

The date with the highest total dissimilarity to all other dates was designated a and assigned a value of 0 on the x-axis. The date with the greatest dissimilarity to date a was designated b and placed at the opposite end of the x-axis. The distance of each date from date a along the x-axis was determined according to the formula:

$$x = \frac{L^2 + Da^2 - Db^2}{2L}$$

where L was equal to the dissimilarity value between dates a and b; Da the dissimilarity value between date a and the date in question; Db the dissimilarity value between date b and the date in question.

In calculation of the y-axis coordinates, the date with the poorest fit on the x-axis was determined according to the formula:

$$e = \sqrt{Da^2 - Db^2}$$

The date with the highest poorness of fit value was located at 0 on the y-axis and designated a'. The date with the greatest dissimilarity to a' was designated b' and located at the opposite end of the y-axis. Dates were then located on the y-axis in the same manner in which they were located on the x-axis.

RESULTS AND DISCUSSION

Preliminary Sampling

Preliminary sampling revealed the filamentous algae present in the Metolius River to be species of *Cladophora*, *Spirogyra*, *Oedogonium*, *Ulothrix*, *Zygnema*, and *Vaucheria*. The diatom flora appeared to consist primarily of species of *Cocconeis*, *Diatoma*, *Achnanthes*, *Rhoicosphenia*, *Gomphoneis*, *Fragilaria*, and *Nitzschia*. Repeated sampling during the summer of 1966 and the autumn and winter months of the same year revealed little change in the composition of the communities at any of the sampling stations. These results were inconclusive, however, as sampling was at irregular intervals.

In addition to the uniformity of composition of the flora observed during preliminary sampling, the distribution of species along the course of the river appeared similar to that observed when sampling was performed regularly.

Regular Sampling

Tributary Streams

Sampling at two-week intervals was begun on April 15, 1967 and permanent mounts of diatoms from each sampling station were prepared from collections made on this and subsequent dates. In addition to samples taken from the Metolius River, samples from tributary streams were made at regular intervals during the summer and autumn months. In this way, it was hoped to determine whether changes occurring in these tributary streams would be reflected by changes in the river itself.

Sampling of the tributary streams included six stations at which samples of filamentous material were collected and from which permanent mounts of diatom material were prepared in the same manner as for the stations on the river. In general, although the flora of the tributary streams differed from that of the Metolius River, no effect upon the distribution of species in the river itself was noted. The floras of the tributary streams were dominated, not by Cladophora as was the case in the river, but by species of Spirogyra, Zygnema, Tetraspora, and Ulothrix. The absence of Cladophora may have resulted from the shading of the smaller streams by surrounding trees and shrubs. Important diatom genera included Synedra, Cocconeis, Fragilaria and Melosira. Sampling of these streams was curtailed during periods of winter snowfall because of the inaccessability of the collection sites.

Metolius River

A list of species collected from the Metolius River is presented in Table 2. This species list is not intended to be complete in view

Table 2. Species of algae collected from the portion of the Metolius River included in the study area, March 1967 to March, 1968.

Division Bacillariophyta

Achnanthes affinis Grun.
Achnanthes calcar Cleve
Achnanthes clevei Grun.
Achnanthes lanceolata (Bréb.) Grun.
Achnanthes minutissima Kütz
Achnanthes peragalli Brun & Hérib.
Amphora ovalis Kütz
Asterionella formosa Hass.
Cocconeis klamathensis Sov.
Cocconeis pediculus Ehr.
Cocconeis placentula Ehr.
Cymbella cistula (Hemprich) Grun.
Cymbella prostrata (Berkeley) Cleve
Cymbella turgida (Gregory) Cleve
Cymbella ventricosa Kütz.
Cymbellonitzchia diluviana Hust.
Diatoma hiemale (Ehr.) Grun.
Diatoma vulgare Bory
Diploneis elliptica (Kütz.) Cleve
Epithemia hyndmanii W. Smith
Epithemia sorex Kütz.
Fragilaria brevistriata Grun.
Fragilaria construens (Ehr.) Grun.
Fragilaria crotonensis Kitton
Fragilaria pinnata Ehr.
Fragilaria vaucheriae (Kütz.) Ehr.
Frustulia rhomboides (Ehr.) DeT
Gomphoneis herculeaneum (Ehr.) Cleve
Gomphonema eriense Grunow.
Gomphonema olivaceoides Hust.
Gomphonema rhombicum Fricke
Hannaea arcus (Ehr.) Patr.
Melosira granulata (Ehr.) Ralfs
Melosira varians C. A. Ag.
Meridion circulare (Grev.) Ag.
Navicula aurora Sov.
Navicula cryptocephala Kütz.
Navicula graciloides A. Mayer
Navicula pupula Kütz.
Navicula radiosa Kütz.
Nitzschia dissipata (Kütz.) Grun.
Nitzschia fonticola Grun.
Nitzschia frustulum Kütz.
Nitzschia oregona Sov.
Nitzschia palea (Kütz.) W. Smith
Rhoicosphenia curvata Kütz.
Stephanodiscus astraea (Ehr.) Grun.
Synedra mazamaensis Sov.
Synedra ulna (Nitz.) Ehr.

Division Chlorophyta

Cladophora glomerata (L.) Kütz.
Oedogonium sp.
Prasiola mexicana J. Ag.
Spirogyra porticalis (Muell.) Cleve
Ulothrix zonata (Weber and Mohr) Kütz.
Zygnema sterile Transeau

Division Chrysophyta

Hydrurus foetidus (Vill.) Trev.
Vaucheria sessilis (Vauch.) DC

Division Cyanophyta

Chamaesiphon incrustans Grun.
Nostoc parmelioides Kütz. ex. Born. et Flah.

of the fact that samples were collected only from selected sites. It is believed that this list includes the most prominent species together with many of the rarer species to be found in the flora of the Metolius River.

Species collected at sampling station 1 on each of the sampling dates are listed in Table 3. At no time were filamentous algae observed in the headwaters. During the month of June, however, macroscopically evident growth of diatoms was observed. This was found to be mainly Diatoma hiemale. As indicated in Table 3, Diatoma hiemale became important in the flora of the headwaters only during the months of June, July, August, and early September, possibly as a result of increased photoperiod. Nitzschia palea displayed a seasonal occurrence, being found only during the months of June and July, while Achnanthes minutissima and Rhoicosphenia curvata remained dominant during most of the calendar year. Increase in density of diatoms in summer is apparently quite common.

The filamentous alga, Cladophora glomerata was found at station 2 (Table 4) throughout the year. As previously noted, the current velocity at this sampling station is relatively high. Margalef (1960), has listed Cladophora glomerata as characteristic of streams in which there is a high current velocity, with other species assuming greater importance where current velocity decreases. Also a prominent species at this sampling station is Cocconeis placentula,

Table 3. Species collected from sampling station 1 between the dates of 4-15-67 and 3-9-68, listed in order of frequency of collection.

	4-15-67	4-29-67	6-4-67	6-18-67	6-30-67	7-13-67	7-28-67	8-11-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
<u>Ach.</u> <u>minutissima</u>	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Rhoic.</u> <u>curvata</u>	x	x				x	x	x	x			x		x		x	x	x	x	x
<u>Diat.</u> <u>hiemale</u>			x	x	x	x	x	x	x	x			x							
<u>Cocc.</u> <u>placentula</u>	x					x			x			x		x			x		x	x
<u>Nitz.</u> <u>palea</u>				x	x		x													
<u>Ach.</u> <u>lanceolata</u>																	x			
<u>Nav.</u> <u>cryptocephala</u>	x																			
<u>Nitz.</u> <u>dissipata</u>					x															
<u>Nitz.</u> <u>fonticola</u>				x																

Table 4. Species collected from sampling station 2 between the dates of 4-15-67 and 3-9-68, listed in order of frequency of collection.

	4-15-67	4-29-67	5-13-67	6-18-67	6-30-67	7-13-67	7-28-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
<u>Clad.</u> <u>glomerata</u>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Cocc.</u> <u>placentula</u>	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x
<u>Ach.</u> <u>minutissima</u>	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x
<u>Nitz.</u> <u>palea</u>		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
<u>Nitz.</u> <u>oregona</u>						x	x	x				x	x	x				x	x
<u>Cymb.</u> <u>cistula</u>			x	x	x	x		x		x									
<u>Gomph.</u> <u>herculeana</u>			x		x					x			x				x		x
<u>Rhoic.</u> <u>curvata</u>	x			x			x											x	x
<u>Cocc.</u> <u>klamathensis</u>								x	x		x	x							
<u>Nitz.</u> <u>fonticola</u>		x	x				x	x											
<u>Ach.</u> <u>lanceolata</u>	x	x																	
<u>Nav.</u> <u>cryptocephala</u>	x								x										
<u>Nitz.</u> <u>dissipata</u>																	x		

which was frequently found growing epiphytically on filaments of Cladophora glomerata. As at sampling station 1, Achnanthes minutissima was important, while Nitzschia palea assumed considerably greater importance here than at station 1. Evidence of seasonal periodicity may be seen for Cymbella cistula, which occurred during the months of May to September.

Station 3 (Table 5) may be characterized as offering a greater diversity of habitats than the first two sampling stations, although the current velocity in many of the areas from which samples were taken was fairly high. This diversity of habitats was due to the presence of a few large rocks and pieces of wood which resulted in areas of decreased current velocity being available for colonization.

Accordingly, several species were found here which were not encountered at stations 1 and 2, among them Spirogyra porticalis, Zygnema sterile, and Oedogonium sp. as well as Ulothrix zonata. The dominant species, however, included three species which were dominant at sampling station 2, namely Cladophora glomerata, Achnanthes minutissima, and Cocconeis placentula. These species, together with the other most frequently collected species, appeared to be perennial, and showed no seasonal periodicity.

Of the less frequently collected species at station 3, Rhoicosphenia curvata appeared during winter and early spring, while Cymbella cistula and the filamentous green alga, Ulothrix zonata,

Table 5. Species collected from station 3 between the dates of 4-15-67 and 3-9-68, listed in order of frequency of collection.

	4-15-67	4-29-67	5-13-67	6-4-67	6-18-67	6-30-67	7-13-67	7-28-67	8-11-78	8-21-67	9-12-67	9-23-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
Clad. glomerata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Ach. minutissima	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Vauch. sessilis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	
Nitz. dissipata			x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Nitz. oregona		x	x		x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x
Cocc. placentula		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		
Nitz. palea		x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		
Spirog. porticalis	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x		x	x		
Gomph. herculeana	x	x		x	x					x		x										x
Rhoic. curvata	x	x														x	x		x		x	x
Ach. lanceolata		x							x	x	x						x					
Cocc. klamathensis	x					x					x	x	x									
Cymb. cistula		x		x	x			x		x												
Ul. zonata		x		x	x	x					x											
Oedogonium sp.						x		x			x		x									
Diat. hiemale				x											x	x						
Nav. cryptocephala															x				x			x
Nitz. fonticola											x					x	x					
Zyg. sterile					x					x			x									
Frag. crotonensis										x	x											
Amph. ovalis														x								
Gomph. olivaceoides																					x	

were found primarily during the spring and summer. The pattern of occurrence of *Cymbella cistula* was similar to that observed at sampling station 2. *Oedogonium*, also a filamentous member of the Chlorophyta, was collected from late June to early October, indicating a summer through early autumn distribution. In no case at this or other sampling stations, however, was *Oedogonium* particularly abundant. Usually only a few filaments were found intermingled with filaments of other algae.

Sampling of station 4 was restricted to rocks near the bank of the river because of deep, rapidly flowing water toward the center of the stream. Current velocity in the areas sampled was considerably less than that of the first three sampling stations. However, there was a marked similarity in dominant species at station 3 and at station 4 (Table 6). *Spirogyra porticalis* became the second most frequently collected form. Of the less frequently occurring species, *Synedra mazamaensis* and *Amphora ovalis* had definite seasonal distributions and were found only during the summer months.

There was a marked similarity between dominant species found at sampling station 5 (Table 7) and those from station 4. This is to be expected, as the habitats afforded by these sampling stations were quite similar. Also, distributions of these dominant species over the year were generally similar between the two stations.

The area sampled at station 8 consisted of large rocks near the

Table 6. Species collected from sampling station 4 between the dates of 4-15-67 and 3-9-68, listed in order of frequency of collection.

	4-15-67	4-29-67	5-13-67	6-4-67	6-18-67	6-30-67	7-18-67	7-28-67	8-16-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
Clad. glomerata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Spirog. porticalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Ach. minutissima	x		x		x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x
Rhoic. curvata	x	x	x		x	x	x	x		x	x	x	x	x		x			x		x	x
Cocc. klamathensis	x			x	x	x	x			x	x	x	x	x		x				x		x
Oedogonium sp.		x	x		x		x	x			x	x	x	x	x	x	x				x	
Cocc. placentula	x	x		x	x	x	x	x	x		x											x
Nitz. dissipata		x	x	x	x	x	x											x	x	x	x	
Vauch. sessilis				x			x	x	x	x			x			x		x		x		
Syn. mazamaensis		x	x	x	x	x	x	x		x												
Amph. ovalis			x		x	x	x				x											
Diat. vulgare				x				x	x							x		x				
Ach. lanceolata	x						x	x	x													
Diat. hiemale	x				x				x							x						
Frag. crotonenisis									x		x								x			x
Gomph. herculeana	x	x	x	x																		
Nitz. oregona		x																x	x		x	
Nitz. palea		x				x		x												x		
Ul. zonata				x			x	x														
Frag. vaucheriae									x													x
Gomph. olivaceoides			x			x																
Hann. arcus		x		x																		
Nitz. fonticola								x													x	
Pras. mexicana		x				x																
Melo. varians																					x	
Syn. ulna									x													
Zyg. sterile								x														

Table 7. Species collected from sampling station 5 between the dates of 4-15-67 and 2-17-68, listed in order of frequency of collection.

	4-15-67	4-29-67	6-4-67	6-22-67	7-3-67	7-18-67	7-31-67	8-16-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68
Ach. minutissima	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clad. glomerata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Spirog. porticalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Cocc. klamathensis	x		x	x	x	x	x		x	x		x	x			x			x	x
Cocc. placentula	x			x	x	x	x	x	x		x	x					x		x	
Diat. hiemale						x	x		x	x		x	x	x	x	x	x	x		
Nitz. oregona		x	x	x	x						x	x	x		x		x			x
Oedogonium sp.					x	x		x	x	x	x	x	x		x			x		
Nitz. dissipata			x	x	x	x		x			x						x		x	x
Nitz. fonticola									x		x	x	x						x	x
Ul. zonata		x		x		x	x		x											x
Pras. mexicana	x		x		x	x														x
Rhoic. curvata	x	x	x		x		x													
Vauch. sessilis						x		x			x		x					x		
Ach. lanceolata	x						x	x											x	
Diat. vulgare			x				x									x		x		
Zyg. sterile				x				x				x	x							
Hann. arcus			x	x	x															
Syn. mazamaensis		x			x			x												
Amph. ovalis		x			x															
Frag. crotonensis									x											x
Nitz. palea					x														x	
Nav. cryptocephala		x																		

edge of the stream where the rate of flow was relatively low. Areas nearer the center of the stream were essentially free of evident growth, probably as a result of higher current velocity. It is notable that the four most frequently collected species at this sampling station were filamentous members of the Chlorophyta (Table 8). This may have been due to the decreased current velocity which allowed such forms to adhere to the rocky substrate rather than being swept away. Also notable was the presence of Prasiola mexicana during much of the year. Station 8 was the first point downstream from the head-waters at which Hydrurus foetidus occurred. However, this species was never particularly abundant at any season. During preliminary sampling, Hydrurus foetidus was occasionally found in small amounts in other parts of the river. Although described as frequently abundant in cold mountain streams by Smith (1950) such was not the case in the upper Metolius River.

Two species of diatoms, Hannaea arcus and Synedra mazamaensis followed the same pattern of summer distribution at station 8 as at station 5. The habitat at station 9 is quite similar to that of station 8 and, with a few variations, the flora of the two sites were similar, both with regard to species composition and relative importance of each of the species in the two flora. Species collected from station 9 are listed in Table 9.

Station 11 included a segment of the Metolius River consisting

Table 8. Species collected from sampling station 8 between the dates of 4-15-67 and 3-9-68, listed in the order of frequency of collection.

	4-15-67	4-29-67	5-13-67	6-4-67	6-22-67	7-3-67	7-18-67	7-31-67	8-16-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
Spirog. porticalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Zyg. sterile	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Ul. zonata	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x
Clad. glomerata	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x		x	
Nitz. dissipata	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			x	x
Ach. minutissima	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x		x
Cocc. placentula	x	x			x	x	x	x		x	x	x	x	x	x	x	x			x	x	
Ach. lanceolata	x	x	x		x		x	x	x	x		x	x	x		x	x					
Vauch. sessilis	x		x	x	x	x	x	x	x								x	x	x	x		x
Pras. mexicana		x		x		x	x	x	x	x	x							x	x			x
Nitz. oregona				x					x	x	x			x				x	x		x	x
Diat. vulgare					x							x		x	x	x	x	x		x		
Hyd. foetidus						x		x	x	x	x	x						x	x			
Hann. arcus			x	x		x	x	x		x	x											
Oedogonium sp.	x								x				x	x	x		x			x		
Diat. hiemale				x													x	x	x	x	x	
Frag. vaucheriae			x								x	x	x									x
Nav. cryptocephala	x	x				x											x					x
Frag. crotonensis									x	x	x							x				
Syn. mazamaensis		x	x					x		x												
Cocc. klamathensis									x			x						x				
Amph. ovalis		x				x																
Gomph. herculeana			x												x							
Nitz. palea				x		x																
Gomph. olivaceoides			x																			
Nitz. fonticola		x																				
Tetraspora sp.						x																

Table 9. Species collected from sampling station 9 between the dates of 4-15-67 and 3-9-68, listed in order of frequency of collection.

	4-15-67	4-29-67	5-13-67	6-4-67	6-22-67	7-3-67	7-18-67	7-31-67	8-16-67	8-23-67	9-12-67	9-24-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
Spirog. porticalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Ach. minutissima	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clad. glomerata	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Nitz. dissipata			x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Vauch. sessilis	x	x	x	x	x		x		x	x	x	x	x		x			x	x	x		x
Cocc. klamathensis	x	x	x	x	x	x	x		x	x		x	x		x	x		x				x
Ul. zonata			x	x	x	x	x	x	x	x	x	x	x		x			x	x	x		
Zyg. sterile	x	x	x	x	x	x	x	x	x	x	x		x	x						x		
Nitz. oregona			x	x	x		x			x	x	x		x		x	x		x	x	x	
Cocc. placentula	x	x	x	x	x	x			x	x	x	x		x						x		
Oedogonium sp.					x		x			x	x	x		x			x	x		x		
Ach. lanceolata	x	x		x			x		x		x									x	x	
Pras. mexicana	x	x		x	x			x				x									x	x
Frag. vaucheriae			x		x	x	x			x		x							x			
Syn. mazamaensis	x	x			x				x								x	x				
Nitz. fonticola		x				x		x			x									x		
Amph. ovalis	x	x				x					x					x						
Hyd. foetidus					x				x	x		x										
Hann. arcus				x	x					x		x										
Diat. vulagre	x								x												x	
Frag. crotonensis										x	x					x						
Diat. hiemale																					x	x
Nav. cryptocephala										x						x						
Rhoic. curvata										x				x								
Epith. sorex								x														
Frag. pinnata								x														
Gomph. herculeana															x							
Nav. graciloides	x																					
Nitz. palea		x																				

of a wide, deep channel, and rapidly flowing water. For this reason, sampling was restricted to rocks along both stream banks where current velocity was quite low. As at stations 8 and 9, dominant species included four filamentous members of the Chlorophyta (Table 10). These filamentous forms, together with associated diatoms, constituted an essentially perennial group of species at this site. Little evidence was found of any seasonal periodicity on the part of any of the species collected. This may in part be a result of the relatively great width of the channel at this point. As a result, this area is essentially free from shading throughout the year.

Although sampling at stations 7 and 10 was limited, it may be safely said that the flora of these sites differed little from that of sampling stations 8 and 9. Filamentous species collected at station 7 included Cladophora glomerata, Spirogyra porticalis, Vaucheria sessilis, and Ulothrix zonata as well as Hydrurus foetidus and Prasiola mexicana. Oedogonium and Zygnema sterile were also collected on occasion. Among the diatom species collected, Achnanthes minutissima, Cocconeis placentula and Nitzschia dissipata were most frequent.

Station 10 at Pioneer Ford Forest Camp, supported the same community as stations 8 and 9. This is to be expected in view of the similarity of habitats afforded by the two locations.

With the exception of stations 1, 2, and 3, a marked similarity

Table 10. Species collected from sampling station 11 between the dates of 5-13-67 and 3-9-68, listed in order of frequency of collection.

	5-13-67	6-4-67	6-22-67	7-5-67	7-20-67	8-4-67	8-18-67	9-14-67	9-24-67	10-14-67	10-28-67	11-12-67	11-26-67	12-16-67	1-6-68	1-20-68	2-3-68	2-17-68	3-9-68
Spir. porticalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Ach. minutissima	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
Ul. zonata	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x
Zyg. sterile	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x	x
Nitz. dissipata	x		x	x	x		x	x	x	x	x	x	x	x	x		x		x
Clad. glomerata	x			x	x	x	x	x	x	x		x			x	x	x	x	x
Nitz. oregona			x		x	x	x	x		x	x	x	x	x			x	x	
Diat. vulgare	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x
Cocc. placentula		x	x	x	x		x	x		x			x						
Syn. mazamaensis			x	x	x	x			x				x				x	x	
Ach. lanceolata		x		x	x		x		x							x			
Cocc. klamathensis				x			x		x	x							x		x
Hann. arcus	x	x	x		x									x	x				
Oedogonium sp.					x	x		x		x				x			x		
Rhoic. curvata		x		x			x		x								x		x
Gomph. olivaceoides	x	x			x							x							
Amph. ovalis							x			x	x								
Nitz. fonticola						x								x	x				
Vauch. sessilis	x					x			x										
Diat. hiemale														x				x	
Frag. vaucheriae					x							x							
Hyd. foetidus	x		x																
Nitz. palea	x					x													
Cymb. turgida																		x	
Nav. graciloides		x																	

among the various sampling sites on the Metolius River was apparent. A lack of filamentous forms appeared to be characteristic of station 1. However, one of the diatoms frequently collected at stations 1, 2, and 3 was a species (Achnanthes minutissima) which was among the most frequently collected at each of the other sampling stations. As previously noted, only one filamentous alga, Cladophora glomerata, was collected from station 2. A notable characteristic of the diatom flora at this site, however, was a prominance of Nitzschia palea, which also was collected frequently at station 3. This species became relatively rare at sampling stations further downstream. Another species of the same genus, Nitzschia dissipata, on the other hand, was recorded only once from station 2, but was one of the more abundant species at station 3 and the remaining downstream sampling stations. No explanation is readily available for this distributional pattern.

It has been pointed out by Whitford (1960a), in a discussion of vertical zonation in fresh water algae, that Nitzschia palea tends to be found near the surface of the water rather than at any great depth. While the Metolius River is relatively shallow at sampling stations 2 and 3, material collected from downstream sites was also taken from shallow areas of the riverbed. For this reason, it is unlikely that depth of the water offers an adequate explanation of the distribution of Nitzschia palea. It was also pointed out by Whitford and by Patrick

(1950) that Nitzschia palea is tolerant of organic pollution and, thus, may serve as an indicator of pollution. It is unlikely that organic pollutants would have found their way into the water of the Metolius River in the short distance between the headwaters and sampling station 2, particularly since this segment of the river flows through privately owned land, and is not subject to the degree of disturbance common below in the recreational areas administered by the Forest Service.

Cladophora glomerata was uniformly present at all stations downstream from station 1. Margalef (1960) stated that streams in which this species is the dominant alga tend toward low species diversity. He also pointed out that Cladophora glomerata is characteristic of rapidly flowing waters, and that this may exert an influence on the diversity of the community. The findings of this study are in accordance with Margalef's in that the species diversity was relatively low for naturally occurring lotic communities.

An increase in the abundance of filamentous algae at sampling stations downstream from station 2 was marked and was particularly noticeable at station 4 and sites downstream from this point. One filamentous species, Vaucheria sessilis, although frequently collected, was only present in small quantities at downstream sites, possibly because of the decreased current velocity at these sites.

The delicate nature of the thalli of filamentous forms such as

Spirogyra, Zygnema and Oedogonium may account for the fact that these forms were less abundant at sites where current velocity is high. In general, at the upstream sampling stations, these species grew only as occasional filaments intermingled with filaments of Cladophora and Vaucheria. Species of Cladophora and Vaucheria, on the other hand, present a more resistant thallus form able to withstand higher current velocities.

Although members of the Cyanophyta did not make up a large part of the flora of the Metolius River, Nostoc parmeliodes was scattered irregularly throughout the study area. This species was difficult to collect, as its color resembles that of the rocks to which it was attached. This difficulty was multiplied during the winter when visibility was reduced. However, it is possible to state that this species of Nostoc was widespread in the Metolius River, and present in most of the study area throughout the year.

Table 11 lists species which had seasonal patterns of distribution in the Metolius River together with the sampling stations at which these patterns were most evident. These species were generally found during the spring and summer months with the exception of Rhoicosphenia curvata which was recorded from station 3 during the winter and early spring. As previously described, the environment afforded by the Metolius River varies but slightly during the year, with the exception of changes in incident solar radiation. Accordingly, these seasonal patterns must have been brought about by the summer increase in sunlight.

Table 11. Species which showed seasonal distributions with sampling stations at which seasonal patterns were most evident.

Species	Sampling Station	Dates
Diatoma hiemale	1	June-October
Nitzschia palea	1	June-July
Cymbella cistula	2, 3	April-September
Rhoicosphenia curvata	3	November-April
Ulothrix zonata	3	April-September
Oedogonium sp.	3	June-October
Amphora ovalis	4	May-September
Synedra mazamaensis	4, 8	April-August
Hannaea arcus	8	May-September

Of the species listed in Table 11, only two diatoms, Amphora ovalis and Cymbella cistula, had seasonal distributions at every station from which they were collected. The fact that a species occurred only during the summer months at one sampling station, but was recorded on a year-round basis at another sampling station may be explained on the basis of differences in shade patterns from one location to another. Although the forest near the river is open and does not afford deep shade, the lowering of the winter sun toward the horizon brings about an increase in shading in some areas. This was apparently sufficient to influence the growth of some species, but not the majority of species which were found to be perennial.

Community Composition

An analysis of community structure was carried out for each of the twenty two sampling dates. The number of times each species was included in the major community is depicted in Figure 14. The number of dates on which the species was recorded as not being a part of the major community is represented by the numbers below the base line. It is readily evident that the majority of species were most frequently included in this major community. Exceptions to this generalization include *Rhoicosphenia curvata*, *Nitzschia palea*, *Diatoma hiemale*, and *Cymbella cistula*. This negative association of *Rhoicosphenia curvata* is due to its relative abundance at the headwaters and its infrequent occurrence at downstream sites.

Nitzschia palea, on the other hand, made up a prominent part of the flora of stations 2 and 3 and, as previously noted, was rarely collected at other sampling sites. In view of the fact that the filamentous species which were a part of the major community were not particularly well established at stations 2 and 3, it is understandable that this species is not usually associated with the major community.

Diatoma hiemale, like *Rhoicosphenia curvata*, made up an important part of the flora at station 1 and was not frequently collected at downstream sites, with the exception of sampling station 5.

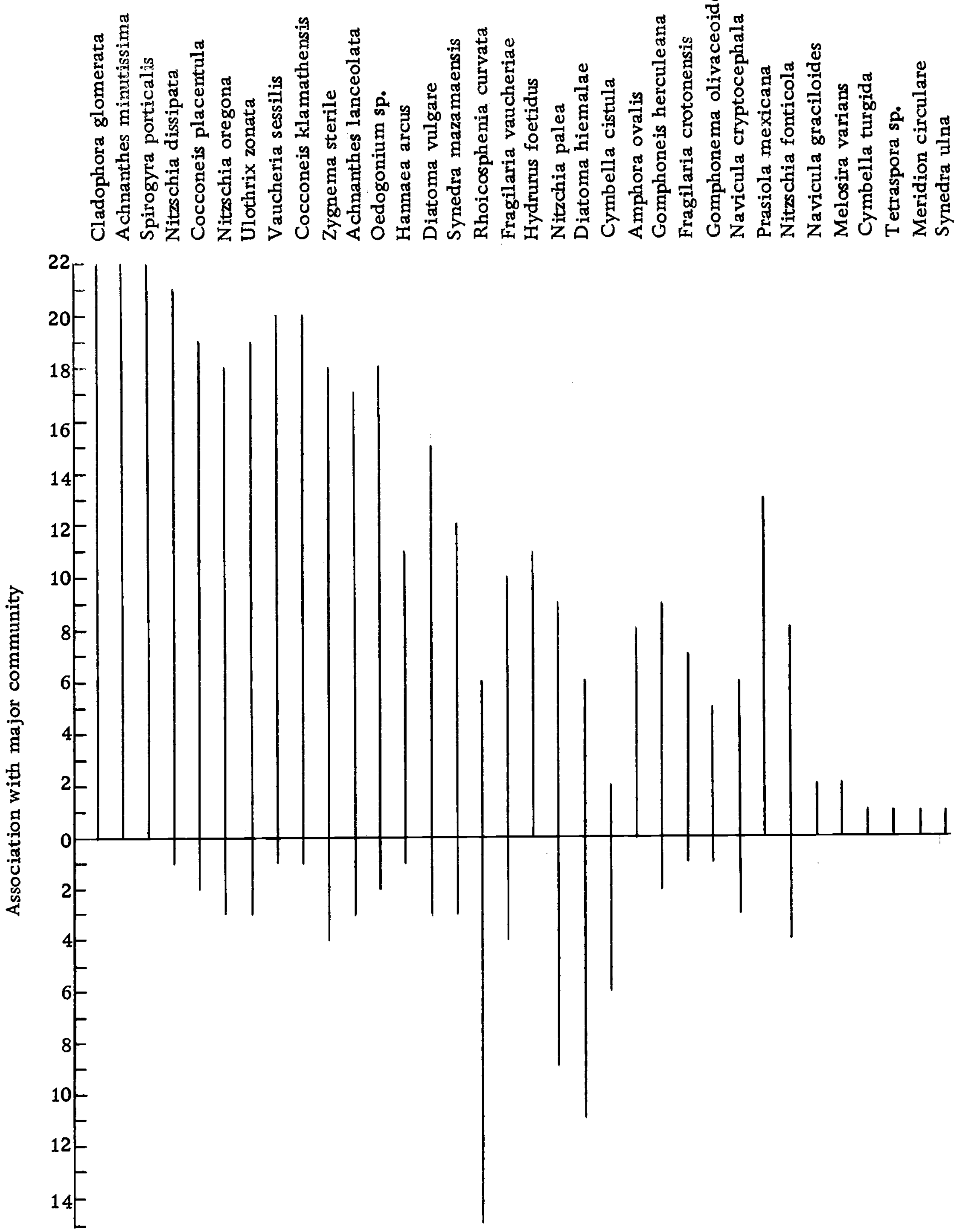


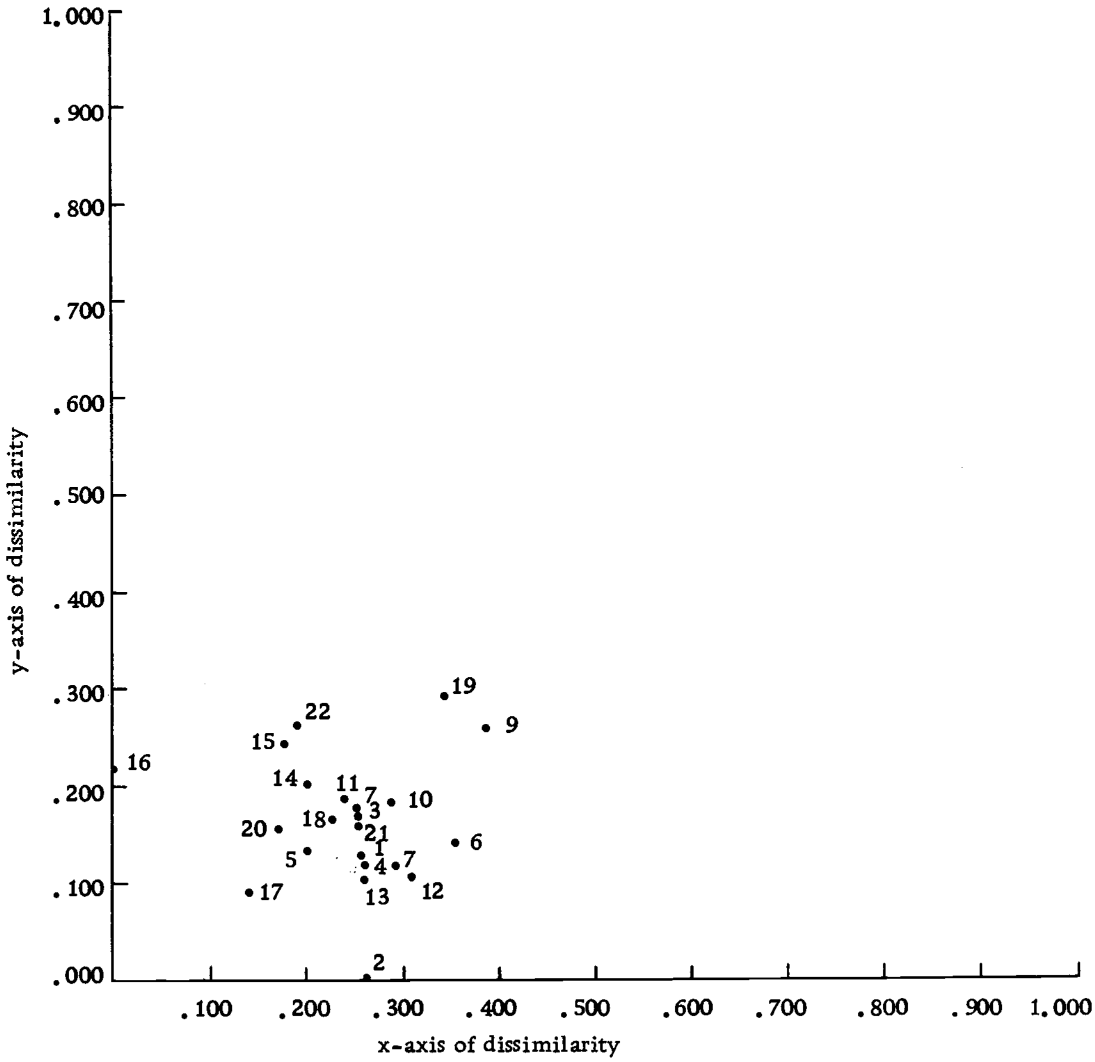
Figure 14. Occurrence of species as a part of the major algal community in the Metolius River on each of 22 sampling dates. (See text for further explanation)

Thus, this species was prominent at a site where species which were important in the river as a whole were not established. A similar situation exists with regard to Cymbella cistula, since this species was found only at stations 2 and 3.

By far the greater number of species were, however, most frequently associated with one another in what would appear to be a single major community occupying suitable habitats in at least the upper 8 km of the Metolius River. This is in contrast to the situation described by Blum (1960) who emphasized that repeatable algal communities are seldom found along the course of a stream. This may be true for streams which do not flow through uniformly descending terrain. However, in the case of the Metolius River, a uniform drop in elevation results in a uniform ecological situation. Also, as many authors have pointed out, the introduction of organic pollutants into a stream may induce local changes in community structure. No such change occurred in the study area due to the lack of organic pollution.

Comparison of Sampling Dates

The two-dimensional ordination of sampling dates is shown in Figure 15. It may readily be seen that there is no tendency for dates to be grouped into a seasonal pattern. Instead, most dates seem to cluster in a circular distribution about a central point, indicating a high degree of similarity.



1 = 4-15-67
2 = 4-29-67
3 = 5-13-67
4 = 6-4-67
5 = 6-22-67
6 = 7-3-67
7 = 7-18-67
8 = 7-31-67
9 = 8-16-67
10 = 8-23-67
11 = 9-12-67
12 = 9-24-67
13 = 10-28-67
14 = 10-28-67
15 = 11-12-67
16 = 11-26-67
17 = 12-16-67
18 = 1-6-68
19 = 1-20-68
20 = 2-3-68
21 = 2-17-68
22 = 3-9-68

Figure 15. Two dimensional ordination of sampling dates based on dissimilarity of species composition.

Of the dates which are not included in the cluster around the center point, there is no tendency toward formation of a second group. Instead, these dates appear to be fairly dissimilar one from another in species composition even though they frequently represent winter samples. This may be due to the difficulty encountered in sampling during the winter when visibility was impaired, and ice covering the rocks at the edge of the stream made access difficult.

It appears, then, that although some species did show a seasonal pattern of distribution (Table 11), there was no major shift in community composition with changing seasons, and sampling dates over the year showed a great deal of similarity with regard to species collected.

Definition and Discussion of Community

If a named community were to be designated for the Metolius River, it may be said to be made up of species generally characterized as inhabiting cool mountain streams free of organic pollution. This community might be designated as a *Cladophora* - *Achnanthes* - *Spirogyra* community in which species of *Ulothrix*, *Oedogonium*, *Cocconeis*, *Diatoma*, and *Nitzschia* play an important role.

Various types of *Cladophora* communities have been described. Among them is that of Sauer (1937) from streams in Germany which included *Cladophora glomerata*, *Epithemia sorex*, *Epithemia turgida*, Cocconeis pediculus, Rhoicosphenia curvata, Diatoma vulgare, Synedra arcus, Synedra ulna, and Nitzschia gracilis. The Cladophora community in Spain described by Margalef (1960) is similar in that it includes Cladophora glomerata, Cocconeis pediculus, Nitzschia gracilis, Synedra ulna, Cymbella ventricosa, Diatoma vulgare, Cocconeis placentula, Rhoicosphenia curvata, Gomphonema parvulum, Melosira varians, Amphora ovalis, Nitzschia palea, Navicula cryptocephala, Navicula radiosa, Ulothrix zonata, and Chamaesiphon.

The similarity between these two communities and that described for the Metolius River is readily apparent. A notable difference is the lack of filamentous forms in the communities of Sauer and Margalef. The only exception to this is the presence of Ulothrix zonata, which was also a part of the community described for the Metolius.

More recently, Blum (1957b) has described Cladophora glomerata as the most conspicuous filamentous alga in unpolluted streams throughout the world. Cladophora glomerata is said to be tolerant of extremes in pH and of pollution but dependent upon abundant light. The effect of decrease in available light was observed at sampling station 5 on the Metolius River. At this site, the growth of Cladophora glomerata was particularly conspicuous as a covering on the rocks in part of the streambed. During the summer months, growth was luxuriant, with a thick mat of filaments being evident. During the months of December through February, however, growth of Cladophora was reduced to small tufts of filaments which did not cover the surface of the rocks.

In studies involving the ecology of Cladophora glomerata, Bellis and McLarty (1967) have pointed out that seasonal periods of maximum growth seemed to be correlated with changes in temperature. The authors also discuss the probable importance of solar radiation in growth patterns for this species. In the situation prevailing in the Metolius River, however, temperature fluctuation is minimal or lacking, and the described variation in the growth pattern of Cladophora glomerata was most likely the result of differences in available light. It is brought out by Bellis and McLarty that more precise definition of the effects of temperature and radiation upon the growth of this species awaits studies of cultures grown under controlled conditions. In a general sense, these authors seem to feel that the prime factors controlling the distribution of Cladophora in the area in which they studied this genus were the presence of a firm substrate and relatively shallow water. Both these conditions were met throughout the portion of the Metolius River which was included in this study.

Of the species other than Cladophora glomerata that occurred with some frequency in the Metolius River, Achnanthes lanceolata, Cocconeis placentula, Diatoma vulgare, and Diatoma hiemale were described by Blum (1960) as preferring mildly alkaline, flowing waters and exhibiting varying degrees of resistance to pollution.

Although Blum characterized Nitzschia palea as an indicator of pollution, he mentioned the ubiquitous nature of this species.

Among the filamentous species, Ulothrix zonata is characterized, also by Blum, as inhabiting cool, well-oxygenated streams and attaining its maximum growth in spring and summer. Such was the case in the Metolius River where Ulothrix was collected most frequently during these months. In the Metolius River, however, this summer occurrence was not related to increase in water temperature.

Although comparisons with streams exhibiting ecological patterns similar to those in the Metolius River will be necessary to determine whether this community represents a repeatable association of ecological significance, available information seems to indicate that similar patterns of association occur in other streams. It is, however, difficult to assess the degree to which these other streams are strictly comparable to the Metolius River.

It does appear that a definable community existed in this case and was repeatable from place to place. Although current velocity varied from station to station, replacement of one group of species by another, with the exception of species of Nitzschia and possibly Rhoicosphenia curvata, did not occur. However, species were added to the flora as current velocity decreased.

It has been the practice of terrestrial ecologists (Daubenmire,

1968) to designate certain communities or associations of plants as indicators of effective environment. In many instances these studies have identified conditions in which one given factor such as available moisture, temperature or photoperiod has exerted a controlling influence. It would appear logical, then, to advance the idea that aquatic plants might also serve as indicators of certain environmental conditions that are exerting their influence at a particular time and place.

Moreover, it seems likely that an association of species in a recognizable community serves as a more sensitive indicator of habitat type than would the presence or absence of a single species. A habitat type might then be described on the basis of community composition.

It may be that synecological definition of habitat types in the lotic environment is more direct than would be similar procedures carried out by the terrestrial ecologist. In terrestrial plant communities, it is common for species to exert a marked influence upon one another via shading, competition for moisture and other factors. In streams in which there is abundant growth of aquatic vascular plant species, shading could play an important role in regulating community composition. Also, in conditions of no or low current velocity, one species may affect another by removing substances from or adding substances to the water. However, in swifly flowing water, it is unlikely that one species exerts any great influence upon another.

Further clarification of this point awaits a more thorough study of the microenvironment of plants growing in a lotic environment. This sort of investigation could best be carried out in the artificial laboratory stream.

Construction of generalizations based on community composition is further complicated by the fact that species of algae apparently differ widely in their sensitivity to changes in environment. Systematic study of the sensitivity and requirements of algal species could provide invaluable information of use in the interpretation of descriptive data regarding distribution of algal species.

Characterization of aquatic habitats on a synecological basis would seem to be particularly useful in view of the pattern of distribution of many algal species as outlined by Whitford (1960). He has stated that many species are cosmopolitan but occupy a highly disjunct pattern of distribution. Apparently, many species can be found in localities widely distant one from the other when conditions are favorable for their existence.

The application of the concept of synecology to the realm of aquatic biology must take into consideration the extremely rapid changes in many lotic habitats and the correspondingly rapid changes in the community. The example of flooding, in which almost the entire algal community may be scoured from the rocks of a stream bed, is only one type of change which may have drastic effects.

It has been pointed out by Butcher (1932) and several other authors that the generation time of the algae is considerably shorter than that of most vascular plants, and that colonization of bare surfaces by algae may be quite rapid. Since colonization may be noticeable within a matter of days under favorable conditions, succession, if such occurs at all, may be expected to be completed fairly rapidly and something approaching climax conditions may be achieved in a relatively short time. Caution must be exercised in drawing conclusions from data regarding community composition that one is dealing with a climax community rather than with a seral stage.

In the case of the Metolius River, sampling over a period of nearly two years revealed little, if any change in species composition and distribution within the study area. On this basis, it may be safely concluded that the community described at station 3 and sites downstream is indeed a climax community. Pioneer species in the colonization of artificially or naturally denuded substrates are frequently diatom species (Butcher, 1932). In view of the fact that diatom species prominent in the headwaters were frequently collected at downstream sampling sites, it is possible that stages in colonization in the lower portion of the study area might reflect the species composition of sampling stations 1, 2, and 3. Stations 1, 2, and 3 therefore, may be considered to be climax, but possibly similar to seral stages of the downstream community.

This named community, Cladophora-Achnanthes-Spirogyra, may then be described as characteristic of a cold, unpolluted mountain stream. Its persistence in time was due to the stable environment unique to a natural lotic situation and confirms the hypothesis that this was a climax community which may be ecologically defined.

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