Ecology of the diatom communities of the upper Madison River system, Yellowstone National Park
by Theodore Scott Roeder

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Botany
Montana State University

Abstract:
The rivers in Yellowstone National Park, receiving thermal discharges from geysers and hot springs, were investigated to determine the relationships between water chemistry and benthic diatom communities.

Examination of diatom collections revealed distinct differences in the floristics of some of the sampling stations. An ordination of the most abundant and frequently occurring species revealed the presence of two distinct communities of diatoms. One was found in the Gardner River where calcium was the dominant cation and the other occurred in the Madison River system where sodium was the dominant cation. Similar communities have been reported from European waters.

The construction of a matrix based on the percentage similarities of the most frequently occurring diatoms at each sampling station provided a method whereby further classification of these two communities was possible. In the Madison River system stations of low and high alkalinity were floristically different. Observed productivity was also greater at the stations with higher alkalinities.

Diversity indices prepared from the samples collected at each sampling station showed seasonal changes that were related to either changing physical parameters of the environment or to competition during the time when the environment was relatively constant.

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ABSTRACT

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INTRODUCTION

The study of algal communities in flowing waters has been approached in two different ways. In the older traditional approach, the complex of different taxa, each considered to have definite ecological requirements, was taken as the basis of study. Community structure was described in terms of species frequency, numerical abundance and species per unit area. The more recent approach emphasizes biomass and productivity and is also concerned with the forces that introduce changes in the energy flow.

The species structure of communities of benthic diatoms has long been used to evaluate conditions in streams which receive various kinds and rates of pollution (Eddy, 1925; Butcher, 1932; Patrick, 1948; Fjerdingstadt, 1950; Foged, 1954; Patrick, Hohn, and Wallace, 1954; Blum, 1956; Hohn and Hellerman, 1963.). However, it has been impossible to compare directly the work of these various investigators due to the variety of methods and techniques used in obtaining and evaluating their data.

Eddy (1925) attempted to correlate successive algal communities with the age of the habitat, i.e., "young water, middle aged water, and old water," each of which was typified by particular groups of algal species.

Butcher (1932), utilizing the colonization of glass slides by benthic algae, evaluated these communities in relation to pollution in terms of floristics and relative species abundance. A modification of this technique was developed by Patrick, Hohn, and Wallace (1954) who used populations of benthic diatoms on glass slides to indicate the degree of pollution of natural waters. In relatively unpolluted waters, species diversity is generally high and usually several species share population dominance. In polluted waters, the number of species is low and there is a great abundance of but one or a few species. The main objection to this type of study is the amount of time necessary to count and identify the large numbers of cells, a problem which precludes the consideration of more than just a few samples. In addition, recent work by Hohn and Hellerman (1963) shows that diatom growth on glass slides may not represent the natural diatom community when water temperatures are low.

According to Odum (1963), in summarizing the work of others, a characteristic feature of communities is that they contain few species which are common, (i.e., represented by large numbers of individuals), and large numbers of species which are rare at any given locus in time or space; however, the actual number of rare species is variable, so the total diversity is also variable. Both Patrick (1948) and Gaufin (1952) point out that either the absence or the presence in small numbers of some "rare" species may be more indicative of water quality than the abundance of more ubiquitous species. Recognition of the importance of these species which may be missing or present in very small numbers will depend largely on the experience of the investigator.

Other workers have used species diversity measurements but have treated the data in a different manner. Patten (1962) used the range of diversity of phytoplankton to indicate seasonal changes as related to nutrient (pollution) changes in Raritan Bay. Margalef (1956) proposed analysis of natural communities by methods derived from information theory, by which diversity can be calculated directly from a sample.

Species diversity is sometimes expressed in the form of an index, by which it is possible to compare species or community diversity directly in different ecosystems or in the same ecosystem at different times. Because diversity indices permit the integration of large amounts of information about numbers and kinds of organisms, such indices may provide a more reliable indication of organic, chemical or thermal pollution than the mere occurrence or absence of certain "indicator" species.

Fjerdingstad (1950) discussed the difficulty of using some of the more commonly encountered indicator species in different situations. In most rivers pollution is seldom of a single type, and diatoms which may be indicative of a certain type of pollution may not be important when pollution is of the composite type.

Several investigators have attempted to classify benthic diatoms according to their pollution tolerance, but there is no agreement as to the true status of many organisms because of local differences in species and environment (Gaufin, 1952). Margalef (1961) has shown that in the event of a sudden increase in nutrients certain species are led to take full advantage of their capacity for population increase. This will result in a decrease in diversity and one or a few species may attain great abundance. "Pure" water areas are usually characterized by large numbers of species, each with small numbers of individuals. Hence, if a river is subject to a number of different situations which affect the aquatic environment, the diversity of the aquatic community will be changed as the situations change. If a stream is sampled at a number of stations progressing from "pure" water areas in the upper reaches of the stream through regions where chemical, organic or thermal enrichment takes place, there should be changes in the diversities of the communities sampled.

Yount (1956), working in the relatively constant, unpolluted environment of Silver Springs, Florida, considered a drop in diversity of benthic diatoms over a period of time to be the result of competition. This decrease in diversity corresponded to an increase in productivity of certain taxa at the expense of others. Thus the change in diversity at any one station over a period of time may be related both to successional changes caused by competition and to the effects of the changing environment.

Jurgenson (1935), Nowak (1940), Butcher (1932, 1940) and Patrick (1948) have stated that it is the attached forms (benthic organisms) which grow and reproduce in a given area that give the most reliable indication as to whether the environment of an area is suitable for aquatic life.

Up to this time no one has attempted to utilize the diversity index concept in describing changes in communities of benthic diatoms. Patten (1962) applied the diversity index concept to planktonic populations rather than to benthic forms. Williams (1961) used only the most abundant planktonic forms in small samples as indicators of water quality but did not utilize his data for calculating diversity.

The purpose of the present investigation was to determine if relationships existed between the diversity and species composition of the benthic diatoms and the water chemistry of rivers which receive thermal discharges from the geysers and hot springs in Yellowstone National Park.

DESCRIPTION OF THE STUDY AREA

Eleven sampling stations were established on the Madison River, its headwater streams the Firehole and Gibbon Rivers, and on the Gardner River. All are located in the western and northern parts of Yellowstone National Park in northwestern Wyoming and adjacent Montana and Idaho (Figure 1). This region is a high plateau, deeply dissected by rivers and surrounded by mountains. Within this area is the greatest concentration of hot springs and geysers in the world today.

At an elevation of 8,209 feet (2,500 m) the Firehole River originates at the outlet of Madison Lake and flows generally northward for 21.5 miles (34.6 km) until it joins the Gibbon River at Madison Junction. As it passes through the Upper Geyser Basin (Old Faithful area), Biscuit Basin, Midway Geyser Basin and the Lower Geyser Basin, this river receives the discharge of a great many geysers and hot springs. Allen and Day (1935) estimated that the total amount of thermal waters flowing into the Firehole River was 54.92 cu ft/sec (1.55 cu m/sec). Fisher (1960) reported an increase in the thermal discharge of about 10 percent following the earthquake activity of 1959.

In the upper reaches of the river (above the Old Faithful area), there is a negligible amount of thermal drainage. The river is small (3-8 m wide), turbulent in some areas and well aerated. Bedrock in this reach of the river is a relatively recent (Pleistocene) plateau flow of rhyolite (Boyd, 1961).