Alpine limnology of selected water bodies on the Beartooth Plateau, Montana, with emphasis on benthos
by Ernest Alden Wells

A Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biological Science
Montana State University

Abstract:
A descriptive investigation of four lakes and their associated creeks and ponds was conducted in an alpine watershed. Benthic macroinvertebrates, zooplankton, phytoplankton, bacteria and physicochemical parameters were studied against a background of morphoedaphic geologic, climatic and fisheries information. The physicochemical parameters indicated the waters of the study area were essentially snowmelt and characteristic of ultraoligotrophic lakes. One lake, however, had summer clinograde oxygen curves and possible incomplete spring mixing. Primary producers were very sparse. - The phytoplankton counts were dominated by many diatom taxa; however, pigment analyses suggested the presence of very small forms not detected in the cell counts. A reverse summer phytoplankton stratification was indicated. Bacterioplankton were too numerous to count.

Although not abundant, zooplankton densities may have been greater than could be supported by the phytoplankton. Lake populations were dominated by pigmented calanoid copepods which occasionally formed surface swarms. At other times they were most dense above 20 m but away from the surface. Pond zooplankton were more dense and dominated by Cladocera, suggesting higher trophic conditions. Photoinhibition and flushing rates as well as low nutrients are suggested as important factors influencing the plankton.

Macrobenthos were more abundant than anticipated from the plankton and physicochemical parameters. They were dominated by Diptera, Sphaeriidae, and Oligochaeta. As depth increased the Chironomidae community shifted from one characteristic of ultraoligatrophic conditions to one typical of oligo-mesotrophic lakes. The pond chironomids indicated greater enrichment. Bacteria and allochthonous detritus, rather than phytoplankton, probably are the main source of nutriment for the zooplankton and benthos. Most of the macrobenthos have been previously reported in running waters and as detritus feeders, probably resulting from the lotic-like shoreline habitats and a detritus based ecosystem.

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APPROVAL

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Ernest Alden Wells

This thesis has been read by members of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

7 February 1986 — George Roemhild
Date — Chairperson, Graduate Committee

Approved for the Biology Department

25 February, 1986 — Peter F. Brussard
Date — Head, Biological Science Dept.

Approved for the College of Graduate Studies

May 16, 1986 — Henry L Parsons
Date — Graduate Dean

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Signature Ernest A. Wells

Date Febuary 7, 1986

I dedicate this work to my wife Susan Binder Wells, whose assistance in the field and laboratory was invaluable, and who endured many years of hardship during the report's preparation, to my daughter Meghan Marie Wells in the first year of her life, and to my parents John B. Wells and Eunice C. Wells, for a lifetime of support and encouragement.

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ABSTRACT

A descriptive investigation of four lakes and their associated creeks and ponds was conducted in an alpine watershed. Benthic macroinvertebrates, zooplankton, phytoplankton, bacteria and physicochemical parameters were studied against a background of morphoedaphic geologic, climatic and fisheries information. The physicochemical parameters indicated the waters of the study area were essentially snowmelt and characteristic of ultraoligotrophic lakes. One lake, however, had summer clinograde oxygen curves and possible incomplete spring mixing. Primary producers were very sparse. The phytoplankton counts were dominated by many diatom taxa; however, pigment analyses suggested the presence of very small forms not detected in the cell counts. A reverse summer phytoplankton stratification was indicated. Bacterioplankton were too numerous to count.

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CHAPTER 1

INTRODUCTION

High altitude communities survive some of the harshest conditions known to man. Alpine aquatic communities withstand long dark winters with heavy ice and snow cover and potentially anaerobic bottom conditions. This is followed by a brief open water season with intense solar radiation and rapid warming. To organisms adapted to prolonged winter darkness, summer may constitute a period of thermal and radiation stress. Exceptionally strong runoff undoubtedly flushes many organisms from the systems. In addition, the aquatic biota may endure ice scour, high winds, low nutrients and temperatures, low gas solubility due to low atmospheric pressure, short periods suitable for emergence, and large water level fluctuations.

What organisms exist in alpine water bodies? Do they represent chance introductions from lower elevations which vary from year to year, and from water body to water body, or are the populations and communities fairly consistent? What adaptations account for their resiliencies, and what is their trophic basis? What similarities exist between distant alpine lakes or with arctic and subarctic habitats? Do rare or undescribed taxa inhabit the isolated lakes? These are some of the questions which stimulated the current investigation. At the onset of this study so little was known about alpine lakes that few testable hypotheses could be developed, and it was anticipated that more questions than answers would develop during the course of this effort.

After reviewing the alpine limnology literature initially available, I realized that before specific questions concerning the function of alpine equatic ecosystems could be studied in a logical manner more information was needed about alpine aquatic community structure. Consequently, a descriptive investigation of selected water bodies in an alpine watershed was designed. Specifically, I hypothesized that the biota of these water bodies was composed of low densities and only a few taxa, since alpine lakes have been described as being very oligotrophic with low biotic diversity (Bushnell et al. 1982; Pechlaner 1971; Pechlaner et al. 1972a; Pennak 1941, 1958, 1963, 1968, 1977; Richards and Goldman 1976; Rodhe et al. 1966; Thomasson 1952). A secondary objective of this effort was to suggest possible trophic conditions within the water bodies, environmental factors influencing the organisms present, and some of the organisms' survival strategies. The final intent of this effort was to contribute towards a broader view of alpine limnology by comparing the study area with the existing literature. Since less information about alpine macroinvertebrates was encountered in the literature than for other aquatic parameters, they were taken as the focal point of the field investigations.

The inaccessability and difficult working conditions of alpine habitats have undoubtedly limited the number of in-depth alpine limnology studies. Although many papers address alpine water bodies, most are based on few observations and few present detailed or long-term results. However, multiple and often conflicting uses of alpine habitats, especially those on public lands, signal the urgent need for alpine lake studies. A justification of paramount importance for alpine limnological research is the need for sound management of alpine lakes based on objectively collected environmental data. The more complete the information on which they are based, the better the decisions are likely to be. Most alpine management plans, including those of the Beartooth Plateau (Marcuson 1980; USFS 1976), have been developed without the benefit of detailed data concerning alpine aquatic habitats.

Other reasons are frequently given for studying alpine water bodies. Conservation oriented individuals and organizations encourage the investigation of alpine lakes in order to learn how to preserve their pristine and natural conditions for aesthetic reasons. Objectives of many alpine lake researchers involve sport fisheries (Anderson 1975, 1980; Donald et al. 1980; Jensen 1978; Lien 1978; Marcuson n.d., 1980; Neave and Bajkov 1929; Nelson 1964; Rabe 1967; Reimers 1958; Reimers et al. 1955; Robertson 1947; Walters 1969; Wrenn 1965; Wurtsbaugh et al. 1975). They investigate why some high altitude stocking programs succeed and others fail, which species survive and reproduce without stunting, what fish density certain lakes will support, and which trout have the lowest impact on the resident biota. For example, Marcuson (1978) was interested in Gammarus as an important alpine fish food on the Beartooth Plateau. He suggested studies of this amphipod as an indicator of appropriate stocking rates and of the feasibility of planting Gammarus in elevated lakes. If alpine habitats are southern extensions or islands of arctic or subarctic ecosystems (Dodds 1917; Falter 1966; Love 1970; Reed and Olive 1958; Thomasson 1956), temperate alpine lakes may be considered ecological models of the more northern and possibly less accessible lakes. Information learned from one system may relate to the other as well.

Some researchers view alpine lakes as unique opportunities to study ecological relationships in undisturbed ecosystems with simplified community structures. These reputedly uncomplicated systems may result from severe but natural environmental conditions, and are often considered ideal for elucidating general principles underlying the function of more complex communities (Anderson n.d.; Dodson 1970, 1974; Rabe and Gaufin 1964; Sprules 1972). However, considering the relative paucity of intensive or long-term alpine lake studies, the number of generalization about the alpine lake in the literature is surprising, and the basic premise of their simplicity warrants examination.

Many alpine lakes may not be as undisturbed by man as commonly thought. The potential sensitivity of alpine lakes to the effects of acid deposition has recently received much discussion (Bradford 1968, 1981; EPA 1984; Galbraith 1984; Grant and Lewis 1982; Harte et al. 1983a, 1983b; Lewis 1982; Lewis and Grant 1979, 1980; Lewis et al. 1983; Mangum 1984; McColl 1980; McColl et al. 1982; Stuart 1984; Tonnessen 1983; Tonnessen and Harte 1980, 1982a, 1982b). Recreational use of alpine areas undoubtedly has an impact on the water bodies. As the size and number of natural lowlands continues to decrease, recreational use of alpine habitats will tend to increase. This activity has been accelerated in the Beartooth mountains by national recognition of the area due to its incorporation into the Wilderness System. Native fish populations have not been reported in Rocky Mountain alpine waters, but it is often difficult to find an alpine water body which has not at some time been stocked. It is likely that the introduction of these exotics has altered the community structure of many alpine lakes.

Mining activities constitute other potential anthropogenic stresses at high altitudes. Although no mining was detected or is currently expected near the lakes of this study, mining has occurred in the Beartooth region since the 1880's, and significant deposits of gold, silver, copper, lead, zinc, tungsten and molybdenum are known for the area (USGS 1978; Wedow 1975). Several exploration parties were encountered during the study, including a hydrogeochemical field team interested in uranium (Aamodt 1977). Proposed or historical Beartooth mining activities include the New World and Independence mining districts, the Horseshoe Mountain area, and the Stillwater drainage where mining and milling of platinum-group metals is anticipated (MTDSL and USFS 1982). Many of these projects include altitudes comparable to the present study.

The impacts of some of these possible actions would be immediate and obvious. The influences of others could be slow and insidious. In fact, man-induced changes may have already occurred in a great many alpine lakes. Some of these changes may never be detected due to a lack of prior knowledge of these unique ecosystems. While high altitude investigations designed to detect specific impacts would be very useful, more generalized studies of environmental conditions are needed as a first step. These studies can identify potentially sensitive species or other conditions useful in detecting adverse environmental changes. Baseline data may provide the basis for detecting water quality degradation through alterations in community structure with time at one location. Alternatively, differences between similar alpine lakes may demonstrate different levels or types of influence by man.

Several difficulties with terminology were encountered. Appropriate aquatic criteria for defining alpine lakes and ponds are unknown. Consequently, in this study the term alpine lake has been reserved for water bodies at or above timberline. This conforms to terrestrial definitions and the aquatic usage by Falter (1966), Shantz (1907), Thomasson (1956) and Vinyard (1951). Other alpine definitions were found in the literature (Dodds 1917; Keefer and Pennak 1977; Love 1970; Pennak 1963, 1977; Strom 1938 and others cited by Falter 1966 and Thomasson 1956; Zschokke 1900 cited by Shantz 1907 and Ward 1904) and many investigators did not define the term or did not provide enough information to determine whether the water bodies conformed to this usage. Nonetheless, useful information from many high altitude investigations, whether clearly alpine or not, has been included. Taxonomic names used by some investigators presented additional difficulties. Several are questionable due to nomenclature changes with time or varying abilities of the researchers. Where possible the terminology of the original investigator was preserved.

CHAPTER 2

STUDY AREA, METHODS, AND MATERIALS

Study Area

Location, Access, and Morphoedaphic Characteristics

The water bodies studied are on the Beartooth Plateau of the Beartooth-Absaroka Wilderness area in the Custer National Forest. Located in Carbon County, Montana, roughly 24 km (15 miles) northeast of Yellowstone National Park, they compose part of the headwaters for the East Rosebud River, a tributary to the Yellowstone River. Access is by backpacking approximately 22.5 km (14 miles) along the East Rosebud/Cooke City Trail (U.S. Forest Service Trails #15 or #567), starting either from near Colter Pass east of Cooke City, Wyoming or from East Rosebud Lake near Alpine, Montana. Approximate elevation gains are 610 m (2,000 ft) for the former and 1,067 m (3,500 ft) for the latter approach. The East Rosebud approach, although steeper, is generally passable earlier in the year than the Cooke City approach. When snow conditions permit, the trail is negotiable by pack animals. However, access often requires use of skis or snowshoes in early July or late September. Paths are not established to the lakes located off the main East Rosebud/Cooke City Trail. The waters of this study, ranging between elevations of 2,800 m and 3,035 m (roughly

9,200-10,000 ft), are shown in Figures 1 and 2. Their morphoedaphic characteristics are presented in Table 1.

Fossil Lake is located on an open, flat plateau area covered with large boulders. It is a few meters from the divide between East Rosebud River and Clark's Fork of the Yellowstone River drainages, and has a relatively large shoreline development (Table 1). Fossil Lake's water source is snowmelt, some rain runoff, and a short, snowfed creek. Medicine Lake is in a steep cirque basin receiving snowmelt, rain runoff, and a short creek which flows from a snowfield area. Boulder fields extend from the cirque walls into the lake. The Medicine Ponds, M1 and M2, are just east of Medicine Lake. They receive rain runoff and snowmelt as their only water source. Dewey Lake and Dewey Pond, D1, are in a large open basin with some very steep walls. Two boulder fields extend into the lake, which receives water from Medicine Outlet Creek and Fossil Outlet Creek. Cairn Lake contributes water to Dewey Lake through Fossil Outlet Creek. Dewey Lake also receives rain runoff, snowmelt, and two creeks from snowfields to the north and southeast. Dewey Outlet Creek and Pond M1 Outlet Creek flow to Twin Outlets Lake, which also receives rain runoff and snowmelt. This lake is in a narrow valley. Very steep walls to the south shade the lake during much of the day. Boulder fields extend into the lake on the south shore. Ponds M2 and D1 have no inlets nor outlet and undoubtedly freeze to the bottom during the winter. Pond M1 has no inlet and the outlet flows only during high water. All water bodies receive snowmelt throughout the ice free months.

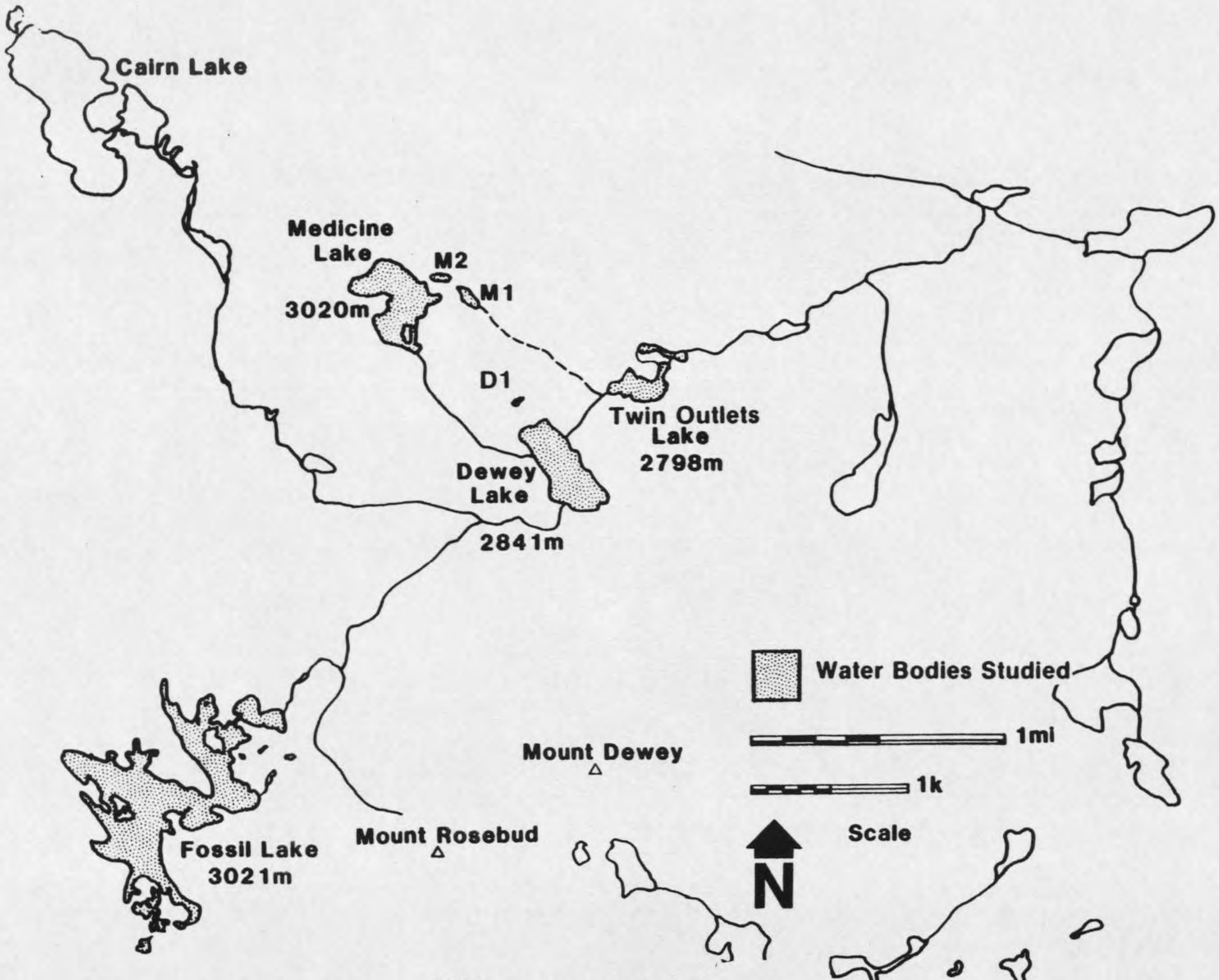

FIGURE 1 BEARTOOTH STUDY AREA