Breaking new waters : a century of limnology at the University of Wisconsin. Special issue 1987

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Special Issue

Breaking New Waters

A Century of Limnology at the University of Wisconsin

Annamarie L. Beckel
with a contributing chapter
by Frank Egerton

From the Editor

It is with pleasure that the Wisconsin Academy of Sciences, Arts and Letters presents this Special Issue of *Transactions*. Limnology, at least as an organized study, had its infancy in Wisconsin, and much of the early research of the organizers (Juday, Birge, Hasler) was published in *Transactions*. These were men of strong commitment to scholarship and excellence in research, and their personal stamp has been indelibly made on limnology.

We at *Transactions* are happy to continue our ties with limnology and to be able to make the current study available. We think it will be of interest not only to Academy members but to people with special interests in limnology.

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Carl N. Haywood

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Foreword

History provides a context to help us understand the present and insights to help us shape the future. We welcome this history of two schools of limnology at a time when the insights that can come from it are of special value. This history project began soon after the formal establishment of the Center for Limnology on the Madison Campus in July 1982. This special issue of the *Transactions* constitutes a look back as Wisconsin limnologists continue the search to break new waters. In a less parochial context this book comes in the year that the 50th meeting of the American Society of Limnology and Oceanography (ASLO) was celebrated in Madison. The Society formed from the efforts of many limnologists, especially Paul Welch at the University of Michigan; ASLO and the collections of scientists it represents are halfway through their first century. Again, a look back can serve us well as we move ahead.

Chancey Juday, the first president of ASLO (then the Limnological Society of America) is one of the principals in this history. He, Edward A. Birge, and Arthur D. Hasler are portrayed on the cover and are catalysts of our history. We thank these limnologists and their many colleagues for a rich history of personal and scientific accomplishment. We thank Annamarie L. Beckel and Frank N. Egerton for preparing these excellent perspectives on two schools of Wisconsin limnology, and we thank the Wisconsin Academy of Sciences, Arts, and Letters for publishing these perspectives.

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Preface

The development of the science of limnology is inextricably entwined with the careers of Edward Asahel Birge and Chancey Juday, and later with that of Arthur Davis Hasler. The limnological research program at the University of Wisconsin-Madison has been one of the foremost in the nation. The research and ideas generated there have played a major role in shaping the growth and development of limnology in North America and abroad.

Scientific limnology began with the publication in 1895 of the first two volumes of Alphonse Forel's monograph, "Le Leman; monographie limnologique," which embraced geology, physics, and chemistry (Egerton 1983, Elster 1974). It was the partnership of Birge and Juday, however, that substantially laid the foundations of limnology in North America (Cole 1979, McIntosh 1977, Welch 1935). The work they and their associates performed during the first 40 years of this century marked the onset of modern American limnology and made conditions in Wisconsin lakes a touchstone for later studies in other regions (Cole 1979). Nearly 200 of the 400 scientific reports written by this group were published in the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters,* of which Birge was an active member. As noted by Frey (1963), a chronological listing of the papers and reports arising from their efforts closely parallels the general development of the science of limnology as reflected by changing rationale, methods of attack, and problems being investigated.

During their forty-year partnership Birge and Juday had chosen no successor to lead the Wisconsin limnological program. With the death of Juday in 1944 and the waning strength of Birge, research in limnology began to decline, and the Wisconsin school nearly went out of existence. Arthur Hasler, a former student of Juday, returned to the University of Wisconsin as an instructor in 1937. Although he seemed like a natural choice for the next leader of the Wisconsin program, neither Birge nor Juday gave him any help or encouragement in his own research endeavors, which were in an entirely different direction from theirs. Hasler turned away from the descriptive, comparative research conducted by Birge and Juday and established experimental limnology as the hallmark of the Wisconsin school. He was instrumental in reestablishing the reputation of the University of Wisconsin as a leader in limnological research.

Hasler retired from teaching and active research in 1978. He made the leadership transition much easier for his successor, John J. Magnuson, than Birge and Juday had for him. Under Magnuson's leadership, the Center for Limnology at the University of Wisconsin-Madison continues to be known internationally for its contributions to the science of limnology.

The purpose of this book is to chronicle the century of development in limnology at the University of Wisconsin-Madison, from Birge's arrival at the university in 1875 to Hasler's retirement from active research in 1978. The first four chapters take a much different approach than the last chapter written by Frank N. Egerton, an historian of science from the University of Wisconsin-Parkside. The first chapters tell the story of Wisconsin limnology from the perspective of the participants—Birge, Juday, Hasler, and their associates—the observers from the "inside." These chapters include relatively little analysis or evaluation of the participants' perspectives or memories—the limnologists themselves tell the story as they saw it. Egerton, on the other hand, considers the development of the Wisconsin limnological community from the analytical and technical perspective of a contemporary historian of science—the observer from the "outside." The main focus of Egerton's discussion is on the contrasting development of the Wisconsin program under the leadership first of Birge and Juday and then of Hasler. He discusses the similarities and differences in outlook, goals, methodologies, and major achievements of the two programs and, in some cases, arrives at different conclusions than the limnologists themselves.

The major sources of information for the first four chapters include interviews and discussions with former students and colleagues of Birge, Juday, and Hasler, as well as interviews with Hasler. Most of these interviews were conducted at a conference, "History of Limnology in Wisconsin," held in May 1983 at the University of Wisconsin Trout Lake Station in northern Wisconsin. Many former students and colleagues who could not attend the conference contributed written interviews. Transcripts of taped interviews, written interviews, and questionnaires are catalogued in the University of Wisconsin archives. I made extensive use of G. C. Sellery's biography of Birge (1956), including C. H. Mortimer's chapter, "An Explorer of Lakes," in which Mortimer evaluates the scientific contributions of Birge. I also acknowledge my debt to David G. Frey and Arthur Hasler for their chapters in *Limnology in North America* (Frey 1963). Additional sources of information included the Birge Collection in the State Historical Society of Wisconsin, correspondence between Juday and two of his students, Stillman Wright and Robert W. Pennak, and the technical publications of Birge, Juday, and Hasler. For his chapter, Egerton conducted extensive interviews with Hasler, but Egerton's analysis of the achievements of the Birge-Juday program and the Hasler program relies on written records and the documented contributions of the Wisconsin school to limnology.

This book is not meant to be a biography of any of the principal players, but Egerton and I do hope to present a picture of how individual personalities can shape the growth and development of a scientific community. There are certainly some major differences in the ways that Birge and Juday and Hasler envisioned their research programs and in the ways they dealt with colleagues, graduate students, funding agencies, and the public that influenced how the Wisconsin program developed.

In the book we have discussed some of the major contributions of the Wisconsin program to limnology. More than 100 limnology related master's and doctoral theses, as well as nearly 800 other publications, were produced by Birge, Juday, Hasler, and their associates between 1875 and 1978. Certainly not all these studies are discussed in detail. Complete lists of the graduate students of Juday and Hasler are included in the appendix. Lists of the publications of Birge and Juday and their students and associates and of Hasler and his students and associates can be obtained from the Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, Wisconsin 53706. For additional discussion of these research projects see the chapters written by Frey and Hasler in *Limnology in North America* (Frey 1963).

Annamarie L. Beckel
University of Wisconsin, 1987

References

Cole, G. A. 1979. *Textbook of Limnology*. C. V. Mosby Co., St. Louis. 426 p.

Egerton, F. N. 1983. The history of ecology: achievements and opportunities, part one. *J. Hist. Biol.* 16(2): 259–311.

Elster, H.-J. 1974. History of limnology. *Mitt. Internat. Verein. Limnol.* 20: 7–30.

Forel, F. A. 1892. *Le Leman: monographie limnologique*. Tome 1. Lausanne, F. Rouge.

______. 1895. *Le Leman: monographie limnologique*. Tome 2. Lausanne, F. Rouge.

Frey, D. G. 1963. Wisconsin: the Birge-Juday era. In D. G. Frey (ed.). *Limnology in North America*. University of Wisconsin Press, Madison. pp. 3–54.

Hasler, A. D. 1963. Wisconsin 1940–1961. In D. G. Frey (ed.). 1963. *Limnology in North America*. University of Wisconsin Press, Madison. pp. 55–93.

McIntosh, R. P. 1977. Ecology since 1900. In F. N. Egerton (ed.). *History of American Ecology*. Arno Press, New York. pp. 353–372.

Mortimer, C. H. 1956. An explorer of lakes. In G. C. Sellery. *E. A. Birge. A Memoir*. University of Wisconsin Press, Madison. pp. 165–211.

Sellery, G. C. 1956. *E. A. Birge. A Memoir*. University of Wisconsin Press, Madison. 221 p.

Welch, P. S. 1935. *Limnology*. McGraw-Hill Book Co., Inc., New York. 471 p.

Acknowledgments

We would like to thank all the participants in the "History of Limnology in Wisconsin" conference held in May, 1983, at the University of Wisconsin Trout Lake Station. We would also like to thank all of those who agreed to be interviewed or who took the time to fill out questionnaires regarding their experiences in the Wisconsin limnological program. The list of conference participants and those who were interviewed or filled out questionnaires is as follows:

John E. Bardach (Ph.D. 1949) was a student of Hasler. His thesis research was on the population dynamics and life history of yellow perch in Lake Mendota. He is officially retired, but continues to hold appointments and to work as adjunct research associate at the East-West Resource Systems Institute at the East-West Center in Honolulu, Hawaii, and in the Departments of Oceanography and Geography at the University of Hawaii.

George C. Becker was a student of Hasler (M.S. 1951) and of John Neess (Ph.D. 1962). Since 1951 he has been conducting research on the fish in the lakes and streams of Wisconsin. He is currently living in Rogers, Arkansas, having retired as Emeritus Professor of Biology and Curator of Fishes at the University of Wisconsin-Stevens Point.

W. A. Broughton was a student of geologist W. H. Twenhofel and also received advice from E. F. Bean, the State Geologist. During the summers of 1937 and 1939 he conducted research on the sediments of Crystal Lake and a number of other lakes and bogs in the Trout Lake area. He is currently living in Plattville, Wisconsin, having retired as the Chairman of the Geology Department at the University of Wisconsin-Plattville.

George L. Clarke was a visiting scientist from the Woods Hole Oceanographic Institute in the summer of 1939 when he worked with Birge and Juday at the Trout Lake Station. There he conducted research on the transparency of lake water and perfected the Clarke-Bumpus plankton sampler. He is currently living in Belmont, Massachusetts.

Faye M. Couey (M.S. 1932) was a student of endocrinologist Frederick Hisaw and parasitologist Chester A. Herrick. In 1931 and 1932 he conducted fish food studies at the Trout Lake Station. He is now living in Kalispell, Montana, having retired from the Montana Fish and Game Department.

Herbert J. Dutton (Ph.D. 1940) was a student of physical chemist Winston Manning and plant physiologist Benjamin Duggar. In the summer of 1940 he had a postdoctoral appointment to work on chromatic adaptation in relation to color and depth distribution of freshwater phytoplankton and large aquatic plants in the Trout Lake region. In 1980 he retired as Chief of the USDA's Oilseed Crops Laboratory, Northern Regional Research Center, Peoria, Illinois, and was subsequently appointed Honorary Fellow, University of Minnesota at the Hormel Institute. He now shares research time between that institution, the Trout Lake Station, and his home on Diamond Lake in Cable, Wisconsin.

W. T. Edmondson, Ph.D., was a student of G. E. Hutchinson at Yale University. He spent the year 1938–1939 studying limnology and doing research at the University of Wisconsin-Madison and at the Trout Lake Station under the sponsorship of Juday. He is now Professor Emeritus of Zoology at the University of Washington in Seattle.

Daniel J. Faber (Ph.D. 1963) was a student of Hasler. His thesis research was on limnetic larval fish in several northern Wisconsin lakes. He is currently a Senior Scientist at the National Museum of Natural Sciences in Ottawa, Ontario.

David G. Frey (Ph.D. 1940) was the last student of Juday. As an undergraduate he worked as an assistant to William Spoor, who was also Juday's student, and to Juday at the Trout Lake Station in 1934. His thesis research was on the growth and ecology of carp in Madison lakes. He is currently Professor Emeritus in the Department of Biology at Indiana University in Bloomington.

Bradford C. Hafford (Ph.D. 1942) was a student of V. W. Meloche, working on techniques for analyzing the chemistry of lake waters. He worked as a chemistry assistant at the Trout Lake Station in 1939 and 1940. He became involved in pollution abatement research in his industrial career and retired as Vice President of Research and Development for the Natural Resources Group of Gulf and Western Industries. He currently lives in Hawley, Pennsylvania.

Donald L. Halverson (M.S. 1918) was a member of the instructional staff and then Director of Residence Halls for 22 years at the University of Wisconsin where he came to know Birge when he was Dean and later, University President, and Juday when he was Professor of Limnology. During the summers of the years Birge and Juday were at the Trout Lake Station, Halverson saw them almost daily as they were close neighbors on the Trout Lake Point. In later years, Halverson and Hasler became close friends. Halverson retired from the university as a Professor of housing. He died September 6, 1987.

William T. Helm (Ph.D. 1958) was a student of Hasler and John Neess. He worked on the population dynamics of young walleye in stocked and unstocked lakes, the effects of alkalization and fertilization in Cather Lake , and, for his doctoral thesis, the ecology of fishes in Lake Wingra. He is currently in the Department of Fisheries and Wildlife at Utah State University in Logan.

John R. Hunter (Ph.D. 1962) was a student of Hasler, working on the net avoidance behavior and reproductive behavior of fishes in both laboratory and field studies. He is currently with the U.S. National Marine Fisheries Service, Southwest Fisheries Center in La Jolla, California.

Richard E. Juday (Ph.D. 1943) is the son of Chancey Juday. He worked as an assistant to "Dad's scientists" at the Trout Lake Station from 1934 to 1940. He completed an undergraduate degree at Harvard University and returned to the University of Wisconsin for a doctorate in organic chemistry. He has recently retired from the Chemistry Department at the University of Montana in Missoula.

Charles M. Kirkpatrick (Ph.D. 1943) was a student of physiologist R. K. Meier and wildlife ecologist Aldo Leopold, working on the endocrinological development of Ring-necked Pheasants. In the summers of 1939 and 1940 he worked as an assistant to Juday and to botanist John Potzger at the Trout Lake Station, where he also conducted independent research on the foods of young Great Blue Herons. He is now Emeritus Professor in Wildlife Ecology in the Department of Forestry and Natural Resources at Purdue University in West Lafayette, Indiana.

Gail Kirkpatrick accompanied her husband to the Trout Lake Station in the summer of 1940. She was paid $50 plus her food and lodging for the summer to work as the cook for about ten of the scientists and graduate students.

E. David Le Cren (M.S. 1947) was a student of Hasler, working on perch population ecology in Lake Mendota. He has recently retired as Director of the Freshwater Biological Association at the Windermere Laboratory in England.

John J. Magnuson joined the Zoology Department at the University of Wisconsin-Madison in 1968. He had completed a Ph.D. in 1961 at the University of British Columbia and had worked on the behavior and physiology of tuna in Hawaii for seven years before coming to Wisconsin. He is currently Director for the Center for Limnology at the University of Wisconsin-Madison.

Villiers W. Meloche was the chief chemist for Birge and Juday at the Trout Lake Station following George Kemmerer's death in 1928. He was known as a pioneer in developing new techniques for the chemical analysis of lake water. He was interviewed in 1979 about his experiences at Trout Lake. Meloche died in 1981.

John C. Neess (Ph.D. 1949) was a student of Hasler. His thesis research on the population ecology of bluntnose minnows was conducted in artificial ponds in the University of Wisconsin Arboretum. He joined the Department of Zoology at the University of Wisconsin-Madison shortly after completing his degree. Over the years he advised a number of Hasler's students on problems in experimental design and statistical analysis.

Robert W. Pennak (Ph.D. 1938) was a student of Juday. He worked as an assistant to Juday at the Madison campus from 1934 to 1936 and at the Trout Lake Station during the summers of 1935 through 1938 while he did his own thesis research on the ecology of psammolittoral organisms (beach interstitial faunas). He is currently Professor Emeritus in the Department of Environmental, Population, and Organismic Biology at the University of Colorado in Boulder.

John J. Peterka (M.S. 1960) was a student of Hasler, working on the survival of trout in bog lakes in northern Wisconsin. He is currently in the Department of Zoology at North Dakota State University in Fargo.

Gerald Prescott was a visiting scientist from Albion College and later, from Michigan State University when he worked at the Trout Lake Station in the summers of 1936 through 1938. He conducted research on the taxonomy and distribution of algae in relation to the chemistry of lake waters. He is currently Emeritus Professor of Botany at Michigan State University in East Lansing and at the University of Montana in Missoula, but resides in Wyoming, New York.

Robert A. Ragotzkie (Ph.D. 1953) was a student of Hasler and Reid A. Bryson, conducting research on the physical limnology, zooplankton, and heat budgets of lakes. He is currently Director of the Sea Grant Institute at the University of Wisconsin-Madison.

Rex J. Robinson (Ph.D. 1929) was a student of analytical chemist George Kemmerer, working on methods for the chemical analysis of lake water. He worked as an assistant to Birge and Juday at the Trout Lake Station in the summers of 1926 through 1929. From 1929 through 1971 he was a member of the Chemistry Department at the University of Washington in Seattle. From 1931 to 1955 he was also a member of the Oceanographic Laboratories at the University of Washington. Robinson retired in 1971 as Emeritus Professor of Chemistry and now lives in Seattle.

Clarence L. Schloemer (Ph.D. 1939) was a student of Juday, but also received advice from Ralph Hile, who was working for the U.S. Bureau of Fisheries when he worked with Birge and Juday at Trout Lake. Schloemer conducted research on the age and rate of growth of bluegill and also worked on the growth of game fish, such as muskellunge and walleyes, in northern Wisconsin lakes. He is currently Professor Emeritus at Michigan State University in East Lansing.

William R. Schmitz (Ph.D. 1958) was a student of Hasler. For his thesis research, he studied winterkill conditions in northern Wisconsin lakes. He was Associate Director for the Trout Lake Station from 1966–1977, and is currently in the Department of Biological Sciences at the University of Wisconsin-Marathon campus.

Edward Schneberger (Ph.D. 1933) was a student of Juday, but also received advice from fisheries biologist Ralph Hile. He conducted research on the bottom fauna of lakes and also on the distribution, ecology, age, and growth of fishes in northern Wisconsin lakes. His thesis research was on the growth of yellow perch in three lakes in the Trout Lake region. Shortly after graduation, he was employed by the Wisconsin Conservation Department, now the Wisconsin Department of Natural Resources. He served as Fisheries Biologist, Superintendent of Fish Management, and Director of Research and Planning. He has retired from the Wisconsin Department of Natural Resources, and he and his wife, Helen, now live in Middleton, Wisconsin.

Helen Schneberger accompanied her husband to the Trout Lake Station during the summers of 1930–1934. In 1932 she was hired to be the cook for the scientists and students at the station.

Fredrick J. Stare, Ph.D., M.D., was a student of C. A. Elvehjem. He was an undergraduate when he worked at the Trout Lake Station as a chemistry assistant to V. W. Meloche in the summers of 1928 through 1931. He founded the Department of Nutrition at Harvard University in 1942 and is currently Professor Emeritus of Nutrition in the Harvard University School of Public Health in Boston, Massachusetts.

Raymond G. Stross (Ph.D. 1958) was a student of Hasler and advisee of John Neess. He continued the experimental lake liming project on Peter-Paul lakes. The research focused on retention of the lime and its effect on water transparency, iron, and phosphorus retention, and on zooplankton production. His study was the first to estimate turnover times in wild *Daphnia* populations. He also studied predator substitution in a fishless lake. He is currently in the Department of Biological Sciences at the State University of New York at Albany.

Dale Toetz, Ph.D., was an undergraduate assistant to Hasler's students, Daniel Faber and William Helm, in 1958 when they were conducting research on walleye year-class strength. He was also a student of John Neess (M.S. 1961) and later received a Ph.D. (1965) from Indiana University. He is currently Professor of Zoology at Oklahoma State University in Stillwater.

Clyde W. Voigtlander (Ph.D. 1971) was a student of Hasler. For his thesis research he worked on the biology of white bass in Lake Mendota. He is currently with the Environmental Quality Staff of the Tennessee Valley Authority in Knoxville.

Leonard R. Wilson (Ph.D. 1935) was a student of botanist Norman Fassett and geologist Frederick Thwaites. In the summers of 1932 through 1934 he worked at the Trout Lake Station as an assistant to Birge and Juday, and in 1936, as a visiting scientist from Coe College in Iowa. He conducted research on vegetation types, abundance, and succession in northern lakes. He is currently George L. Cross Research Professor of Geology and Geophysics, Emeritus, and Curator of Micropaleontology and Paleobotany at the Museum of Science and History at the University of Oklahoma in Norman.

Warren J. Wisby (Ph.D. 1952) was a student of Hasler. He conducted both laboratory work and field research on homing in salmon. Wisby also studied homing in black bass. He is currently Associate Dean of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami in Florida.

Thomas E. Wissing (Ph.D. 1969) was a student of Hasler. His thesis research was concerned with the ecological energetics of young-of-the-year white bass in Lake Mendota. He is currently Professor of Zoology at Miami University in Oxford, Ohio.

Stillman Wright (Ph.D. 1928) was a student of Juday, conducting research on zooplankton in Madison lakes and in South America. The summers of 1925 and 1927 he was employed by the U.S. Bureau of Fisheries as an assistant to Juday in investigations of northern lakes. Wright began working for the U.S. Bureau of Fisheries in 1938 and retired from the Office of Foreign Activites of the Bureau in March 1963. He currently resides in Chapel Hill, North Carolina.

Claude E. ZoBell was a visiting scientist from Scripps Institution of Oceanography when, as a Postdoctoral Fellow at the University of Wisconsin from September 1938 through May 1939, he studied the role of bacteria in lake metabolism. Janice Stadler, who was subsidized by the Works Progress Administration, was his full-time research assistant at the University of Wisconsin. ZoBell is currently Professor Emeritus of Marine Microbiology at the Scripps Institution of Oceanography, University of California, San Diego, La Jolla.

We would like to thank those people who helped conduct interviews: Carl Bowser, Department of Geology and Geophysics; Thomas Frost, Associate Director for the Trout Lake Station, Center for Limnology; and Jean Lang, University-Industry Research Program. We also appreciate the advice and comments of Art Spingarn, Botany Department, William Coleman, History of Science Department, Thomas Brock, Department of Bacteriology, Timothy Kratz, Center for Limnology, Robert McIntosh, Department of Biological Sciences, University of Notre Dame, W. T. Edmondson, Department of Zoology, University of Washington, and Katherine Webster, Wisconsin Department of Natural Resources, who reviewed early manuscripts of the book. The cooperation of the State Historical Society of Wisconsin in providing photographs for the book is also greatly appreciated.

1 Beginnings

Limnology at the University of Wisconsin began with the research of Edward A. Birge, who arrived in Madison in 1875 as an instructor of natural history at the university. Birge had begun studying Cladocera, a group of zooplankton, while he was a student at Williams College in Massachusetts. He continued research on the systematics of Cladocera at his new university post, but it was not until more than 20 years later, when Birge became interested in the physical and chemical conditions controlling the seasonal distribution of zooplankton in Lake Mendota, that his research became limnological.

About the turn of the century when Birge's research interests were turning toward limnology, he acquired a partner—a young limnologist from Indiana named Chancey Juday. The story of limnology in Wisconsin from 1900 to 1940 is the story of this famous partnership.

Birge was born in 1851 and grew up on a farm near New Haven, New York. He received A.B. (1873) and A.M. (1876) degrees from Williams College in Massachusetts. In the fall of 1873 Birge went to the Museum of Comparative Zoology in Cambridge to work with Louis Agassiz, probably the most well-known geologist and biologist in the country at that time.

> "Agassiz had all of the large collection of sea-urchins in the Museum brought out and placed on long tables in one of the corridors. I was to work them over, arrange and reclassify them, a task which would have occupied me for a couple of years or more. Agassiz visited me daily, asked about my progress, advised me as to books, etc. I suppose that if he had lived I should now be a specialist on the group of Echinodermata."
>
> E. A. Birge, 1936, "A House Half Built," an address to the Madison Literary Club.

Agassiz died only three months after Birge arrived, but Birge was given the opportunity to continue his education at Harvard, which was then organizing a graduate school (Sellery 1956). In 1875, before he had completed his doctoral degree, Birge left Harvard for Wisconsin.

At the time Birge arrived at the University of Wisconsin the school was only 25 years old and had only four to five hundred students. Birge was the first trained zoologist at the university, despite the fact that the 1870–1871 course catalog lists zoology as a department equipped for graduate work (Noland 1950). He constituted a one-man biology department, teaching courses in zoology, botany, bacteriology, human anatomy, and physiology (Frey 1963). After only four years as an instructor, including time off to complete a Ph.D. at Harvard in 1878, Birge was promoted to professor.

Birge played a major role in developing a research program in zoology and physiology at the University of Wisconsin. Before his arrival, there had been almost no biological research conducted at the university nor were there facilities or equipment for doing so. An 1850 inventory of the university library listed only one book on zoology, two on conchology, two on natural history, two on chemistry, 11 on medicine, and 62 on theology (Noland 1950).

Birge was among the first to emphasize individual laboratory work by students as a method of teaching. Although he initiated research courses for students, Birge found little time for his own research on Cladocera.

> "It is significant of the state which the University had then reached [1880] that no thought entered my head, or that of anyone else, that I should apply part of this time in research. Nor was there any thought of developing zoological teaching to the stage of graduate and professional courses. I decided to offer advanced undergraduate courses which should give a better scientific training to future students of medicine. . . . This teaching fully occupied my time for a decade, 1881–1891, and during those years there was little or no work on lakes. . . . During those years my interest in lakes and their inhabitants was not dead but was dormant."
>
> E. A. Birge, 1936, "A House Half Built."

Birge's first attempts at research were concerned primarily with the anatomy and systematics of Cladocera and were not really limnological. He has started studying *Daphnia* at Williams College and had continued his research at Harvard.

> "When the time came for a thesis *Daphnia* came to the fore again. I used my study of its anatomy and I worked up the group of microcrustacea to which it belongs as represented in Fresh Pond at Cambridge and later at Madison, especially in Lake Wingra. The resulting thesis was a very poor one, judged by any modern standards, even the most charitable, but it was the first attempt in this country to give a systematic account of the group of crustacea."
>
> E. A. Birge, 1936, "A House Half Built."

He became an authority on the taxonomy and ecology of Cladocera, as was recognized later when he was asked to write a chapter on Cladocera for H. B. Ward and G. C. Whipple's *Freshwater Biology* (1918). Prior to that monograph, Birge had written just four major papers dealing with the systematics of Cladocera, (1879, 1892, 1893, 1910b).

About the turn of the century his research took a distinct limnological turn, not so much by design as by accident. Birge had encountered a short paper by France' (1894) on diel migration, which demonstrated that in Lake Balaton in Hungary, the zooplankton come to the surface at night and do not descend to greater depths until about dawn, where they remain until early afternoon (Frey 1963). Birge was interested in determining how extensive the migration might be in Lake Mendota, a deeper lake than Balaton. To sample discrete water depths, he designed a vertical tow net that could be opened at any depth by means of a messenger and then closed again by a second messenger after pulling the net through a desired thickness of water (Frey 1963). Birge and his two senior thesis students, O. A. Olson and H. P. Harder, collected microcrustacea from different depths and counted the numbers of each species. This procedure was repeated every three hours, day and night, for several groups of days in July and August and also later in the year. When they had counted the crustacea in all the catches, they found no evidence of vertical migration at dusk or dawn, but Birge and his students did find an unexpected vertical distribution of the plankton.

> "No one could have had limnology less in mind than I did when in 1894 I started to work out, by quantitative methods, the annual story of the microcrustacea of Lake Mendota . . . for the best authority tells us that the word limnology did not appear in English until more than a year after our work began. . . .
>
> "I meant to make a thorough study, so I selected a primary station about half way out to Picnic Point, where the water is about sixty feet deep. This depth was to be divided into six levels of ten feet each; the crustacea were to be collected separately from each level, and the different

species determined and counted. This process was to be continued for a year or more. In fact, it went on until the end of the year 1897, and included from the several depths nearly five thousand catches, each containing up to a dozen forms of crustacea, of which eight species were abundant. . . .

"May I not venture just a hint that, when a monument seems to suit my condition better than a dinner, a spar-buoy properly painted and firmly anchored there [end of Picnic Point] would suitably commemorate my transfer from zoology to limnology.

"In the early days of this study, Mendota surprised me by a revelation of a peculiarity in her life as a lake which was to determine my thinking and my work in science for all the following years. As our crustacea-catching continued into midsummer we found that our booty began to disappear from the lower waters of the lake. The process continued until the lake became divided into two widely different parts. There was an upper lake, about 30 feet thick, whose water was warm and was filled with abundant plant and animal life. Below this lay an abrupt transition to the lower and colder half of the lake, which was not only cold but also without living plants and animals. . . .

"As Mendota cooled in autumn its upper and active stratum gradually became thicker and the lake reached its full activity at all depths in late October or early November, an activity limited only by the lower temperature of the water. This process is repeated every year.

"This story, which Mendota told me without my asking for it was the revelation that sent me into limnology."

E. A. Birge, 1940, First Symposium on Hydrobiology, held in Madison on Birge's 89th birthday to honor him for his contributions to limnology.

In these studies of zooplankton in Lake Mendota, Birge became more and more intrigued with the physical and chemical conditions controlling the distribution of the crustacea. Research on the seasonal distribution of plankton led him directly into an investigation of thermal stratification and lake chemistry.

These early studies of plankton distribution in Lake Mendota (Birge, Olson, and Harder 1895, Birge 1897) marked the beginning of limnology at the University of Wisconsin and of Birge as a limnologist (Frey 1963, Mortimer 1956). In these reports Birge not only described the seasonal and vertical distribution of eleven species of crustaceans, he also documented the story of the lake's seasons of circulation and stratification. It was not the first presentation of the annual temperature cycle in a lake, but Birge's interpretation of it in terms of the interplay of sun and wind has become classic (Mortimer 1956). In a paper on the annual thermal regime of Lake Mendota (Birge 1898), he noted many phenomena that are now part of our general understanding of the thermal dynamics of lakes—the lowering of the thermocline during summer, the increase in water temperature beneath the ice, the marked rise in temperature of the bottom water during the destruction of thermal stratification in autumn, and the variations in position and thickness of the thermocline under various wind stresses (Frey 1963). In this report, Birge introduced the word "thermocline" to limnology and oceanography. He introduced "epilimnion" and "hypolimnion" in a later paper on temperature seiches (Birge 1910a).

About the same time that Birge was completing his first plankton studies on Lake Mendota, the Wisconsin legislature established the Wisconsin Geological and Natural History Survey. The Wisconsin Academy of Sciences, Arts, and Letters, of which Birge was an active member, had played an instrumental role in the creation of the Survey. In 1893, the Academy had established a committee composed of Chairman C. R. Van

Hise, Birge, C. R. Barnes, G. L. Collie, and A. J. Rogers, to draw up a bill for presentation to the state legislature (Bean 1937). The legislature, however, was reluctant to consider the bill.

> "In 1873 the Wisconsin legislature commissioned what has come to be known as the [Thomas C.] Chamberlin Survey, which resulted in four volumes on the geology of Wisconsin, the last published in 1882. The legislature incorrectly thought that once a survey was done, it was done, there was no need to do another.
>
> "University scientists, however, agitated for a permanent survey. In 1893 the Wisconsin Academy of Sciences, Arts and Letters appointed a committee, led by geologist Charles Van Hise, to put together a proposal for a bill to establish a permanent survey. The bill was finally approved in the 1897 session."
>
> M. E. Ostrom, Director and State Geologist of the Wisconsin Geological and Natural History Survey, 1987, personal communication.

The legislature allocated $5000 a year for the Survey and appointed Birge as the Director (Bean 1937). He now had at his disposal considerably greater resources for conducting research. He found, however, that he had little time for research. Birge was not only Director of the Survey, but also Chairman of the Zoology Department (1875–1906), Dean of the College of Letters and Science (1891–1918), and Commissioner of Fisheries (1895–1915) for the state of Wisconsin. And in 1900 he was appointed Acting President of the University of Wisconsin, a position he held until 1903 (Frey 1963, Noland 1950). To keep his research program from suffering he began to look for a partner. He found Chancey Juday, whom he hired as Biologist for the Survey in 1900.

> ". . . the founding of the Survey in 1897 is an all important fact. . . . Looked at in the large, the story from this time on is a new one. . . . The most important result in the end was that it made possible the presence and work of Dr. Juday. . . . He was the first and for years the only limnologist in the country, and we knew the fact though we did not discover the word for a good many years."
>
> E. A. Birge, 1936, "A House Half Built."

Chancey Juday was born in 1871 in Millersburg along the northern edge of the lake district in Indiana. He received his A.B. (1896) and A.M. (1897) degrees from Indiana University where he met Carl Eigenmann, who in 1895 had established a biological station on Turkey Lake (currently Lake Wawasee) only a few miles from Juday's home (Frey 1963). It may have been through Birge's contacts with Eigenmann that Birge learned of the young limnologist who had studied plankton in Turkey Lake (Juday 1897), Lake Maxinkuckee (Juday 1902), and Winona Lake (Juday 1903). In Lake Maxinkuckee Juday had also studied the diurnal movements of plankton.

Juday's first assignment as Survey Biologist was to study diel migration of zooplankton in Mendota and other lakes of southeastern Wisconsin (Frey 1963). After only a year with the Survey, however, Juday developed tuberculosis and had to leave the Midwest. For the next few years, while he served on the biology or zoology staffs of the Universities of Colorado and California, there was a hiatus in limnology at the University of Wisconsin (Frey 1963, Noland 1945).

Juday rejoined the Survey in 1905 and was made a half-time lecturer in Limnology in the Department of Zoology at the University of Wisconsin in 1908. In 1909 he began teaching the first courses offered at the university in limnology and plankton organisms.

From October 1907 to June 1908 Juday travelled in Europe, visiting universities and biological stations in Germany, Denmark, Sweden, Austria, Hungary, Italy, France, and England, where he became acquainted with the leading aquatic biologists of Europe (Juday 1910). In February 1910 Juday travelled to Central America to study four semi-tropical lakes in Guatemala and El Salvador. As a result of his research there, he published one of the first studies in tropical limnology (Juday 1915).

Birge and Juday's early efforts as a team were concentrated on the Madison lakes, especially Mendota, and on other lakes in southeastern Wisconsin. Although their first joint paper was published in 1908, Birge and Juday's first major effort came in 1911 when they published the now classic paper on dissolved gases, "The inland lakes of Wisconsin: The dissolved gases of the water and their biological significance." The dissolved gases study had evolved directly from Birge's research on the seasonal distribution of microcrustacea in Lake Mendota.

> "It was an obvious guess that exhaustion of oxygen was at least one of the factors at work in summer, in the deeper water of Lake Mendota, to exclude the higher life of the lake from that region. So in 1904 there began the serious study of the dissolved gases of the lake water. Along with this there necessarily went careful observations of temperature; a little was done with light; much was done on conditions and changes in the minute life of the waters as affected by dissolved gases. The center of this activity was chemical and, therefore, with this study began that cooperation in our work of various University departments; out of this cooperation has come much of its success.
>
> "To this investigation Dr. Victor Lehner gave his time and energy without stint; he devised apparatus and methods; he directed the earlier work in person; then he initiated Dr. R. C. Benner as his successor."
>
> E. A. Birge, 1936, "A House Half Built."

During the five-year study a tremendous amount of information on water chemistry, temperatures, and plankton was accumulated from 156 lakes, mainly in southeastern Wisconsin, although many lakes in the northeastern and northwestern lake districts were examined briefly (Birge and Juday 1911). The 259-page report showed how seasonal changes in the distribution of dissolved gases are geared to the annual cycle of circulation and stratification and to the activities of plants, animals, and bacteria.

> "Judged by its influence on the subsequent development of limnology, the dissolved-gases report is the most outstanding single contribution of the Wisconsin school. In the remarkable introductory essay . . . Birge charts those regions of the lake environment which he had so largely helped to explore, and outlines some problems lying ahead. Holding within its many subsidiary ones, was the main problem: 'Why do lakes differ so widely in productivity or in ability to support a population of plankton?' This was a puzzle destined to occupy Birge and Juday for the rest of their lives, and one to which limnologists are still striving to find the solution."
>
> C. Mortimer, 1956, "An Explorer of Lakes."

In the 1911 dissolved gases study Birge and Juday established two traditions that were to continue throughout the course of their partnership and were to become trademarks of their work. The first tradition was a multidisciplinary approach to limnological research; the second was the collection of tremendous amounts of data. Birge and Juday recognized limnology as a synthetic science. Collaboration with scientists from other disciplines reached its height during later years when Birge and Juday were conducting research in Wisconsin's northeastern lake district. Many of these collaborators are discussed by Frank Egerton in chapter five.

> "The title pages of most of these reports carry the names of more than one author, and the list of such collaborators exceeds 50. The number is far greater of those who have helped bring together the data for these reports but who took no part in writing them. I emphasize the large number of collaborators, for the study of lakes is a synthetic science. . . . The biologist alone is quite helpless if he attempts to determine the laws governing the production of fish in a lake. He must ask help from the chemist, physicist, geographer, geologist, and meteorologist if he is to understand these laws or even appreciate their presence and estimate their influence."
>
> E. A. Birge, 1936, "A House Half Built."

> "A good many European limnologists used to talk about the broad base of limnology. Theinemann, Ruttner, Wolterek, and some of the other major European limnologists would stress the fact that limnology consisted of chemistry, plankton, bottom fauna, geology, microbiology, physics, rooted aquatics, and so forth. But these other people never gave it more than lip service. For the first time, Birge and Juday synthesized and realized as Birge put it, 'in order to find out how a lake keeps house, you've got to study all of these various aspects of the lake.' In my own view, they were really the first group in the world to put into being the idea that limnology is a synthesis of many different kinds of sciences."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

The second tradition, collecting a wealth of data, was based on Birge and Juday's belief that if enough data are gathered, the data will speak for themselves. They both thought that theorizing on the basis of too few data could be dangerous, and they shared a disdain for "desk-produced" papers.

> "As our work has progressed we have been increasingly impressed by the complexity of the questions involved. This has become more and more manifest as our experience has extended to numerous lakes and to many seasons. If this report had been written at the close of the first or second year's work, it would have been much more definite in its conclusions and explanations than is now the case. The extension of our acquaintance with the lakes has been fatal to many interesting and at one time promising theories."
>
> E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

Martin Gillen, a long-time friend and former student of Birge's, related this story:

> "I asked him [Birge] one evening, 'How many tests have you made with your "light machine" in the northern lakes?' He said, '19,952.' I replied, 'Well, Doctor, it will not be very long now before you will be able to announce a solution of this problem.' He stopped a moment, shook his head, and said, 'Martin, I think after this work is kept up twenty-five or thirty years longer, we may have the answer to it all.' "
>
> M. Gillen, 1940, First Symposium on Hydrobiology.

Birge and Juday were field limnologists and were somewhat skeptical of the value of laboratory experiments.

> "I suspect that [G. Evelyn] Hutchinson's conclusions regarding the killing of Cladocera by the zinc in Bear Lake was like a good many other conclusions derived from laboratory experiments;

they are not valid in nature. Limnologists still have a lot to learn about plants and animals in their natural environment."

C. Juday, 1940, letter to S. Wright.

Birge was attracted to the complexity of lakes and the then fashionable concept of a lake as a closed system, a microcosm or a "unit of environment," an individual with physiological processes analogous to those of an organism (Frey 1963, Mortimer 1956). No doubt both Birge and Juday were influenced by Stephen A. Forbes classic paper (1887) on the lake as a microcosm. The concept of the lake as a "unit of higher order" became a guiding principle in their work.

"Perhaps the chief interest which our work has had for us has been the fact that its progress has revealed to us the existence of physiological processes in lakes as complex, as distinct, and as varied as those of one of the higher animals. . . . These are examples of questions whose solution demands not merely a knowledge of the biology of the several species of algae, but also the study of the several lakes as physiological individuals of a higher order."

E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

"The lake is the one true microcosm, for nowhere else is the life of the great world, in all of its intricacies, so clearly disclosed to us as in the tiny model offered by the inland lake."

E. A. Birge, 1936, "A House Half Built."

As indicated in the dissolved gases report, Birge and Juday were aware of the rapid changes occurring in the young science—that limnology was evolving from the "natural history" phase toward being a true science.

"Various papers which have been recently published on the problems of limnology show that the science is passing from the initial stage of the collecting of more or less disconnected facts to that of the establishment of principles."

E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

The dissolved gases study led directly to quantitative studies of plankton standing crops (Birge and Juday 1922), and still later to an investigation of the dissolved organic content of lake waters (Birge and Juday 1926, 1927a, 1927b, 1934) as a means of studying the differences among lakes in their ability to produce organic matter. As was true of much of their research, their investigations of dissolved organic matter led to the development of new techniques and equipment.

"With 1911 began the second stage in our education. We took up the determination of the kinds, quantities, and composition of the fundamental foodstuffs produced in Lake Mendota. At first we employed the standard methods; the use of fine silk nets to strain this food from the water; the methods were modified so as to give quantitative results. But it was plain that much of the finer foodstuffs escaped through the meshes of the net and our problem was to find a way of obtaining this food in large amounts and in a shape such that further studies could be made on it. The solution came to us from Dr. Hotchkiss, the State Geologist. He had seen a milk clarifier at work in our Agricultural Department and suggested that such a machine might do our work.

"This was the introduction into limnology of the continuously acting centrifuge and it wrought a revolution in our possibilities of investigation. . . . In the years of our study we strained through the silk net more than 2000 tons of water from Lake Mendota and obtained from this water foodstuffs amounting to about one and one-half pounds of dry organic material. We ran through the centrifuge nearly 200 tons of water and extracted about 10 ounces of dry foodstuffs. . . . With this new and powerful extractor we were able to get a definite notion of the quantity of this food stuff and of its nutritive value as determined by chemistry. For the first time we had a definite notion of one important element in the lake's housekeeping. . . ."

E. A. Birge, 1936, "A House Half Built."

The study involved thousands of analyses which brought Dr. Henry Schuette and others in the university chemistry department into a collaboration more intensive than that in the dissolved gases study (Mortimer 1956). The main effort was expended in determinations of organic matter and nitrogen content. When this pioneer survey was extended to other lakes, the effort was aided greatly by the development, under Professor George Kemmerer's direction, of techniques for estimating minute amounts of carbon and nitrogen (Mortimer 1956). Like the dissolved gases study, the quantitative studies of plankton standing crops are considered among Birge and Juday's major contributions to limnology (Frey 1963, Mortimer 1956).

After 1917 Birge and Juday's efforts shifted away from the Madison region; from 1921 to 1924 they carried out intensive chemical and biological investigations of Green Lake, the deepest lake in Wisconsin. By the mid-1920s, however, their attention was drawn to the lake district in northern Wisconsin, where in 1925 they established the Trout Lake research station.

"The third stage of our education by the lakes, that from 1917 to 1924, was the most important and fruitful. . . . It culminated in the discovery that lake waters contain, in solution, a very large quantity of organics. . . . Here we had for the first time a definite notion of the total quantity of food and eaters handled by the lakes in the process of their housekeeping. . . . Thus after nearly 20 years of experience in the study of lakes we had learned to ask the question: How does a lake keep house? Twenty years had been sufficient time to teach us how to ask the question with a fair degree of intelligence, though they were far too few to give more than a hint at the answer. But we did not think little of the progress we had made.

"So we celebrated that turning point in our history by departure to new waters. Our field work on gases had made us acquainted with the lake region of Northeastern Wisconsin whose center may be placed at Trout Lake. Here is a triangular area of some 3000 square miles that contains literally thousands of lakes. These differ in every character. . . . Thus these lakes present to the student what may well be called a countless number of native experimental plots, where nature is trying out her experiments in aquiculture [*sic* aquaculture], under a wide variety of conditions and with every degree of success and failure in the limitless range of experiment.

"So we were bold enough to make the fourth period of our work a beginning of the study of a group of lakes, instead of concentrating our labors on one or two lakes or at most on a few. We hoped to get a sort of average for the varied housekeeping present in a group, and thus to arrive at a better understanding of the general principles underlying the process."

E. A. Birge, 1936, "A House Half Built."

References

Bean, E. F. 1937. State geological surveys of Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 30: 203-220.

Birge, E. A. 1879. Notes on Cladocera. *Trans. Wis. Acad. Sci. Arts Lett.* 4: 77-112.

______. 1892. Notes and list of Crustacea Cladocera from Madison, Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 8: 379-398.

______. 1893. Notes on Cladocera, III. *Trans. Wis. Acad. Sci. Arts Lett.* 9: 275-317.

______. 1897. The vertical distribution of the limnetic crustacea of Lake Mendota. *Biol. Centr.* 17: 371-374.

______. 1898. Plankton studies on Lake Mendota, II. The crustacea of the plankton from July, 1894, to December, 1896. *Trans. Wis. Acad. Sci. Arts Lett.* 11: 274-448.

______. 1910a. On the evidence for temperature seiches. *Trans. Wis. Acad. Sci. Arts Lett.* 16: 1005-1016.

______. 1910b. Notes on Cladocera, IV. *Trans. Wis. Acad. Sci. Arts Lett.* 16: 1017-1066.

______. 1936. *A House Half Built.* An address before the Madison Literary Club, October 12. In the Birge papers, State Historical Society of Wisconsin. 33 p.

______. 1940. *Edward A. Birge, Teacher and Scientist.* Addresses delivered at a dinner on September 5, 1940, given to honor Birge for his contributions to the science of limnology and in commemoration of his eighty-ninth birthday by the Symposium on Hydrobiology. University of Wisconsin Press, Madison. 48 p.

______ and C. Juday. 1911. The inland lakes of Wisconsin. The dissolved gases of the water and their biological significance. *Wis. Geol. Nat. Hist. Surv.*, Bull. 22, 259 + x p.

______ and ______. 1922. The inland lakes of Wisconsin. The plankton. I. Its quantity and chemical composition. *Wis. Geol. Nat. Hist. Surv.*, Bull 64, 222 + ix p.

______ and ______. 1926. The organic content of lake water. *Proc. Natl. Acad. Sci.* 12: 515-519.

______ and ______. 1927a. Organic content of lake water. *Bull. U.S. Bur. Fish.* 42: 185-205.

______ and ______. 1927b. The organic content of the water of small lakes. *Proc. Amer. Phil. Soc.* 66: 357-372.

______ and ______. 1934. Particulate and dissolved organic matter in inland lakes. *Ecol. Monogr.* 4: 440-474.

______, O. A. Olson, and H. P. Harder. 1895. Plankton studies on Lake Mendota. I. The vertical distribution of pelagic crustacea during July, 1894. *Trans. Wis. Acad. Sci. Arts Lett.* 10: 421-484.

Forbes, S. A. 1887. The lake as a microcosm. *Bull. Peoria (Ill.) Sci. Assoc. 1887.* Reprinted in *Bull. Ill. Nat. Hist. Surv.* 15: 537-550 (1925).

France', R. H. 1894. Zur Biologie des Planktons. *Biol. Centr.* 14: 33-38.

Frey, D. G. 1963. Wisconsin: the Birge-Juday era. In D. G. Frey (ed.). *Limnology in North America.* University of Wisconsin Press, Madison. pp. 3-54.

Juday, C. 1897. The plankton of Turkey Lake. *Proc. Indiana Acad. Sci.* 1896: 287-296.

______. 1902. The plankton of Lake Maxinkuckee, Indiana. *Trans. Amer. Microscop. Soc.* 24: 61-62.

______. 1903. The plankton of Winona Lake. *Proc. Indiana Acad. Sci.* 1902: 120-133.

______. 1910. Some European biological stations. *Trans. Wis. Acad. Sci. Arts Lett.* 16: 1257-1277.

______. 1915. Limnological studies on some lakes in Central America. *Trans. Wis. Acad. Sci. Arts Lett.* 18: 214-250.

Mortimer, C. H. 1956. An explorer of lakes. In G. C. Sellery. *E. A. Birge. A Memoir.* University of Wisconsin Press, Madison. pp. 165-211.

Noland, L. E. 1945. Chancey Juday. *Limnol. Soc. Amer.*, Spec. Publ. 16: 1-3.

______. 1950. History of the Department of Zoology, University of Wisconsin. *Bios* 21: 83-109.

Sellery, G. C. 1956. *E. A. Birge. A Memoir.* University of Wisconsin Press, Madison. 221 p.

Ward, H. B. and G. C. Whipple. 1918. *Freshwater Biology.* John Wiley & Sons, Inc., New York. 1111 p.

2 New Waters

The "Trout Lake Limnological Laboratory of the Wisconsin Geological and Natural History Survey," as it was called by Birge and Juday, was established in June, 1925, shortly after Birge retired from the university presidency at the age of 73. Birge and Juday were attracted to Wisconsin's northeastern lake district by the great number and diversity of lakes. Their hope was that by studying these lakes, which varied widely in their physical, chemical, and biological characteristics, they would discover general limnological principles.

Their research on the northeastern lakes, where the relatively soft water makes analyzing for chemical content difficult, was made possible by the development of microanalysis.

> "Dr. Pregl, Professor of Chemistry in the University of Graz, had devised methods and apparatus for what he called microanalysis, in which were employed incredibly small quantities of material. . . . The Survey purchased his apparatus in 1923, but no chemist in the University, or for that matter in the country, had ever used the method, and none seemed to think that it was a practical affair. . . . It [the apparatus] stood in my office, unused for a year or so, when it attracted the attention of Dr. Kemmerer, who was then giving much of his research time to aiding our work. He remodeled the apparatus, putting in electrical methods instead of gas. He simplified it. . . . This was the second time that apparatus had revolutionized our work, the first being the use of the centrifuge in obtaining plankton. The centrifuge and microanalysis have made limnology into a new and wholly different science."
>
> E. A. Birge, 1936, "A House Half Built."

For the first three years the research station was in an old schoolhouse and garage near the Wisconsin State Forestry Headquarters on Trout Lake. Part of the garage building served as an office and laboratory. The chemistry laboratory was in the nearby schoolhouse. Birge had a room in the Forestry Headquarters Building for sleeping, but Juday and the others slept in tents on the lake shore and ate their meals with the forestry workers (R. Robinson 1983, personal communication). Beginning in 1927 Juday brought his family to Trout Lake, and they stayed in a log cottage near the station. Juday's son Richard, who later graduated with a Ph.D. (1943) in chemistry from the University of Wisconsin, began helping as a field assistant in 1934.

> "I started rowing Dick Wilson around in '34. From then through the summer of '40 I worked every summer here. Before that, we had cabins in various places. Sometimes, I'd just go out and Father would say, 'Well, we're going to such and such lakes,' and then we'd go tag along."
>
> R. Juday, 1983, "History of Limnology in Wisconsin Conference."

Just getting to the northeastern lake district was a major feat in itself. In 1925 there were only 20 miles of paved roads between Madison and Trout Lake. The other 200 miles was rough gravel. On one of his first trips to Trout Lake Juday broke an axle on his Model T Ford (R. Juday 1983, personal communication). Getting out to the lakes to get samples was also no easy task.

> "We used a Model T Ford for transportation to the neighboring lakes. The 'improved' roads were gravel and became very rough during heavy summer usage. Remote lakes were served with dirt roads, usually of very poor quality. Many lakes were inaccessible except by trail. We made use of rowboats at resorts whenever available. If no boat was available, we set up a portable wood-frame canvas boat or inflated a portable rubber boat. A few times one of us would swim out a distance from shore to take a water temperature and obtain a water sample."
>
> R. Robinson, 1983, personal communication.

If one of the researchers swam, it was not Birge or Juday, as neither of these eminent limnologists could swim (A. Hasler and R. Juday 1983, personal communication). However, Juday's daughter, Mary, notes that her father could swim a little (M. Juday 1987, personal communication).

Even though the facilities were modest, the staff grew from three biologists (Birge, Juday, and Stillman Wright, a graduate student of Juday) and one chemist (Stanton Taylor, a graduate student of George Kemmerer) in 1925 to seven biologists and three chemists by 1928. By the mid-1930s there would be as many as twenty-two scientists and assistants at the Trout Lake Station each summer.

In 1928 the Wisconsin Conservation Department (later the Department of Natural Resources) gave the Survey permission to use two wooden bathhouses on the shore of Trout Lake for permanent laboratories. Birge and Juday had another building constructed, and every few years added an additional building to the station facilities. Some were built during the Depression of the 1930s using WPA labor.

Juday was the director of the research station from 1925 until his retirement in 1942. During those years the north-central lake district was the main center for limnological research at the University of Wisconsin. The approach at Trout Lake was not so much problem oriented or lake oriented. The researchers were concerned primarily with surveying large numbers of lakes for various chemical and biological properties and studying the range of variation of these properties and their presumed controls, especially as they related to drainage and seepage lakes (Frey 1963). Under Juday's direction, and with the help of student labor, more than 500 lakes were examined, chiefly during the period 1925 to 1932, for water chemistry, plankton, and for the intensity and color of underwater illumination. A complete set of field determinations comprised 19 different chemical, physical, and biological items (Frey 1963). George Kemmerer directed the chemical work for Birge and Juday at Trout Lake and in Madison from 1925 to his death in 1928. Rex Robinson was a graduate student working under the direction of Kemmerer.

> "During the summers I was at Trout Lake we investigated well over 500 lakes in Vilas and adjoining counties. . . . As most of the lakes had not been investigated limnologically before, we would first sound the lake for depth with lead and calibrated line to establish our station at the location of deepest depth. Water temperatures at different depths were taken to establish the thermocline. Samples of water and plankton were then taken at appropriate depths. Readings for turbidity were usually taken with the Secchi disc.
>
> "After our samples were taken we would hurry home to the laboratory for the analytical work. Thousands of analyses were made during the summer's work. The normal list included: pH, dissolved oxygen, free and fixed carbon dioxide, soluble phosphate, organic phosphorus, soluble silicate, nitrate, nitrite, ammonia, organic nitrogen. Each day the results were reported

to Dr. Birge or Dr. Juday. Dr. Birge evaporated water samples to determine water residue and also to obtain samples for C-H analyses later in Madison. Dr. Birge made light penetration measurements by making measurements at different water depths with a photometer. He also made measurements for different bands of wavelengths by covering the eye of the photometer with different colored glass filters. . . .

"Our lives were busy ones. Breakfast at 7 a.m. and off to the selected lake(s) of the day as soon as we could load up the auto with the necessary bottles and needed equipment. We worked seven days a week. The only diversion for the young folks was fishing on Trout Lake or the Saturday night dance at the Trout Lake Dance Pavilion at the south end of Trout Lake. But those were pleasant summers and I treasure the memories."

R. Robinson, 1983, personal communication.

The period from 1925 to the early 1940s was an extremely productive time for the two limnologists and their many colleagues. At the University of Wisconsin, zoologists, botanists, chemists, bacteriologists, geologists, and others were being drawn more and more into a cooperative program (Frey 1963).

"The research that was being carried on up here was really at the forefront of limnology around the world. . . . Even though they were doing these extensive studies here, they were also doing the intensive studies on the six lakes. [Trout, Nebish, Weber, Crystal, Muskellunge, Silver (Sparkling)]. They were involved in really current things."

D. Frey, 1983, "History of Limnology in Wisconsin Conference."

The research Birge and Juday wanted to conduct required the participation of people from many disciplines and a large number of "helping hands." Birge was particularly well placed in Madison to obtain those "helping hands." As former Dean and President he could enlist the help of university chemists, biologists, bacteriologists, physicists, and instrument-makers. He was able to obtain financial support for the work, for equipment, and for assistance in the field.

"One of Birge's great contributions was his ability to go across the university and find the expert he needed. There weren't many places in the world where you had such a combination of talent. Birge's political savvy and his aggressiveness, combined with his having attained a leadership role in the university at a very young age, enabled him to get both money and experts."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Most of the funding for research conducted during this period came directly from the state through the Geological and Natural History Survey. Birge and Juday also obtained money from the university, the Wisconsin Alumni Research Foundation, the Wisconsin Conservation Department and the U.S. Bureau of Fisheries, with whom Juday maintained a consulting and cooperating relationship for many years. The limnologists also received substantial funds from private sources, such as the Brittingham Fund, which was established by Thomas Brittingham in 1927 with the understanding that his gifts would be applied to subjects that were of "prime scientific importance, yet so complex and so remote from immediate practical use that we [Birge and Juday] did not think it right to employ the limited state funds in their study" (Birge 1940). Birge and Juday were not above a bit of "book juggling" to get additional funds for equipment.

"They did have one unique way of getting funds. They were able to get some money from the Bureau of Fisheries for labor. If they needed equipment they would put somebody on the payroll for a month. When the check came, that individual endorsed it and they bought the equipment. I know I endorsed several of those checks."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

The involvement of so many people in the research program at Trout Lake and in Madison makes their contributions to limnology difficult to summarize. The single major effort at Trout Lake was the broad survey involving more than 500 northeastern lakes. Juday and Birge (1933) reported on transparency, color, and specific conductance for most of these lakes. Following Kemmerer's death, direction of the chemical work was taken over by Villiers W. "Mel" Meloche, who was a pioneer in the application of new instruments to chemical analyses. In the chemical reports, which were written in association with Meloche, the researchers reported analyses of silicon, iron, manganese, calcium, magnesium, fluoride, chloride, sulfate, and ammonia, nitrite, nitrate, and nitrogen. The ranges and frequency distributions were given, as well as the distribution with depth and the relation to the general chemical conditions in the lakes (Juday, Birge, and Meloche 1938). They also reported on phosphorus content (Juday and Birge 1931), sodium and potassium (Lohuis, Meloche, and Juday 1938), dissolved oxygen and oxygen consumed (Juday and Birge 1932), and carbon dioxide and pH (Juday, Birge, and Meloche 1935).

"I provided the chemists and Birge and Juday provided the facilities. . . . I brought up platinum dishes to evaporate water to get residues. We took the samples back to Madison, and, with the help of assistants, we analyzed the residues for chemical content. . . . We made the best use of the available equipment and invented equipment that would make the analyses faster. Advances in instruments opened new fields of research.

"The great advances in physical, analytical chemical instrumentation occurred close to the end of the war in 1945. Prior to that, much was done by the 'guess by gosh' method."

V. Meloche, 1979, personal communication.

One of the assistants to Meloche was Fredrick Stare, who later founded the Department of Nutrition at Harvard University. When he was at Trout Lake he was an undergraduate majoring in chemistry. Stare recalled that it was not all work and no play.

"I enjoyed very much working with Meloche up here. We used to go trout fishing with homemade reels. We'd take two pie plates and put them together somehow. In the flange between the pie plates you could wrap quite a bit of string. We used to catch loads of trout way down deep—100, 110, 125 feet. It was loads of fun."

F. Stare, 1983, "History of Limnology in Wisconsin Conference."

It may have been the assistants, many of whom did not have their own thesis projects to work on, who had the most fun at Trout Lake. Bradford Hafford worked as a chemistry assistant in 1939 and 1940.

"On Trout Lake we generally trolled for walleyed pike in the evening for supper. After sexing the catch, we would filet and eat them—delicious. My wife Jean caught the largest walleye on our side of the lake, about a six pounder. The record only held for about a day when Dick Juday brought in a fish one half pound larger. It developed later that Dick had stuffed his fish with more than one pound of lead sinkers before weighing."

B. Hafford, 1983, personal communication.

Life at Trout Lake was certainly far more work than play, however. In addition to the broad chemical and biological survey of lakes, Birge and Juday selected for intensive study six lakes that covered the range of chemical and biological conditions found in northern lakes.

> "The research assistants were organized into crews with two or three assistants per crew, a fish crew, a microbiology crew, a chemical crew, and a plankton crew. . . . I was on the plankton crew and regularly about every ten days, we would visit one of six lakes that were chosen for intensive study. These were Trout, Nebish, Weber, Crystal, Muskellunge, and Silver [Sparkling] lakes.
>
> "Early on most mornings we would hitch up the boat and trailer to the plankton truck, we went out and took our chemical samples, took the plankton samples and brought them back to the laboratory. We went out in all kinds of weather. If it rained that day it didn't make any difference, you went out anyway. If it was windy, you went out anyway. We used these heavy old oak boats in those days. There were no life preservers. The boats were heavy, but none of us ever worried about having the boat dump over. If it had dumped over, I'm sure we would have drowned. . . . We never gave it a thought and worked along blissfully. . . .
>
> "We would come back with our water samples late in the morning or around noon and then the chemists would run pH, carbon dioxide, dissolved oxygen, and so forth, and either I or someone else would run the plankton samples through the Foerst centrifuge for phytoplankton counts. We used the Juday plankton trap for quantitative zooplankton counts. In addition to our regular chores of taking plankton and chemical samples, we often had other temporary assignments given to us. For example, frequently, once or twice a week I would be required to go out and take bottom fauna samples. We'd use an Ekman dredge and a Peterson dredge and bring the samples back to the lab and count the bottom organisms and have it entered into the record."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Although Birge was into his 80's by the time the survey investigations were in full swing, he was a determined and relentless researcher.

> "One time I was driving Birge over near Sayner somewhere. We were on a gravel road and we came around a curve and somebody came toward us. We couldn't get out of the way and the little Model A slowly tipped on its side. Birge had been sitting next to me and was now down on the lower side of the tipped car and I was up against him. Birge was now 85 years old. I managed to get out of the left door of the car and I helped haul Birge out of the thing too. It had tipped over so gently there wasn't any appreciable damage to it. And we both got around and saw the dumped over car just off the edge of the road and Birge, being a devout churchman said, 'Goddammit Pennak, put it back on its wheels, the Survey must go on.' "
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

At the Trout Lake Station Birge continued his studies of light penetration that he had begun in Madison in 1912. He had been the first to measure the penetration of sunlight into a wide range of lakes with precise equipment. Birge used a "pyrolimnometer," an instrument produced by collaboration with university physicists. The instrument measured the total energy of the sun's rays by the electrical effect they produced when falling on the sensitive surface of the thermopile. Using the pyrolimnometer, Birge, with the assistance of a student helper, Hugo Baum, measured the transmission of solar radiation and the factors influencing the differences in transmission observed among lakes and from one depth to another in the same lake. Lester Whitney, who conducted several studies of light transmission (1938, 1941), extended Birge's measurements on light transmission to intensities as small as 2 x 10^{-6} of surface light by means of a photoelectric cell and an amplifier.

"Les Whitney was a marvelous technician. He was marvelous at cooking up apparatus. I had an electronic thermometer that was custom-made for me by Les Whitney that would read temperatures to a hundredth of a degree and get reliable replicates from one reading to another."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

With the help of J. P. Foerst, a mechanic and instrument maker in the Physics Department, Birge and Juday and their colleagues developed new instruments or modified existing ones. From rough sketches or from suggestions as to the kinds of data needed, Foerst was often able to devise pieces of equipment, many of which are standard items even today (Frey 1963).

"Somehow Birge and Juday got money to pay Foerst specially to concoct instruments for them in the physics workshop. They modified the Ekman dredge, which had originated in Sweden. They invented the Kemmerer water sampler. Juday, along with Birge I suppose, invented the plankton trap—various sizes of it. And Foerst built for Juday the little Foerst centrifuge that was used for centrifuging water samples to get out the phytoplankton and seston determinations. . . ."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

The equipment invented, particularly the super-centrifuge, was not always considered entirely safe by the research assistants.

"Both Birge and Juday were anxious to get out every bit of colloidal material that was in the water. They weren't satisfied with the Foerst centrifuge, which works on the same principle as a cream separator. So they got hold of an air compressor that could deliver 200 psi constantly. It was said to be the largest portable air compressor in all of northern Wisconsin. That thing was installed in the Plankton lab on a concrete base and it delivered this jet—actually a multiple jet—of compressed air against a rotor that we were using to try and separate out little tiny fractions of colloidal particles still left in the water. It was a terrifying thing. All of us were frightened to death of it. It had a rather large rotor and we were afraid that at the speed at which it was running— it would run on a cushion of air— that the bowl would fly apart. As a result we built a heavy protective covering for the thing out of 2 x 4's. We used to turn the thing on, quick run out of the lab, and assume a low profile in the event that the thing ever blew apart."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

George Clarke, a visiting scientist from the Woods Hole Oceanographic Institute, perfected the Clarke-Bumpus sampler while at Trout Lake. And Herbert Dutton, a postdoctoral student working with physical chemist Winston Manning and chemist Farrington Daniels, also used equipment that was ahead of its time in his research on chromatic adaptation in relation to color and depth distribution of freshwater phytoplankton and large aquatic plants at the Trout Lake Station in 1940.

"I used a spectrophotometer before there were spectrophotometers. It was a glass prism about

12 inches tall. When I did my first measurements of the absorption spectra of pigments it was a matter of watching a galvanometer on a meter stick. But it was an effective instrument.''

H. Dutton, 1983, ''History of Limnology in Wisconsin Conference.''

As the work of Birge and Juday and their colleagues became better known, they began attracting the attention of the European limnologists who began citing their work and visiting the University of Wisconsin and the Trout Lake Station. Certainly in Madison, faculty and students interested in limnology recognized that Trout Lake was the ''place to be,'' that good and important research was going on there.

''We chemistry students knew about Trout Lake as an exciting, challenging place to live and work. . . . There was an aura about coming to Trout Lake. If you were real good and real lucky you might have that opportunity. So I think the people that came up here, came up quite starry-eyed and were the top people.''

H. Dutton, 1983, ''History of Limnology in Wisconsin Conference.''

While at the Trout Lake Station, graduate students and other researchers had very little contact with Birge even though he continued to come up to the station every summer through 1938. Juday was the one who directed the research and the students.

''Juday was the real clearinghouse. We all talked with him and I think Juday talked with Birge. . . . Dr. Birge didn't have a great deal to say. He would ask a very pointed question at times. But he never really had any suggestions.''

L. R. Wilson, 1983, ''History of Limnology in Wisconsin Conference.''

''Birge was a driver, he was the front man, he was the publicity man, he was the fund-raiser as I pictured it. Juday was kind of in the background in those things. Yet he was the consistent, steady slugger. I think he probably had more of the ideas than Birge had.''

E. Schneberger, 1983, ''History of Limnology in Wisconsin Conference.''

Their associates at the Trout Lake Station were largely unaware of Birge and Juday's scheme of research, but there was no question that the pair had long-term plans for their research program.

''During my first year as a graduate student [1934] I was assigned the task of presenting to a proseminar group a paper on aspects of the life of Professor Birge as an outstanding biologist. . . . He [Birge] graciously gave me over an hour's time and during this time outlined the 10 year research program he had in mind. He was about 85 years old at the time.''

C. Schloemer, 1983, personal communication.

The students and technicians always knew in detail what they would be doing from day to day, but the outline of the research plan and the goals of the research were never discussed with them. Juday rarely went out into the field with the research assistants except to show them how to take samples (Pennak 1983, personal communication).

''Certainly there was a fabric and plan laid out by Dr. Juday's broad concepts, but it was such that we really couldn't interpret quite what the overall pattern was. . . . You had the feeling that you had a specific problem and you did it. You didn't quite see the broader aspects and implications of the particular research you were doing, where it fitted in. . . . Certainly there was no overview of where we were going."

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

The problem of communication was exacerbated by the lack of seminars or any formal set-up for the exchange of ideas. There were certainly discussions around the poker table in addition to the "I'll raise you 30," as well as conversations that were a combination of shop talk and story-telling around bonfires on the beach. In later years students did discuss ideas and research problems over the dinner table. Neither Birge nor Juday, however, participated in these activities. Nor did Birge and Juday introduce their students to the many European researchers who visited Trout Lake or the university.

"In the four summers I was here we didn't have a single seminar presentation. . . . This is one reason why theory and empirical ideas simply did not come out in the open because we did not have this kind of discussion."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Graduate student theses were, for the most part, independently conceived and executed. There was very little guidance from either Birge or Juday. Students were given a free hand and time to do their own research while they worked for Birge and Juday, but it was an individualistic effort—the student was on his own to either sink or swim. Fortunately, most swam.

Funding for the Trout Lake Station had always been relatively meager, but in 1931 the Wisconsin state legislature discontinued funding for the natural history portion of the Geological and Natural History Survey. The funding cut-off may have had as much to do with old political rivalries as the Depression of the 1930s.

"Dr. Birge and Bob LaFollette, Sr., got to be rather bitter enemies when LaFollette was governor [Birge was then university president]. They differed on how they thought the university should be operated. Dr. Birge was quite insistent on trying to keep the activities pretty well within the bounds of the campus, while LaFollette wanted the university spread out, to be of more service to the people of the state. . . . So when LaFollette's son Phil became governor, that animosity apparently continued because with one stroke of the pen, he wiped out the funds for the natural history part of the budget, which left Juday and me out of a job. But the university came to the rescue and took it over. So after that it was funded by a university appropriation and Juday was given university status [full professorship in zoology, formerly he had been a half-time lecturer]."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

Living and working conditions at the Trout Lake Station had never been luxurious, but the Depression made things even worse. There was no running water or electricity in the living quarters, and the ice box was a hole in the ground insulated with *Sphagnum* moss.

"In 1935 we all lived in a leaky tarpaper shack that served as both bunkhouse and cookhouse. In later years we had a frame bunkhouse. . . . This was Depression time and we were just recovering from the Depression of the '30's. . . . We worked from about 7:15 to about 4:30 or 5:00, six days a week, although we did very little on Saturday afternoons. Sunday we were free.

We slept, did our laundry, we read, we loafed. There was no booze. There wasn't even any beer. There were no radio stations in the area, so a radio up here wouldn't do you any good. . . . Saturday nights most of us would indulge in a poker game or otherwise we would go into Minocqua and walk up and down what was then the entirety of Minocqua, about three or four blocks long and one block deep."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

"My impression of the Trout Lake laboratory [1939 and 1940] was that we were very poor. All the equipment was very much out of date . . . trucks literally falling apart . . . the boats were in bad order. Oars were short—it was almost a matter of stealing oars from one another to get a good oar to go with your boat. We had no more than three or four motors at that time and it was hard to keep the motors running. It was really in poor shape."

C. Kirkpatrick, 1983, "History of Limnology in Wisconsin Conference."

Despite the Depression and the harsh conditions it imposed, the research program at Trout Lake flourished. In addition to the lake survey work, Birge and Juday's colleagues and students at Trout Lake made wide-ranging studies of lake sediments and sedimentation processes, aquatic bacteria, aquatic plants, psammolittoral organisms, fisheries ecology, and lake productivity and community structure. (A complete list of the papers published by Birge and Juday and their associates can be found in C. Juday and A. D. Hasler, 1946. A list of publications dealing with Wisconsin limnology 1871–1945. *Trans. Wis. Acad. Sci. Arts Lett.* 36: 469–490.)

Juday, Birge, and Meloche (1941) published an extensive paper on the chemistry of lake sediments involving 18 lakes in northeastern Wisconsin and three in southeastern Wisconsin. W. H. Twenhofel, a geologist from Madison, and his students, W. A. Broughton and Vincent E. McKelvey, studied sediments and sedimentation both in the Madison area and at Trout Lake. Paul S. Conger, a visiting scientist from the Carnegie Institution in Washington, examined diatoms in sediment cores in Crystal Lake and was one of the first researchers to use diatoms to interpret previous ecological conditions in a lake. Pollen chronologies in lake and bog sediments were examined by Leonard R. Wilson and John E. Potzger, a visiting scientist from Butler University.

Birge and Juday recognized early the importance of bacteria in lakes. Their early studies on numbers of bacteria in Mendota were continued by E. B. Fred and Letitia M. Snow. Claude E. ZoBell was a visiting scientist from Scripps Institution of Oceanography when he studied the role of bacteria in lake metabolism. Ruby Bere was one of the first persons to make direct microscopic counts of bacteria in waters. Studies of this type were extended by William Stark and Elizabeth McCoy in the lakes of northeastern Wisconsin. During this interval quite a number of persons, including Yvette Hardman, William Stark, Mary A. Jansky, and Dorothy E. Kinkel, received Master's and Ph.D. degrees in bacteriology on problems directly related to limnology (Frey 1963).

Gerald Prescott, widely known for his research on algae, came from Albion College and later, Michigan State University to work at Trout Lake in the late 1930s. His book, *Algae of the Western Great Lakes Area* (Cranbrook Press) was based on these investigations. In 1952 he would receive the first grant for ecological research ($3900) from the National Science Foundation for "Ecological Survey of Arctic and Alpine Algae in Relation to Glaciation and the Disjunctive Distribution of Phanerogams" (Burgess 1981). Prescott was also renowned as the best poker player at Trout Lake.

"My excuse for having been here was my interest in algae and the work on phytoplankton that G. M. Smith did back in the 1920s on these same lakes. . . . Dr. Birge, through the Wisconsin Geological and Natural History Survey, picked me to complement his studies and do the filamentous and other groups of algae. . . .

"Birge and Juday encouraged my interest in relating types of flora to water chemistry and to fish production . . . to get a bird's eye view of the kinds and quantities of algae in different kinds of lakes and relate that to the chemistry and to the amount and kinds of fish produced. . . . In my wanderings I tried to visit every and almost any lake in this whole area.

"I came to this lake in Boulder one afternoon. I didn't bother anybody else and waded out with my little scum skimmers to do my collecting. In a very short time the director of the camp [YMCA] came out on the porch and bellowed out, 'What are you doing out there?' The wind was blowing and I didn't know what to tell him. I couldn't explain about algae and fish food organisms and so forth. He kept bellowing at me. I felt really embarrassed, so I made my collection and left. I felt so guilty that I wrote a letter to the director and apologized for not giving him a full six weeks' course in algae with the wind blowing against me. The net result was that he sent me an invitation to come out and have dinner with the boys."

G. Prescott, 1983, "History of Limnology in Wisconsin Conference."

Norman Fassett, Leonard R. Wilson, John E. Potzger, and Willard A. Van Engel studied the distributions of aquatic plants in lakes varying widely in chemical and biological characteristics. They were concerned with communities or associations of plants in relation to soil type and depth zone. Wilson was also interested in the successional relationships of communities from primitive lakes with inorganic soils to advanced lakes with organic soils, and he attempted to relate the distribution and abundance of aquatic plants to various environmental factors (Frey 1963). Wilson's research was, of course, done before the advent of SCUBA gear.

"The first summer we worked on Weber Lake my wife rowed the boat while I had a little square of iron that I dropped down. Then I'd dive down and pick up plants and bring them to the top. I crawled over most of Weber Lake bottom right to the extent of the attached vegetation. . . . I think I also crawled over more of the bottom of Trout Lake than anybody in existence. We did something like 68 transects and it was a tremendous job."

L. R. Wilson, 1983, "History of Limnology in Wisconsin Conference."

Robert Pennak, a graduate student of Juday's, pioneered in the study of the psammolittoral community—organisms living in interstitial water on beaches. He collected extensive data on the horizontal and vertical distribution of the various organisms and on the chemistry of the psammolittoral zone.

"After I did my thesis work and it was published in *Ecological Monographs* (1939) as an 80-page paper—of course you couldn't get a paper that long accepted these days—it immediately attracted the attention of marine biologists. In 1939, the year after I got my degree, I went to Wood's Hole and did a similar project on Wood's Hole beaches with reference to the tide lines. We discovered that there is indeed a similar kind of assemblage of microfauna on sandy ocean shores.

"Now this was pioneer work—nobody had done anything like this ever. Since those days very little of this kind of work has been done on freshwater, but in the ocean the thing has absolutely burgeoned. So now there is an international society of myobenthologists and they publish their own journal having to do with organisms living in—they've now gone down into the mud bottom below tide level as well—the sandy beach area here . . . but in freshwater habitats there's been almost nothing done since I did my pioneer work back now so many years ago."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Minna Jewell, from Thornton College in Illinois, spent several summers at the Trout Lake Station studying freshwater sponges. She had studied stream ecology with Victor Shelford at the University of Illinois and had hoped to conduct research on water pollution. She began studying sponges at the suggestion of Edward Schneberger, a former student.

"Two things were wrong about her continuing her profession: her desire to study stream pollution—people weren't accepting those things in those days—and women's lib hadn't come along yet, so being a woman, she had trouble finding employment. . . . I felt she was going to pot at Thornton and needed some activity to use her talent. I had seen these sponges in lakes here and I conceived the idea that that would be a good project for her."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

Jewell was somewhat eccentric—she wore G.I. clothing from World War I and called her sponges, "spon-jāz" (Pennak 1983, "History of Limnology in Wisconsin Conference"). She is most fondly remembered, however, as someone who was always ready to take a struggling student "under her wing."

Juday and Birge had been receiving research support from the U.S. Bureau of Fisheries for some years, but with the establishment of the Trout Lake Station they also began receiving support for research on fish from the Wisconsin Conservation Department. This phase of aquatic investigation at the University of Wisconsin may be considered to have started with the study begun in 1925 by Stillman Wright on the growth of the rock bass. From this time on there was a steady succession of papers concerned with various aspects of fishery biology and management, including a number of now classic papers by Ralph Hile on cisco and rockbass. Hile was a recent graduate of Indiana University and was employed by the U.S. Bureau of Fisheries. He was sent to work with Birge and Juday, and he and Schneberger worked together on much of the fisheries research conducted at Trout Lake. Schneberger later became Head of Fisheries for the Conservation Department and was instrumental in arranging for the continuation of cooperative fisheries research between the university and the department.

Other papers in fishery biology were written either by Juday, based on data gathered by WPA workers, or by students, such as Edward Schneberger, Clarence Schloemer, George Bennett, William Spoor, and David Frey, who received their Ph.D.'s under Juday's supervision (Frey 1963).

One very important paper of this period described the method developed by Zoe Schnabel (1938) and her colleagues, E. Hull and M. Ingraham in the Mathematics Department, for estimating the size of a fish population by marking and recapturing. Schnabel's work was done between 1936 and 1938 when she was a graduate assistant in the Computing Laboratory of the Mathematics Department in Madison.

"The laboratory had been established in the early 30s to assist university researchers with the statistical analysis of data. Members of the mathematics faculty served as consultants and I and an assistant did the computations, using a standard 8-bank calculator and a manual-type 13-bank model which had been motorized. Dr. Chancey Juday . . . was one of the first persons to use the laboratory. He and his associates were doing studies on the fish populations of several Wisconsin lakes using capture-recapture procedures. My paper of 1938 summarized the methods which had been developed in the laboratory for estimating population size."

Z. Schnabel Albert, 1980, in letter to David R. Anderson.

In the last decade of his productive life as a limnologist, Juday turned his attention to the measurement of the rates of energy fixation and the subsequent utilization of energy within the trophic structure of the ecosystem (Frey 1963). Juday and his associates made some fundamental contributions to this area of research. Plant ecologist John T. Curtis and Juday, for example, conducted one of the very early bioassays of productivity. In 1936, Winston Manning, a physical chemist at the University of Wisconsin, joined the summer program at Trout Lake with a much more sophisticated approach toward productivity. Herbert Dutton, a post-doctoral student advised by Manning, conducted some of the earliest field research on chromatic adaptation.

"I was working with Dr. Manning and we had just discovered that carotenoids absorbed energy and transferred it to chlorophyll A with an efficiency almost equal to the chlorophyll in chlorophyll B or chlorophyll A itself. So the logical extension of that was, 'how did it work in real life and how would it do in Trout Lake—is there any chromatic adaptation?' So far the study was a matter of examining the family of *Potomageton* as it extended out into Trout Lake to see whether there was any correlation of color with depth."

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

During World War II Manning worked on the Manhattan project and later became the Associate Director of Argonne National Laboratories. He had asked Dutton to join him on the Manhattan project, an offer Dutton reluctantly turned down.

"Winston Manning wrote to me and said, 'We have a discovery that is as important as x-rays. (This was the Manhattan project.) Would you like to join us?' I went to my bosses in the government and they said it was not important work and that what I was doing [analyzing dehydrated foods] there was much more important. They told me, 'If you want to go, go, but your job won't be here when you return.' "

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

Other research on lake productivity included the first study of the amount and distribution of chlorophyll in lakes, which was carried out on northeastern lakes in 1937 by Zygmunt Kozminski, a visiting scientist from the Wigry Hydrobiological Station in Poland. In two other papers Juday attempted to set up an energy budget for Mendota (Juday 1940) and to investigate the relationships between various components of the standing crop of organic matter (Juday 1942). Perhaps the most important study in this series was the last one by Juday, J. M. Blair, and E. F. Wilda (1943) in which the daily productivity for an entire lake was determined from continuous records of dissolved oxygen at several depths, as measured by dropping mercury electrodes (Frey 1963). Juday also attempted to increase production in Weber Lake by adding fertilizers. He and his colleagues tried various commercial mineral fertilizers, as well as soybean meal and cottonseed meal.

Despite the large number of research projects conducted during this era, relatively few students received graduate degrees under the direct supervision of Birge and Juday. Very early in his career Birge took on heavy administrative duties that probably precluded supervising graduate students. By the time he and Juday established the Trout Lake Station, Birge was already 73 years old. During the late 1800s Birge did supervise a number of Bachelor's theses and a few Master's theses including those of Julius Nelson and Ruth Marshall, but Birge never had any Ph.D. students. Juday had been hired as Biologist with the Wisconsin Geological and Natural History Survey with a simultaneous appointment as Lecturer in the Zoology Department. He was not made a professor until 1931 when he was 60 years old and did not begin supervising students until late in his career.

Juday's first Ph.D. students were Stillman Wright, Edward J. Wimmer, and Abraham H. Wiebe, who completed their degrees in 1928 and 1929. Juday supervised the Ph.D. research of ten other students including Willis L. Tressler (1930), J. P. E. Morrison (1931), Ruby Bere (1932), Edward Schneberger (1933), William A. Spoor (1936), Arthur D. Hasler (1937), Robert W. Pennak (1938), George W. Bennett (1939), Clarence L. Schloemer (1939), and David G. Frey (1940). (A list of Juday's Ph.D. students and their theses is included in the Appendix.) Even though Juday had only 13 Ph.D. students during the "Trout Lake years" a number of students in the departments of Botany, Chemistry, Geology, and Bacteriology received Ph.D.'s based on limnological research.

Mortimer (1956) suggests that Birge and Juday's survey work at Trout Lake did not contribute as significantly to limnology as did their research on Wisconsin's southern lakes, partly because a great deal of the data they collected on northern lakes was never fully analyzed.

> "The plankton studies were never published, the bottom fauna studies were never published, the super-centrifuge studies were never published, the seston data were never published. These are golden data because they represent samples taken in the same way over a whole series of years from the same series of lakes, the like of which does not exist anywhere in limnology. I greatly regret that Juday did not live long enough or give the data to somebody else to work them up for publication. . . . They should be published somehow or other because there will be an enormous demand for them. They are unique, they are massive, and for this reason mean a lot to limnology as a whole."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin conference."

Not only did much of their data remain unanalyzed, but Birge and Juday did not attempt to put their data on various aspects of the physics, chemistry, and biology of lakes into any kind of larger picture, or to build any type of limnological theory from their observations. Most of the papers published using data from the 500-lakes survey were concerned less with interpretation of results than with descriptive presentation (Frey 1963). They were certainly in tune with the times, as the ecological sciences in North America from 1920 to 1950 were largely descriptive rather than theoretical (Egerton 1977). Juday, in particular, disdained the new mathematical approach to limnology.

> "[Edward] Deevey tells me that H. [G. Evelyn Hutchinson] is writing a book on Limnology and it is to be chiefly mathematical. So you can look forward to the worst."
>
> C. Juday, 1941, letter to R. Pennak.

> "The Yale school of mathematical-limnologists is having a high time displaying their mathematical abilities. The interesting part about it is that they are applying mathematical for-

mulae used in sub-atomic physics where all of the forces are presumably uniform to limnological problems where there are all sorts of un-uniform factors involved, such as differences in temperature in different habitats, in waves and currents, in soil substrata, etc. Apparently they do not have brains enough to see the point in the two very different situations. It is quite interesting to see that Deevey seems to think that a single sample from the bottom of a lake may be sufficient to tell the story of the bottom fauna, so why take more. He can prove mathematically that it is adequate. In a short time I shall expect them to tell all about a lake thermally and chemically just by sticking one, perhaps two, fingers into the water, then go into a mathematical trance and figure out all of its biological characteristics. As the next stage in their evolution they will probably be able to give a lake an 'absent treatment' similar to a spiritualist, so it will not be necessary to visit a lake at all in order to get its complete chemical, physical and biological history. Then all limnological problems will soon be solved and they will be looking for greener pastures. Such is life in limnology."

C. Juday, 1942, letter to R. Pennak.

When Juday was asked in 1941 to review for the journal *Ecology* Raymond Lindeman's now classic paper on energy flow in ecosystems (Lindeman 1942), he recommended that the paper be rejected because there were insufficient data to support the theoretical model and because he felt theoretical essays were inappropriate for *Ecology* (Cook 1977). The same recommendation was made by Paul Welch of the University of Michigan. At that time Juday and Welch were considered the two most prominent limnologists in the country (Cook 1977). Lindeman's paper was accepted for publication in 1942 despite Juday and Welch's severe criticism.

". . . a large percentage of the following discussion is based on 'belief, probability, possibility, assumption and imaginary lakes' rather than actual observation and data. . . . According to our experiences, lakes are 'rank individualists' and are very stubborn about fitting into mathematical formulae and artificial schemes proposed by man."

C. Juday, 1941, review of Lindeman's paper for *Ecology* as quoted by Cook (1977).

"It seems to me unfortunate if the space which should be occupied by research papers is partly consumed by 'desk produced' papers unless they be of a most unusual and significant kind. In my humble opinion this kind of treatment is premature. Limnology is not yet ready for generalizations of this kind. . . . What limnology needs now most of all is research of the type which yields actual significant data rather than postulations and theoretical treatments."

P. Welch, 1941, review of Lindeman's paper for *Ecology* as quoted by Cook (1977).

G. Evelyn Hutchinson, who with his students would lead the way in theoretical ecosystems ecology and limnology, came to the defense of Lindeman's paper. Lindeman had gone to work with Hutchinson at Yale University in 1941 after completing his Ph.D. degree at the University of Minnesota. Hutchinson's response to Juday and Welch's reviews contained an implicit criticism of Birge and Juday's research on Wisconsin's northern lakes.

"Far from agreeing with Referee 2 [Welch] as to what limnology needs, I feel that a number of far-reaching hypotheses that can be tested by actual data and which, if confirmed, would become significant generalizations, are far more valuable than an unending number of marks on paper indicating that a quantity of rather unrelated observations has been made. . . .

"At times I have felt quite desperate about the number of opportunities that have been missed in the middle Western regions for obtaining data confirming or disproving the hypotheses that have been forced on us by our little lakes."

G. E. Hutchinson, 1942, response to Juday and Welch's reviews of Lindeman paper as quoted by Cook (1977).

W. T. Edmondson had graduated from Yale in 1938, having worked in Hutchinson's lab since early high school. He spent a year at the University of Wisconsin, including a summer at Trout Lake working on sessile rotifers, before returning to Yale for a Ph.D.

"Yale and Wisconsin were vastly different. The Wisconsin emphasis seemed to be to assemble measurements of some property from a large number of lakes, finding ranges and means (many of the standard statistical techniques used commonly today had not yet been invented). There was a little but not much attempt to notice relations between variables, and minimal attention to the limnological processes that would connect them together, e.g. the oxygen and phosphorus cycles. There was some trend in that direction, but it had not got very far in 1939. Some visitors were plowing new ground, as Manning with measurements of photosynthesis. There were some gestures toward experiments, as with the ineffective lake fertilization studies. This whole approach may have been conditioned by the summer laboratory system; measure something like mad all summer, then spend the winter doing arithmetic to find out what you had.

"In New Haven, there was plenty of data gathering, but it was directed at something other than a statistical description of a population of lakes. I have seen Hutchinson come in from a lake and spend the rest of the day running phosphates, titrating oxygens, filtering samples, and then running up the results with a slide rule, but some ideas had been thought out ahead of time and the particular samples were collected for a purpose beyond just finding out what was there."

W. Edmondson, 1983, personal communication.

Limnology was such a new science and there were still so few limnologists in the world that the research conducted by Birge and Juday and the scientists and students working with them must still be considered pioneering and a major contribution to the understanding of limnological processes.

"One of the great contributions of the team was in how they observed. . . . They brought instruments and approaches to observing lakes that were new and difficult. . . . They collected data in these lakes that had never been gathered by anyone with the precision and accuracy that they did."

R. Ragotzkie, 1983, "History of Limnology in Wisconsin Conference."

In the 1920s and 1930s limnological research flourished not only at the University of Wisconsin and Yale, but also at the University of Michigan and the University of Illinois. Limnology was beginning to attract larger numbers of students and in 1936 the Limnological Society of America was organized. Juday was elected its first president, having played a role, albeit somewhat reluctantly, in the formation of the society. He was reelected to the post the following year.

"We had a hydrobiological program at the AAAS meeting in Pittsburgh during the holiday season and had a very good turnout; over a hundred at the meeting. We also decided to organize a Limnological Society of America. It will be launched at the 1935 meeting in St. Louis next December. I am curious to see how many people can be induced to join it. Welch has been wanting to organize for the past three or four years, but some of us have been discouraging him; we decided, however, to let him try it after talking the proposition over at the Pittsburgh meeting."

C. Juday, 1935, letter to S. Wright.

In a mere five years since the formation of the Society, Juday would witness the tremendous growth of interest in limnology, but he remained skeptical that this interest would last.

"Last week I attended the AAAS meetings in Columbus, chiefly those of the limnologists and ecologists. One of the striking things about the limnological sessions was the large attendance, from 100 to 200 at all sessions—most of them youngsters. Limnology is certainly on the boom; everybody is talking about it now and all kinds of colleges and universities are now offering courses in it. I am wondering how long the boom will last."

C. Juday, 1940, letter to S. Wright.

Although the limnological research program at Trout Lake and in Madison survived the Depression relatively well and even flourished during those years, the program began to decline as Birge and Juday grew older. World War II also took its toll.

"Four of us came up June 20 to get things ready for the summer campaign which opened up on July first. . . . I have a crew of five this summer; Dean Fred asked me to reduce our force to a minimum, so I asked for men to help in only two projects, namely, fish population studies and a crew for plankton together with bottom fauna and flora. . . . Counting the wife of one of the boys who is cooking for the crew, we have a total of eight as compared with 21 last year."

C. Juday, 1942, letter to S. Wright.

". . . the Laboratory there [Trout Lake] is going to be one of the war fatalities this coming summer. It is impossible for me to get competent assistants, so I shall not go up to Trout Lake this summer, the first summer I have missed since 1925."

C. Juday, 1943, letter to S. Wright.

Although he had set out to write a comprehensive review of Wisconsin limnology, Juday died March 29, 1944, before he could complete it. He was also unable to finish a number of papers he had hoped to write using the large amounts of unpublished data he and his colleagues had collected at Trout Lake.

"At the present time I am preparing a book on our Wisconsin investigations and it is a tough job to get the stuff all lined up and correlated. I would much rather prepare papers on the great amount of data that we have accumulated during the years and which has not been utilized for papers so far. But that is something to look forward to after the book is completed."

C. Juday, 1943, letter to S. Wright.

Although Birge lived until June 9, 1950, the last paper he published was with Juday in 1941. The two partners had been very similar in some ways, but widely different in others. Despite a professional partnership that lasted more than four decades, the two had not been close friends.

"Birge and Juday were colleagues, but not necessarily friends. Juday was not a social person. . . . Birge and Juday got along well. I think Juday looked up to Birge . . . but Birge and Juday went their separate ways socially. . . . Juday was pleasant, affable, but rather withdrawn. He was not a pusher, but he was a great scientist. . . . Juday was always willing to show you what was going on if you were interested. He was cordial and helpful and liked you as long as you were interested in limnology."

D. Halverson, 1985, personal communication.

Mary Juday, however, notes that the Juday and Birge families often socialized and frequently spent holidays together. She and her older brother, Chancey, called Birge's wife, Anna Grant Birge, "Grandma" (M. Juday, 1987, personal communication).

The two partners varied considerably in their teaching styles. Birge was considered an excellent teacher, who inspired loyalty and admiration. His first bacteriology class included Harry L. Russell, who went on to a distinguished career in bacteriology and to become Dean of the College of Agriculture at the University of Wisconsin.

"As my class advisor, he [Birge] warned against the danger of over-specialization in too narrow a field. He insisted on my taking courses in history under another marvelous teacher in the University, Professor William F. Allen, when I wanted to load my schedule with more courses in science. He wished his students to secure an all-round training, to get the breadth of view that comes only from a broad survey of the various fields of knowldege. The specialist in pursuit of his own particular line digs his canyon of activity deeper and deeper, narrowing his vision more and more until he loses his perspective on the broader problems of life. Dr. Birge belongs to the group that views the world from the mountain top rather than from the canyon depth."

H. Russell, 1940, First Symposium on Hydrobiology.

Martin Gillen, another of Birge's early students, was inspired to create a nature preserve. He purchased 6000 acres including 22 lakes on the boundary between Wisconsin and Michigan's Upper Peninsula "to be guarded from the further scars of the white man's civilization and forever dedicated to the study of the sciences relating to the flora and fauna of our state" (1940, First Symposium on Hydrobiology). When asked how, after a lifetime of activity in legal and industrial affairs, he had become interested in the work of biologists, Gillen responded:

"Thirty-nine years ago [1894], as a young student at the University of Wisconsin, my electives included biology and bacteriology. All this summer [1933 when Birge was 81] I have watched Dr. Birge in dungarees accompanied by 16 or 17 young scientists still exploring the field I once studied, still working to lay the foundation upon which will be based the solution to problems that confront our people, our state, and our nation. I am once again his student and helper and there is much to be done."

M. Gillen, 1940, as quoted by General Ralph Immell
at the First Symposium of Hydrobiology.

Unlike Birge, Juday is not remembered for his teaching skills or inspiring lectures. Although his former students have the highest regard for his knowledge of limnology and his skill as a researcher, they recalled that his courses in limnology and plankton organisms were "just deadly."

Whereas Juday had been known as mild-mannered, quiet, and withdrawn, Birge was renowned for his caustic comments and astringent wit. He was not so much beloved by his students as respected and admired.

Birge was concerned for his students' training, but he seemed relatively unconcerned about their general welfare. According to the story related by E. Schneberger (1983, personal communication), one of Bernhard Domogalla's tasks while he was working as a student assistant for Birge in Madison was to take water temperatures in Lake Mendota throughout the year. One spring when the ice was getting thin and "black," Birge asked Domogalla to take the water temperature with the Whitney thermometer, but added, "if you start going through, throw the thermometer toward shore—it's the only one we have."

Birge must have had his tender side, however, even though it was rarely seen. While Schneberger was at the Trout Lake Station, his wife, Helen, who was the "camp cook" in 1932, and his young daughter, Wilma Jean, came with him in the summers of 1930 to 1934. Birge always remembered to write a letter and get a present for Wilma Jean on her birthday (H. Schneberger 1983, personal communication).

Both men were relatively distant and taciturn. Neither had much use for small talk, which was not so much the result of rudeness, but rather the inability to make conversation upon any topic but an important one. Juday seemed to be completely devoted to limnology and spent nearly every waking moment working.

> "Father used to work a seven-day week including evenings and Sundays. . . . He was definitely a 'workaholic.' He had virtually no outside interests. He didn't read books for pleasure. He didn't go to movies or any of that stuff. . . . Mother was much more outgoing. . . . They always got along well I think. She felt her role was to make it easy for him to do what he wanted. So she took charge of raising us. Father was rather remote I'd say. He was around, but he didn't take any great interest in what was going on. . . . I never worked with Dad, I never learned zooplankton, which was his speciality. . . . He did not discuss his work with us."

R. Juday, 1983, "History of Limnology in Wisconsin Conference."

Birge was certainly hard-driving, but unlike Juday, he was a man of wide-ranging interests and a voracious reader of philosophy, history, religion, and novels, as well as science. The rumor was that he served on the City Library Board in Madison just so he could read the new books before they went on the shelves. He was also known as a religious man. He regularly attended the First Congregational Church where he taught an adult class and gave annual sermons on St. Paul at the Grace Episcopal Church. His religious beliefs, his scientific views, and his considerations of literature seemed to have been integrated into a coherent philosophy of life.

> ". . . something must be done in the right way and this is true of religion just as it is of those other things. It is true that if you practise the violin in the right way, the instrument finally talks to you and you to it. It is also true that you may practice scales till you die and never find music—only technique. And of course the same is true of religion. That is why St. Paul says, 'Walk by faith' not merely 'Walk.' And it isn't easy to say what this necessary faith is in this connection or indeed in any other. How must you study Latin grammar so as to get on the inside of Latin literature? If you do it in the right way the result comes—certainly and, as you see afterwards, inevitably. If done in the wrong way—grudgingly or of necessity or 'for marks' or in many other ways—nothing results that is worthwhile. So of science—work may result in technique and nothing more if it is done in that spirit. . . . And the thing must be done simply and in a way for its own sake—not 'to be seen of man' . . . or for any other reward. Especially you mustn't be looking for a revelation of music or science or religion or of God in any similar relation. If you do the revelation isn't likely to come."

E. A. Birge, 1925, in a letter to Mrs. Peckham, widow of well-known biologist, George W. Peckham of Milwaukee, as quoted by Sellery (1956).

Birge and Juday form an outstanding example of the value of partnership. Their ability to work together despite their differences, the strength of their personalities, and their intense interest in lakes shaped the growth and development of limnology not only in Wisconsin, but in North America and Europe as well. But they had chosen no successor and the Wisconsin school declined for some years before another strong leader, Arthur D. Hasler, took over and led the Wisconsin limnological school in an entirely new direction.

References

Birge, E. A. 1936. *A House Half Built.* An address before the Madison Literary Club, October 12. In the Birge papers, State Historical Society of Wisconsin. 33 p.

______. 1940. *Edward A. Birge, Teacher and Scientist.* Addresses delivered at a dinner on September 5, 1940, given to honor Birge for his contributions to the science of limnology and in commemoration of his eighty-ninth birthday by the Symposium on Hydrobiology. University of Wisconsin Press, Madison. 48 p.

Burgess, R. L. 1981. United States. In E. J. Kormandy and J. F. McCormick (eds.). *Handbook of Contemporary Developments in World Ecology.* Greenwood Press, Westport, Connecticut. pp. 67–101.

Cook, R. E. 1977. Raymond Lindeman and the trophic-dynamic concept in ecology. *Science* 198: 22–26.

Egerton, F. N. 1977. Introduction. In F. N. Egerton (ed.). *History of American Ecology.* Arno Press, New York.

Frey, D. G. 1963. Wisconsin: the Birge-Juday era. In D. G. Frey (ed.). *Limnology in North America.* University of Wisconsin Press, Madison. pp. 3–54.

Juday, C. 1940. The annual energy budget of an inland lake. *Ecology* 21: 438–450.

______. 1942. The summer standing crop of plants and animals in four Wisconsin lakes. *Trans. Wis. Acad. Sci. Arts Lett.* 34: 103–135.

______ and E. A. Birge. 1931. A second report on the phosphorus content of Wisconsin lake waters. *Trans. Wis. Acad. Sci. Arts Lett.* 26: 353–382.

______ and ______. 1932. Dissolved oxygen and oxygen consumed in the lake waters of northeastern Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 27: 415–486.

______ and ______. 1933. The transparency, the color and the specific conductance of the lake waters of northeastern Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 28: 205–259.

______, ______, and V. W. Meloche. 1935. The carbon dioxide and hydrogen ion content of the lake waters of northeastern Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 29: 1–82.

______, ______, and ______. 1938. Mineral content of the lake waters of northeastern Wisconsin. *Trans. Wis. Acad. Sci. Arts Lett.* 31: 223–276.

______, ______, and ______. 1941. Chemical analyses of the bottom deposits of Wisconsin lakes. II. Second report. *Trans. Wis. Acad. Sci. Arts Lett.* 33: 99–114.

______, J. M. Blair, and E. F. Wilda. 1943. The photosynthetic activities of the aquatic plants of Little John Lake, Vilas County, Wisconsin. *Amer. Midland Nat.* 30: 429–446.

______ and A. D. Hasler. 1946. A list of publications dealing with Wisconsin limnology 1871–1945. *Trans. Wis. Acad. Sci. Arts Lett.* 36: 469–490.

Lindeman, R. L. 1942. The trophic-dynamic aspect of ecology. *Ecology* 23: 399–418.

Lohuis, D., V. W. Meloche, and C. Juday. 1938. Sodium and potassium content of Wisconsin lake waters and their residues. *Trans. Wis. Acad. Sci. Arts Lett.* 31: 285–304.

Mortimer, C. H. 1956. An explorer of lakes. In G. C. Sellery. *E. A. Birge. A Memoir.* University of Wisconsin Press, Madison. pp. 165–211.

Schnabel, Z. E. 1938. The estimation of the total fish population of a lake. *Amer. Math. Monthly.* 45: 348–352.

Sellery, G. C. 1956. *E. A. Birge. A. Memoir.* University of Wisconsin Press, Madison. 221 p.

Whitney, L. V. 1938. Continuous solar radiation measurements in Wisconsin lakes. *Trans. Wis. Acad. Sci. Arts Lett.* 31: 175–200.

______. 1941. A general law of diminution of light intensity in natural waters and the percent of diffuse light at different depths. *J. Opt. Soc. Amer.* 31: 714–722.

3 New Directions

Under the leadership of Arthur Davis Hasler, limnological research at the University of Wisconsin shifted away from the classical, descriptive studies conducted by Birge and Juday, toward the new field of experimental limnology, in which the precise methods of the experimental laboratory were applied to research in the field.

> "I could see that it was presumptuous to try to make a reputation by following in the Birge and Juday research tradition. Moreover, you couldn't get money for that type of research— recording the environment. . . . Besides, my research interests were in a different direction— experiments in the natural environment."
>
> A. D. Hasler, 1985, personal communication.

Hasler and his students were among the first limnologists to do field experiments that included controls and repetitions. Moreover, they improved the experimental techniques used in the field. Under Hasler's leadership, rigorous experimental methodology became the hallmark of the Wisconsin limnological school.

> "Experimental work was done in Germany at the turn of the century with fertilizers and carp ponds. And the Chinese did it before that. So experimental limnology is not a tradition which started here. . . .
>
> "We all ask who was the first to do something. It's usually pretty hard to say. What we did was to refine experiments and equipment, to improve upon them. . . . We were not necessarily the first to do things, but we were perhaps the first to 'do them right.' "
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler spent much of his career trying to show skeptical laboratory scientists that rigorous experiments could be conducted outdoors.

> "Having been raised in a department of molecular biologists and cytologists, it's been quite a chore to justify being an experimental scientist to them. I believe that the average laboratory biologist just can't quite conceive that outdoor research can be done in a rigorous way. We've always had a battle to convince them that what we were doing experimentally was legitimate. They think we're at Trout Lake fishing or sunning ourselves."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

In the course of their research, Hasler and his associates not only became far more experimental than Birge and Juday, they also came to view lakes in a different way. Birge and Juday saw the lake as a microcosm, a unit of the environment. Hasler and his associates began to give much greater consideration to the watershed.

> "We've emphasized the fact that lakes are mirror images of the landscape around them. . . . This stems from my collaboration with Wisconsin botanists, especially ecological botanists like Fassett and Curtis. They taught me early how a lake is influenced by what drains into it. . . . I think my ideas about salmon homing stem from that, the fact that the vegetation and the soils

lend to the river a quality of odor that makes it unique. No two rivers are alike. So this whole idea of interactions between land and water is something we emphasize."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler [b. 1908] had grown up in Utah—a state not known for extensive limnological resources. He attended Brigham Young University as an undergraduate.

"My father was a physician and his plan was for my brother, who was in medical school, and me—that the three of us should set up a clinic when I got through too. But the Depression occurred at that time and my father was stricken with cancer, which took him out of practice for several years. So the financial structure of the family fell apart. In those days you couldn't borrow money to go to medical school so it meant that I had to find some alternative to medicine. . . . That was my junior year of college."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

During his junior year at Brigham Young, Hasler accompanied one of his professors on a research expedition to the Granddaddy Lakes in the Uinta Mountains and soon became interested in limnology. Unable to pursue a career in medicine, he entered graduate school at the University of Wisconsin in 1932. His major professor was Chancey Juday.

"When I first began to think about being a limnologist I wrote several letters, one to A. S. Pearse, a former professor of zoology at Wisconsin, but then at Duke University. He had written a book on ecology and I wrote him asking what a young man ought to do to prepare himself. His answer was 'first become a physiologist and then become an ecologist.' So I came to Wisconsin and that's just exactly what Juday did for me—he requested that I get my minor in physiological chemistry and physiology. So obviously it was the concept of the time—to get students trained in experimental thinking."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

For his thesis research Hasler worked on the digestive enzymes of copepods and cladocerans (Hasler 1935, 1937) with H. C. Bradley in the Department of Physiological Chemistry. The experiments, most of which were carried out at the Wood's Hole laboratory in Massachusetts, were conducted with controls and repetitions. His experience with controlled experiments made Hasler aware of the deficiencies in the field "experiments" conducted at the Trout Lake Station when he worked with Juday during the summers of 1933 and 1934.

"I was here in 1934 when Weber Lake was being fertilized with a sequence of chemicals. One year it was soybean meal, another year it was phosphorus, another year it was lime. I was part of the team putting the chemicals in for that series of tests. I won't call them experiments. When you think about what was known of experimentation at the time—principally owing to R. A. Fisher, who had written a book on biometry and design of experiments for agriculture plots—the Weber study couldn't qualify as an experiment.

"One of the benefits of working as an assistant to Juday, however, was learning how to do scientific work outdoors, how to work in the field. And it was valuable experience going from lake to lake to see the variability."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler's first experience with manipulating animals under controlled conditions in the field came early in his career. Before he had completed his Ph.D. thesis, he was hired by the United States Bureau of Fisheries to work on Chesapeake Bay in Yorktown, Virginia. He was to conduct field experiments on the effects on oysters of effluents from paper pulp mills (Hasler *et al.,* 1938, Hasler *et al.,* 1947). Hasler worked as an assistant biologist for the U.S. Bureau of Fisheries from 1935 to 1937.

After completing his doctoral degree, he was asked to return to the University of Wisconsin in 1937 as an instructor in the Zoology Department. He had been invited back to Wisconsin not by Birge or Juday, but by Michael F. Guyer, who was then Chairman of the Zoology Department. Birge and Juday were approaching retirement and Guyer's intent was for Hasler to take over their duties. These arrangements had been made without consulting Birge and Juday, however (Hasler 1979, personal communication).

> "Birge and Guyer were antagonists. Guyer came into zoology [from the University of Cincinnati in 1911] with the understanding that Birge would have nothing to do with his program. He [Guyer] built that little lab [1933] at the end of Park Street [on Lake Mendota] and he wouldn't allow either Birge or Juday to set foot in that lab. . . . Who brought me into zoology? Not Birge or Juday, but Guyer."
>
> A. D. Hasler, 1983 "History of Limnology in Wisconsin Conference."

Hasler had never been well acquainted with Birge, who was already 81 when Hasler first came to Wisconsin, and he has always felt that Birge viewed him as a young upstart. (Hasler 1979, personal communication). Neither Birge nor Juday invited him to use their facilities on Trout Lake, but he was assigned to Guyer's new boat house on Lake Mendota. The basement provided boats and space for aquaria, and the room above had apparatus and desks for students. A Quonset hut near the lake lab was made available for aquaria about 1950.

Shortly after returning to Wisconsin, Hasler, in cooperation with Roland K. Meyer, began conducting physiological research on fish. They were among the first biologists in North America to study fish endocrinology in their investigations of the use of pituitary extracts for inducing premature spawning in trout and muskellunge (Hasler, Meyer, and Field 1939, 1940). Hasler and Meyer (1942) also investigated the respiratory responses of normal and castrated goldfish to fish and mammalian hormones. During this time Hasler was also conducting field research on fish in Crater Lake, Oregon (Hasler 1938, Hasler and Farner 1942), and in Lake Mendota, and spent two summers teaching and conducting research at the Lake Geneva School of Science in southeastern Wisconsin (Hasler and Nelson 1942).

When Juday retired in 1941, Hasler took over the course work and research area for which Juday had been responsible, but supervision of the Trout Lake Station went to Lowell Noland of the Zoology Department in 1942, and then later to other university faculty. Hasler would not become director of the Trout Lake Station until 1962, the year he built the Limnology Laboratory on Lake Mendota.

> "There were advantages to my not being appointed director of the station earlier. I might have gotten stuck in the Birge-Juday research tradition. As it was, I was able to start in my own direction early. I got into the salmon work on the west coast, which I might not have had I been confined to the station."
>
> A. D. Hasler, 1979, personal communication.

World War II disrupted limnological research in Madison and at Trout Lake, as it did elsewhere. During the spring and summer of 1945 Hasler served with the United States Air Force Strategic Bombing Survey in Germany. After the war's end, he was able to visit a number of biological stations and laboratories in England, Germany, and Austria. He met animal ecologist Charles Elton at the Bureau of Animal Populations in Oxford, England, fish physiologist Werner Jacobs of the Zoologisches Institut at the University of Munich, alpine limnologist and ecologist Professor Otto Steinbock at the University of Innsbruck, and the director of the Reichsanstalt für Fisherel Weissenbach, Dr. W. Einsele, who in 1939 and 1940 had been conducting experiments adding phosphorus to lakes near the Bodensee.

Hasler also met his "scientific hero," Professor Karl von Frisch, a man he had admired for several years "because of his outstanding research on the sensory abilities of fish, bees, and other animals" (Hasler 1945). Von Firsch recalled his first meeting with Hasler in his autobiography.

> "The first days of the occupation were full of incident and excitement. There were innumerable strict rules, and quite often our homes were being searched by soldiers with rifles at the ready. We lived in constant fear that the military might requisition our houses for the troops. So when one fine day in June an American jeep with four officers stopped in front of our home, we were not a little worried. However, the man who got out first did not inquire about billets but asked after me and my honey-bees. My wife directed him to the observation hives, and there, for the time being, he remained. He was Professor A. D. Hasler, biologist at the University of Wisconsin, who was staying in Salzburg to investigate war damage. . . . Hasler came often to our house that summer, we became fast friends, and later visited each other in our laboratories."
>
> K. von Frisch, 1967, *A Biologist Remembers.*

In his reports on the post-war conditions of European biological stations, Hasler described the devastation the war had brought to so many laboratories and research facilities including those of von Frisch.

> "The director of the Zoologisches Institut [University of Munich], Professor von Frisch, was forced to move to his summer cottage near Salzburg when his residence in Munich was completely destroyed. Because he thought the Munich residential area would not be bombed he had moved his library to his home. Thus one of the finest libraries in sensory physiology was blown up. . . . He has worked extensively on sense of smell, color changes in fish and was the discoverer of 'Schreckstoff,' a secretion from injured skin of *Phoxinus* which, in extremely small concentrations, is perceived by schools of this minnow who are alarmed and seek cover."
>
> A. D. Hasler, 1945, "A War Time View of European Biological Stations."

Hasler would visit with von Frisch again in 1954 when, on a Fulbright Research Scholarship, he returned to Germany with his wife Hanna and their six children. During that year Hasler also met the German animal behaviorist Konrad Lorenz. Hasler's own ideas on fish homing behavior would be greatly influenced by Lorenz's studies of imprinting—the process of rapid and irreversible learning during a critical period of development that generally elicits a stereotyped pattern of behavior.

With his background in physiology, and inspired by his many discussions with von Frisch, Hasler, with his students, began research on the sensory physiology of fish when he returned to Madison in 1945.

> ". . . a returning veteran, T. J. Walker expressed interest in olfactory physiology of fish and re-

quested a Ph.D. research topic. Having become interested in macrophytes through Prof. N. C. Fassett (Botany) and the research of another graduate student of mine, J. D. Andrews, I suggested to Walker that we test the ability of fish to distinguish aquatic plants by smell. I reasoned there might be some interaction between fish and macrophytes—after all, they lay their eggs on them, eat insect larvae living on them, and find cover among them from predators."

A. D. Hasler, 1983, personal communication.

About this same time Hasler became fascinated with the mystery of how salmon find their way from the open ocean to their natal stream to spawn. The combination of his fascination with salmon homing, his interest in Lorenz's recent studies of imprinting, and his and his students' research on the abilities of fish to discriminate plants by odor led Hasler and his student, Warren Wisby, to develop a hypothesis about salmon homing. The olfactory hypothesis for salmon homing, first presented by Hasler and Wisby in 1951, had three basic tenets: 1) because of local differences in soil and vegetation of the drainage basin, each stream has a unique chemical composition and thus, a distinctive odor; 2) before juvenile salmon migrate to the sea they become imprinted to the distinctive odor of their home stream; and 3) adult salmon use this information as a clue for homing when they migrate through the home stream network to the home tributary (Hasler and Scholz 1983). The story of the research on salmon homing and orientation conducted by Hasler and his associates is told in greater detail in Chapter 5.

Research on salmon homing and orientation became Hasler's life work and the research for which he became best known. With his graduate students and associates, he spent the better part of 35 years testing the olfactory hypothesis of salmon homing. The list of students and collaborators in the homing research includes Warren J. Wisby, Ross M. Horrall, Andrew E. Dizon, Aivars B. Stasko, Dale M. Madison, Jon C. Cooper, Peter Hirsch, Peter B. Johnsen, and Allan T. Scholz. Hasler drew together the various studies on fish homing behavior in 1966 for *Underwater Guideposts* and again in 1983 for *Olfactory Imprinting and Homing in the Salmon,* the latter written in collaboration with his student, Allan Scholz.

The olfactory homing hypothesis explained how salmon recognize their home stream, but it could not explain their movements in the open sea. In a series of field and laboratory tests conducted from 1955 through 1971, Hasler and his associates, Horrall, Wisby, Wolfgang Braemer, Horst Schwassmann, E. S. Gardella, H. F. Henderson, and Gerald Chipman, demonstrated that a number of fish species possess a sun-compass mechanism and that they can orient by the sun to maintain a constant compass direction in unfamiliar territory.

"Here again Karl von Frisch, who discovered this [sun-compass orientation] in bees, and Gustav Kramer in Germany, who discovered it independently in birds, were sources of inspiration. Our contribution lay not in the concept, but in the methodology of demonstrating how fish use sun-compass orientation."

A. D. Hasler, 1983, personal communication.

The first major funding for the salmon research came from the Office of Naval Research (ONR). After the war the Navy also supplied Hasler and his students with sophisticated equipment.

"George Sprugel, research coordinator for ONR, heard my research report at a national scientific meeting on the sense of smell of fishes and orientation, held about 1947. He invited me to write a research proposal to finance the beginning of our studies on salmon. . . .

"From the contacts we had with the ONR, they provided us with these expensive instruments free-of-charge. You couldn't buy them on the market or at least you didn't have enough money to buy them on the market. . . . Because of our connections with ONR, all kinds of surplus navy equipment became available after the war . . . including sonar for recording pelagic fish and doing bathymetric maps of lakes, underwater sound recorders for listening to fish 'voices', a motor launch, jeeps and ultrasonic transducers."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Although perhaps best known in scientific circles for his research on salmon homing, Hasler and his students were also involved in a great many other research areas. From the very beginning of his career Hasler had been influenced by the work of R. A. Fisher, and he encouraged his students to study statistics. Two of his early students, John Neess and Richard Parker, minored in statistics. Hasler and his students began applying "R. A. Fisher criteria" to field experiments.

"When R. A. Fisher applied the methods of biometry to the design of experiments on agricultural field plots, and their evaluation through multiple correlations, he performed an invaluable service to biology. In doing so, he broke with the traditions of experimentation, which had been imposed by the exact sciences—namely, the manipulation, during an experimental series, of only one factor at a time."

A. D. Hasler, 1964, "Experimental Limnology."

Hasler's first graduate students, Jay D. Andrews (1944), Elizabeth Jones (1947), and John C. Neess (1949), constructed experimental ponds for studies of interactions among macrophytes and plankton, and in Neess' project, fish and macrophytes. Although Neess' study got off to a rough start, eventually it was successfully completed.

"Four ponds were dug in the Gardner Marsh [University of Wisconsin Arboretum] for use by John Neess in his Ph.D. thesis project. The initial attempt to dig the ponds with explosions of dynamite failed. The force impelled the peat straight in the air and it cascaded right back again. This feat became known in Arboretum circles as 'Hasler's Folly.' "

A. D. Hasler, 1983, personal communication.

The desire to simulate more natural conditions than experimental ponds soon led Hasler to perform the "whole lake manipulations" for which he became so well known. Many of the ideas and techniques for these studies grew out of the interdepartmental communication Hasler fostered throughout his career.

"The monthly meetings of the Graduate Biological Division provided occasions to meet senior colleagues campus wide. . . . At one of the meetings I conversed with Bob Muckenhirn about our brown-water and acid bog lakes. He introduced me to Prof. Emil Truog who had studied the chemistry of bog soils. He had observed that the drainage of these limed soils became clear, and hence allowed that we might clear up our bog lake with calcium hydroxide, $Ca(OH)_2$. [Some scientists had already tried calcium carbonate, $CaCO_3$, which did not work because it is insoluble in lake water.] Laboratory studies confirmed this hunch, hence we could then try to alkalize a whole lake, which we did experimentally in Cather, and later in the twin lakes, Peter and Paul."

A. D. Hasler, 1983, personal communication.

The Cather Lake study was a "before and after" experiment. That is, William Helm, a student of Hasler, investigated the limnological characteristics of Cather Lake for two years, and then commercial hydrated lime ($Ca(OH)_2$) was added. But Hasler was not entirely satisfied with the rigor of this type of experiment.

> "When you go to bigger things than ponds—dealing with larger units and manipulation—you get into a great deal of difficulty. There, rigorous experiments are much more difficult to accomplish and you have to make modifications or concessions about rigorous research when you deal with large bodies.
>
> "The concession we made with Bill Helm's program [Cather Lake], when we were trying to reduce the bog colloids in the lakes by lime treatment (calcium hydroxide), was that we chose to study the plankton and fish populations for two years and then have two years of treatment, so that we had a before and after type experiment. The weakness is that you don't know whether some natural events might have caused the change rather that the lime you put in.
>
> "Then I learned from John Curtis [Botany] about the lakes up at the Notre Dame property, the former Gillen Estate. I had told John that I needed to go one step closer to rigorous and he told me that there was a lake there that had a constriction in it. Now we had a lake that we could divide by a barrier so that we could have a reference lake and an experimental one—I don't call it control, but reference, because unless they're identical in their size, volume, and so forth, you can't use the word control. We upgraded the rigor of the before and after design by the Peter and Paul situation."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler's students, Waldo E. Johnson and Ray Stross, conducted research using the two halves of the hourglass-shaped lake. Both projects, as well as the Cather Lake study, are discussed in Chapter 5. Johnson was later hired by the Canadian government where he worked his way up in the administration of water management.

> "Johnson was instrumental in convincing the Canadian government to set aside a vast area of twenty-odd lakes in Manitoba for experimental research. Obviously his training in Wisconsin on Peter and Paul Lakes gave him this motivation. . . .
>
> "It was in one of these Canadian lakes that a very crucial experiment on eutrophication took place. Using the same technique we used on Peter and Paul, they divided a lake with an artificial barrier and put phosphates on one side and left the other side as a reference. They showed that you could develop a eutrophic lake. Then when they stopped fertilizing it, the lake became normal again. So these two experimental lakes in the 70s were definitive tests of the eutrophication hypothesis. All over the country, people, especially engineers, had doubted that phosphorus was the critical element in eutrophication. . . . So I'm proud of the contribution the Peter and Paul experiment made on the North American scene."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

These were the days before the National Science Foundation and large-scale government funding for research. Hasler obtained the money for the lake manipulation studies by contacting the owners of small lakes and getting their support. Many of these projects could not have been done on public lands because of legal restrictions or public interference. Some of the lake-shore property owners, such as Guido Rahr, Ben McGiveran, and Stib Stewart, made substantial contributions to the university to support the projects. In several instances four-year research assistantships were established by private donors, thus enabling several graduate students to gather data for master's or doctoral theses. The grants were rarely ample, however. The conditions under which students conducted field research had not improved much since the Depression of the

1930s. William Schmitz, a student of Hasler, recalled the conditions he found when he took over the Cather Lake project.

"I remember the first night when I was given the task of taking over the research in Chippewa County [Cather Lake]. I think we'd been married for two years—I still called her my bride. It was on a June night that we drove down the hill to the converted chicken shack, a Quonset hut made of plywood. We opened the door and she looked in there and she was starting to feel pretty apprehensive. There was no electricity. There was no light at all, other than the headlights on the truck. The air was so thick with mosquitos in the month of June that you could hardly breathe. We went in and moved all this junk. . . . We had to move the boats and the paint buckets, the anchors and the rope, the poles, and the weed collections to clear a path to the bunkbed.

"During the night she heard crawling and moving. I shined the flashlight over on the table. The deermice had taken up residence in the desk, where they were eating creel cards and chemical records, and also nursing their young. The bats were fluttering in between the ceiling. The poor woman was beside herself.

"All the things that had to be kept cold, I kept in the hypolimnion in a basket. It smelled like rotten eggs once you got the package open even though everything was alright. She left after about a week, so I spent the next three summers pretty much alone."

W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

Many lake-shore property owners gave money to the limnology program because they felt the research might have practical applications, such as making bog lakes suitable for trout; they could also get a tax deduction by giving money for research.

"We used applied aspects of research to get money, but what we were really interested in were hypotheses and ideas about lakes."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

References

Hasler, A. D. 1935. The physiology of digestion of plankton Crustacea. I. Some digestive enzymes of *Daphnia. Biol. Bull.* 68: 207–214.

______. 1937. The physiology of digestion in plankton Crustacea. II. Further studies on the digestive enzymes of a. *Daphnia* and *Polyphemus;* b. *Diaptomus* and *Calanus. Biol. Bull.* 72: 209–298.

______. 1938. Fish biology and limnology of Crater Lake, Oregon. *J. Wildl. Mgt.* 2: 94–103.

______. 1945. This is the enemy. *Science.* 102: 431.

______. 1964. Experimental limnology. *Bioscience* 14: 36–38.

______. 1966. *Underwater Guideposts. Homing of Salmon.* University of Wisconsin Press, Madison. 155 p.

______ and D. S. Farner. 1942. Fisheries investigations in Crater Lake, Oregon, 1937–40. *J. Wildl. Mgt.* 6: 319–327.

______ and P. S. Galtsoff, W. A. Chipman, and J. B. Engle. 1938. Preliminary report on the cause of the decline of the oyster industry of the York River, VA, and effects of pulp-mill pollution on oysters. *U.S. Bur. Fish. Invest.* Report No. 37. 42 p.

______ and ______, ______, ______, and H. N. Calderwood. 1947. Ecological and physiological studies of the effect of sulfate pulp mill wastes on oysters in the York River, VA. *Fish. Bull. of the Fish and Wild. Ser. No. 51:* 59–186.

______ and R. K. Meyer. 1942. Respiratory responses of normal and castrated goldfish to teleost and mammalian hormones. *J. Exptl. Zool.* 91: 391–404.

______ and ______, and H. M. Field. 1939. Spawning induced prematurely in trout with the aid of pituitary glands of the carp. *Endocrinology.* 25: 978–983.

______, ______, and ______. 1940. The use of hormones for the conservation of muskellunge, *Esox masquinongy immaculatus* Garrard. *Copeia* 1940: 43–46.

______ and M. N. Nelson. 1942. The growth, food, distribution and relative abundance of the fishes of Lake Geneva, Wisconsin in 1941. *Trans. Wis. Acad. Sci. Arts Lett.* 34: 137–148.

______ and A. T. Scholz. 1983. *Olfactory Imprinting and Homing in Salmon. Investigations into the Mechanism of the Imprinting Process.* Springer-Verlag, New York. 134 + xix p.

von Frisch, K. 1967. *A Biologist Remembers.* New York, Pergamon Press. 200 p.

4 Expansion

With the establishment of the National Science Foundation (1950) and the Atomic Energy Commission (1946), the era of "big money" in science began and Hasler was on the ground floor. Early in his career Hasler became a "grant getter," a person who could get the money that would allow other people to carry out the research. From these new funding agencies, he was able to obtain substantial monies for his research and for the construction of a new laboratory on Lake Mendota in 1962. He was also fortunate to be in a state where there was strong interest in conservation. Cooperation between the state of Wisconsin and the university allowed Hasler and his students to have access to state resources, primarily through the Conservation Department (now the Department of Natural Resources).

> "Hasler made a conscious decision early on. He could do his own research or get into biopolitics—grantsmanship—and have lots of graduate students. He made the decision to be associated with biopolitics. Hasler recognized early what his strengths were—he could get money to provide the setting for other people to do research.
>
> "He was the right man at the right time. Right after Sputnik, there was a big push for science. Money was available everywhere. Hasler had one of the few programs in the country that had shown progress. The salmon experiments and the research on Peter and Paul Lakes were well known. . . . He devoted himself full-time to getting funds. Hasler saw the opportunity and he took it."
>
> C. Voightlander, 1983, personal communication.

Although many of his graduate students and colleagues feel that Hasler had a "grand scheme" for the Wisconsin limnological school and that grant-getting was a part of that scheme, Hasler recalls his past actions as being less well-planned.

> "There was a lot of opportunism in my activities—opportunism and ambition—rather than long-range planning. . . . I just like working with more than one thing at a time. I enjoy multiple activities and a variety of personalities."
>
> A. D. Hasler, 1985, personal communication.

In addition to money, Hasler also had lots of good, innovative ideas. The ideas and the availability of funds attracted top-notch graduate students, who had good research ideas of their own. Hasler soon had a large number of students involved in a broad range of research topics. In his pet area, salmon homing and orientation, he called the shots. But otherwise, he was not intimately involved in his students' research. Like Birge and Juday, Hasler expected students to be independent and develop their own ideas, and he gave students the freedom to make their own decisions.

> "Students had to be independent to survive. The lake lab was no place for someone who was dependent. . . . Students had to define their own projects, their own line of inquiry, preferably in a proposal on paper, then Hasler approved the ideas. Hasler was hard-nosed about research, but he allowed a great deal of latitude."
>
> C. Voightlander, 1983, personal communication.

Hasler's favorite quote comes from Louis Pasteur, "Chance favors only the prepared mind." Hasler tried to create an environment in which both he and his students could take advantage of serendipity. He felt that the best preparation for the generation of good ideas for research was to be in a stimulating environment.

> "New and challenging ideas for research were the principal features which attracted money, equipment, collaborators, and graduate students into the limnology program. . . . I tell my students to discuss their ideas with others and not to be afraid if an idea is stolen. You don't belong in science if you have so few ideas you fear having one stolen. You get ideas by discussing them. Hence you gain more than you lose."
>
> A. D. Hasler, 1983, personal communication.

Hasler established a program to bring in eminent scientists and, unlike Birge and Juday, he made a point of introducing them to the graduate students. Through his research grants, he kept a flow into the lab of well-known people from around the world. These scientists commonly brought with them new ideas and experimental methods.

> "We had talent from all over the world coming in and I'm sure we picked up ideas and sharpened our own. We had a policy of taking a visitor who was going to be there for a week and sitting him down with every graduate student without our presence. The student could sharpen his ideas against another bright guy."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

The environment Hasler provided—innovative ideas, talented graduate and post-doctoral students, interdepartmental collaboration, and visiting scientists from around the country and the world—sparked the generation of new ideas.

> "The resources for advanced graduate students were ideal—lots of technical help as well as intellectual stimulation. . . . There was also a tradition of excellence that one felt must be continued—one occasionally felt that Birge and Juday were watching. . . .
>
> "New graduate students were inundated with ideas from other graduate students. . . . Most of the research ideas came from other students. . . . All of this, of course, subject to the approval and modification by ADH—and the constant scrutiny and 'constructive criticism' by other students."
>
> C. Voightlander, 1983, personal communication.

Hasler's graduate students commonly took their research problems, especially problems in experimental design and statistics to Hasler's former student, John C. Neess, who joined the Zoology Department after completing his Ph.D. degree in 1949. Within the first couple years as a faculty member, Neess separated from Hasler and the limnology lab because he did not want to be thought of as Hasler's successor (Neess 1983, personal communication). He continued, however, to advise Hasler's students.

> "John Neess was a person who was a friend as well as advisor. . . . When we would have difficulties we would go to John, particularly on things like sampling and statistical analysis. . . . John's habit of being available was a tremendous resource for us because you could catch him almost any time. How he got his own work done I don't know. We were always after him for help and he gave it willingly."
>
> W. Helm, 1983, "History of Limnology in Wisconsin Conference."

Hasler's students formed a congenial and mutually supporting group. For many students, the most influential people in the actual development of research—writing, experimental design, and conceptual development of the problem—were fellow graduate students (Hunter, Voightlander, and Wissing 1983, personal communication). At both formal and "brown bag" seminars, which were often attended by people from the Wisconsin Conservation Department, Hasler's students openly exchanged and challenged research ideas. They also commonly helped each other with their field research.

> "As long as I have been associated with limnology in Madison, neither up here [Trout Lake] nor in Madison, did you get any sense of competition or the withholding of information or guarding of information. People were generous with collaboration."
>
> W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

> "Everybody helped each other. We all got experience doing these different things. . . . Hasler didn't explicitly tell students to help on other projects, but there was peer pressure."
>
> R. Ragotzkie, 1983, personal communication.

Hasler's students were involved in a broad range of research areas, only a few of which are discussed here. One major area of study was the extension of the use of radionuclides in experimental limnology. E. Zicker, K. Berger, and Hasler (1956) first began using isotopes to trace the movements of nutrients, specifically phosphorus, in lakes. They found that radiophosphorus, applied to the surface of the mud, does not diffuse readily into the water in an undisturbed system.

Hasler then proposed using lakes as models of the sea in experiments designed to study the physical-biological transport of nuclides in marine situations.

> "The Office of Naval Research held a conference in the 1950s on marine disposal of radioactive waste. We biologists challenged the disposal in meromictic [thermally and chemically stratified] areas because migratory animals would transport it to surface waters. We simulated this in a meromictic lake in Wisconsin. To have done it at sea would have been too expensive and technically impossible."
>
> A. D. Hasler, 1983, personal communication.

From preliminary studies conducted in a small, chemically stratified lake in northwestern Wisconsin, Hasler and his student, Gene Likens, discovered that dipteran larvae transported measurable quantities of radioiodine from the deep water of the lake to the surface and thence, as pupated flying insects, to the shoreline, indicating that radioactive wastes could be transported to the surface and out of the lake or ocean by animals (Likens and Hasler 1963). Likens and Hasler also used radiosodium to measure the movements of water in a lake during both ice-covered and open-water conditions (Likens and Hasler 1962).

The research conducted by Hasler's students and associates covered almost every aspect of what is considered traditional limnology. Studies, for example, included research on the distribution of cobalt in lakes (Parker and Hasler 1969), heat budgets in Madison lakes (Stewart 1973) and in the Madison River in Yellowstone National Park (Wright and Horrall 1967), airborne litterfall as a source of organic matter in lakes (Gasith and Hasler 1976), the distribution of zooplankton in Lake Mendota (Ragotzkie and Bryson 1953), plankton crustacea in Lake Michigan (McNaught 1966, McNaught and Hasler 1966), invertebrates on aquatic plants (Andrews and Hasler 1942), the population ecology of chironomids (Dugdale 1955), ecology of riffle insects in the Firehole River in Wyoming (Armitage 1958, 1961), caloric values of various invertebrates (Wissing and Hasler 1968, 1971b), and the behavioral ecology of caddisflies (Gallepp 1974a, 1974b, 1976, 1977).

Another contributor to the Wisconsin limnological program was G. A. Rohlich of the Departments of Civil and Environmental Engineering and Water Chemistry. The research of Rohlich and his associates was concerned primarily with the origin and quantities of plant nutrients in the Madison lakes and tributaries (see Hasler 1963).

The Wisconsin school of limnology under Hasler's direction conducted far more research on fish than was customary elsewhere.

> "Neither Birge, Welch, nor Hutchinson emphasized the fish of lakes and rivers. It was one of my goals to correct this neglect. Only in 1982 was a textbook published [Goldman] on limnology that had even a chapter on fish communities."
>
> A. D. Hasler, 1983, personal communication.

The following list of research topics is by no means exhaustive, but it does illustrate the breadth of research on fishes conducted by Hasler and his associates. Many of the early studies, such as those on the movements, distribution, and population ecology of perch (Bardach 1951, Hasler 1945, Hasler and Bardach 1949, Hasler and Villemonte 1953, Hergenrader and Hasler 1965, 1967, 1968), carp (Neess, Helm, and Threinen 1955, 1957), cisco (John 1956, John and Hasler 1956), white bass (Horrall 1961, Voightlander and Wissing 1974, Wright 1968), and yellow bass (Helm 1958, Wright 1968) were conducted in Lake Mendota and Lake Wingra.

Research was not confined to Madison-area lakes, however. There were also studies on the trout introduced into alkalized and nonalkalized lakes in northern Wisconsin (Johnson and Hasler 1954), on alleviating winterkill conditions in northern lakes (Schmitz 1959, Schmitz and Hasler 1958), on the feeding ecology of trout in the Brule River in northern Wisconsin (Hunt 1965), on muskellunge and perch populations (Gammon and Hasler 1965), and on limnetic larval fish in northern Wisconsin lakes (Faber 1967). Hasler's student, Francis Henderson, with limnology technician Gerald Chipman developed an ultrasonic transmitter for use in studies of fish movements (Henderson, Hasler, and Chipman 1966).

Another student, William Helm, was the first to build and use an electroshocker in Wisconsin. In this case, necessity was truly the "mother of invention." Helm had been trying to conduct research on walleye in northern Wisconsin and was frustrated in his efforts to catch them.

> "I tried daytime seining, nighttime seining, nice gravely beaches, woody areas—nothing. I was not getting walleye. So we tried to figure out whether we could trawl. From what I could tell of the bottom, that was not a very good prospect.
>
> "I had read somewhere about boom shockers. We had an old surplus generator sitting in a shed down in Madison, so I grabbed that and had an Arkansas traveler boat brought up here. Between a few things I scrounged in Madison and stuff that I bought at a hardware store up here, I put together a boom shocker to find out whether it would work. And it did. So we regrouped and constructed it well enough that it would work for that fall and then went ahead and shocked. It was, to my knowledge, the first workable boom shocker in the state of Wisconsin. . . .
>
> "All that fall there was a steady procession of people in here to look at that boom shocker to see how it worked, because I was collecting walleye with a very, very low mortality rate. We

were also collecting musky with a low mortality rate, so the musky people came charging over here. During the wintertime I built a real gaudy thing, one that allowed me to vary the electrospacing depending on water hardness, conductivity. . . . It improved the efficiency tremendously.''

W. Helm, 1983, ''History of Limnology in Wisconsin Conference.''

Some students also continued in one of Hasler's original lines of research in fish physiology. James Gammon investigated the conversion of food in young muskellunge (Gammon 1963), Thomas Wissing examined the effects of swimming and food intake on the respiration of young-of-the-year white bass (Wissing and Hasler 1971a), and Calvin Kaya investigated the effect of photoperiod and temperature on the gonads of green sunfish (Kaya and Hasler 1972). S. Chidambaram, in collaboration with zoologist, Roland K. Meyer, conducted research on the effects of brain lesions and ACTH on the blood of bullheads (Hasler, Chidambaram, and Meyer 1973).

In addition to training students to be qualified limnologists, Hasler also trained them to be scientists who would be at home on the sea, in a marine bay, on a saltwater lake, or in a river. He also tried to train his students to be opportunists, to be flexible enough to take advantage of new research opportunities and funding sources when they arise.

''I didn't know a damn thing about atomic energy when we got into the isotope research. I had to learn it. I advise my students to train themselves to be able to change. . . . The best thing you can do in your earliest stages is to give yourself the kind of training that isn't final. Get the basics, so you can tackle anything in a systematic, intelligent way with the curiosity, the motivation, and the inspiration to learn it. . . . I think it's a great shame if anyone starts with any subject in science today with the idea that he's going to be doing that all his life. He's a fool to think he can get away with it.''

A. D. Hasler, 1983, ''History of Limnology in Wisconsin Conference.''

His students were also trained to be able administrators of their own research programs.

''Hasler's goal was to train people capable of directing a laboratory in totality. . . . He always said, 'There's more to this business than rowing around the lake.' And he made sure that students knew how to write grants, run a lab, and deal with the public and the politicians. . . . Graduate students did the grant writing. Hasler was the editorial manager.''

C. Voightlander, 1983, personal communication.

Students did get plenty of training in running the limnology lab, because Hasler travelled a great deal and was often absent from the lab. The lab was, for the most part, organized and run on a day-to-day basis by students. There were committees—the boat committee, library committee, and so forth. No one was required to work on Hasler's pet projects, but he did require personal responsibility in managing the lake lab in Madison.

Hasler's training of students ensured that many would find their way into influential research and administrative positions. As previously discussed, Waldo Johnson was instrumental in getting the Canadian government to set aside an experimental lakes area in Manitoba. Robert Ragotzkie is the Director of the Sea Grant Program at the University of Wisconsin. Gene Likens is Director of the Institute of Ecosystem Studies at the New

York Botanical Garden. John Bardach recently retired as Director of the East-West Resource Systems Institute in Hawaii. H. Francis Henderson is in charge of the Fish Stock Evaluation Branch of the Food and Agriculture Organization in Rome. Richard A. Parker is Dean of the Graduate School at Washington State University in Pullman, and Warren Wisby is Associate Dean for the Rosenstiel School of Marine and Atmospheric Science at the University of Miami.

From the 1940s to the late 1950s the Trout Lake Station had been relatively unimportant to the development of the Wisconsin limnological program. With the coming of the second World War and the retirement of Juday in 1941, limnological research at the station had come to a standstill. Not only had Hasler not been invited to use the facilities, but his research interests had been focused on lakes in southeastern Wisconsin. Although some students, including Oscar Brynildson, William Helm, Ray Stross, Waldo Johnson, Gene Likens, and William Schmitz, had been conducting research on several northern Wisconsin lakes, the Trout Lake Station did not serve as a base for the limnologists until the late 1950s. Hasler's students recall that in the 1940s and 1950s there was no great agitation to "get something going" at Trout Lake. The station was viewed as a "rough and ready" place with no good research facilities. There was no modern laboratory there until 1967. The real emphasis was on Lake Mendota in Madison, the liming of bog lakes in northeastern Wisconsin, and the salmon homing and orientation research.

From 1942 through 1955, the Trout Lake Station was used by a variety of researchers other than limnologists, including parasitologist Chester Herrick, plant ecologist John Curtis, and wildlife ecologist Robert Dorney. In 1947 Hasler and some of his graduate students made a brief trip north to take to Madison any equipment that might be useful for research on Lake Mendota (Neess and Le Cren 1983, personal communication). Their trip became quite an expedition.

"The Trout Lake Station had been 'mothballed' soon after the outbreak of the war and had remained unvisited for some while. In the summer of 1947, Art Hasler decided that he would visit it to see that the bathhouse laboratories were still standing and such equipment as was there was still in good shape. Accordingly an expedition was planned. We were to drive up from Madison on one day, spend the night there and return the next. . . . One of the stores in Madison had recently bought a batch of ex-Army 'jungle hammocks' that they were selling off for $5.00 each. Several of us had bought one of these and we thought that we would try them out at Trout Lake.

"The party consisted of Art Hasler, John Neess, John Bardach, Ed Nelson, and David Le Cren. . . . We found the huts still standing and full of miscellaneous apparatus (and junk!) just as they had been left some five years before. Art checked things over and rescued some items to use on Mendota. . . .

"Ed disdained the hammocks (which, considering his weight, was wise) and settled down in his sleeping bag onto the sand. The rest of us chose pairs of pine trees and tied up the ropes of our hammocks. However, the fun then began. The hammocks had fly-sheets over the top of them connected to the hammock proper with mosquito-netting. One had to open a zip, insert one's top half and then leap off the ground and pull one's legs in. This was easier said than done, and most of us promptly ended upside down in the fly-sheet. I believe that Art actually rotated two or three times before coming to rest. It then became apparent that the strings on which the hammocks were suspended had been quietly rotting away while stacked in some damp Army store. There was a succession of loud reports, as under tension, first one and then another gave way under the strain of shaking laughter that had by now afflicted the party. I think that John Neess and David did eventually spend quite restful nights in their hammocks.

The others involuntarily joined Ed on the ground; he by now was cursing us for keeping him awake with our mirth and oaths."

D. Le Cren, 1983, personal communication.

In 1962 Hasler had applied for and obtained funds from the National Science Foundation to build a modern research laboratory on Lake Mendota. He was able to have William Kaeser appointed architect for the building to assure a unique style for the prized lake site. In 1967 he was approached by the university administration to get money for a new laboratory on Trout Lake. With matching funds from the university, the National Science Foundation provided money to build the new research facilities. A few graduate students (Philip Doepke, Daniel Faber, James Gammon, William Helm, William Schmitz) had used the facilities at Trout Lake in the 1950s and 1960s, but research activity did not really pick up there until after the new lab was built.

"When I came up in '57 it was the first contact the limnology group had had with the station since the '40s. . . . There was a little resistance to our using the station at first, but I think it was a matter of guarding territories. . . .

"When I was up here, there was a minimum level of activity—only three people working on projects living over here at the time. . . . We were almost in a vacuum."

W. Helm, 1983, "History of Limnology in Wisconsin Conference."

The Department of Natural Resources owned the land on which the first station had been built. The state wanted the station moved from its original location and offered an 80-acre site on the south shore of South Trout for the new laboratory. William Schmitz, one of Hasler's former students and now a faculty member at the University of Wisconsin-Marathon campus, was appointed Associate Director of the station in 1966. In 1965 he had gone to meetings in Warsaw and visited stations in Austria, Denmark, northern Germany, and Poland to garner ideas for the new laboratory at Trout Lake. Under Schmitz's supervision, the new laboratory was built in 1967. Some of the old wooden buildings that Birge and Juday had used as laboratories were pushed across the ice from the old station on the north shore of South Trout to the new site and used for living quarters and warehouses. Birge and Juday had intended the Trout Lake Station to be a temporary research facility (Juday and Birge 1930). With the building of the new lab, the station became a permanent laboratory and went from being only a summer station to providing facilities for research year-round. Hasler remained Director of the station until 1975 when John J. Magnuson succeeded him.

Hasler continued the tradition of interdisciplinary research begun by Birge and Juday. During the Hasler era, however, the involvement of other departments was more biological and behavioral than chemical and physical. Students took courses and sought advice from Norman Fassett, who was interested in aquatic macrophytes, John Curtis, a plant ecologist, Aldo Leopold, a wildlife ecologist, and James Crow, a population geneticist who coadvised Hasler's student, Ralph Nursall.

"In the late 1940s the students of Hasler, Leopold, and Fassett formed a congenial group even though they were doing different things. . . . The University of Wisconsin was one of the few places that had several ecologists, who were all good and who all worked well together. It was a strong campus. Leopold and Fassett recognized ecology as an important discipline, so there were lots of contacts for graduate students interested in ecology."

J. Neess, 1983, personal communication.

Hasler and his students consulted other faculty in addition to the ecologists. Psychologists were intimately involved in designing the behavioral tests used in experiments on the olfactory, homing, and orientation abilities of fish. Faculty from soil physics and soil chemistry advised with the work on liming bog lakes, and faculty and technicians from mechanical engineering helped design and construct equipment for the limnologists.

> "As far as I'm concerned, the engineering people were of most use to me. I borrowed gas meters for measuring air flow. I consulted with Professor Villemonte, who was very helpful. They weren't helpful entirely out of generosity. They got to go fishing up there [Trout Lake]. Every time I consulted with anybody I usually had to spend a half day fishing with them. I fished with everybody. . . . I fished with good fishermen, bad fishermen, and indifferent fishermen. But you know, it was fun to have done that, because you also had a chance to spend some time with them and you pick their brain and you have an enjoyable time."
>
> W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

Hasler and his students also sought statistical advice from Arthur Chapman in the Statistics Department in the School of Agriculture. And when computers first came into use, the limnologists sought advice on their application to limnological data.

Interdepartmental cooperation became institutionalized in 1962 when the Graduate School approved as an experimental program the interdepartmental Oceanography and Limnology Graduate Program.

> "In the 1960s several professors across the campus agreed to collaborate in offering a graduate curriculum in O & L. Acknowledging that traditional zoology and botany were too restrictive, especially in the areas of water chemistry, physics, meteorology, geology, geophysics, microbiology and hydrology, our program opened O & L to disciplines other than biology."
>
> A. D. Hasler, 1983, personal communication.

The O & L Program attained full status as a recognized degree program in spring 1969. Participating departments include Bacteriology, Botany, Civil and Environmental Engineering (including Water Chemistry), Geology and Geophysics, Meteorology, the Institute for Environmental Studies, and Zoology.

In 1972, through the efforts of Hasler, Robert Ragotzkie, a former student, and Clifford Mortimer, a limnologist from the University of Wisconsin-Milwaukee, Sea Grant status was granted to the University of Wisconsin system. It was only the sixth Sea Grant College in the nation and the first in the Midwest. Ragotzkie was appointed Director of the Sea Grant Program, which in Wisconsin stresses applied research on the Great Lakes. In the course of the salmon homing and orientation research, Hasler and his students had conducted extensive experiments on Lake Michigan, but the Sea Grant Program expanded the scope of Great Lakes research, as well as the resources available to the Wisconsin limnological school.

Even though Hasler and his students were well-funded, the rapid growth of Wisconsin's limnology program from the 1950s to the 1970s still made substantial financial demands on the Zoology Department of which it was a part. Like any leader of a strong research program, Hasler generated some ill-will among a few of his colleagues through competition for departmental funds. He and his students in the lake lab were also isolated from the rest of the Zoology Department, so at times there was a lack of communication between the limnologists and the other zoologists.

"Art wanted the limnology program self-contained and he tried to run the limnology lab as a separate institution. He didn't like being just a faculty member within a department. He went outside the department [to university deans] to get influence, which was irritating to other departmental faculty. Hasler thought the only claim to fame that zoology had was the limnology program—an attitude that tended to irritate other members of the department."

J. Neess, 1983, personal communication.

The intradepartmental conflicts Hasler had with other zoology faculty were, however, relatively minor. Hasler served three years as Chairman of the department, having been elected by a majority vote of the Zoology staff and appointed by the Dean of Letters and Science. And, the rivalries did not affect his students.

"Once he made a commitment to a student, he would back you to the hilt, especially in departmental conflicts. Conflicts did not filter down to affect students. There were certain people you avoided on your committees. Hasler shielded his students from his antagonists in the Zoology Department. It was not an overwhelming problem for us. The students were not penalized."

T. Wissing, 1983, personal communication.

Unlike Birge and Juday, who had remained socially aloof from their students and were uninvolved in their personal lives, Hasler made strong efforts to reduce the social distance between him and his students and among the students themselves. He often entertained students in his home.

"I first met Hasler in September, 1943. He was not like Birge. Hasler was a good person to have as a friend. You could depend on him for personal support."

J. Neess, 1983, personal communication.

Hasler's wife Hanna held regular monthly meetings of the "Fish Wives," a group composed of graduate students' wives.

"Hanna Hasler's meetings of the wives were important. They provided support for the graduate students through the wives. The Haslers' always gave gifts to the wives when their husbands graduated. . . . There's a feeling of closeness among the graduate students that continues 20 years later."

D. Faber, 1983, personal communication.

The Haslers' efforts at providing personal support as well as academic and financial support for students may have stemmed from values learned early. Both Hasler and his wife had been brought up as Mormons where they learned a strong sense of community.

"Being raised a Mormon played a big role in shaping my values. I learned to be a team worker, learned public speaking, and how to conduct meetings. . . .

"As a scientist, one has difficulties. . . . I could have said, 'to hell with my church, I'm just going to quit and not have anything to do with religion.' But then, how am I going to teach my children and other young people I deal with how a scientist thinks? One thing I took on was evolution. I used to give lessons at our church on evolution. The church doesn't accept it at all, but I thought our young people ought to be exposed to evolution. And the Mormon church for many years wouldn't let Blacks hold the priesthood. I took this on and gave many talks about the biology of the equality of man and called for a change in policy, which took place about 1980. Of course, many other Mormon intellectuals did as I did. If I'd run away and thrown stones from the outside there wouldn't have been any change. . . . A lot of scientists just pull away from these things and don't help to change society.

"Theologically, I'm not a good Mormon, but I'll defend them to my dying day. . . . I had five sons and one daughter. My colleagues in the Mormon community in Madison took the children to baseball games and Boy Scout activities, taught them social dancing, and took them on canoe trips when I was away on research trips and committee assignments in Washington. They were surrogate fathers to them. . . . They were also supportive and compassionate during my late wife's illness with cancer. . . .

"As a scientist, it hasn't been easy to be a Mormon. . . . In 1965 I was one of two candidates for a deanship at a large West Coast university. I had been told by a friend that I had the position. But when I was called the next day, I was told I didn't get it because I was a Mormon. In retrospect it was my good fortune, for I could not have done exciting salmon experiments [which led to Hasler's election to the National Academy of Sciences] had I become an administrator."

A. D. Hasler, 1985, personal communication.

Despite his personal interest in students, Hasler did have an authoritarian presence. He was on a first name basis with a graduate student only after that person became a Ph.D. student. Hasler was also known for his insistence on keeping the lake lab neat and clean. Particularly trying to the graduate students were the preparations they had to make in advance of a site visit from the National Science Foundation.

"Site visits literally involved white-glove inspections with white lab coats. Hasler would have someone behind him taking notes. There would be a flurry of cleaning up. Hasler was very meticulous. The graduate students once even suggested renting a truck for a day to load everything on, so the lab would look neat for the site visit."

C. Voightlander, 1983, personal communication.

As busy as Hasler was with his graduate students and research, he made time for public service. From the time he returned to the University of Wisconsin and taught his first course in limnology in 1938, Hasler was concerned with conservation.

"In a state with over 5000 lakes it was my view that every drug store clerk should learn the rudiments of limnology. Because limnology was not in the college student's vocabulary in 1938, the course bore the designation *Conservation of Aquatic Resources.*"

A. D. Hasler, 1983, personal communication.

Long before the ecological awareness of the 1960s and 1970s, Hasler worked with politicians and lobbied for legislation to protect Wisconsin's lakes and streams. He even recruited Fritz Albert to make a "propaganda" film, "What's Happening to Our Lakes?" Unlike Birge and Juday, who had avoided controversial issues such as water pollution and were criticized for leaving the polluted Madison lakes to work on the unspoiled lakes in northern Wisconsin, Hasler and his students were often involved in the research and politics of water pollution and resource conservation (Hasler 1938, 1947, 1967, 1969a, 1969b, 1972, 1973).

In 1972, while he was president of the International Association for Ecology, Hasler helped obtain funds for the workshop on Global Ecological Problems, which was sponsored by The Institute of Ecology. One product of this workshop was the book *Man in the Living Environment. A Report on Global Ecological Problems.*

"I've always taken some pride in having had the opportunity to be a scholar, a teacher, and a public servant. There's been a lot of satisfaction in serving broadly in the community. . . . But I don't want to pat myself on the back, because public service has also had its rewards. When I served on committees I met people with whom I could discuss research and get new ideas."

A. D. Hasler, 1985, personal communication.

Hasler was also active in professional societies. He was selected by the executive committee of the American Society of Limnology and Oceanography to be the chairman of the 15th International Congress of Limnology held in Madison in 1962. It was the first time the Congress had been held outside Europe. He applied to the National Science Foundation for funds to support the Congress, which included publication of the book *Limnology in North America,* edited by David Frey, a former student of Chancey Juday.

By 1978, when Hasler retired from teaching and directing the limnology lab, he had trained 53 doctoral students and 41 master's degree students and had co-advised many others (listed in appendix). Many of these students "minored" with collaborating colleagues across the campus. Although he became Emeritus Professor in 1978, Hasler continues to write and to remain active in the activities of the limnology lab, and especially in professional societies such as the prestigious National Academy of Sciences to which he was elected in 1969 and the American Academy of Arts and Sciences to which he was elected in 1972 (see Chapter 5).

Unlike Birge and Juday, who had left the limnology program without strong leadership when they retired, Hasler ensured continuation of the program at Wisconsin by bringing in and training new people to take over when he decided to step down. Hasler recommended John J. Magnuson for appointment in 1968. Magnuson had grown up in the Midwest and had obtained bachelor's (1956) and master's (1958) degrees in fisheries from the University of Minnesota and a Ph.D. (1961) in zoology and oceanography from the University of British Columbia. His major professor was Peter Larkin, but he was also advised by C. C. Lindsey and Bill Hoar.

After completing his doctoral degree, Magnuson went from British Columbia to Hawaii where he was the program leader for the tuna behavior and physiology program sponsored by the Bureau of Commercial Fisheries (now part of the National Oceanographic and Atmospheric Administration). Hasler felt that Magnuson's experience as a "blue-water oceanographer" and his strong background in behavior and physiology would help broaden Wisconsin's research program. One of Magnuson's duties was to direct the Trout Lake Station.

"I fell in love with the station and the northern lakes. It fit in with my background and interests. In Hawaii, I had become interested in how tuna respond to vertical environmental gradients. This interest transferred well to lakes in northern Wisconsin where there are vertical gradients in temperature, oxygen, carbon dioxide, and hydrogen sulfide."

J. Magnuson, 1985, personal communication.

Magnuson had been warned by some colleagues not to take the position in Wisconsin, warned that in working with Hasler he would not have the freedom to develop his own research interests. He quickly discovered, however, that the warnings were unfounded.

"I did not want to become Art's successor with his lines of research, and he did not push me in that direction. . . . I found that Hasler was rigid in some ways—when I tried to hang a picture of Birge on my office wall he gave me a lecture about 'false idols.' I also had to attempt to keep my desk clean. But he provided a great deal of freedom where I wanted it. He did not try to control my teaching, research, or use of facilities. . . . We exploited each other in the best sense of the word. My association with Art opened doors for me that might never have been opened."

J. Magnuson, 1985, personal communication.

There has been no abrupt change in the direction of limnological research as there had been between the Birge and Juday era and the Hasler era, and the transition between leaders has been much smoother. Magnuson has gone in his own direction, however.

"We've tried to take the best of both schools (descriptive-comparative and experimental) and incorporate that into our approach. We didn't choose the approach of one school and reject the other. . . . One element that was not exemplified in either era was mathematical or ecosystems theory—the advances in theoretical ecology were not made at Wisconsin. We hope to add a more theoretical approach.

"We also want to encourage tolerance and diversity, and provide an environment where new ideas are welcome, where people are unrestricted by certain directions or avenues. We want to prevent any one faction, discipline, approach, taxon, or whatever from 'winning.' When only one 'wins,' it is everyone's loss."

J. Magnuson, 1985, personal communication.

Shortly after Magnuson's arrival, James Kitchell, a recent graduate of the University of Colorado (Ph.D. 1970), was hired in 1970 in a postdoctoral appointment with the International Biological Program. This program included a major research project on Lake Wingra. Kitchell became a faculty member in the Zoology Department in 1974.

"Kitchell greatly enriched our program with an ecosystems approach to limnology. He exemplifies both the use of hypothesis testing in manipulating ions of natural lakes and extending the results through computer modeling and simulation. He also is a good team player and enjoys crossing the boundary between fundamental ecological studies and their application to significant problems in fisheries management."

J. Magnuson, 1985, personal communication.

The limnological research program at the University of Wisconsin-Madison is also strengthened by contributions from scientists not directly associated with the limnology lab. Thomas D. Brock of the Department of Bacteriology is widely known for his research on thermophilic microorganisms in hot springs (Brock 1978). He and his students and associates have also conducted extensive research on Lake Mendota, particularly on the phytoplankton, zooplankton, and bacteria. These studies, as well as previous research on Lake Mendota conducted by Birge and Juday and their associates, are described and synthesized in *A Eutrophic Lake: Lake Mendota, Wisconsin* (Brock 1985). Other contributors include Robert Ragotzkie, Director of the Sea Grant Program, Stanley Dodson, Jeffrey Baylis, and Marion Meyer of the Zoology Department, Michael Adams and Timothy Allen of the Botany Department, David Armstrong and Anders Andren of the Water Chemistry Department, and Carl Bowser, Mary Anderson, and Clarence Clay of the Geology and Geophysics Department.

On July 1, 1982, Hasler finally gained a long-term goal when, at Magnuson's urging, E. David Cronon, Dean of Letters and Science at the University of Wisconsin, created the Center for Limnology as a separate institution within the university. Magnuson was appointed Director for the Center and Kitchell became Associate Director for the Limnology Laboratory in Madison. Thomas M. Frost, a recent graduate of Dartmouth College (Ph.D. 1978) who had spent two years on a postdoctoral appointment (University of

Colorado) in Venezuela studying tropical limnology, was appointed Associate Director for the Trout Lake Station. Under Magnuson's leadership, the Wisconsin school continues to be known internationally for its contributions to the science of limnology.

References

Andrews, J. D. and A. D. Hasler. 1942. Fluctuations in the animal populations of the littoral zone in Lake Mendota. *Trans. Wis. Acad. Sci. Arts Lett.* 34: 137–148.

Armitage, K. B. 1958. Ecology of the riffle insects of the Firehole River, Wyoming. *Ecology* 39: 571–580.

———. 1961. Distribution of riffle insects of the Firehole River, Wyoming. *Hydrobiologia* 17: 152–174.

Bardach, J. E. 1951. Changes in the yellow perch population of Lake Mendota, Wisconsin, between 1916 and 1948. *Ecology* 32: 719–728.

Brock, T. D. 1978. *Thermophilic Microorganisms and Life at High Temperatures.* Springer-Verlag, New York. 465p.

———. 1985. *A Eutrophic Lake. Lake Mendota, Wisconsin.* Springer-Verlag, New York. 308 p.

Dugdale, R. C. 1955. Studies in the ecology of the benthic Diptera of Lake Mendota. Ph.D. Thesis, University of Wisconsin.

Faber, D. J. 1967. Limnetic larval fish in northern Wisconsin lakes. *J. Fish. Res. Bd. Can.* 24: 927–937.

Gallepp, G. W. 1974a. Diel periodicity in the behaviour of the caddisfly, *Brachycentrus americanus* (Banks). *Freshwat. Biol.* 4: 193–204.

———. 1974b. Behavioral ecology of *Brachycentrus occidentalis* Banks during the pupation period. *Ecology* 55: 1283–1294.

———. 1976. Temperature as a cue for the periodicity in feeding of *Brachycentrus occidentalis* (Insecta: Trichoptera). *Anim. Behav.* 24: 7–10.

———. 1977. Responses of caddisfly larvae (*Brachycentrus* spp.) to temperature, food availability and current velocity. *Am. Midl. Nat.* 98: 59–84.

Gammon, J. R. 1963. Conversion of food in young muskellunge. *Trans. Amer. Fish. Soc.* 92: 183–184.

——— and A. D. Hasler. 1965. Predation by introduced muskellunge on perch and bass, I: Years 1–5. *Trans. Wis. Acad. Sci. Arts Lett.* 54: 249–272.

Gasith, A. and A. D. Hasler. 1976. Airborne litterfall as a source of organic matter in lakes. *Limnol. Oceanogr.* 21: 253–258.

Hasler, A. D. 1938. Pulp-mill pollution in the York River, VA, and its connection with the decline of the oyster industry. *Gamma Alpha Record* 28: 44–45.

———. 1945. Observations on the winter perch population of Lake Mendota. *Ecology* 26: 90–94.

———. 1947. Eutrophication of lakes by domestic drainage. *Ecology* 28: 383–395.

———. 1963. Wisconsin 1940–1961. in D. G. Frey (ed.). *Limnology in North America.* University of Wisconsin Press, Madison. pp. 55–93.

———. 1967. Technology and man's relation to his natural environment. In C. P. Hall (ed.) *Human Values and Advancing Technology.* Friendship Press, New York. pp. 158–167.

———. 1969a. Acting responsibly to our environment, a profoundly human issue. *Intercol Bulletin* 1: 2–12.

———. 1969b. Cultural eutrophication is reversible. *Bioscience* May: 425–431.

———. 1972. A zoologist's responsibility to our living environment. *Amer. Zool.* 12: 9–11.

———. 1973. Poisons, phosphates, preservation, people and politics—a fish eye's view of ecology. *Trans. Am. Fish. Soc.* 102: 213–224.

——— and J. E. Bardach. 1949. Daily migrations of perch in Lake Mendota, Wisconsin. *J. Wildl. Mgt.* 13: 40–51.

———, S. Chidambaram and R. K. Meyer. 1973. Effect of hypophysectomy and ACTH on glycemia and hematocrit in the bullhead, *Ictalurus melas. J. Exp. Zool.* 184: 75–80.

——— and J. R. Villemonte. 1953. Observations on the daily movements of fishes. *Science* 118: 321–322.

Helm, W. T. 1958. Some notes on the ecology of panfish in Lake Wingra with special reference to the yellow bass. Ph.D. Thesis, University of Wisconsin. 88 p.

Henderson, H. F., A. D. Hasler and G. G. Chipman. 1966. An ultrasonic transmitter for use in studies of movements of fishes. *Trans. Am. Fish. Soc.* 95: 350–356.

Hergenrader, G. L. and A. D. Hasler. 1965. Diel activity and vertical distribution of yellow perch *(Perca flavescens)* under the ice. *J. Fish Res. Board Can.* 23: 499–509.

______ and ______. 1967. Seasonal changes in swimming rates of yellow perch in Lake Mendota as measured by sonar. *Trans. Am. Fish. Soc.* 96: 373–382.

______ and ______. 1968. Influence of changing seasons on schooling behavior of yellow perch. *J. Fish. Res. Board Can.* 25: 711–716.

Horrall, R. M. 1961. A comparative study of two spawning populations of the white bass, *Roccus chrysops* (Rafinesque), in Lake Mendota, Wisconsin, with special reference to homing behavior. Ph.D. Thesis, University of Wisconsin. 181 p.

Hunt, R. L. 1965. Surface-drift insects as trout food in the Brule River. *Wis. Acad. Sci. Arts Lett.* 54: 51–61.

John, K. R. 1956. Onset of spawning activities of the shallow water cisco, *Leucichthys artedi* (LeSueur) in Lake Mendota, Wisconsin, relative to water temperatures. *Copeia* 2: 116–118.

______ and A. D. Hasler. 1956. Observations on some factors affecting the hatching of eggs and the survival of young shallow-water cisco, *Leucichthys artedi* LeSueur. *Limnol. Oceanogr.* 1: 176–194.

Johnson, W. E. and A. D. Hasler. 1954. Rainbow trout production in dystrophic lakes. *J. Wildl. Mgt.* 18: 113–134.

Juday, C. and E. A. Birge. 1930. The highland lake district of northeastern Wisconsin and the Trout Lake limnological laboratory. *Trans. Wis. Acad. Sci. Arts Lett.* 25: 337–352.

Kaya, C. M. and A. D. Hasler. 1972. Photoperiod and temperature effects on the gonads of green sunfish, *Lepomis cyanellus* (Rafinesque), during the quiescent, winter phase of its annual sexual cycle. *Trans. Am. Fish. Soc.* 101: 270–275.

Likens, G. E. and A. D. Hasler. 1962. Movements of radiosodium (Na 24) within an ice-covered lake. *Limnol. Oceanogr.* 7: 48–56.

______ and ______. 1963. Biological and physical transport of radionuclides in stratified lakes. In V. Schultz and Klement (eds.). *Radioecology.* Reinhold Publ. Corp., New York. pp. 463–470.

McNaught, D. C. 1966. Depth control by planktonic cladocerans in Lake Michigan. Univ. of Mich. Great Lakes Res. Div. Publ. 15: 98–108.

______ and A. D. Hasler. 1966. Photoenvironments of planktonic Crustacea in Lake Michigan. *Verh. Internat. Verein. Limnol.* 16: 194–203.

Neess, J. C., W. T. Helm, and C. W. Threinen. 1955. Carp census on Lake Wingra. *Wis. Conserv. Bull.* 20: 1–4.

______, ______, and ______. 1957. Some vital statistics in a heavily exploited population of carp. *J. Wildl. Mgt.* 21: 279–292.

Parker, M. and A. D. Hasler. 1969. Studies on the distribution of cobalt in lakes. *Limnol. Oceanogr.* 14: 229–241.

Ragotzkie, R. A. and R. A. Bryson. 1953. Correlation of currents with the distribution of adult *Daphnia* in Lake Mendota. *J. Mar. Res.* 12: 157–172.

Schmitz, W. R. 1959. Research on winterkill of fish. *Wis. Conserv. Bull.* 24: 1–3.

______ and A. D. Hasler. 1958. Artificially induced circulation of the lake by means of compressed air. *Science* 128: 1088–1089.

Stewart, K. M. 1973. Detailed time variations in mean temperature and heat content of some Madison lakes. *Limnol. and Oceanogr.* 18: 218–226.

Voightlander, C. W. and T. E. Wissing. 1974. Food habits of young and yearling white bass, *Morone chrysops* (Rafinesque), in Lake Mendota, Wisc. *Trans. Am. Fish. Soc.* 103: 25–31.

Wissing, T. E. and A. D. Hasler. 1968. Calorific values of some invertebrates in Lake Mendota, Wisconsin. *J. Fish. Res. Board Can.* 25: 2515–2518.

______ and ______. 1971a. Effects of swimming activity and food intake on the respiration of young-of-the-year white bass, *Morone chrysops*. *Trans. Am. Fish. Soc.* 100: 537–543.

______ and ______. 1971b. Intraseasonal change in caloric content of some freshwater invertebrates. *Ecology* 52: 371–373.

Wright, T. D. 1968. Changes in abundance of yellow bass *(Morone mississippiensis)* and white bass *(M. chrysops)* in Madison, Wisconsin lakes. *Copeia* 1: 183–185.

Wright, J. C. and R. Horrall. 1967. Heat budget studies on the Madison River, Yellowstone National Park. *Limnol. Oceanogr.* 12: 578–583.

Zicker, E. L., K. C. Berger, and A. D. Hasler. 1956. Phosphorus release from bog lake muds. *Limnol. Oceanogr.* 1: 296–303.

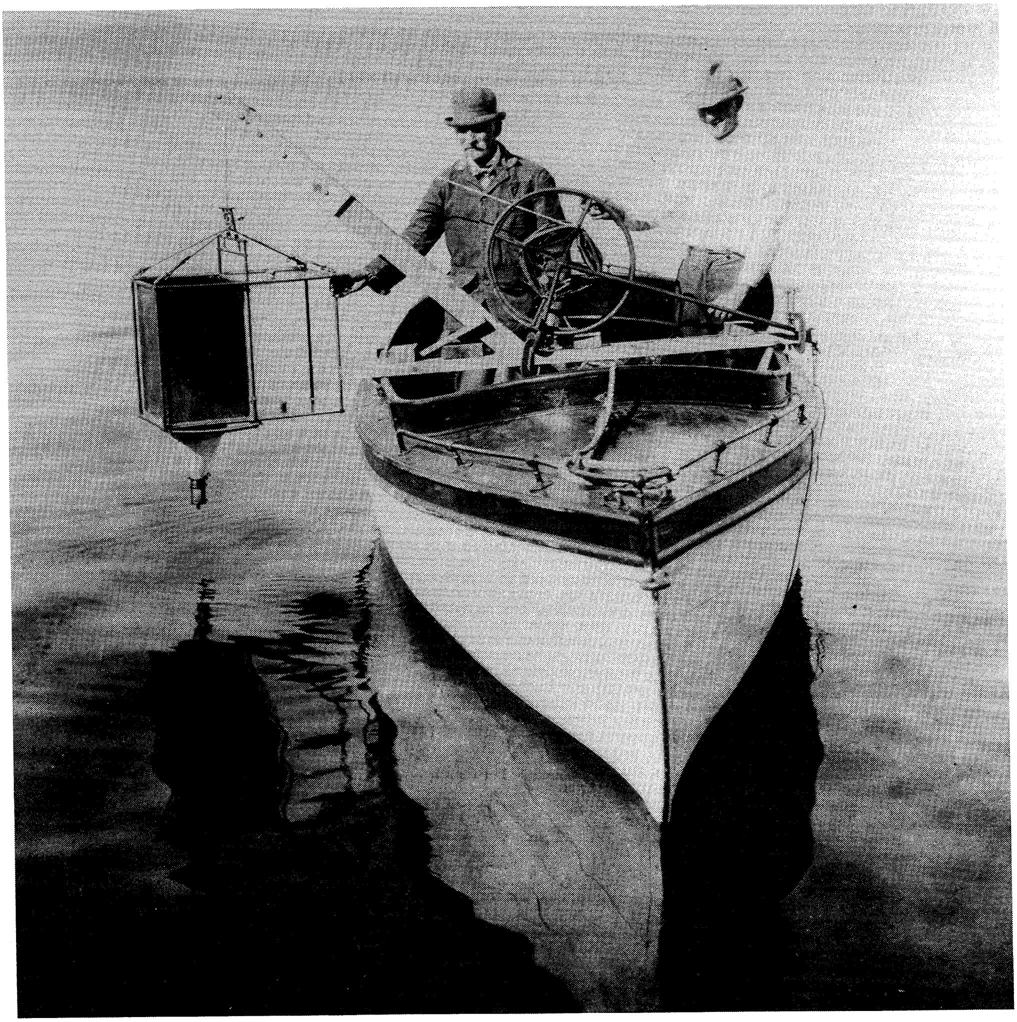

Fig.1. E. A. Birge and C. Juday with plankton trap on Lake Mendota, about 1917. Source: State Historical Society of Wisconsin.

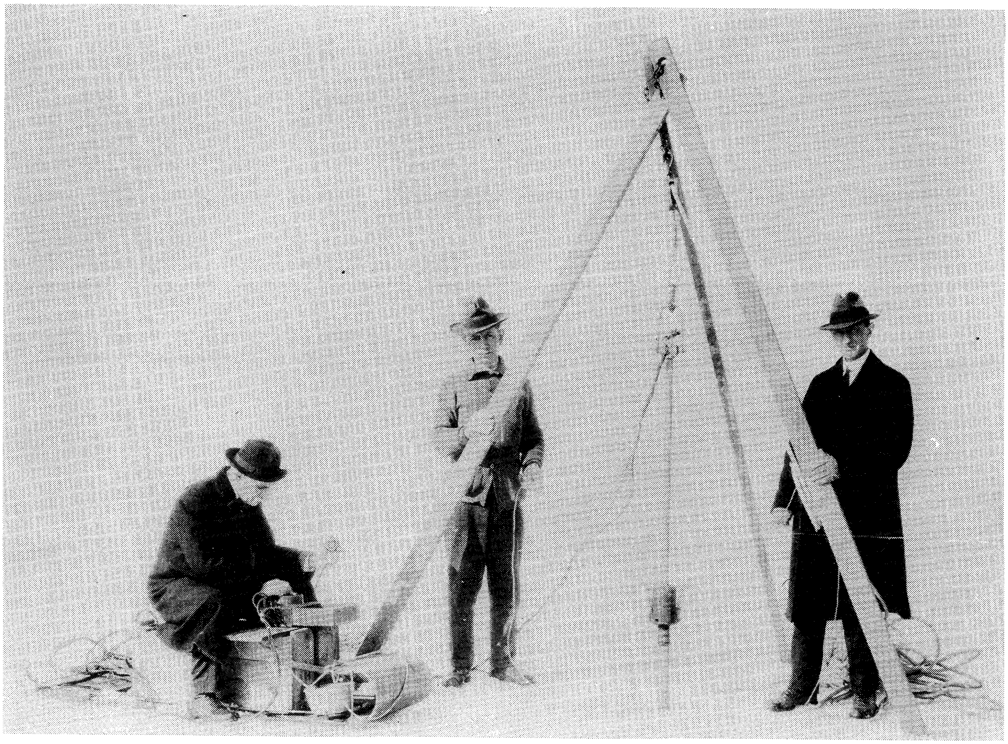

Fig. 2. E. A. Birge, H. W. March, and C. Juday on Lake Mendota with the first mud thermometer, about 1927. Source: State Historical Society of Wisconsin.

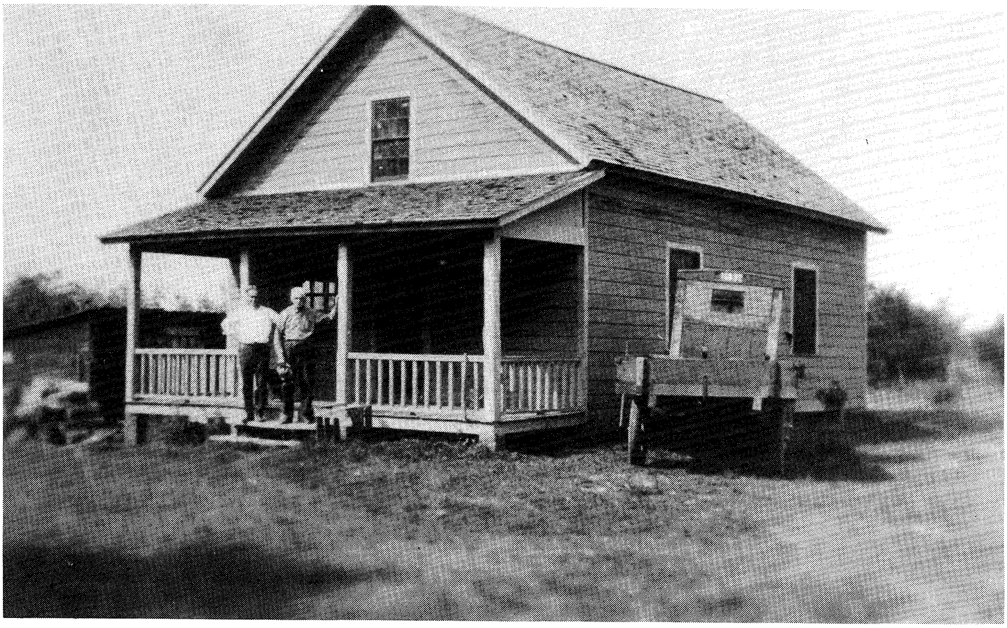

Fig. 3. Stillman Wright and E. A. Birge at the first Trout Lake Station, 1925. Source: Stillman Wright.

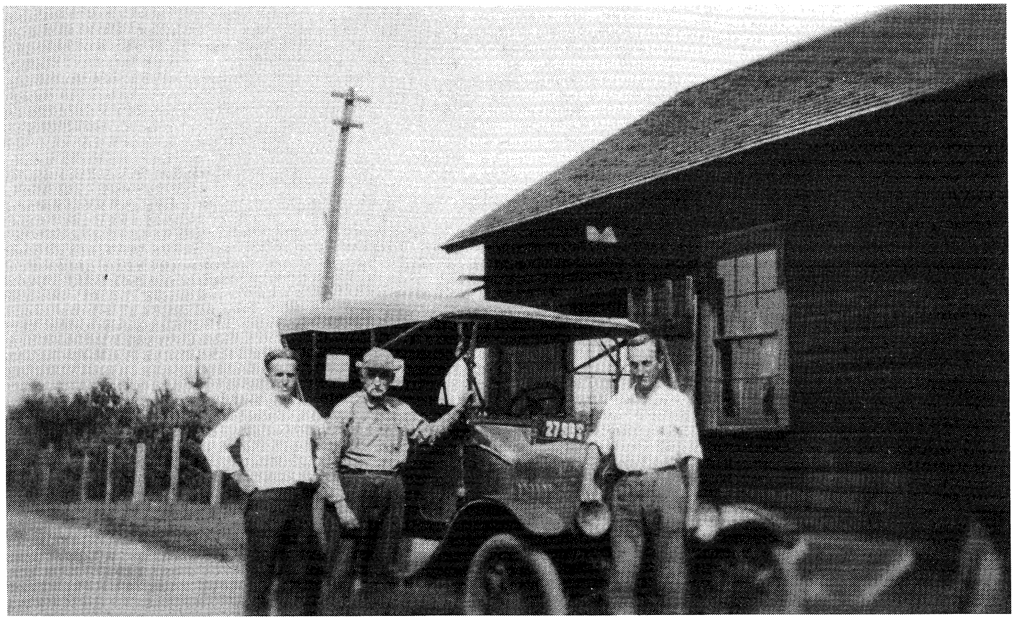

Fig. 4. Stillman Wright, E. A. Birge, and C. Juday at the first Trout Lake Station, 1925. Source: Stillman Wright.

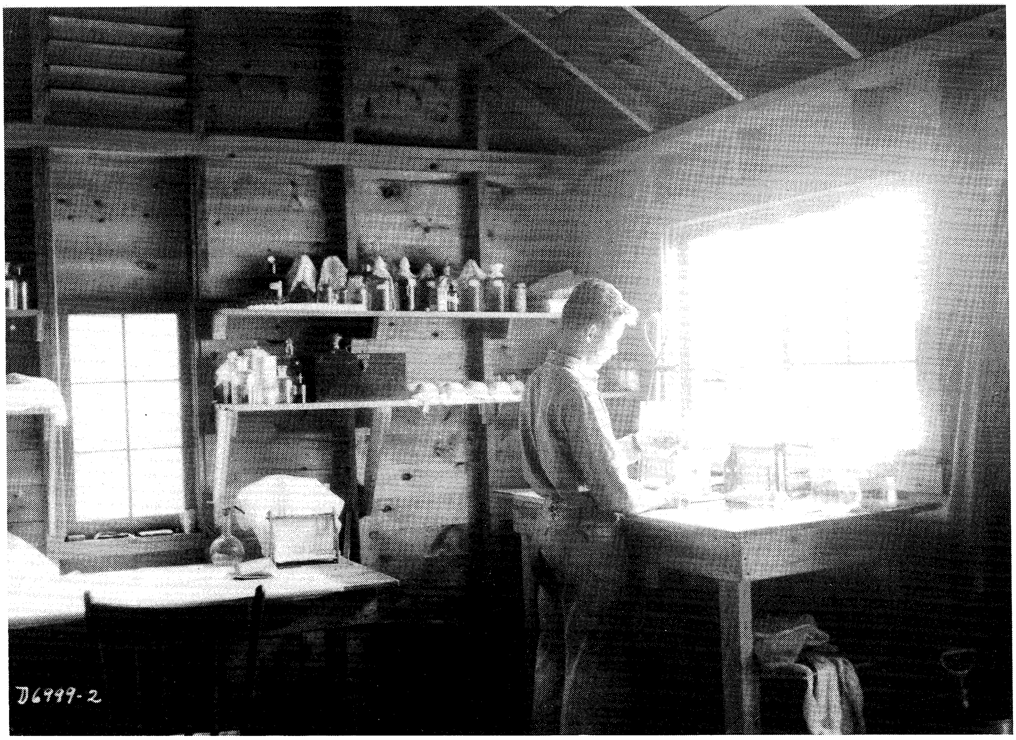

Fig. 5. Fredrick Stare working in the chemistry laboratory at the Trout Lake Station, 1929. Source: State Historical Society of Wisconsin.

Fig. 6. E. A. Birge and C. Juday, 1930. Source: State Historical Society of Wisconsin.

Fig. 7. E. A. Birge with the "sun machine" (on top of car) on Crystal Lake in northern Wisconsin, about 1930. Source: State Historical Society of Wisconsin.

Fig. 8. E. A. Birge and Hugo Baum making observations with the "sun machine," about 1933. Source: State Historical Society of Wisconsin.

Fig. 9. Hugo Baum and A. D. Hasler building lime floats at the Trout Lake Station, 1933. Source: State Historical Society of Wisconsin.

Fig. 10. C. Juday, Villiers (Mel) Meloche, Edward Schneberger, and William Spoor at the Trout Lake Station, 1933. Source: State Historical Society of Wisconsin.

Fig. 11. The Trout Lake Crew in the summer of 1933. Back row (L to R): V. W. Meloche, L. R. Wilson, Ray Langford, A. D. Hasler, Robert Hunt, Harold Schomer. Front row (L to R): Hugo Baum, Edward Schneberger, C. Juday, Sam X. Cross, Militzer, and William Spoor. Source: State Historical Society of Wisconsin.

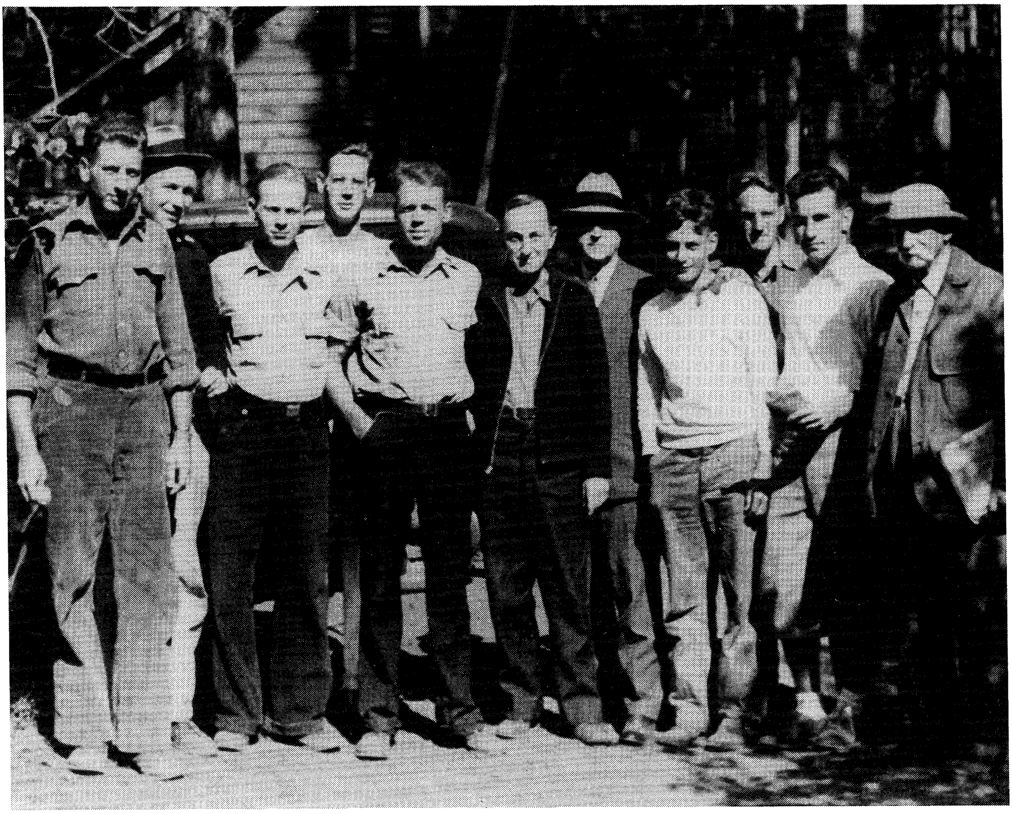

Fig. 12. The Trout Lake Crew in the summer of 1934. (L to R): David Frey, Martin Baum, John Schreiner, Don Kerst, Harold Schomer, C. Juday, E. B. Fred, Richard Juday, A. D. Hasler, Paul Pavcek, and E. A. Birge. Source: State Historical Society of Wisconsin.

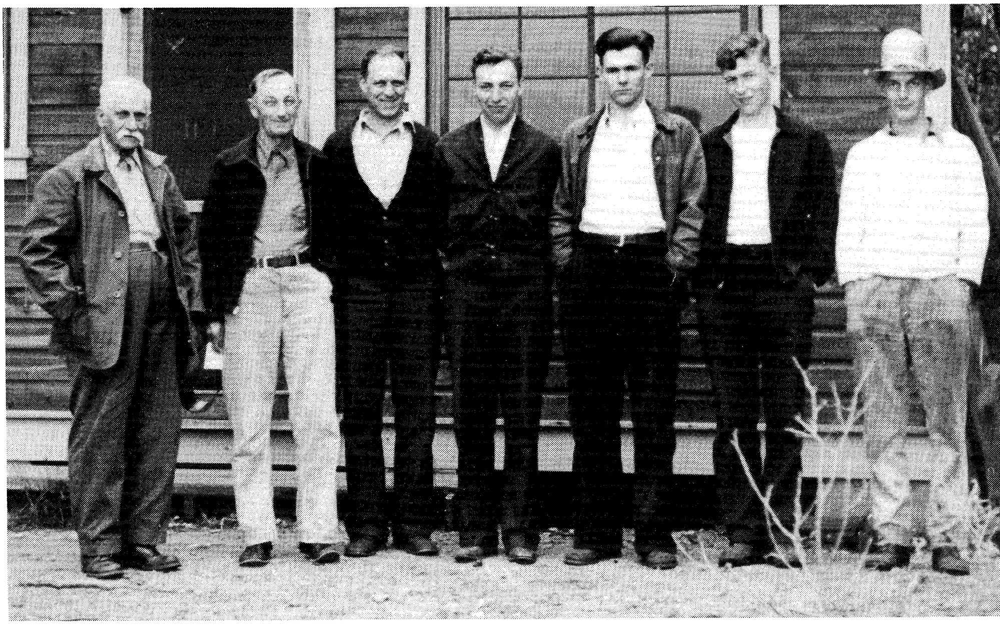

Fig. 13. The Trout Lake Crew in the summer of 1935. (L to R): E. A. Birge, C. Juday, Lester Whitney, Delmont Lohuis, John Curtis, Martin Baum, Richard Juday. Source: Robert Pennak.

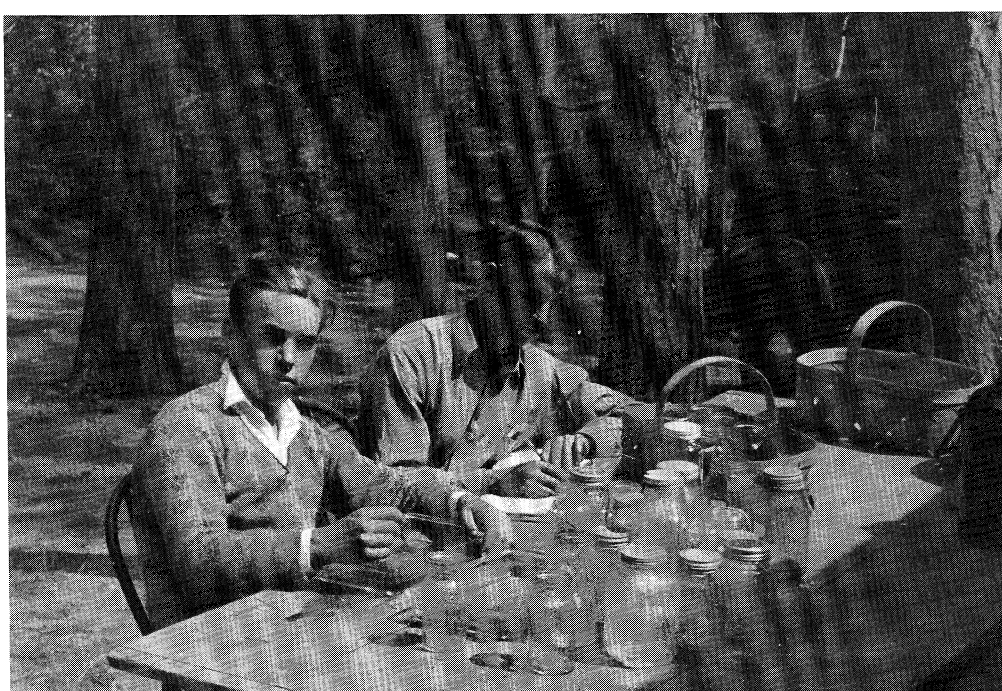

Fig. 14. Robert Pennak and Al Dimond counting benthic fauna, Trout Lake Station, 1937. Source: Robert Pennak.

Fig. 15. The Trout Lake Crew in the summer of 1938. Back row (L to R): Robert Pennak, Lester Whitney, Paul Conger, Herbert Stecker, Richard Juday, Gerald Prescott, L. R. Wilson, Willard Van Engel, and Nelson Rogers. Front row (L to R): Francis Davis, Donald Farner, Winston Manning, C. Juday, E. A. Birge, George Clarke, and Gillette. Source: State Historical Society of Wisconsin.

Fig. 16. Trout Lake Station about 1940. Source: Charles Kirkpatrick.

Fig. 17. Part of Trout Lake Crew in 1940. (L to R): Charles Moore, Vincent McKelvey, Genevieve McKelvey, unidentified, Gail Kirkpatrick, John Potzger, and Fred Granburg. Source: Charles Kirkpatrick.

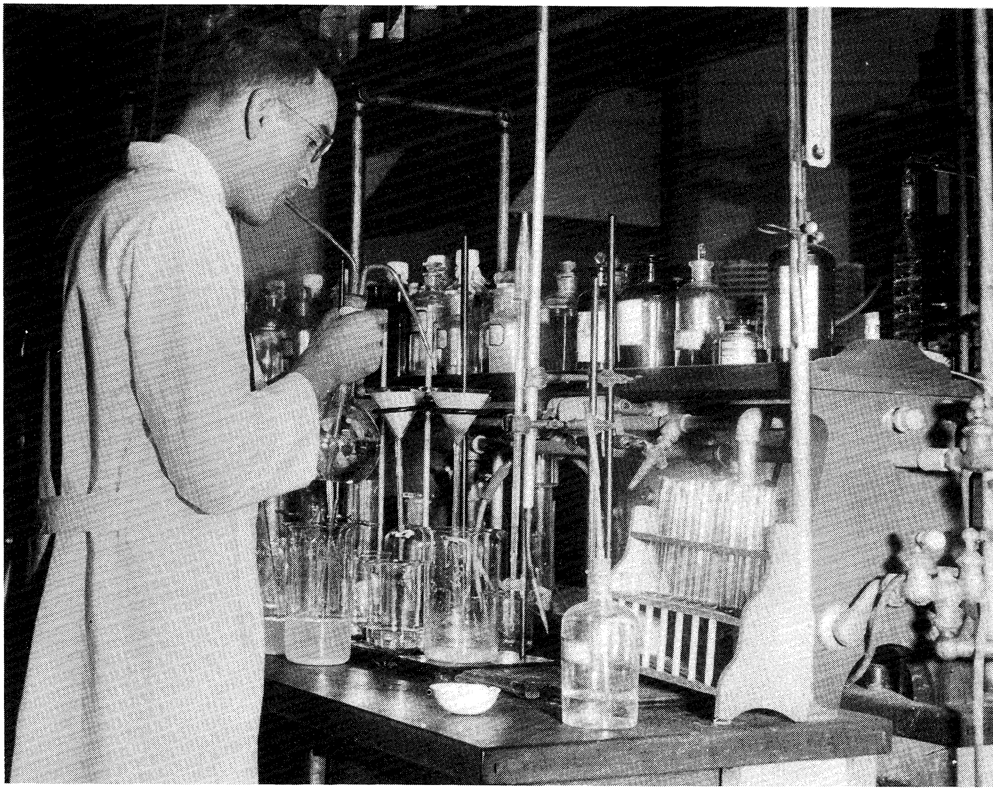

Fig. 18. Arthur D. Hasler at U.S. Fisheries Service Laboratory in Yorktown, Virginia, 1936. Source: Arthur Hasler.

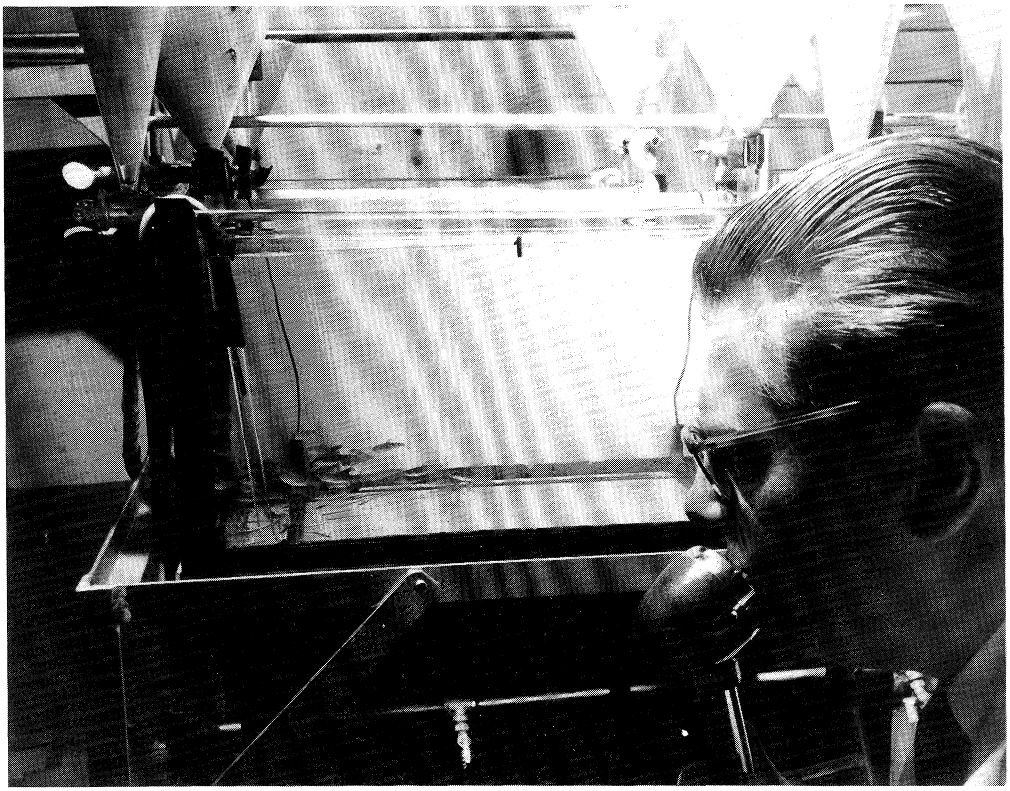

Fig. 19. Warren Wisby training bluntnosed minnows to identify the water from different Wisconsin rivers by the sense of smell, about 1951. Positive training is by food reward; negative, by mild electrical shock. This work on behavior by smell led to studies of olfactory imprinting in homing salmon. Source: Arthur Hasler.

Fig. 20. Fritz Hasler, A. D. Hasler's son, sprays fluidized $Ca(OH)_2$ hydrated lime or calcium hydroxide on Peter Lake to alkalize the water and precipitate the bog colloids that reduce water clarity, about 1952. The adjoining Paul Lake serves as the untreated reference lake. Peter and Paul Lakes are in the University of Notre Dame Environmental Research Center in Michigan. Source: Arthur Hasler.

Fig. 21. William R. Schmitz and A. D. Hasler at Saw Mill Pond on the Guido Rahr Property adjacent to the University of Notre Dame Environmental Research Center, about 1956. They are studying the possibility of using air bubbles to "turn over a lake," that is, disturb the stratification of the lake and thereby aerate it. The air tube goes the full length of the lake. Source: Arthur Hasler.

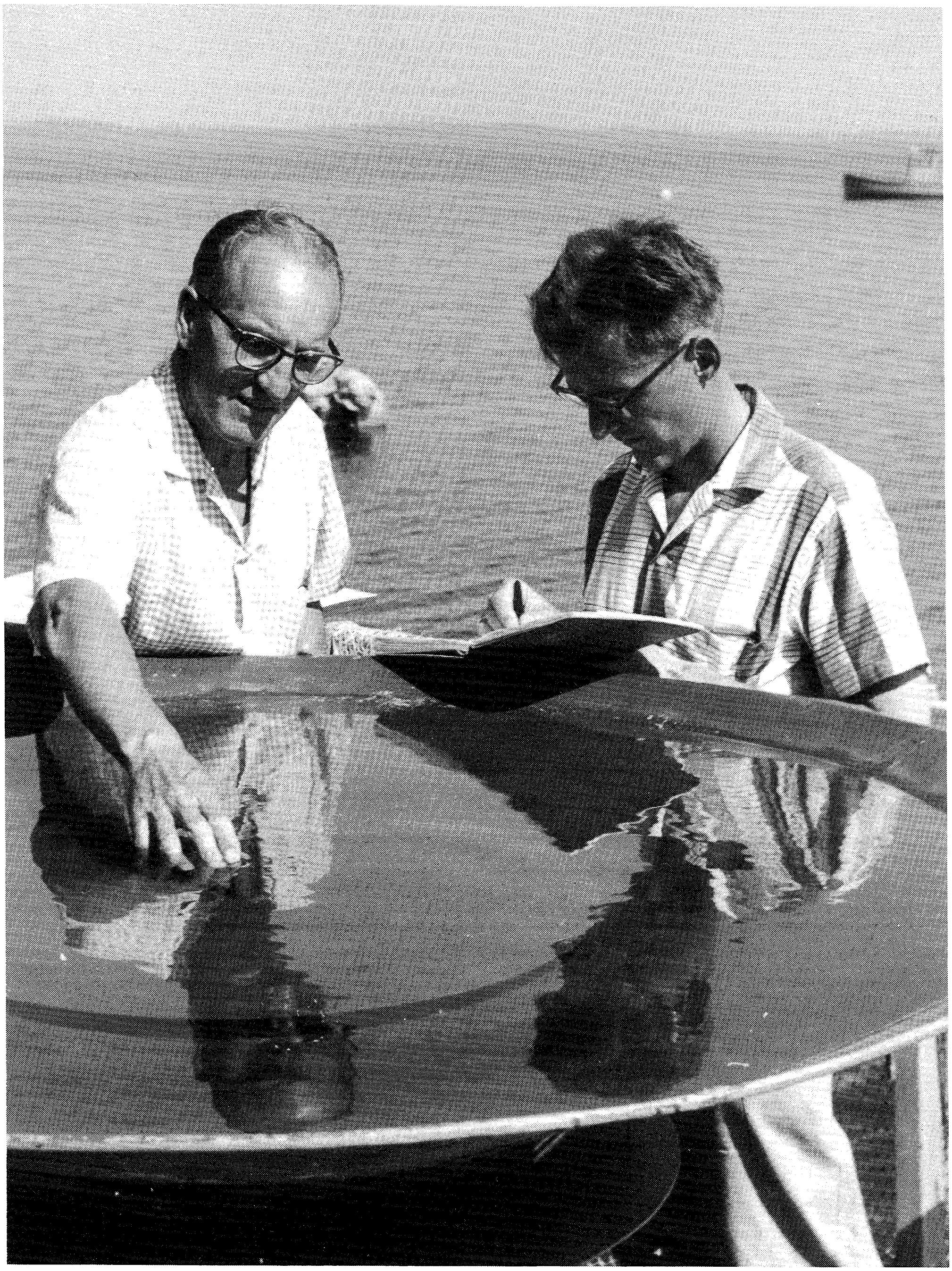

Fig. 22. A. D. Hasler and Wolfgang Braemer, a German ethologist from the Max Planck Institut, studying sun-compass orientation in fish, about 1957. Fish were placed in the center of the tank and trained to enter only the northerly compartments. The shade, peace, and quiet of a chamber were the rewards. Electric shock was given if incorrect direction was taken. Source: Arthur Hasler.

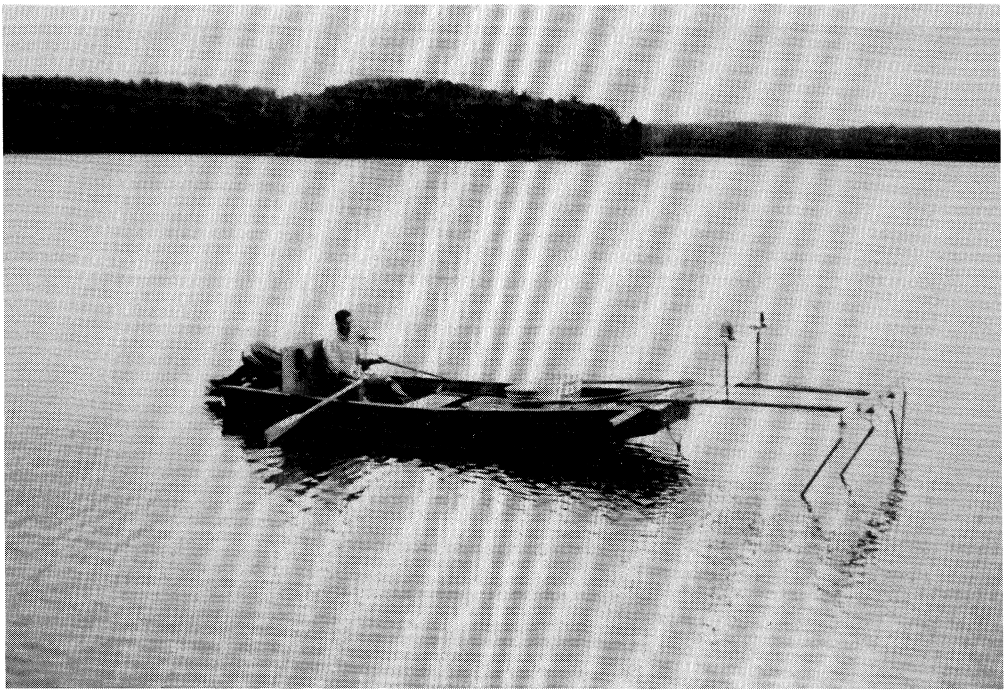

Fig. 23. William Helm and Wisconsin's first operational boom shocker, 1958. The shocker was built by Helm and was used for his walleye studies on Little John, Erickson, and Sparkling Lakes in northcentral Wisconsin. Source: William Helm.

Fig. 24. Physicist John W. Anderegg, Gene Likens, and A. D. Hasler on Cather Lake in northern Wisconsin about 1961. Anderegg is holding a scintillation counter used for the detection of isotopes in a study of the movement of radioactive nuclides from the bottom of a stratified lake. Source: Arthur Hasler.

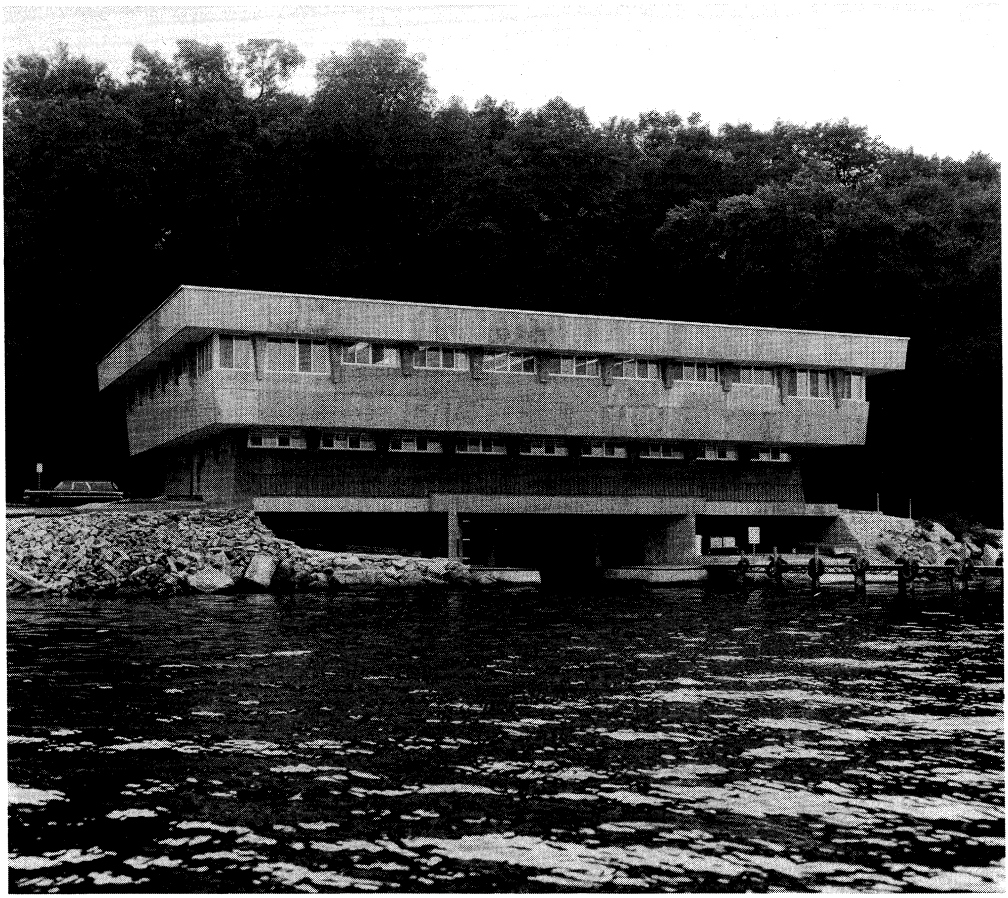

Fig. 25. The Limnology Laboratory on Lake Mendota shortly after it was built in 1963. The building was designed by architect William Kaeser. Source: Arthur Hasler.

Fig. 26. Limnology Laboratory Crew in 1964. Back row: Clyde Voigtlander, Allan Kingsbury, Don McNaught, Erich Schwartz, John Williamson, Tom Wright, Ed Gardella, Jim Bruins, Pete Wall, Paul Sager, Phil Doepke, Nick Lenz. Second row: Gary Hergenrader, Kenton Stewart, Jonce Sapkarev, Ken Maleug, Fran Henderson, Gerald Chipman, Andy Dizon, David White. Front row: Arthur Hasler, Mits Teraguchi, Arne Salli, Henry Eichhorn, Tom Wirth, Russell Dunst, Mike Parker. Source: Arthur Hasler.

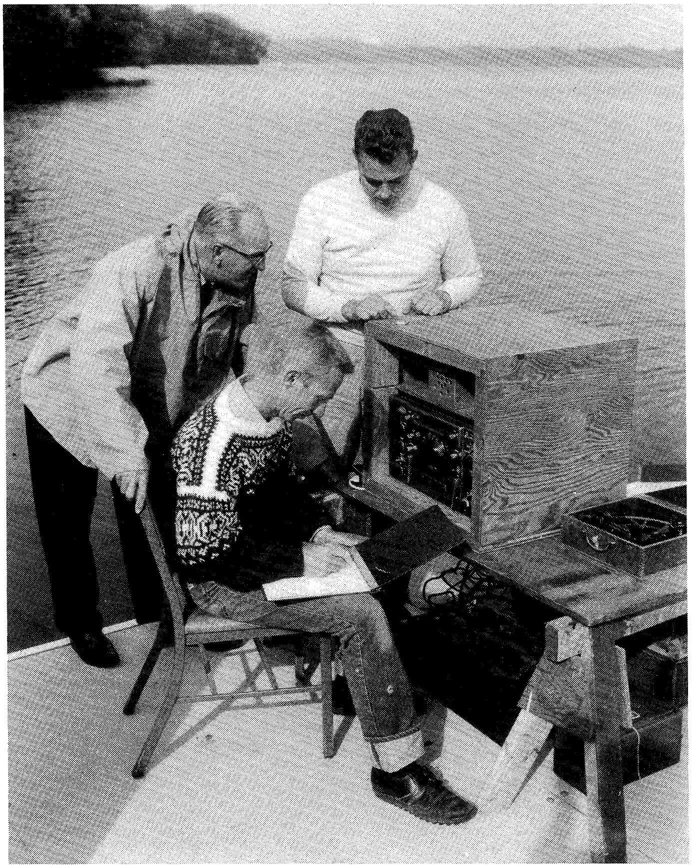

Fig. 27. A. D. Hasler, Francis Henderson, and Gerald Chipman tracking fish that have been released with electronic transmitters in Lake Mendota, about 1965. Source: Arthur Hasler.

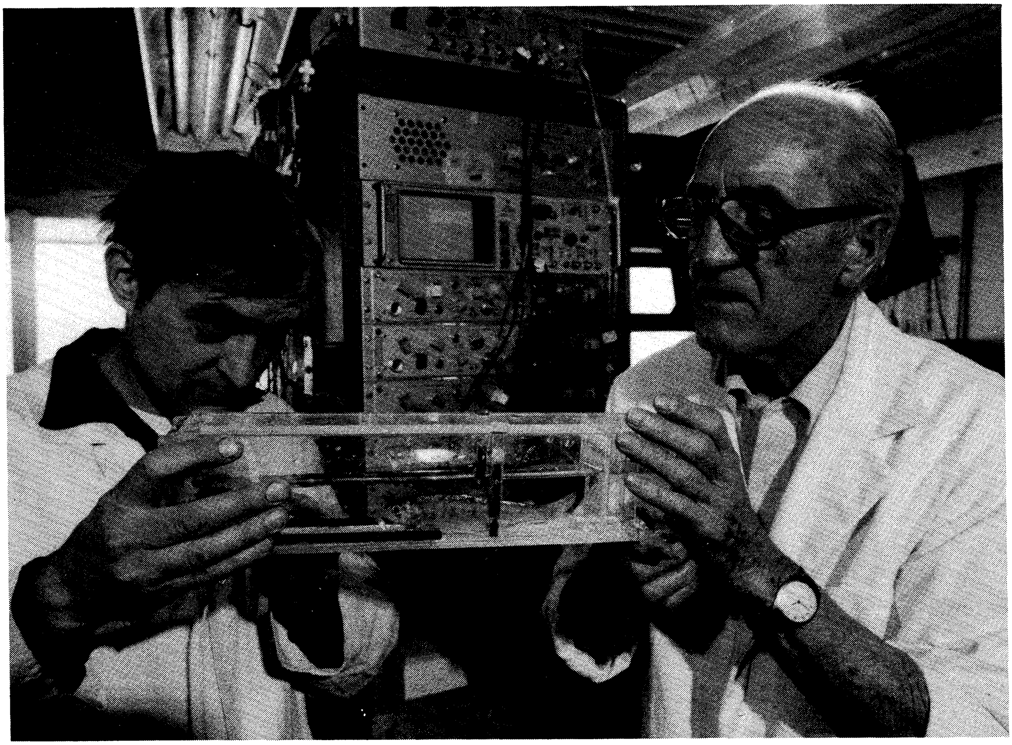

Fig. 28. Peter Hirsch and A. D. Hasler conditioning the hearts of fish to electric shock, about 1976. When one odor is presented the fish receives an electric shock; it receives no shock when a second odor is presented. After the fish is trained, it is possible to determine when it detects the odor because its heart stops beating. This technique is thought to have greater validity than direct electronic monitoring of the olfactory bulb. Source: Arthur Hasler.

Fig. 29. Participants in the 1983 "History of Limnology in Wisconsin" conference with the Trout Lake Laboratory in the background. First row: Arthur D. Hasler, Walt Haag (Center for Limnology facilities manager). Frank Egerton (UW Parkside science historian), Annamarie Beckel (CFL assistant researcher), Thomas Frost (CFL Associate Director for the Trout Lake Station), Robert Ragotzkie (former student of Hasler), Paula Barbian (CFL research specialist). Second row: John Magnuson (CFL Director), Robert Pennak (former student of Juday), Gail Kirkpatrick, L. R. Wilson (former associate of Birge and Juday), Edward Schneberger (former student of Juday), Gerald Prescott (former associate of Birge and Juday), Herbert Dutton (former associate of Juday). Third row: Jean Lang (University-Industry Research Program), Carl Bowser (UW Dept. Geology and Geophysics), David Frey (former student of Juday), Charles Kirkpatrick (former associate of Juday), William Helm (former student of Hasler), Fredrick Stare (former associate of Birge and Juday), Timothy Kratz (CFL associate scientist), Richard Juday (son of Chancey Juday). Not shown: William Schmitz (former student of Hasler), Helen Schneberger. Source: Don Chandler.

Fig. 30. "Old-timers" at the 1983 History Conference. Front row: Robert Pennak, L. R. Wilson, Arthur Hasler, Edward Schneberger, Charles Kirkpatrick, Gail Kirkpatrick, Fredrick Stare. Second row: Richard Juday, Gerald Prescott, David Frey, Herbert Dutton. Source: Don Chandler.

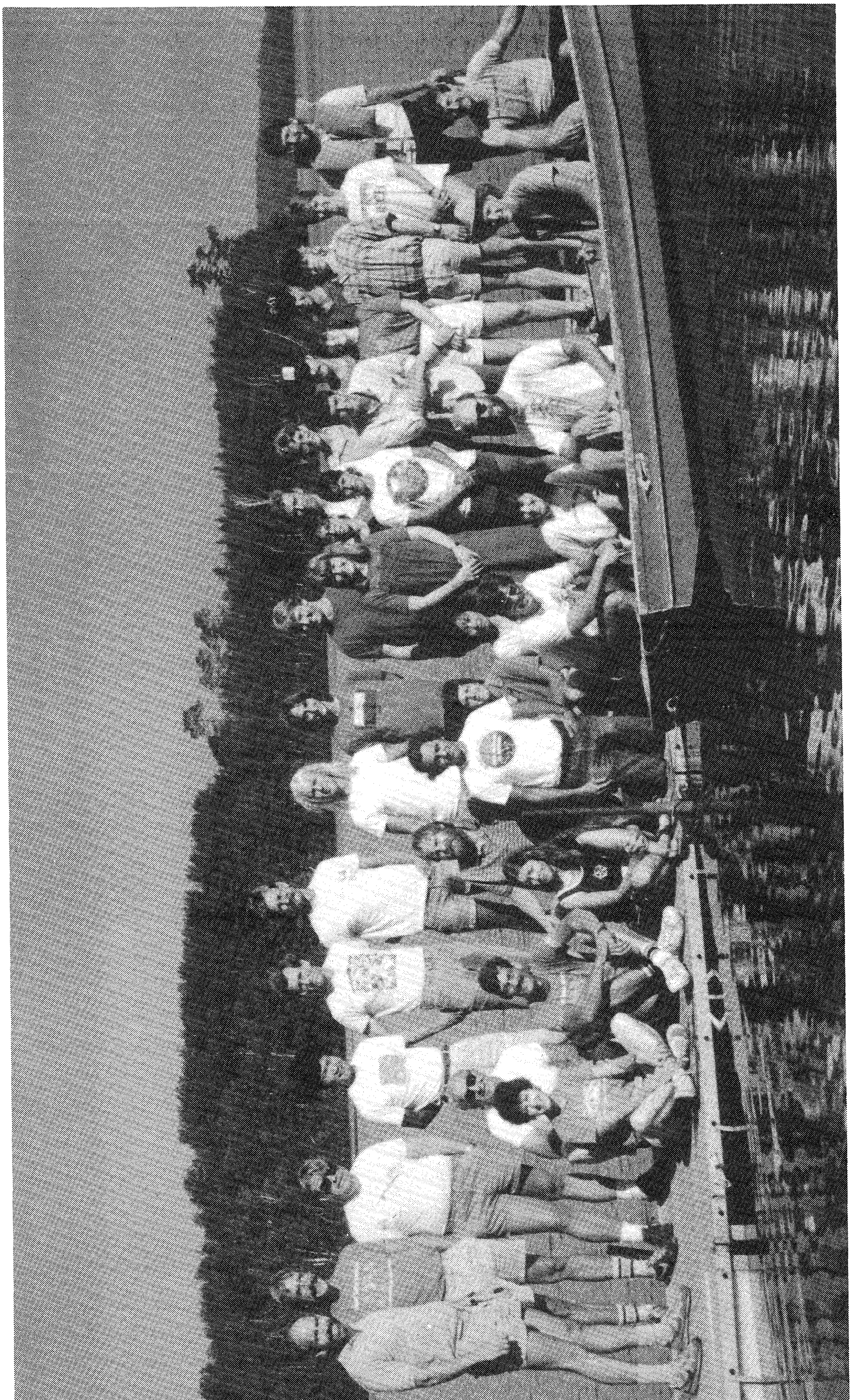

Fig. 31. The Trout Lake crew in the summer of 1987. Front Row: Susan Knight, Walt Haag, Tim Kratz, Joan Elias, Tim Meinke, Dan Schneider, Louise Weber, Yan Zhao, Rick Hanson, Amy McMillan, Malcolm Butler, Doug Lieurance, Ned Grossnickle. Back Row: Tom Frost, Carl Watras, Ken Brown, Xi He, Steve Klosiewski, Christer Bronmark, John Morrice, Robert Walasek, Erik Schoff, Annamarie Beckel, Emily Greenberg, Michelle Marron, Dave Benkowski, Amy Finley, Mark Kershner, Dave Simon, Lauren Elmore, Ned Haight, Robert Wood, Pat Charlebois, Tim Simonson.

Fig. 32. Personnel at Lake Mendota Laboratory in the fall of 1987. Front Row: *Maria Gonzalez, Dan Schneider, Jim Yasko, Barbara Benson, Gerald Chipman, Joyce Tynan, Dennis Heisey, Redwood Nero, Dale Robertson, John Post, Dave Benkowski, Pat Sanford, Paula Barbian, Linda Holthaus, Rob Striegl, Jim Kitchell, Xi He, Don Stewart, Cliff Kraft.* Back Row: *Jo Temte, Mike Vanni, John Magnuson, Dave Egger, Glen Lee, Myriam Ibarra, Jennifer Twomey, Terry Schenck, Mary Smith, Barry Johnson, Mike Miller, Muhamed Alam, Connie Linehan (hidden), Greg Slater, Steve Carpenter, Charoen Nitithamyong, Cindy Lunte, Jay Nelson, Rusty Wright, Tom Frost, Mike Jech, David Hill, Paul Jacobson.*

5 The Wisconsin Limnology Community

Frank N. Egerton

The Wisconsin limnology community appears to have been foremost in America throughout this century. This chapter focuses upon the development and operation of this community during the periods in which it was run first by Edward Asahel Birge and Chancey Juday and then by Arthur Davis Hasler. Unlike the previous chapters, which dealt primarily with how the participants themselves viewed their own experiences in the Wisconsin limnological school, this chapter takes a more analytical and sociological approach to investigating the development of a scientific community.

Although historical studies published in the past two decades leave us much better informed than previously about the history of ecology (Egerton 1977, 1983–1985, McIntosh 1985), much of the history of ecology for the twentieth century has yet to be written. Writing it is a formidable task because of the diffuseness of the science and the sheer volume of contributions from ecologists. One needs a definite point of view. The one used here—the history of a scientific school—provides not only a point of view, but also yields some different conclusions than earlier historical accounts of the Wisconsin limnological community.

The three basic requirements for a cohesive scientific community are scientists, ideas, and resources—both financial and material. Any active group of scientists will possess all of these, but to transform a group into a scientific community, one or more of the scientists must provide a coherent research program that the group follows. To understand a particular scientific community, one must discover the important characteristics of its scientists, ideas, and resources. These basic attributes are so different in the Wisconsin limnological community under Birge and Juday and under Hasler that one could argue they were different even though the Hasler community grew out of the Birge and Juday tradition. The Birge-Juday period is already fairly well known from earlier historical accounts. The Hasler period is less well known. Fortunately, I am able to draw upon Hasler's memories as a resource. For these two reasons I devote more discussion to the Wisconsin school under his direction than under Birge and Juday's.

Ronald Tobey has already used effectively this approach of focusing on a scientific community to write the history of "the first coherent group of ecologists in the United States, the grassland ecologists of the Midwest" (1981: 5). However, it was not just grassland ecology that arose in America's Midwest but also terrestrial animal ecology and limnology. Price (1963) has argued that it is easier for new sciences to arise in young universities than in older ones, where the funds for science are already committed to established sciences. In the 1890s, when the ecological sciences arose, eastern universities were decades, if not centuries, older than midwestern ones. Not surprisingly, then, limnology arose in the Great Lakes states. The science was not stimulated by proximity to the Great Lakes, however. Investigations on large lakes require more elaborate and expensive equipment than those on smaller lakes, and when a science gets started, research budgets are usually limited (Beeton and Chandler 1963: 537). It was the numerous small lakes in the glaciated areas of these states that first challenged America's limnologists.

A historian of a limnological community in North America starts off in a better position than did Tobey when he began work on the history of American plant ecology, because American limnologists have already written a partly historical assessment of their science (Frey 1963a). The occasion for doing so was the meeting in Wisconsin of the 15th Congress of the International Association of Limnology held in 1962. The initiative for writing *Limnology in North America* came from David G. Frey and Arthur D. Hasler, both former graduate students at Wisconsin. Frey wrote the first chapter, "Wisconsin: The Birge-Juday Era" (1963b), and Hasler the second, "Wisconsin, 1940–1961" (1963a). No other state is accorded two chapters and most of the chapters encompass several states. Because *Limnology in North America* was published by the University of Wisconsin Press and its publication was arranged by two limnologists who received doctorates from that state's university, one may wonder if the history of limnology in Wisconsin received preferential emphasis. A Wisconsin historian is not the best judge of the matter, but I can point out that the Congress was held in this state in recognition of the achievements of the Wisconsin limnological school.

Scientists in Michigan, Illinois, Indiana, and Ohio also produced important early contributions to limnology. Michigan and Illinois are given chapters in the book, but Indiana and Ohio are lumped together into a regional chapter with Tennessee, Kentucky, and West Virginia (Gerking 1963). Judging by the book's space allocations, only Illinois and Michigan rate serious consideration as early rivals for leadership with Wisconsin. If Illinois is compared with either Wisconsin or Michigan in this respect, it is rather like comparing prairie ecology at the Universities of Nebraska and Chicago, the one being in the midst of the prairie and the other on its edge. In Illinois rivers are much more prominent than lakes, and, correspondingly, limnology was oriented toward rivers (Gunning 1963). On the other hand, both Michigan and Wisconsin have numerous lakes formed by glaciers. Michigan's limnological work seems to be the strongest rival to Wisconsin's (Chandler 1963, Robertson 1976). The early differences in limnology at Michigan and Wisconsin are not easily summarized, but in the long run Wisconsin distinguished itself under Birge and Juday by emphasis on energy budgets of lakes and under Hasler by emphasis on experimentation.

The Birge-Juday Period

Tobey (1981) is undoubtedly correct in seeing the relative success of different scientific communities as due to a combination of intellectual, social, and other factors. When one evaluates these factors in plant ecology, Frederic E. Clements, the founder of the Nebraska school, does not seem to have had a suitable personality for founding a scientific community. He lacked an outgoing personality; he had no charisma. He was absorbed in his research, and after a decade of teaching he exchanged his academic career for one as a full-time research scientist at the Carnegie Institution of Washington. Clements was, however, probably indispensable as founder of the Nebraska community of prairie ecology, and his publications dominated the outlook there for four decades. Yet, it was his student and collaborator, John Weaver, who did most of the training of the other students, without whom there might have been a Nebraska collaboration, but no cohesive community.

With regard to the characteristics of its founder, the situation in limnology at Madison, Wisconsin, was not very different from that in plant ecology at Lincoln, Nebraska. The founder of the Wisconsin school of limnology was Edward A. Birge, whose career indicates that he also was more absorbed in research and administration than in teaching. His personality was as stiff as Clements'. Although he never left the university, when opportunity came, he did leave the classroom (in 1911) for various administrative posts, including, finally, the presidency of the university (Sellery 1956). He apparently also lost interest in training biologists. Lowell E. Noland, while a graduate student in zoology, worked one summer as Birge's research assistant at Trout Lake, and in the fall back in Madison, Birge would walk by him with no sign of recognition (pers. comm.).

Birge began his career as an invertebrate zoologist. He had gone to Williams College in 1869 to prepare for medical school, but stayed on after receiving his B.A. degree to earn a M.A. degree in science. He went to Harvard for his doctoral degree, where he was Louis Agassiz's last student, though Agassiz died shortly after Birge arrived. Although one might argue that Agassiz had established a comparative zoology community at Harvard, virtually all of his students defected from Agassiz's Cuverian paradigm to some form of evolutionary biology. Moreover, with Agassiz past his prime, whatever community of zoology he had once held together had all but disappeared before Birge arrived (Dexter 1965, 1974, 1979). Birge certainly learned some zoology from him, but he must have learned little or nothing about running a scientific community.

Birge's studies on invertebrates in Lake Mendota led him as easily into limnology as had similar studies on Lake Geneva led François A. Forel into this science several decades earlier (Egerton 1962, 1978). Although Forel spent practically his entire career teaching anatomy and physiology to premedical students at the Académie de Genève in Lausanne and never trained limnologists, he is the true founder of this science. His great study on all aspects of science concerning Lake Geneva (1892–1904) may still be the most exhaustive monograph on any lake in the world. He realized, however, that beginning students could not be expected to read his three large volumes; he therefore published the first textbook on limnology (1901).

Tobey attributes the distinctive character of prairie ecology in Nebraska in part to Clements' attempt to adapt the methods that C. G. Oscar Drude used in the forests of Germany to the prairies of America. Birge faced a less dramatic challenge in his transfer of Forel's methods to Wisconsin lakes, although in his long scientific career Birge would have plenty of opportunities to develop new methods and equipment.

Just as Clements' publications dominated American plant ecology from the early 1900s until World War II, so Birge's dominated American limnology during the same period. And, as Clements had Weaver to train disciples, so Birge had Chancey Juday. Of course, there were differences as well as similarities between the situations at Nebraska and Wisconsin. Juday was not one of Birge's students. He had studied limnology at Indiana University under Carl Eigenmann and had then come to Madison in 1900, with only a master's degree, as Birge's assistant and collaborator. In 1908 he visited European universities and field stations engaged in hydrobiological research (Juday 1910), which was for him "a great stimulus, an insight into the newer approaches in European limnology, and contact with the leading men in the field" (Noland 1950: 96).

Both Birge and Juday, in the development of their limnological interests, made the same kind of progression that Forel had, from a strong interest in the invertebrate life in lakes, to the quest for the factors controlling those life forms, particularly the physical and chemical attributes of lakes (Mortimer 1956, Frey 1963b). The shift in emphasis was gradual and never led to abandonment of their earlier interests. The turning point seems to have been Birge's masterful presidential address to the American Microscopical Society in July, 1903, on "The Thermocline and Its Biological Significance" (Birge 1904). Although he did not discover the thermocline, by measuring the temperature of lake waters at different seasons of the year, Birge made the first thorough study on the thermocline and the mixing of waters in spring and fall in lakes in temperate climates. He also explained the implications of temperature stratification for the life of lakes. He, Juday, and their collaborators also studied light penetration, dissolved minerals, and hydrogen ion concentration in the lakes of Wisconsin.

Unlike Clements, Birge did not develop a comprehensive theory to guide his research and that of his co-workers and thereby provide intellectual cohesion for the Wisconsin community. One reason the early differences between the Wisconsin and Michigan schools of limnology are not very obvious is that in America limnology did not develop the theoretical polarity that Tobey claims distinguished the Nebraska and Chicago communities of prairie ecology. Nevertheless, Birge and Juday had a definite research agenda. They, with their research associates and students, took an inventory of the environmental factors that prevailed in the Wisconsin lakes, and they monitored various environmental factors at different lakes for various periods. Their late emphasis upon the energy budgets of lakes constitutes, if not a theory, at least a theoretical perspective.

Birge never had doctoral students; he did supervise the thesis research of two or three dozen candidates for the bachelor's degree and also those of a few candidates for the master's degree. Juday began lecturing in limnology in 1909. However, he might never have advised graduate students had not his position with the Wisconsin Geological and Natural History Survey been eliminated entirely during the Depression year of 1931. Subsequently, Birge was able to have him appointed to a professorship in zoology at the university. The research on which Juday collaborated with Birge was more than equivalent to writing a doctoral dissertation, and in 1933 Indiana University bestowed upon him an honorary doctoral degree.

Juday was to supervise the doctoral research of 13 graduate students (listed in the appendix). One of them, Robert W. Pennak, later dedicated his *Fresh-Water Invertebrates of the United States* (2nd ed., 1978) "To the memory of C. Juday." It may seem surprising that a leading community of limnology produced only 13 doctorates in its first four decades. However, this is at the same rate doctorates in prairie ecology were being graduated from the University of Nebraska during the same period (Tobey 1981: 120–121). Had either university produced two or three times as many, some of them would have had difficulty finding suitable jobs. The Depression was a bad time to be a graduate student or to look for employment.

An ecology community that produces only 13 doctorates in four decades may be respectable, but is it a leading community? The minimal requirement of a leading scientific community is probably that it produces both outstanding students and outstanding scientific contributions. The quantity of both need not be great, but surely it is unusual for a leading scientific community not to produce a high number of either students or publications. The Wisconsin limnological group in the Birge-Juday period was very productive in publications. Since its productivity in students was not high, how did it manage to be so productive in research? High productivity is usually a result of having many students engaged in publishable research. Birge and Juday's great industry and commitment to research were important, but not sufficient to account for all the papers that were published. If students did not do a large portion of the research as thesis projects, who did? Some of it was done by hired student assistants, such as Noland who worked for Birge that summer at Trout Lake. However, a large portion of it was done by other scientists, mostly on the faculty of the University of Wisconsin, but some hired briefly by the Wisconsin Geological and Natural History Survey, and later by the Works Progress Administration.

The Wisconsin limnological school under Birge and Juday was probably very atypical of successful scientific groups. Until 1925 the community was small and not very cohesive. There was a Birge-Juday research partnership and occasional graduate students whose limnology-related dissertations were supported by the Wisconsin Geological and Natural History Survey. Examples of this type of work include research done by Smith, Rickett, and Schuette.

The study of lake algae began in the 1910s and 1920s when Gilbert Morgan Smith (b. 1885) compiled lists of algal species found in Wisconsin lakes for the Wisconsin Geological and Natural History Survey. Smith's interests were not limited to taxonomy, however, as indicated in his study of "The Vertical Distribution of Volvox in the Plankton of Lake Monona" (1918). He was from Beloit and received his B.S. degree from Beloit College in 1907. He took his Ph.D. in botany from the University of Wisconsin in 1913, and was a member of the botany faculty until he left for Stanford University in 1925.

Harold W. Rickett (b. 1896) received his bachelor's, master's and doctor's degrees from the University of Wisconsin and stayed on two years as an instructor before leaving for the University of Missouri in 1924. While at Wisconsin, he published quantitative studies on the larger aquatic plants in Lake Mendota and Green Lake (1920, 1921, 1924).

Henry A. Schuette (1885–1978) was from Green Bay, educated in chemistry at the University of Wisconsin, and was a member of the university's chemistry faculty for his entire career. He wrote a doctoral dissertation on the biochemistry of plankton in Lake Mendota (Ph.D. 1916, dissertation published in 1918) and retained a research involvement in the biochemistry of aquatic plants for another decade (Frey 1963b: 30, 52) before turning to his main researches on the biochemistry of human foods (Ihde 1978).

The addition of such studies to the work of Birge and Juday added to the intellectual foundation for a scientific community. However, more was needed before one could say that a community existed.

Most university professors give up research in their discipline when they become administrators. Those who do not generally conduct research at a lesiurely pace. The fact that Birge could continue his research even while president of the university (1918–1925) is probably owing to his long years of working with Juday. During these years Birge could have merely discussed what needed to be done with Juday and depended upon the latter to carry out the actual work, with Birge stepping in again to assist in evaluating the results and writing the papers for publication. When Birge retired from the presidency on September 1, 1925, six days before his 74th birthday, he and Juday had won a distinguished reputation for the scope and quality of their work. If Birge had rested on his laurels and played bridge and shuffle board for the rest of his life an outstanding limnological community at the University of Wisconsin might never have come into being.

Once free of other responsibilities, however, Birge's research ambitions were far greater than he and Juday alone could ever accomplish. The conventional way to satisfy such ambitions is for a professor to attract graduate students to share in the research. This avenue was not open to a retired professor, however, and apparently he had not yet thought of having Juday made a professor. The high quantity and quality of scientific papers that the Wisconsin limnological school ultimately published required the participation of many experienced scientists. Such an aggregation could seldom have been assembled anywhere before World War II because of financial constraints. A university professor ordinarily could not build a very large "empire" on campus because he could not provide the financial and social incentives to lure colleagues away from the priorities established within their own disciplines.

What incentives could Birge offer his colleagues that were strong enough to enable him to build a much larger "empire" than was commonly possible? As an eminent retired scientist/administrator, he continued to have considerable influence within the university, and collaboration with him might enhance one's career. Furthermore, he could provide research funds, equipment, and facilities. Although the Carnegie Institution of Washington began supporting ecological research early in this century (Colin 1980, McIntosh 1983), it supported the work of only a few scientists. During those years the federal government mainly supported research done by its own scientists (Dupree 1957). The research of science professors at state universities was usually supported with state funds, which were seldom ample. Although Birge was on record as opposed to any university policy favoring one department to the detriment of another (Sellery 1956: 19), his impartiality must not have applied to competition for research funds. His clout as an administrator apparently was used to channel a disproportionate amount of university funds into limnological research.

Even so, these university funds were not enough to satisfy the needs of his research program. Therefore, he came to dominate two other state institutions that could provide additional funds: the Wisconsin Academy of Sciences, Arts and Letters and the Wisconsin Geological and Natural History Survey. The Academy is a private organization, the Survey, a state organization. Birge was director of the latter from its establishment in 1898 until funding for the Natural History section was discontinued in 1931. He thus controlled both the research and publication funds of the Survey, and he was the heaviest user of the publication funds of the Academy.

In 1925, after retiring, Birge established a limnological research station in northern Wisconsin at Trout Lake, where he and Juday conducted much of their own summer's research, and where they brought both graduate students (often in non-biological sciences) and visiting scientists to conduct research. Some of his colleagues in Madison believed that Birge decided to establish the station in northern Wisconsin so that he could study lakes and their life away from human pollution. The pleasant summer climate at Trout Lake must have been encouraging. More importantly, Birge and Juday had already studied intensively several lakes in southern Wisconsin. The major attraction of northern Wisconsin was the great variety of pollution-free lakes. By conducting extensive surveys there they were hoping to find general principles that would apply to all lakes. For some of these researches they tapped still another new source of funding, the Wisconsin Conservation Department.

The University of Wisconsin was not a pioneer in establishing a limnological research station. In fact, it was rather much slower than neighboring states in doing so. The university's Madison campus is located on one lake and near a string of others. Because these lakes were fully utilized by limnologists from the earliest days of Birge, it would have been difficult to make a compelling case to the university administration for building student facilities at Trout Lake. Even now, the summer courses in limnology are taught in Madison. Thus, the Trout Lake station has always been exclusively for research. At times, this meant that the university administration felt less concerned for its fate than it might have if the station had been a teaching facility. On the other hand, the facilities there probably accommodated more research scientists than would have been convenient if its existence had ever been justified on the basis of a teaching mission.

Frey (1963b: 29) surveyed the productivity of this school from 1924 to 1944 and found that

> during this interval more than 260 papers were published by the Wisconsin group and their associates. The peak came in the late '30's and early '40's, with as many as 34 papers listed for a single year (Juday and Hasler, 1946). During this period the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* were dominated by the enormous and varied limnological output of this group of limnologists, sometimes to the virtual exclusion of other studies.

This domination was achieved at the cost of some colleagiality. The university's Professor of Chemistry and History of Science, Aaron J. Ihde, recalls that (pers. comm.)

> the limnologists created a bad storm in the Academy because they virtually monopolized the *Transactions,* to the exclusion of the papers of members in other areas. I remember caustic remarks at the time and the dissent probably forced the limnologists to eventually publish elsewhere. Birge was, of course, still active and no one in the Academy was anxious to cross swords with him. However, 34 papers in one volume was too much for even the timid academicians.

The involvements of the faculty members ranged from one-time to long-time. Most of them established reputations independently of the limnological community, but a few were known primarily for their work with the group. Some of these collaborations are discussed briefly by Frey and are also indicated by the authorships and acknowledgements of the papers listed in Frey's "Wisconsin: The Birge-Juday Era" (1963b: 44–54). It will suffice here to discuss briefly some of the more important collaborators in order to indicate the nature of their involvement with the limnological community.

The Botany Department evidently regretted losing Rickett, whom it had trained in the study of aquatic vascular plants, because in 1925 it hired another with this specialization: Norman C. Fassett (1900–1954), from Massachusetts; his degrees were all from Harvard. Fassett's *Manual of Aquatic Plants* (1940; 2nd ed., 1957) became the standard work on the subject for North America. Fassett had "a forceful and stimulating personality," and he devoted much time and care to building up the university's herbarium (Bean et al. 1954). Another botanical collaborator who enjoyed a national reputation was John T. Curtis (1913–1961). From Waukesha, he received his bachelor's degree from Carroll College in 1934 and his Ph.D. from the University of Wisconsin in 1937. His interests were broad, and when he worked with Juday in 1935 Curtis was a plant physiologist. However, during and after World War II, Curtis' interests shifted to plant ecology. His *Vegetation of Wisconsin* (1959) remains a classic, both for its accurate picture of Wisconsin's vegetation and as a model for other studies (Cottam *et al.* 1961, Stearns 1961).

In bacteriology, the limnologists were able to attract the collaboration of the remarkable Edwin B. Fred (1887–1981) long enough to get four papers published in 1924–1925 concerning the ecology of lake bacteria, but Fred was too busy with his own scientific and administrative goals to be absorbed for long into someone else's group (D. Johnson 1974). However, as Dean of the Graduate School (1935–1943) Fred was in a powerful position to assist administratively with Birge and Juday's research. Furthermore, Fred's student, Elizabeth McCoy (1903–1978), who became his colleague and sometimes his collaborator, occasionally became actively involved with the limnological school from the 1930s onward. She was a native of Madison and owned a farm on the banks of Lake Monona. Her concern for preserving Wisconsin's lakes and streams motivated her to continue research on lake bacteria even after her retirement. Her value as a collaborator is indicated in this judgement from her colleagues: "It is doubtful that anyone can match Elizabeth McCoy's breadth and depth of knowledge about microorganisms and their activities" (Bennett *et al.* 1978).

The limnologists had a number of important chemistry collaborators. George I. Kemmerer (1879–1928), from Janesville, was motivated to collaborate, in part at least, by his lifelong interest in "the application of scientific methods in the study of problems related to fish and game conservation" (Mathews *et al.* 1928, Ihde 1975). William H. Peterson (1880–1960), a professor of biochemistry, came to the University of Wisconsin after receiving his master's degree from Columbia University in 1909. He then taught chemistry to home economics students while earning his Ph.D. from the university in agricultural chemistry. He is best known for his long-time collaboration in research with E. B. Fred. He was also the dissertation advisor to more than fifty doctoral students. He published, either alone or in collaboration, more than 300 scientific papers—mostly on the chemistry of microorganisms (Baldwin *et al.* 1960).

One of Peterson's students was Bernhard P. Domogalla (1894–1970), from Milwaukee, who collaborated with Peterson, Fred, and Juday in the mid 1920s in studies on the nitrogen content of lakes around Madison. As a student Domogalla assisted Birge in taking lake temperatures. The story of Birge's notorious instructions to him one winter day is told elsewhere in this volume. Domogalla served as the biochemist for Madison (1924–1946). Because Lakes Mendota and Monona, which are adjacent to the city, began experiencing repulsive algal blooms in summer from eutrophication caused by sewage, Domogalla experimented for eleven years with the application of copper sulfate to the lakes. Copper sulfate was applied by the freight car load in concentrations high enough to kill algae, but presumably low enough to spare fish (Domogalla 1935, 1941, Brock 1985). His researches eventually led to the development of the commercially significant algicide, Cutrine. He occasionally employed university faculty and students for city water research, but by 1943 he was unable to obtain research funds for all his projects. Domogalla therefore employed a familiar Birge tactic and filed excess salary claims for his regular employees and used those funds to hire part-time research personnel. By 1946, when this practice was discovered, the misappropriated funds totaled $1220. He was forced to resign and to donate $3000 worth of his personal equipment to the city in restitution (*The Capital Times,* 18 Dec. 46). He then returned to Milwaukee and opened a biochemical consulting firm (Scott 1970), and was soon advising governments in North and South America on controlling water pollution (*Badger Chemist* no. 5, 1957: 8).

Villiers Willson ("Mel") Meloche (1895–1981) was an active collaborator with Birge and Juday in the 1930s. Their last joint paper appeared in 1941. Meloche was born in Port Huron, Michigan, but in 1905 his parents decided to move to Madison to enable their four children to take advantage of its educational opportunities. All four graduated from the University of Wisconsin, with Mel Meloche receiving three degrees and then joining the chemistry faculty. His involvements with Birge and Juday were similar to those of Kemmerer in the 1920s. Meloche enjoyed working at Trout Lake so much he made his summer home there, and he often had his graduate students come up during the summer and assist in his researches. He supervised the dissertations of 44 doctoral students in chemistry (Ihde 1981).

The geologist who actively collaborated with Birge and Juday was William Henry Twenhofel (1875–1957), a Kentuckian who had received his education at Yale, and who was a member of the Wisconsin faculty from 1916 until his retirement in 1945. He was widely known for his textbooks on sedimentation, and he and his students published a number of studies on the sediments in Wisconsin lakes in the 1930s and 1940s (Bryan *et al.* 1957).

Birge and Juday's main collaborator in physics was Lester Vincent Whitney (1902–1964), who was from Chicago but received his three physics degrees from the University of Wisconsin. He began working with Birge and Juday early in the 1930s and continued to do so after joining the faculty of Southwest Missouri State College in 1937. He studied the transmission of solar heat and light through the waters of Wisconsin lakes. His studies were supplemented by the physics dissertation of Harry Raymond James (b. 1890, Ph.D. 1934; see James and Birge 1938).

Zoologists are absent from the list of collaborators because that was Birge and Juday's area of expertise. Nevertheless, members of the zoology faculty also occasionally were included in limnological projects. For example, Frey's bibliography includes four papers written by Lowell E. Noland (1896–1972), an invertebrate zoologist on the faculty (Burns *et al.* 1972). A potentially valuable member of the Wisconsin limnological school was ecologist Arthur S. Pearse (1877–1956), who taught zoology at the University of Wisconsin from 1911 to 1927 and published eight papers on fish ecology cited by Frey. Although he enjoyed living in Madison, he left in 1927 because he felt that he had been assigned unfairly heavy teaching responsibilities (Pearse 1952: 32–34).

Some of the scientists from other states who worked for one or more summers at Trout Lake published studies that advanced the knowledge of Wisconsin limnology. For example, John E. Potzger (1886–1955), a professor of botany at Butler University, contributed five papers from 1942 to 1944 on the vascular plants along the shores of northern Wisconsin lakes (Frey 1963b: 51, Anon. 1956). Another example is Gerald W. Prescott (b. 1899), who would become well known for his research on North and South American algae. Prescott came to the Trout Lake Station from Albion College and later Michigan State University to study the taxonomy and distribution of algae in relation to the chemical characteristics of the lakes. Leonard R. Wilson (b. 1906), who had been one of Norman Fassett's Ph.D. students, returned to the station from Coe College in Iowa to investigate the distribution and quantity of aquatic plants in northern lakes.

G. Evelyn Hutchinson, who stayed too briefly to make such a contribution, has nevertheless published his recollection of his experience.

> Professor E. A. Birge and Professor Chancey Juday were kind enough to let me spend a week at the Trout Lake Laboratory in Vilas County, in northeastern Wisconsin. I had learned a fabulous amount about limnological technique but had come away with two feelings of dissatisfaction. One was that it would be nice to know how to put all their mass of data into some sort of informative scheme of general significance; the other was that it would be nice to have either tea or coffee, without seeming decadent and abnormal, for breakfast. I now suspect a connection.

The last thought occurred to Hutchinson when reflecting upon Juday's having advised the editor of *Ecology* not to publish Raymond Lindeman's paper on the trophic-dynamic concept because it was based upon insufficient data (Hutchinson 1979: 248; see also Cook 1977).

An important test of leadership for a scientific school is the recognition that its leaders receive from their peers. For Birge and Juday, that recognition is summarized by Frey (1963b: 6):

> Both men were active in national affairs, serving variously as president of the American Microscopical Society, American Fisheries Society, Ecological Society of America, and the Wisconsin Academy of Sciences, Arts, and Letters. Moreover, Juday was one of the persons instrumental in bringing about the birth of the Limnological Society of America, and he was elected president for its first two years. Juday was awarded the Leidy Medal by the Academy of Natural Sciences of Philadelphia in 1943, and Birge and Juday together were awarded the Einar Naumann Medal by the International Association of Limnology in 1950 in recognition of their important and numerous contributions to the field.

The Limnological Society of America was established in 1936; in 1948 it became the American Society of Limnology and Oceanography (Lauff 1963).

Birge retired from teaching in 1911, from the university presidency in 1925, and from his scientific research in 1941; he died in 1950 at age 98. Juday retired from teaching in 1937 and from the directorship of the Trout Lake Limnological Laboratory in 1942; he died in 1944 at age 73. Juday had had to work as long as he could because Birge had never arranged for him to receive any retirement pay from the Geological and Natural History Survey, though he may have received a little from the university. Mrs. Juday, after her husband's death, expressed her displeasure at Birge's neglect by not consulting him on the disposal of Juday's library. She sent his books to the Academy of Natural Sciences of Philadelphia.

The Hasler Period

Arthur Davis Hasler was one of those 13 students who obtained a doctorate under Juday. The continuity of the Wisconsin limnological community from Birge and Juday to Hasler would appear to be, therefore, a routine matter. In reality, it was far from routine, and limnology might well have been a casualty rather than a beneficiary of the transition if the university had hired a less determined and industrious limnologist than Professor Hasler proved to be. Birge and Juday both faded from the university scene just as the country was becoming distracted by World War II, and the post-war years were a period of such comprehensive readjustment that many traditions were discarded in favor of new approaches and new directions. Hasler was shrewd enough to wed the university's old commitment to limnology to new methods, and thereby emerge from the transition period with a stronger program than existed before he took over. To understand how and why this happened we need to examine his early life, education, and professional experience down to the time when he deliberately established his new methods for the Wisconsin limnological school.

He was born a Mormon at Lehi, Utah, on January 5, 1908. No one who knows him doubts his own strong conviction that his pioneering Mormon background provided him with ethical and intellectual values that contributed substantially to his successful career. His boyhood interests were in fishing, raising livestock, camping, nature study, and the Boy Scouts. These interests did not lead him inevitably into limnology, however. While an undergraduate at Brigham Young University he seriously considered following his father's example in becoming a physician and was only deflected from that by the financial constraints of the Depression and an ill father. While considering a medical career, however, he developed a permanent interest in physiology. His major in zoology encompassed both this new subject and also many of his boyhood interests. His broad interests were to be strong assets later when he directed the Wisconsin limnological school.

Having decided that it was financially more expedient to go to graduate school than medical school (in the former he could earn expense money as he studied), Hasler became a graduate student at Madison in 1932. Acting on the advice of A. S. Pearse and Juday, he minored in medical physiology and physiological chemistry. His major was zoology, with emphasis on limnology and the physiology of crustacea.

At the time, there was considerable interest in the food of plankton, especially in whether or not some of these organisms can use dissolved organic matter. Birge and Juday were themselves investigating aspects of the subject (1922, 1934). Juday suggested, therefore, that Hasler undertake his dissertation research on the physiology of digestion in plankton crustacea. Hasler agreed. Despite Birge and Juday's experience on related topics, Hasler performed his research under the supervision of Professor H. C. Bradley, in the Department of Physiological Chemistry. As an undergraduate, Hasler had learned in Professor Wayne Hale's chemistry class of the importance of duplicating experimental findings. Now, under Professor Bradley, it was a routine matter that "the experiments were duplicated and run with controls" (Hasler 1935: 212); routine, that is, in physiology and in physiological chemistry, and routine at certain biological laboratories at Woods Hole, where Hasler spent the summer of 1935 testing the results he had obtained from the fresh-water cladoceran, Daphnia, upon the marine copepod, Calanus (Hasler 1937). Experimental controls and duplication were not routine, however, in the Birge-Juday school.

By 1935, Hasler had had experience with controlled laboratory experiments and uncontrolled field experiments when he assisted Juday with the Weber Lake studies. While at Woods Hole, Paul Galtsoff of the U.S. Fish and Wildlife Service employed him to conduct research on the effects of sulfate pulp mill wastes on oysters in the lower stretches of the York River in Virginia. It was presumed that the wastes adversely affected the oysters, but proof of the significance of this pollution was needed before action could be taken. Hasler transferred sick oysters from the polluted York River to the nearby unpolluted Piankatank River (near where these rivers enter Chesapeake Bay) and healthy oysters from the Piankatank to the York. Undisturbed oysters in both locations served as controls. He found that sick oysters recovered when moved to the Piankatank and healthy oysters became sick when moved to the York (Galtsoff *et al.* 1947). This project constituted a large-scale controlled experiment in the field.

In 1937, at Prof. Michael F. Guyer's invitation, Hasler returned to the University of Wisconsin as an instructor. Neither Birge nor Juday offered Hasler any help in establishing his own limnological research after he returned. However, Guyer assigned to him a small two room laboratory on Lake Mendota. That was as far as the red carpet extended. Juday was still in charge of the Trout Lake station, and he did not invite Hasler to use it. Hasler was promoted to assistant professor in 1941, associate professor with tenure in 1945, and full professor in 1948. Yet, he did not feel free to use the Trout Lake station until 1950. There had been such strong faculty resentment toward Birge and Juday for administering the Trout Lake Station exclusively for limnology that a reaction set in with their departure, and the station was administered by scientists from other disciplines until 1962.

Clements had his Weaver and Birge his Juday, but Hasler had to establish and maintain his scientific community without a lieutenant. Not that he did not recognize the desirability of having one, and several times he attempted to obtain one. He agreed with the Department of Zoology's decision to hire his student, John C. Neess (Ph.D. 1949), believing that he would assume such a role. Neess, however, preferred to work alone. Neess also declined to seek outside funding to support research, which limited the scope of his and his students' research. When he obtained tenure, Hasler's chances of obtaining a lieutenant decreased. Nevertheless, Neess was available to help Hasler's students, and he was of substantial assistance to some of them, particularly with statistical and sampling problems.

Hasler thought he had finally gained a lieutenant in another of his former students, H. Francis Henderson (Ph.D. 1963), but Henderson was unable to obtain tenure (although he remains a productive fishery biologist, now with the U.N.'s Food and Agriculture Organization in Rome). With Henderson's departure, and at Hasler's recommendation, the Zoology Department in 1968 hired John J. Magnuson and appointed him Director of the Trout Lake Station. He was both a productive scientist and a "team player." Before Magnuson arrived, however, Hasler had already demonstrated his ability to maintain and direct a first-rate limnology community. How had he done so for so long without a lieutenant?

Hasler depended upon his ability to work with many different colleagues and graduate students. This strategy was a flexible arrangement that made maximum use of the talents of all involved. Furthermore, his graduate student, Robert A. Ragotzkie (Ph.D. 1953), who had a double major in zoology and meterology, eventually obtained a faculty position in the Department of Meterology. And another of his students, Ross M. Horrall (Ph.D. 1961), was appointed project associate in limnology at the University of Wisconsin in 1965, and later, associate scientist in the Marine Studies Center. Ragotzkie and Horrall's cooperation and advising were important for the growth and vitality of the Wisconsin limnological school.

Hasler also maintained cohesiveness among his students by conducting a weekly seminar, begun about 1948 (and still going strong). The seminar included speakers from both on and off campus. Limnology graduate students were expected to speak before this seminar about their dissertation research, and Hasler treated their presentations as practice sessions for speaking at a scientific society's annual meeting. He also expected his students to attend the weekly seminars held by the Zoology Department.

To advise effectively his large number of graduate students while maintaining his own scientific productivity, Hasler hired able research managers, paid out of research grants. This position, which required a M.S. degree, was held at different times by Henry Eichhorn (1959–1964), James Bruins (1964–1969), Jane Ruck (1970), and David Egger (1970–present). During Hasler's Fulbright year abroad, Warren J. Wisby, who had received his Ph.D. under Hasler the year before (1952), assumed this position, which then carried more responsibility than usual. The Zoology Department also had a full-time mechanic (Frank Eustice at first, later Glen Lee), and between Hasler's grants and the department's resources, funds were sometimes available to hire an electrical engineer, Gerald Chipman. Furthermore, William R. Schmitz (Ph.D. under Hasler, 1958) served as Assistant Director of the Trout Lake Station beginning in 1967.

For special occasions, Hasler obtained special assistance. In 1961 he brought Associate Professor John C. Wright from Montana to help organize the first International Congress of Limnology held in the U.S. In the early 1970s, when Hasler served as Director of the Institute of Ecology, Royce LaNier and Felix Rimberg assisted him for two years, helping assemble specialists to write an evaluation of the status of ecology for the 1972 U.N. Conference on the Human Environment in Stockholm (Workshop on Global Ecological Problems 1972). Nor did Hasler shirk teaching for the sake of his and his students' research. For forty years he taught courses in limnology, ecology of fishes, comparative physiology, field zoology, and second-semester freshman zoology to about 150 students per year (including me in limnology in the fall of 1960).

Soon after Hasler joined the faculty, his interest in the physiology of fish led to experiments conducted jointly with his colleague, Roland K. Meyer, an endocrinologist. They conducted experiments on fish both in the laboratory and in outdoor fish hatchery raceways, always maintaining other fish in controlled conditions. In both of their projects they advanced the time of spawning by injections of carp pituitaries (Hasler, Meyer and Field 1939, Hasler and Meyer 1942). This line of research was not pursued long before being interrupted by World War II. Much later, it would be important for aquaculture, especially in China.

The rise of Nazism and the coming of war were painful for all Americans, but especially so for those with ties to the Germanic people and culture. Hasler's father was the son of Swiss pioneers, but both his father and he spent their Mormon field service (a generation apart) in Germany and Austria. This experience stimulated a permanent interest in the German language and culture, and led Arthur Hasler to become fluent in German. Furthermore, his late wife, Hanna Prüsse Hasler (1908–1969), was from an immigrant German family that retained a high regard for its heritage. When Hasler began lecturing in hydrobiology and in comparative physiology in 1937, he became aware that much of the literature needed by his students was available only in German. While studying this literature, he came to admire the work done by the German zoologist, Karl von Frisch. Von Frisch was an especially brilliant experimentalist (his research eventually won him a Nobel Prize; see Frisch, 1967a, b). When Hasler entered Germany in the spring of 1945 with the U.S. Strategic Bombing Survey, he took the opportunity to become friends with von Frisch in Munich at the partially destroyed Zoologisches Institut, which the Rockefeller Foundation had built for von Frisch before the war (Hasler 1945, 1946). Besides the studies on the language of bees that brought him such fame, von Frisch and his students made fundamental investigations into the sensory physiology of fish. This latter work especially interested Hasler and influenced his own outlook and research.

Another scientist whom Hasler visited during his time away from military duties was Wilhelm G. Einsele at the Anstalt für Fischerei, Weissenbach am Attersee, near Salzburg, Austria. Although all of Einsele's pre-war assistants were casualties of the war, he had managed to carry on his work with the help of women and older fishermen. His primary objective was to increase the productivity of fish in the Attersee and other Austrian lakes. His research had included an attempt to increase the natural phosphate level of a small South German lake (Schleinsee) by adding large quantities of superphosphate (Einsele 1941). This research attracted Hasler's interest, and later he encouraged one of his graduate students to publish a literature review on the "Development and Status of Pond Fertilization in Central Europe" (Neess 1949a).

After five months Hasler returned to the U.S. concerned for the welfare of the biologists whom he had met in western Europe and stimulated by his opportunity to learn first-hand from their work. Although he returned to Wisconsin to pick up his limnological work, there had been enough disruption and stimulation to cause him to reflect upon what he wanted to accomplish as a scientist. There was some momentum left over from the Birge-Juday period and from his own work before 1945 that he could draw upon, but with nothing new to offer in the post-war period, undoubtedly he would have found that momentum quickly spent. It was then, after his own long experiences with experimentation and after having witnessed the experimental work of von Frisch and Einsele, that Hasler realized he wanted to leave his mark on limnology by helping to make it a far more rigorous experimental science than it was in 1945. This approach was already an integral part of his teaching, but in two papers published in 1947 and 1948, he took the opportunity to remind his peers that they should carefully design experiments with controls (Hasler 1947: 391, Hasler and Einsele 1948: 530). It was easy for him to cite published articles showing uncritically designed field experiments, but he found only one showing critical awareness of the problem (Mottley 1942). Some years later he published an article on experimental limnology illustrated with examples from his and his students' work (Hasler 1964).

Although it would be risky to make a strong claim of uniqueness for Hasler's controlled field experiments, it nevertheless seems true that he was unique in seizing upon this approach to limnology as an organizing principle for the program of a limnological school. Such an organizing principle is just what is needed for developing a cohesive scientific school (Crane 1972, Tobey 1981). Good ideas, however, are important only when successfully implemented. How did Hasler use this organizing principle in relation to particular scientists, ideas, and resources to achieve an outstanding scientific school?

Hasler continued the Birge-Juday example of consulting faculty from other sciences concerning research projects, but he depended rather less than they had upon those scientists as active collaborators and rather more upon graduate students in limnology. Hasler supervised the dissertation research of 53 doctoral students and partially directed that of 14 others; he also supervised the thesis research of 41 master's degree students. In this respect, he was following the normal pattern of development for a scientific community, although we may doubt that the leaders of many scientific communities graduate as many students. The limnological ideas that he and his school explored were as diverse as those explored by the school under Birge and Juday. But while the work of Birge and Juday had been narrow in scope to begin with and had gradually expanded, the range of Hasler's interests and competencies were broad from the start. He could therefore attract a range of students who had somewhat different interests from each other. He was able to find some means of support for them while in graduate school and a job when they left.

The financial and material resources available to the Hasler group were substantially better than they had been for the Birge and Juday group, partly because of the cumulative advantages of their earlier activities, but mostly because the country was willing and able to allocate more resources to science after the war than before. However, although more resources became available around 1950, there was competition for them, and any scientist who obtained enough to run a scientific school had to have a research program that was convincing to his peers who allocated the resources. It was a definite help to have momentum already when the National Science Foundation (on the history of the NSF see England 1982), the Federal Water Quality Administration, and the Atomic Energy Commission were established. Before funds from these agencies became available in the 1950s, Hasler and his students obtained research funds from the Graduate School, the Wisconsin Conservation Department, the Office of Naval Research, and several private donors.

Elizabeth Jones (now Mrs. David G. Frey) was the first of Hasler's students whose dissertation topic exemplified the experimental approach of his group. Her task was to investigate whether rooted aquatic vegetation and algae found in the same body of water either compete for nutrients or produce inhibitors. R. N. Pond's experiments (1903) had not indicated any connection, but later observations of algae blooms on Lake Mendota indicated that blooms were not as abundant in years in which the rooted vegetation of the lake flourished. She tested the question in four silos, each 3.6 m in diameter and 1 m deep, which were placed in a large fish hatchery pond (drained, then refilled). Her research was supported with funds (via the Graduate School) from both the Wisconsin Alumni Research Foundation and the Wisconsin Conservation Department. She received her degree in 1947, having found that rooted vegetation does inhibit algae (Hasler and Jones 1949). Although this was a successful example of the Hasler approach to experimental limnology in the field, the silos in the hatchery pond were artificial environments, even if they were outdoors.

The next step would be to conduct experiments in somewhat less artificial environments. Another of his early doctoral students, John C. Neess, investigated the population ecology of the bluntnose minnow (Neess 1949b). Six small identical ponds were dug at the University Arboretum and each was stocked with 12 males and 12 females. This investigation was also experimental limnology, in a sense; the ponds were an experimental situation. However, the reason there were six ponds was to provide data on the range of variation that might develop under similar circumstances. (It turns out there was considerable variation in the colonization of the ponds by plants and also in the rate of increase of the minnows.) Nevertheless, after the ponds were established, there was no attempt to use some as controls and to alter conditions in others.

In 1948 Hasler decided to test on northern bog lakes the possibility that he and Einsele proposed, that dystrophic lakes could be made more transparent if they were alkalized with hydrated lime (1948: 549). Encouraged by Professor Emil Truog in the Department of Soil Science, Hasler tested the suggestion in his laboratory and obtained favorable results. Therefore, it seemed worth trying on a bog lake. Assisting in this project were two graduate students, Oscar Brynildson and William Helm, who would later write doctoral dissertations under Hasler's supervision. They ran their alkalization experiments on Cather and Turk Lakes, on property belonging to Ben McGiveran in Chippewa County. (Probably it would have been difficult to obtain permission to conduct these experiments on state-owned lands.) The experimental plan was to collect limnological and fishery data on these bog lakes for two years before treatment, then replace the resident fish with rainbow and brown trout, treat both lakes with hydrated lime (which, unlike powdered limestone, is readily soluble), and finally to measure the lakes' productivity under the new conditions. The hypothesis was that increased transparency would allow plant growth at greater depths than in the naturally brown humic water, plant growth would increase the dissolved oxygen, and introduced trout would make better use of the new situation for growth than would the original resident species. Their findings supported these assumptions (Hasler, Brynildson and Helm 1951).

Hasler next decided that he needed to use at least one pair of lakes for conducting even cleaner and more tightly controlled experiments within the same season. The ideal example of the Hasler approach was, therefore, the dissertation research of Waldo E. Johnson on Peter and Paul Lakes on Notre Dame University's property in Gogebic County near the Wisconsin state line. These lakes are adjacent and are connected by a narrow neck. If the connection were filled in, two similar lakes could be used, with one (untreated) serving as a reference lake. The use of lakes so far from Madison for dissertation research indicates that experimental limnology is not necessarily a convenient science.

These slightly acid bog lakes seemed ideal for the experiments, and being isolated, were free from incidental public interference. Notre Dame University granted permission to use them and to build an earthen dam across their connecting neck. Using these lakes, one could determine not only the likely importance of some single factor, as in Jones' dissertation, but also the actual importance of the factor upon the life of a lake in nature. For example, Johnson used Peter and Paul Lakes to study the changes produced by alkalization upon rainbow trout productivity (Peter being the treated and Paul the reference lake). He found that productivity increased, because the alkalization of brown-water bog lakes increased the light penetration and stimulated photosynthesis in deep water, hence preventing oxygen depletion at times (especially in winter) when otherwise some of the trout would have died (Johnson and Hasler 1954: 133). His research was supported by grants from the Guido Rahr Foundation and from J. Bruce Allen of Chicago (*ibid.,* 113). Johnson later convinced the Fisheries Research Board of Canada to establish an experimental lake station near Winnipeg, with him as director (Johnstone 1977: 263–269).

Johnson had used these lakes to answer only a limited series of questions relating to fish productivity. Therefore it seemed desirable to have another graduate student use Peter and Paul Lakes to investigate more generally the changes in metabolism of dystrophic lakes caused by the addition of hydrated lime. Raymond G. Stross undertook this project for a doctoral dissertation. Both Johnson and Stross also studied their experimental problems on two or three other lakes to get a broader experience. Stross completed his dissertation in 1958 and the results, that the rate of turnover of the zooplankton was markedly greater in the alkalized lake, were published shortly thereafter (Stross and Hasler 1960). These studies also indicated that lime, presumably an important source of bicarbonate, may be a limiting factor in primary production (see also Hutchinson 1963: 685). The experimental condition established at Peter and Paul Lakes continued in effect under Hasler's auspices for some three decades, after which time bottom sediments could be used to trace the long-range effects of increased light penetration owing to the continued artificial alkalization and enrichment with bicarbonate (Kitchell and Kitchell 1980).

Thus far in discussing the Hasler period of Wisconsin limnology the emphasis has been upon the distinctive aspects of Hasler's methodology and outlook, to illustrate how different the community had become under his direction. Nevertheless, it would not have progressed as rapidly as it did in this new period had he not also utilized the earlier resources. The Trout Lake Station was the most conspicuous of these resources (though not available to him until 1957). Also very important were faculty members who had worked with Birge and Juday and had become experts on aspects of limnology touching their professional teaching and research.

The university administration appointed a faculty Lakes and Streams Committee that functioned from 1952 to 1963. The committee's concern was with water purity in the complex of lakes connected to the Yahara River in the vicinity of the university. Lake Mendota especially was something more than a scenic asset to the university and city and a convenient place to do research. By virtue of having become the most studied lake in the world (Brock 1985), it was now part of America's (and the world's) historical heritage. The coordinator of the committee was bacteriologist William Sarles, and the membership included Hasler in limnology, Gerald Gerloff and F. K. Skoog in botany, Verner Suomi and Reid Bryson in meteorology, Robert Muckenhirn and Marion Jackson in soils, Gerald Rohlich in civil and environmental engineering, and Mel Meloche in chemistry. The committee's accomplishments included working with State Legislator Norman Anderson and law professor Jacob Beuscher on a bill, passed in 1965, to divert sewage from the Yahara drainage basin to the Nine Springs Treatment Plant. Hasler also served for many years on Madison's Lake Mendota Problems Committee (Threinen 1968). By taking an active part in such committees, Hasler built relationships with both older and newer faculty members. These relationships were important for advancing such an interdisciplinary subject as limnology.

As stimulating as he found some of his interactions with colleagues in related disciplines at Madison, it had been even more stimulating for Hasler to interact with European authorities on subjects in which he was directly involved. He decided, therefore, that it was important to bring to Madison for lectures and discussions such authorities from both Europe and North America. Among the first of them was Karl von Frisch, who came in 1949 and whose memories of the trip are included in his autobiography (1967a: 165–166). Another was C. H. Mortimer, who was a visiting professor in Madison in 1962–1963 and who came back to the University of Wisconsin-Milwaukee in 1966 as Distinguished Professor of Zoology and first Director of the Center for Great Lakes Studies. By 1962, Hasler was bringing in between six and fifteen per year. Many of them were brought in with funds from the Federal Water Quality Administration. In addition to these distinguished guests, Hasler was also able to arrange for young limnologists from Europe and Asia to come and work with him in Madison. These post-doctoral students not only carried back with them insights gained from the Wisconsin limnological community, they also left behind the stimulating influence of their knowledge and perspective, contributing thereby to the sophistication of all those involved.

It was equally important, both to Hasler and his students, that he continue to travel to distant places to broaden his knowledge of limnology and fishery biology. He took short trips at various times to Lake Tahoe, Crater Lake, Hawaii, and Point Barrow in the U.S., to Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia in Canada, and abroad to U.S.S.R. (including Siberia), China, Japan, Eniwetok Atoll, Bikini, Argentina, Brazil, Guyana, Mexico, Puerto Rico, Costa Rica, Guatemala, England, France, Spain, Portugal, Netherlands, Poland, East and West Germany, Finland, Scandinavia, Iceland, Italy, Yugoslavia, Czechoslovakia, Romania, Ghana, and Israel. He returned from these refreshing trips with many valuable ideas.

In 1953 Hasler was awarded a Fulbright Research Scholarship that enabled him to go, with his wife and their six children, to the University of Munich for the academic year 1953–1954. There he conducted research in association with von Frisch. It was from von Frisch's strong interest in the physiology and behavior of fish that Hasler hoped to benefit. Hasler brought with him several years of his own experimental knowledge on the sense of smell in fish, and now he wished to expand his understanding of the ways fishes perceive their environment.

It was appropriate that he return to Munich for some of this work, because his earlier acquaintance with von Frisch and his researches played a role in getting Hasler interested in doing research on this subject. In 1946, the year following his visit to occupied Germany, Hasler had returned to his hometown of Provo for a vacation. This was a chance to indulge once more in two favorite hobbies of his youth—hiking the trails and fishing the streams of the Wasatch Mountains. As he climbed the eastern slope of Mt. Timpanogos, he pondered the question of how salmon find their way back to their home stream to spawn. His thoughts were momentarily interrupted by a homing experience of his own: "I approached a waterfall which was completely obstructed from view by a cliff; yet, as a cool breeze, bearing the fragrance of mosses and columbine, swept around the rocky abutment, the details of this waterfall and its setting on the face of the mountain suddenly leapt into my mind's eye. In fact, so impressive was this odor that it evoked a flood of other boyhood associations, long since vanished from conscious memory." If the smell of his boyhood haunts evoked such a strong memory association in him, perhaps it did the same for salmon; here was a hypothesis worthy of investigation (Hasler and Scholz 1983: xi–xiii). Later, when he recalled this experience, he appreciated the observation made by Louis Pasteur in his opening speech to the Faculte des Sciences at Lille, 7 December 1854: "chance only favours the prepared mind" (Vallery-Radot 1923: 79).

Hasler's serendipitous experience on Mt. Timpanogos led to his most important line of research. But was his idea for this research based upon a fortuitous impression, or is the parallel between fish and human memory real? The range of childhood experiences in humans is so vast that this would be a difficult question to answer scientifically. However, if someone else unaware of Hasler's experience reported a similar one, this would strongly support the possibility of his experience representing a parallel capacity in fish and humans. I have found such a report in Wallace Stegner's *Wolf Willow: A History, a Story, and a Memory of the Last Plains Frontier* (1962: 17–21). Stegner (b. 1909) grew up along the Frenchman River in southern Saskatchewan, and he returned to his childhood haunts after several decades to experience again memories of the region. One memory in particular haunted him, associated with the river bank where he once swam and fished. Returning to the spot did not satiate his quest until he smelled once more the odor which he earlier associated with the place—an odor he discovered coming from the flowers of a shrub along the bank, wolf willow.

Are salmon guided by the memory of smell when they return from the sea to their home stream to reproduce? It is a question presumably susceptible to a "yes" or "no" answer. Yet, for Hasler, it was a question that led to a lifetime of research, and not just for himself. Among the essential characteristics of a leader of a scientific school is the ability to establish a meaningful research program for himself and others in the school. This subject became the most important of the various research themes developed at the Wisconsin limnological school under Hasler's direction. It is appropriate, therefore, to follow it in more detail than the others, to see both what was learned and how the school worked.

If Hasler had been teaching in a western university, perhaps he would have begun work immediately upon salmon. Being located in Wisconsin, however, he wondered if his question might not be clarified, at least in part, by some initial studies on other species. If salmon are guided by odors, perhaps some common Wisconsin fish, such as the bluntnose minnow *(Pimephales notatus),* might be also. It was worth an investigation, and probably worth a doctoral dissertation for an interested graduate student. Theodore J. Walker (Ph.D., 1948) was one who was interested, and he studied the capacity of this minnow to discriminate between the odor of water-milfoil *(Myriophyllum exalbescens),* common hornwort *(Ceratophyllum demersum),* and 12 other species. Hasler and Walker sought the assistance of Wisconsin faculty in psychology concerning experimental apparatus, experimental design, and measurements having statistical significance. Walker found that he could, in 2.5 months, train his fish to distinguish the odors of these plants.

The fish obtained food—positive conditioning—when it went toward the odor of one species, but an electrical shock—negative conditioning when it went toward the odor of a second species (Walker and Hasler 1949).

These findings were encouraging, but there is a great leap between showing that a minnow can discriminate between two plant odors and claiming that salmon use odors for homing. The next step in bridging this gap was to show that bluntnose minnows can discriminate between the odors of different streams. Warren J. Wisby, who had written his M.S. thesis under Hasler on "Techniques for Investigating the Ecological Aspects of the Behavior of Fishes" (1950), undertook this research for a doctoral dissertation (Ph.D. 1952). Norman Fassett advised on the selection of two streams near Madison, Otter and Honey Creeks, that had strikingly different water chemistry, soils, and plant communities. The minnows were then trained in an experimental situation similar to that used by Walker. Later Hasler explained the influence of these streams on fish as analogous to the differences in aroma and taste to humans of wines made from grapes grown on different soils and in different climates. Wisby found that in two months he could train his minnows to distinguish between the waters of the two streams. Then when the olfactory sacs of trained fish were destroyed the fish no longer distinguished between these waters, which proved that smell rather than taste supplied the cue. Experiments using chemical fractionations of the component parts of the waters indicated that the minnows were responding to a volatile, organic substance in the waters. These experiments were also later done successfully on salmon (Hasler and Wisby 1951: 224).

But did the capacity of fish in nature to discriminate odors equal their capacity to do so in the laboratory? Would salmon with occluded nasal chambers make the same choice of a breeding stream as they made with normal olfactory chambers? Only a test of salmon in nature would answser satisfactorily the latter question. Wisby and Hasler, with the collaboration of Lauren R. Donaldson from the University of Washington, captured salmon above the junction of the Issaquah Creek and East Fork of Issaquah Creek (east of Seattle). Half of those captured were tagged as controls, and the other half were tagged as experimental fish in which the olfactory sacs were plugged with vaseline-coated cotton. All fish were then trucked downstream well below the junction of the creek. Most of those with normal olfaction swam back up the stream of their previous choice, but those with occluded "noses" were as likely to choose one stream as the other. "The results, therefore, are in accord with those which would be expected if the fish were relying on their sense of smell in making this choice" (Wisby and Hasler 1954).

The success of all these investigations indicated that Hasler's hunch was on the right track—the organic odors of each stream were different. He therefore wrote a comprehensive physiological monograph on "Odour Perception and Orientation in Fishes" (1954) and, for the more general audience of *Scientific American,* "The Homing Salmon" (Hasler and Larsen 1955).

Yet, even though Hasler's hunch about the salmon's selection of a stream being controlled by odor seemed correct, he came to realize that this could not be the whole story. Stream odors might be the cue for salmon to recognize their home river, but how did they find their way back to the correct river after several years at sea? Something else must be operating in this segment of their homing. Use of the sun for orientation was a possibility that came to his mind—its importance for migrating birds was already under investigation (Griffin 1952: 382–384, Kramer 1953). Hoping to investigate this possibility, Hasler sought a Fulbright Research Scholarship for the 1953–1954 academic year to work in Munich with von Frisch and to visit Gustav Kramer in Wilhelmshafen. They were both doing exciting work on the use of the sun for orientation, the former working with bees and the latter with birds. Hasler also visited Konrad Lorenz at Buldern bei Dulmen. In Munich Hasler found that the common European minnow, *Phoxinus laevis,* could orient itself toward a lamp (simulating the sun) in a laboratory setting in order to obtain food, even when other environmental factors were varied randomly (Hasler 1956a).

After that stimulating year abroad, he returned to Madison pondering further questions concerning sun orientation. Could fish be trained to orient themselves when the lamp was moved around the room to simulate the apparent movement of the sun across the sky during the day? Could a capacity for sun-compass orientation also be demonstrated in fish in a natural environment? These questions would be answered affirmatively in an article that is especially interesting from our standpoint of illustrating a scientific community in action. The leader of an effective group must be able to raise significant, but solvable, questions that will keep both him and his associates productively occupied. These two questions are both on fish orientation, yet one falls within the domain of the laboratory and the other within the domain of field studies. In practice, few scientists are as active as Hasler has been in both domains; by inclination most will pick one or the other as their preference, and their imagination will then operate primarily on questions raised within that domain.

Hasler was aware of this tendency, and as collaborators on this project he had Wisby (then a "postdoc"), who as a graduate student had worked under him in both laboratory and field, Ross M. Horrall, a graduate student whose inclinations ran toward field research, and Wolfgang Braemer, a German behavioral physiologist whose inclination for laboratory research was influenced by his loss of a leg in World War II. Horrall's initial experiments on homing in white bass in Lake Mendota (Hasler *et al.* 1958) were continued for his doctoral dissertation (Ph.D. 1961). Braemer's experiments on sun-compass orientation formed the basis for "A critical review of the sun-azimuth hypothesis" (Braemer 1960). Even that was not to be the end of this line of research. Hasler started another graduate student, Horst O. Schwassmann (whom he had met in Germany before Schwassmann immigrated to Milwaukee), on the study of sun-compass orientation in fish native to different latitudes. Schwassmann and Hasler trained fish in Madison, then moved them to a different latitude (on the equator in Brazil) and attempted to retrain them. This work was far enough along in 1960 for them to report preliminary results at the Cold Spring Harbor Symposium on biological clocks (Hasler and Schwassmann 1960), and Schwassmann continued this research for his doctoral dissertation (Ph.D. 1962).

To discover whether they returned home by random or directed swimming, Hasler and Horrall tracked the movements of displaced white bass in Lake Mendota by attaching floating plastic balls to the fish with a nylon thread and fish hook (illus. in Hasler 1963: 66, Hasler 1966a: 88). This technique was adequate for the small-scale study in Lake Mendota, but was unsatisfactory for tracking salmon because the float interfered with the speed and changes in depth of the fish. Hasler assigned the task of developing a more flexible tracking technique to another graduate student, H. Francis Henderson. With assistance from Gerald Chipman, an electronics engineer, Henderson developed a sonic transmitter that could be inserted into a fish's stomach or abdomen and could transmit signals up to 200 m for about 15 hours (Hasler and Henderson 1964, Hasler 1966: 128–129). This research was sufficient for Henderson's dissertation (Ph.D. 1963) and secured his appointment to the faculty in the Zoology Department.

By 1963 Hasler, his students, and research associates had studied the homing abilities of fish from enough different perspectives for him to develop a comprehensive synthesis of their findings. He found the time to write *Underwater Guideposts: Homing of Salmon* during a semester spent at the University of Helsinki as a Distinguished Exchange Professor. This book, which appeared in 1966, was an important milestone for him as a scientist and as the leader of an important scientific community. Many scientists devote their entire career to the elucidation of various narrow questions and never publish a comprehensive synthesis. Such had been the case with Birge and Juday. They had achieved prominence by virtue of the high quality and vast quantity of their work. They had explored many aspects of limnology, but for a synthesis, they depended upon the attention their work received in such textbooks as *The Life of Inland Waters* (1916; 2nd ed., 1930; 3d ed., 1937) by the Cornell limnologists James G. Needham and J. T. Lloyd and *Limnology* (1935) by Paul S. Welch of the University of Michigan. Because there had been only a few competing communities of limnology, their work did receive due attention. Hasler, however, worked in a far larger arena, where the approach of Birge and Juday would have attracted far less notice than it had in their day. Hasler's book provided a convincing and detailed answer to a long-standing puzzle: how could salmon swim out into a vast, trackless ocean and yet return to the stream of their birth to spawn? The book is also a more prominent record of the most important achievement of the Wisconsin limnological school under his direction than were individual scientific papers. It illustrates the use of experimentation in both laboratory and field for solving limnological problems.

Even if Hasler did not, after that, merely rest on his laurels, there were so many different subjects under investigation at the Laboratory of Limnology by 1966 that one might expect that the subject of salmon homing would have been dropped—after all, it had been done. Furthermore, both the Atlantic and Pacific salmon live a long way from Madison; it would be more convenient and practicable to study problems that could be solved within the state of Wisconsin. However, at about the time that such thoughts were going through Hasler's head, "the Departments of Natural Resources in Michigan and Wisconsin introduced coho salmon into the Great Lakes to feed on and thus reduce the alewife population and to revitalize the Lake Michigan fishery" (Hasler and Scholz 1983: xv). The coho flourished—to the delight of sports fishermen—and thus provided an opportunity to answer questions still lingering from earlier investigations and also new ones arising from the management of salmon in the Great Lakes. Hasler's decision to exploit this unexpected opportunity was another example of "chance favoring the prepared mind."

The primary question that intrigued him was how olfactory imprinting occurred in young salmon. At the end of their paper on "Discrimination of stream odors by fishes and its relation to parent stream behavior" Hasler and Wisby had suggested the experiment of "exposing salmon to a constant, artificial odor through the fingerling stage and then determining if the fish conditioned in a hatchery could be decoyed to a neighboring stream upon return from the sea" (1951: 237). Neither they nor apparently anyone else had actually tried it, but twenty years later it was an experiment that could be tried in rivers flowing into Lake Michigan. Some of Hasler's graduate students in the 1970s—Andrew E. Dizon (M.S. 1966, Ph.D. 1971), John C. Cooper (Ph.D. 1974), Peter J. Hirsch (Ph.D. 1977), Peter B. Johnsen (M.S. 1976, Ph.D. 1978), Allan T. Scholz (M.S. 1977, Ph.D. 1980)—collaborated with him and Horrall in designing and carrying out experiments on salmon imprinting. They raised thousands of salmon, mostly inland in

Wisconsin hatcheries, imprinted them to morpholine, and later released them in Lake Michigan. When sexually mature, they began to search for their home stream. Morpholine was then used to scent one of the rivers. The number of imprinted salmon, distinctively marked, returning at sexual maturity to the scented stream was ten times greater than the number of controls returning to the stream. Another chemical, phenethyl alcohol, worked equally well in another series of duplicate experiments. These experiments were repeated several times to establish their validity.

There were as many as seven co-authors to some of the papers published by this group working on salmon homing in Lake Michigan in the 1970s. All of their work was finally collected and synthesized in Hasler and Scholz's book, *Olfactory Imprinting and Homing in Salmon* (1983 with references). The work of this group has not only broadened and deepened our understanding of salmon physiology and ecology, it has also provided the key insights needed to transform the salmon fishery from a wild one of modest value into an invaluable domestic one (Hasler and Scholz 1978, 1980, Thorpe 1980, Donaldson and Joyner 1983). Furthermore, their work has been singled out as a model of a rigorous experimental method applied to a field problem in biology (Baker and Allen 1982: 14–19).

This work on salmon is atypical of a limnological school. Textbooks on limnology frequently have little or nothing to say about fish—a ridiculous bias, in Hasler's opinion. However, in his effort to redress that omission, he did not err in the other direction and neglect the more typical preoccupations of the limnologist. His own article, "Wisconsin, 1940–1961" (1963) is an ample survey of all aspects of limnology pursued at the University of Wisconsin under his leadership, and other examples of research conducted by Hasler and his students are provided in preceding chapters. One emphasis of the Wisconsin school under Hasler was on limnological research during the winter. Birge and Juday had taken a few winter measurements, mostly in Madison, but no one before Hasler had conducted so many winter studies. Twenty-two of his 195 published papers report on research performed in severe winter conditions, many at northern lakes far from Madison.

The Birge-Juday community existed for almost forty years and the Hasler community slightly more than forty years. The two periods are thus comparable in duration, and this invites a comparison in achievement. The Hasler community seems to have been more productive and more influential than was the Birge-Juday community. This is, of course, what one would expect, because science has been better supported since 1940 than it was previously, and a larger number of Americans have been active scientists since that date than before. Limnology has grown along with other sciences, and the Wisconsin story reflects that. On the other hand, competition for science resources, students, and honors has also increased with the increase in the number of active scientists. For example, regardless of how rapidly the American Society of Limnology and Oceanography has grown, only one member is honored each year with its presidency. Thus, it would be surprising if limnology in America had not grown steadily during the period in which Hasler headed the Wisconsin group, but all of that growth could have occurred on other campuses. It was only because Hasler seized the opportunities that so much of the growth in American limnology continued to occur at Wisconsin.

Publications are lasting indicators of scientific achievements, but other measures are also important. Students are one, and the 41 who received their M.S. degree and the 53 who received their Ph.D. degree under Hasler's direction are impressive indicators of success. Although some of these students were supported in part by teaching or research assistantships, a scientific school cannot achieve distinction unless it attracts research funds. For his time, Birge was notably successful in this respect, and Hasler was even more so. The record of this success, discussed to some extent earlier in this chapter, is found in the acknowledgments of the theses and publications coming from this community.

Another measure of academic success, so dear to the heart of administrators, are university buildings. Birge had established the Trout Lake Station, although it was housed in very modest wooden structures. Michael Guyer had also used university funds to build the small lab on Lake Mendota, first used under Hasler. However, Hasler and associated faculty and research assistants had to retain offices in Birge Hall, because their lab at the end of Park Street was too small to hold offices. This inconvenience was compounded by the fact that the limnological school was essentially an informal subdivision of the Department of Zoology. Although Hasler served as chairman of that department in 1953 and again from 1955 to 1957, whenever new needs arose in limnology, they had to be evaluated within the competing needs of the department as a whole. Sometimes the needs of this growing field had to be deferred to the needs of some discipline that attracted fewer students (its equipment could still become obsolete) because the latter had already waited a long time to have its needs met.

A way around this impediment came in 1962, when Hasler obtained funds from the National Science Foundation to build a new Laboratory of Limnology on the shore of Lake Mendota. Because he had obtained the NSF funds, Hasler was given the initiative to choose the site, the general plan for the building, and the architect. He was already acquainted with Albert Gallistel, Superintendent of Buildings and Grounds, from their long association on the Arboretum Committee. Hasler knew that Gallistel shared his concern for landscape architecture and environmental quality. They agreed on a site west of the Memorial Union, near the Hydraulics Lab. By placing it there, they prevented an automobile road from being built along the lake (as opposed to the bike and foot path that is still there). In 1957 Hasler and a few colleagues had led the faculty opposition that had saved the view from the Union becoming a 600-car parking lot— advocated by university regent Oscar Rennebohm and approved by President E. B. Fred— by convincing the faculty and its parking committee that the lake was too sacred to the university and to science to be desecrated by the contemplated landfill.

The general concept for the cantilevered laboratory was sketched by Mrs. Holger Jannasch, a German architect who spent a year in Madison with her husband, a postdoctoral fellow and an eminent marine and freshwater microbiologist. Hasler chose William Kaeser, a Madison architect, to develop her plan in detail, and in 1963 Hasler proudly described it in the *American Zoologist* (p. 339):

> An attractive formed-concrete building cantilevered over the waters of Mendota has recently been completed. The new Laboratory of Limnology provides offices, laboratories, conference rooms, a library, and supporting facilities for a staff of 35 people, as well as adequate fish-holding and storage facilities. The basement level encloses a boat slip opening to Mendota between concrete entrance piers. A large shop, rooms for gear and boat storage, fish holding tanks, small rooms for recording instruments, motors, and batteries, and a shower room with locker facilities complete the lower floor.
>
> The first floor includes laboratories for graduate students and visiting personnel, for paleo- and latitudinal-limnology, hydrobotany, and microbiology. A dark room, culture room, isotope room, instrument room, and chemical laboratory are also included. The second floor consists of laboratories for the study of the behavior and physiology of fishes, zooplankton and

benthos, physical limnology, and fishery biology. Offices of the director, secretaries, a library, large aquarium room, graduate laboratories, and offices for investigators are welded into a working unit. The laboratory was designed not only for the needs of the students and faculty, but also to meet those of visiting investigators.

Because of his success in obtaining NSF funds for this laboratory, the university later asked him to try to obtain funds for a sorely needed laboratory at the Trout Lake station. He agreed to try, providing the university this time put up half the money; it did, and he obtained the other half from NSF in 1966.

Hasler remained head of the Laboratory of Limnology from its opening in 1963 until his retirement—from formal duties, at least—as Professor Emeritus in 1978. Occasionally administrative posts interested him but did not come his way. In retrospect, he is glad they did not, because administrative responsibilities would have interfered with his salmon research, for which he has received so much enthusiastic recognition, both nationally and internationally. He has maintained membership in 19 professional societies and held various offices in a number of them, including president of the American Society of Limnology and Oceanography (1949–1950), Ecological Society of America (1961), American Society of Zoologists (1971), International Association for Ecology (1967–1974), and of the latter Association's First Congress (The Hague, 1974). He has been elected to membership or honorary membership in a number of scholarly organizations, both here and abroad, including the prestigious National Academy of Sciences (1969) and the American Academy of Arts and Sciences (1972). In 1977 the American Fisheries Society honored him with its Award of Excellence. In 1980 both the American Institute of Biological Sciences and the Sea Grant Association presented him with distinguished service awards.

One might suppose that, as a past president of both the American Society of Limnology and Oceanography and the Ecological Society of America, Hasler's greatest professional involvements would be with one or both of those societies. Since joining the National Academy of Sciences, however, that organization has been the main focus of his scientific activities. He was proud of the fact that, when elected, only he and one other limnologist, G. Evelyn Hutchinson, were members of that august body of 900 senior scientists. He assisted in writing two of its reports for 1969, *Resources and Man* (269 pp.) and *Eutrophication: Causes, Consequences, Correctives. Proceedings of a Symposium* (661 pp.). Other National Academy of Sciences reports he helped prepare are entitled: *Biology and the Future of Man* (1970) and *Rehabilitation Potential of Western Coal Lands* (1974).

By every standard of scientific success, Hasler has been acknowledged by his peers as a leading scientist and the head of a leading scientific school. He has always enjoyed the involvements and interactions that his successes have brought, but he has also resisted the temptation to "wheel and deal" just for ego satisfaction. That is a trap that, among other things, leads to the neglect of one's students. Although Hasler demanded high levels of performance from his students, in return he gave generously of his time, thoughts, and efforts. One student, Scholz, remembered "his cussedness and refusal to give up in the face of adversity during a bout with colon cancer in 1971–1972." The 53 students who had received doctorates under him showed their appreciation by returning to Madison for a commemorative celebration when he retired in March, 1978. They also commissioned a composition in his honor, a quartet for horn and strings by David Diamond of the Juliard School of Music. This idea came from their awareness that, for 25 years, Hasler had played horn for the Madison Civic Symphony. The premier performance was by the Pro Arte Quartet in Madison in October, 1978, with Douglas Hill as hornist.

A further recognition of his achievement as head of an outstanding school of limnology was the large drawing of his academic "genealogical tree" by Kandis K. Elliot in 1978. This chart is an imaginative and thoughtful display of the history of the Wisconsin limnological school under his direction, as revealed by the master's and doctor's degrees of his students. It hangs in the Laboratory of Limnology.

When Hasler retired in 1978 and turned over the Center for Limnology to his colleague, John J. Magnuson, he, like Birge and Juday after 1937, continued his professional activities. Because those activities have enhanced the reputation not only of himself, but also of the limnological school, it is relevant to give some indication of them. In 1981 he submitted to the National Academy of Sciences (NAS) a proposal, "Salmon for Peace in the North Pacific," for a cooperative program of salmon ranching to be undertaken by the Soviet Union, the People's Republic of China, and Japan. The proposal includes the establishment of hatcheries, the use of artificial imprinting, and the restocking of the Amur (Heilong) and Wusuli (Ussuri) Rivers along the China-U.S.S.R. border. In 1983 the Chinese Fisheries Society, intrigued by the proposal, invited him to China under auspices of the NAS Distinguished Scholar Exchange Program. Hasler accepted the invitation and traveled around that country explaining his plan and also giving more general lectures and advice on limnology and fishery biology. He was received by very enthusiastic audiences. In 1984, because there are good prospects for developing a valuable fishery, the Soviet embassy requested that he evaluate a plan for international collaboration (Hasler 1984), and he also traveled to the U.S.S.R. as a NAS Distinguished Scholar for six weeks in 1986.

Conclusions

The history of a scientific community appears to be a very good way to present the history of modern ecology. By its nature ecology is a science that has imprecise boundaries, and any historical study should have a plausible way to delimit its scope. Ideally, history of science should include both substantive history of achievements and the circumstances under which the scientists worked. The history of a scientific community permits the presentation of both. In this case the focus is on the contrasting development of the limnology community at the University of Wisconsin under the leadership first of Birge and Juday and then of Hasler.

Birge and Juday were intent upon doing limnology, not upon developing a scientific school. Although there were theoretical aspects of their work, no elaborate scientific theory guided their endeavor. They achieved leadership in American limnology by virtue of the quality and quantity of their descriptive limnology. Their limnological community developed slowly and was really a by-product of their efforts to expand the number of scientists involved in their research. It might have been limited to their colleagues had Juday not gotten bumped from the Wisconsin Geological and Natural History Survey during the Depression, which led to his full-time appointment as a professor of zoology with graduate students. While they imparted to their students some of the skills and perspective needed by competent scientists, their primary objective remained the production of limnological knowledge, not the running of a scientific school.

Hasler was one of Juday's 13 doctoral students, but his work under other biologists at the university was as important to him as his limnological training under Juday. Both as a student and later as a faculty member Hasler compared his experience in the Wisconsin limnological community under Birge and Juday with what went on elsewhere in the university, and he decided that he should offer his students a richer experience than he had received. Furthermore, whereas they had started out as zoologists and had only gradually developed broader interests in the aquatic environment, Hasler's interests were very broad from the time he arrived in Wisconsin from Utah. In addition, he also had a methodological commitment—even a mission—that guided much of his pioneering work and his teaching. He set for himself high standards of performance in teaching, research, and service to university, community, and profession. Remarkably, he was able to maintain that commitment for more than four decades. Those Mormon values of his childhood had been good enough for a lifetime. Hasler handed over to Magnuson a much stronger limnology program than he had received.

Acknowledgments

My foremost debt is to Professor Emeritus Arthur Davis Hasler, who patiently explained his work to me and also helped me to understand how the Wisconsin limnological school worked during the period of his involvement with it. I also appreciate Professor Emeritus Aaron J. Ihde's providing me with information on Wisconsin chemists and their reactions to the limnologists during the 1930s. Annamarie L. Beckel and William Coleman have provided much-appreciated advice, both substantive and stylistic. And I thank M. Elaine Wright, in the Office of the Secretary of the Faculty, for sending me copies of memorial resolutions on former faculty members.

References

Anon. 1956. In memoriam, John E. Potzger, 1886–1955. *Wis. Acad. Rev.* 3: 75.

Baker, Jeffrey J. W. and Garland E. Allen. 1982. *The Study of Biology*. Ed. 4. Reading, MA: Addison-Wesley.

Baldwin, I. L., Robert H. Burris, Noble Clark, Chester P. Higby, and Marvin J. Johnson. 1960. Memorial resolution on the death of Emeritus Professor William Harold Peterson. *Univ. Wis. Fac. Doc.* 1436.

Bardach, J. E., John J. Magnuson, R. C. May, and J. M. Reinhardt, eds. 1980. *Fish Behavior and Its Use in the Capture and Culture of Fishes*. Manila: ICLARM.

Bean, E. F., John T. Curtis, H. C. Greene, Joseph J. Hickey, and John W. Thomson. 1954. Memorial resolutions on the death of Professor Norman Carter Fassett. *Univ. Wis. Fac. Doc.* 1141.

Beeton, Alfred M. and David C. Chandler. 1963. The St. Lawrence Great Lakes. In Frey 1963a, ch. 19.

Bennett, E. Maxine, Robert H. Burris, Robert P. Hanson, Arthur D. Hasler, Kenneth B. Raper, and William B. Sarles. 1978. Memorial resolution on the death of Emeritus Professor Elizabeth McCoy. *Univ. Wis. Fac. Doc.* 316.

Birge, Edward A. 1904. The thermocline and its biological significance. *Amer. Microscop. Soc. Trans.* 25: 5–33 + 2 pls.

______ and Chancey Juday. 1922. The inland lakes of Wisconsin. The plankton I. Its quantity and chemical composition. *Wis. Geol. & Nat. Hist. Surv. Bull.* 64: 1–222 + ix pp.

______ and ______. 1934. Particulate and dissolved organic matter in inland lakes. *Ecol. Monogr.* 4: 440–474.

Braemer, Wolfgang. 1960. A critical review of the sun-azimuth hypothesis. *Cold Spring Harbor Sym.* 25: 413–427.

Brock, Thomas G. 1985. *A Eutrophic Lake: Lake Mendota, Wisconsin*. New York: Springer-Verlag 1985 xii + 308 pp.

Bryan, George S., Richard C. Emmons, Emil Truog, Stanley A. Tyler, and Lewis M. Cline. 1957. Memorial resolutions on the death of Emeritus Professor William Henry Twenhofel. *Univ. Wis. Fac. Doc.* 1262.

Chandler, David C. 1963. Michigan. In Frey 1963a, ch. 3.

Colin, Patrick L. 1980. A brief history of the Tortugas Marine Laboratory and the Department of Marine Biology, Carnegie Institution of Washington. In Sears and Merriman 1980, 138–147.

Cook, Robert E. 1977. Raymond Lindeman and the trophic-dynamic concept in ecology. *Science* 198: 22–26.

Cottam, Grant, Arthur D. Hasler, Robert J. Muckenhirn, Jonathan D. Sauer, and John F. Stauffer. 1961. Memorial resolution on the death of Professor John T. Curtis. *Univ. Wis. Fac. Doc.* 1486.

Crane, Diana. 1972. *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: Univ. Chicago Press. x + 213 pp.

Dexter, Ralph W. 1965. The "Salem Secession" of Agassiz zoologists. *Essex Inst. Hist. Coll.* 101: 27–39.

______. 1974. From Penikese to the Marine Biological Laboratory at Woods Hole—the role of Agassiz's students. *Essex Inst. Hist. Coll.* 110: 151–161.

______. 1979. The impact of evolutionary theories on the Salem group of Agassiz zoologists (Morse, Hyatt, Packard, Putnam). *Essex Inst. Hist. Coll.* 115: 144–170.

Domogalla, Bernhard. 1935. Eleven years of chemical treatment of the Madison lakes:—its effect on fish and fish food. *Amer. Fish. Soc. Trans.* 65: 115–121.

______. 1941. Scientific studies and chemical treatment of the Madison lakes. Pp. 303–310 in: *A Symposium on Hydrobiology*. Madison: Univ. Wisconsin Press.

Donaldson, Lauren R. and Timothy Joyner. 1983. The salmonid fishes as a natural livestock. *Sci. Amer.* 249, no. 1 (July): 50–58.

Dupree, A. Hunter. 1957. *Science in the Federal Government: a History of Policies and Activities to 1940.* Cambridge, MA: Harvard Univ. Press. xi + 460 pp.

Egerton, Frank N. 1962. The scientific contributions of François Alphonse Forel, the founder of limnology. *Schweiz. z. Hydrol.* 24: 181–199.

______. 1977. A bibliographic guide to the history of general ecology and population ecology. *Hist. Sci.* 15: 189–215.

______. 1978. François Alphonse Forel (1841–1912). *Dictionary of Scientific Biography* 15: 158–159.

______. 1983–85. The history of ecology: achievements and opportunities. *J. Hist. Biol.,* 16: 259–311; 18: 103–141.

Engel, J. Ronald. 1983. *Sacred Sands: the Struggle for Community in the Indiana Dunes.* Middletown: Wesleyan Univ. Press. xxii + 352 pp.

England, J. Merton. 1982. *A Patron for Pure Science: the National Science Foundation's Formative Years, 1945–1957.* Washington: National Science Foundation. x + 443 pp.

Frey, David G., ed. 1963a. *Limnology in North America.* Madison: Univ. Wisconsin Press. xvii + 734 pp.

______. 1963b. Wisconsin: the Birge-Juday era. In Frey 1963a, ch. 1.

Forel, François Alphonse. 1892–1904. *Le Léman: Monographie Limnologique.* 3 vols. Lausanne: F. Rouge.

______. 1901. *Handbuch der Seenkunde: Allgemeine Limnologie.* Stuttgart: Engelhorn. x + 249 pp.

von Frisch, Karl. 1967a. *A Biologist Remembers.* Transl., Lisbeth Gombrich. New York: Pergamon. ix + 200 pp.

______. 1967b. *The Dance Language and Orientation of Bees.* Transl., L. E. Chadwick. Cambridge, MA: Harvard Univ. Press. xiv + 566 pp.

Galtsoff, Paul S., Walter A. Chipman, Jr., James B. Engel, and Howard N. Calderwood. 1947. Ecological and physiological studies of the effect of sulfate pulp mill waste on oysters in the York River, Virginia. *U.S. Fish & Wildl. Serv. Fish. Bull.* 43: 57–176.

Gerking, Shelby D. 1963. Central states. In Frey 1963a, ch. 7.

Griffin, Donald R. 1952. Bird navigation. *Biol. Rev.* 27: 359–393.

Gunning, Gerald E. 1963. Illinois, In Frey 1963a, ch. 5.

Hasler, Arthur D. 1935. The physiology of digestion of plankton Crustacea. I. Some digestive enzymes of *Daphia. Biol. Bull.* 68: 207–214.

______. 1937. The physiology of digestion in plankton Crustacea. II. further studies on the digestive enzymes of a. *Daphnia* and *Polyphemus;* b. *Diaptomus* and *Calanus. Biol. Bull.* 72: 290–298.

______. 1945. This is the enemy. *Science.* 102: 431.

______. 1946. War time view of European biological stations. *Bios.* 28: 81–93.

______. 1947. Eutrophication of lakes by domestic drainage. *Ecology.* 28: 383–395.

______. 1954. Odour perception and orientation in fishes. *Fish. Res. Bd. Can. J.* 11: 107–129.

______. 1956a. Influence on environmental reference points on learned orientation in fish *(Phoxinus). Zeit. Vergl. Physiol.* 38: 303–310.

______. 1965b. Perception of pathways by fishes in migration. *Quart. Rev. Biol.* 31: 200–209.

______. 1963a. Wisconsin, 1940–1961. In Frey 1963a, ch. 2.

______. 1963b. The Laboratory of Limnology and associated field units of the University of Wisconsin. *Amer. Zool.* 3: 337–340.

______. 1964. Experimental limnology. *BioScience* 14: 36–38.

______. 1966. *Underwater Guideposts: Homing of Salmon.* Madison: Univ. Wisconsin Press. xii + 155 pp.

______. 1984. Editorial: How lucky can you be? *J. Great Lakes Res.* 10: 333.

______, Oscar M. Brynildson, and William T. Helm. 1951. Improving conditions for fish in brown-water bog lakes by alkalization. *J. Wildl. Mgt.* 15: 347–352.

______ and Wilhelm G. Einsele. 1948. Fertilization for increasing productivity of natural inland waters. *N. Amer. Wildl. Conf. Trans.* 13: 527–552.
______ and H. Francis Henderson. 1964. Tracking migrating salmon. *Science* 146: 426.
______ and James A. Larsen. Aug. 1955. The homing salmon. *Sci. Amer.* 193, no. 2: 72–76 + cover.
______ and Gene E. Likens. 1963. Biological and physical transport of radionuclides in stratified lakes. In Schultz and Klement 1963, pp. 463–470.
______ and Roland K. Meyer. 1942. Respiratory responses of normal and castrated goldfish to teleost and mammalian hormones. *J. Exper. Zool.* 91: 391–404.
______, ______ and Howard M. Field. 1939. Spawning induced prematurely in trout with the aid of pituitary glands of the carp. *Endocrinol.* 25: 978–983.
______ and Allan T. Scholz. 1980. Artificial imprinting: a procedure for conserving salmon stocks. In Bardach *et al.* 1980, pp. 179–199.
______ and ______. 1983. *Olfactory Imprinting and Homing in Salmon: Investigations into the Mechanism of the Imprinting Process.* New York: Springer-Verlag. xix + 134 pp.
______, ______ and Ross M. Horrall. 1978. Olfactory imprinting and homing in salmon. *Amer. Sci.* 66: 347–355.
______ and Horst O. Schwassmann. 1960. Sun orientation in fish at different latitudes. *Cold Spring Harbor Sym.* 25: 429–441.
______ and Warren J. Wisby. 1951. Discrimination of stream odors by fishes and its relation to parent stream behavior. *Amer. Nat.* 85: 223–238.
______ and ______. 1958. The return of displaced largemouth bass and green sunfish to a "home" area. *Ecology* 39: 289–293.
Hutchinson, G. Evelyn. 1963. The prospect before us. In Frey 1963a. ch. 26.
______. 1979. *The Kindly Fruits of the Earth: Recollections of an Embryo Ecologist.* New Haven: Yale Univ. Press. xiii + 264 pp.
James, Harry R. and E. A. Birge. 1938. A laboratory study of the absorption of light by lake waters. *Wis. Acad. Sci. Arts & Lett. Trans.* 31: 1–154.
Ihde, Aaron J. 1975. Kemmerer remembered, with some reflections on limnology. *Badger Chem.* 22: 14.
______. 1978. Henry August Schuette, 1885–1978. *Badger Chem.* 25: 1, 4–6.
______. 1981. V. W. Meloche, 1895–1981. *Badger Chem.* 28: 1, 4–5.
Johnson, Diane. 1974. *Edwin Brown Fred: Scientist, Administrator, Gentleman.* Madison: Univ. Wis. Press. x + 179 pp.
Johnson, Waldo E. and Arthur D. Hasler. 1954. Rainbow trout production in dystrophic lakes. *J. Wildl. Mgt.* 18: 113–134.
Johnstone, Kenneth. 1977. *The Aquatic Explorers: a History of the Fisheries Research Board of Canada.* Toronto: Univ. Toronto Press. xvi + 342 pp.
Juday, Chancey. 1910. Some European biological stations. *Wis. Acad. Sci. Arts & Lett. Trans.* 16: 1257–77.
______. 1942. The summer standing crop of plants and animals in four Wisconsin lakes. *Wis. Acad. Sci. Arts and Lett. Trans.* 34: 103–135.
______ and Arthur D. Hasler. 1946. List of publications dealing with Wisconsin limnology, 1871–1945. *Wis. Acad. Sci. Arts & Lett. Trans.* 36: 469–490.
______, C. L. Schloemer and C. L. Livingston. 1938. Effect of fertilizers on plankton production and growth of fish in a Wisconsin lake. *Prog. Fish Cult.* no. 40: 24–27.
Kitchell, Jennifer A. and Kitchell, James F. 1980. Size-selective predation, light transmission, and oxygen stratification: evidence from the recent sediments of manipulated lakes. *Limnol. Oceanogr.* 25: 389–402.
Kramer, G. 1953. Wird die Sonnenhöhe bei der Heimfindeorientierung verwertet? *J. Ornithol.* 94: 201–219.

Lauff, George H. 1963. A history of the American Society of Limnology and Oceanography. In Frey 1963a, ch. 25.

Likens, Gene E. and Arthur D. Hasler. 1962. Movements of radiosodium (Na 24) within an ice-covered lake. *Limnol. Oceanogr.* 7: 48–56.

McIntosh, Robert P. 1983. Pioneer support for ecology. *BioSci.* 33: 107–112.

______. 1985. *The Background of Ecology: Concept and Theory.* Cambridge: Cambridge Univ. Press. 1985. xiii + 383 pp.

Mathews, J. H., S. H. Goodnight and R. J. Roark. 1928. Memorial resolutions on the death of Professor Kemmerer. Univ. Wis. Fac. Meeting Min. 3 Dec., pp. 124–125.

Mortimer, C. H. 1956. E. A. Birge, an explorer of lakes. In Sellery 1956, pp. 163–211.

Mottley, C. McC. 1942. Experimental designs for developing and testing a stocking policy. *N. Amer. Wildl. Conf. Trans.* 7: 224–232.

Neess, John C. 1949a. Development and status of pond fertilization in central Europe. *Amer. Fish. Soc. Trans.* 7: 335–358.

______. 1949b. A contribution to aquatic population dynamics. Ph.D. diss., Univ. Wisconsin. iv + 103 pp.

Noland, Lowell E. 1950. History of the Department of Zoology, University of Wisconsin. *Bios.* 21: 82–109.

Pearse, Arthur S. 1952. *Adventure . . . Trying to be a Zoologist.* Durham: Author. 68 pp.

Pond, R. N. 1903. The biological relation of aquatic plants to the substratum. *U.S. Commissioner of Fish and Fisheries Report* 117: 483–526.

Price, Derek de Solla. 1963. *Little Science, Big Science.* New York: Columbia Univ. Press. xv + 119 pp.

Rickett, Harold W. 1920. A quantitative survey of the flora of Lake Mendota. *Science,* 52: 641–642.

______. 1921. A quantitative study of the larger aquatic plants of Lake Mendota. *Wis. Acad. Sci. Arts Lett. Trans.* 20: 501–527.

______. 1924. A quantitative study of the larger aquatic plants of Green Lake, Wisconsin. *Wis. Acad. Sci. Arts Lett. Trans.* 21: 381–414 + 2 pl.

Robertson, Carol Kelly. 1976. Limnology in Michigan: an historical account. *Mich. Acad.* 9: 185–202.

Russell, Harry L. 1940. Doctor Birge as a teacher. In University of Wisconsin 1940, pp. 7–14.

Schultz, Vincent and Alfred W. Klement, Jr., eds. 1963. *Radioecology: Proceedings of the First National Symposium on Radioecology.* New York: Reinhold; Washington: A.I.B.S. xx + 746 pp.

Scott, G. M. 1970. Bernard P. Domogalla, 1894–1970. *Wis. Acad. Rev.* 17: 16.

Sears, Mary and Daniel Merriman, eds. 1980. *Oceanography: the Past.* New York: Springer-Verlag. xx + 812 pp.

Sellery, George C. 1956. *E. A. Birge, a Memoir.* Madison: Univ. Wis. Press. vii + 221 pp.

Stearns, Forest W. 1961. Resolution of respect, John T. Curtis, 1913–1961. *Ecol. Soc. Amer. Bull.* 42: 167–170.

Stegner, Wallace. 1962. *Wolf Willow: A History, a Story, and a Memory of the Last Plains Frontier.* New York: Viking Press. vi + 397 pp.

Stross, Raymond G. and Arthur D. Hasler. 1960. Some lime-induced changes in lake metabolism. *Limnol. Oceanogr.* 5: 265–272.

Thorpe, John E., ed. 1980. *Salmon Ranching.* New York: Academic Press. x + 434 pp.

Threinen, C. W. 1968. *What About Lake Mendota.* Madison: n.p. 18 pp.

Tobey, Ronald C. 1981. *Saving the Prairies: the Life Cycle of the Founding School of American Plant Ecology, 1895–1955.* Berkeley: Univ. Calif. Press. x + 315 pp.

University of Wisconsin. 1940. Edward A. Birge, teacher and scientist: addresses delivered at a dinner on September 5, 1940 given to honor him for his contributions to the science of limnology and in commemoration of his eighty-ninth birthday by the Symposium on Hydrobiology. Madison: Univ. Wis. Press. 48 pp.

Vallery-Radot, Rene. 1923. *The Life of Pasteur.* Transl., R. L. Devoshire. Garden City: Doubleday, Page. xxi + 484 pp.

Wisby, Warren J. and Arthur D. Hasler. 1954. Effect of olfactory occlusion on migrating silver salmon *(O. kisutch). Fish Res. Bd. Can. J.* 11: 472–478.

Workshop on Global Ecological Problems. 1972. *Man in the Living Environment.* Madison: Univ. Wis. Press. xxiii + 288 pp.

Appendix

Ph.D. Students with Chancey Juday

Bennett, George W.
1939. Ph.D. Limnological investigations in Wisconsin and Nebraska. I. The limnology of some gravel pits near Louisville, Nebraska. 63 p. II. The growth of the large mouthed black bass, *Huro salmoides* (Lacépède), in the waters of Wisconsin. III. Growth of the small-mouthed black bass, *Micropterus dolomieu* (Lacépède), in Wisconsin waters.

Bere, Ruby.
1932. Ph.D. the bacterial content of some Wisconsin lakes. 27 p. The effect of freezing on the number of bacteria in ice and water from Lake Mendota. 18 p. Copepods parasitic on fish of the Trout Lake region, with descriptions of two new species.

Frey, David G.
1940. Ph.D. Growth and ecology of the carp, *Cyprinus carpio* Linnaeus, in four lakes of the Madison region, Wisconsin. 248 p.

Hasler, Arthur D.
1937. Ph.D. The physiology of digestion of plankton Crustacea. I. Some digestive enzymes of *Daphnia*. II. Further studies on the digestive enzymes of A. *Daphnia* and *Polyphemus*, B. *Diaptomus* and *Calanus*.

Morrison, J. P. E.
1931. Ph.D. A report on the Mollusca of the northeastern Wisconsin lake district. Studies on the life history of *Acella haldemani* ("Desh." Binney).

Pennak, Robert W.
1938. Ph.D. The ecology of the psammolittoral organisms of some Wisconsin lakes, with special reference to the Tardigrada. Copepoda, and Rotaroria. 180 p.

Schloemer, Clarence L.
1939. Ph.D. The age and rate of growth of the bluegill, *Helioperca macrochira* (Rafinesque). 113 p.

Schneberger, Edward.
1933. Ph.D. The growth of yellow perch (*Perca flavescens* Mitchell) from Nebish, Silver and Weber lakes in Vilas County, Wisconsin. 73 p.

Spoor, William A.
1936. Ph.D. The age and growth of the sucker. *Catostomus commersonii* (Lacépède), in Muskellunge Lake, Vilas County, Wisconsin. 90 p.

Tressler, Willis L.
1930. Ph.D. Limnological studies of Lake Wingra. 35 + v p.

Wiebe, Abraham H.
1929. Ph.D. Productivity of fish ponds. I. The plankton. 95 + ii p.

Wimmer, Edward J.
1928. Ph.D. A study of two limestone quarry pools.

Wright, Stillman.
1928. Ph.D. Studies in aquatic biology. I. A chemical and plankton study of Lake Wingra. 35 p. II. A revision of the South American species of *Diaptomus*. III. A contribution to the knowledge of the genus *Pseudodiaptomus*.

M.S. and Ph.D. Students with Arthur Davis Hasler

Allsopp, Herbert W.
1949. M.S. No thesis.

Andrews, Jay D.
1946. Ph.D. The macroscopic invertebrate populations of the larger aquatic plants in Lake Mendota. 104 p.
Armitage, Kenneth B.
1954. Ph.D. The comparative ecology of the riffle insect fauna of the Firehole River, Yellowstone Park, Wyoming. 50 p.
Bardach, John E.
1949. Ph.D. Contribution to the ecology of the yellow perch (*Perca flavescens* Mitchell) in Lake Mendota, Wisconsin. 74 p.
Batha, John.
1966. M.S. Observations on movements of freshwater mussels. 43 p.
*Baumann, Paul C.
1972. M.S. Distribution, movement, and feeding interactions among bluegill and three other panfish in Lake Wingra. 48 p.
Becker, George C.
1951. M.S. No thesis.
*Bjerke, John.
1962. M.S. The use of ribonucleic acid in zooplankton as an index of biological productivity in freshwater lakes. 80 p.
*Bott, Thomas L.
1968. Ph.D. Ecology of *Clostridium botulinum* type E. 85 p.
Brynildson, Clifford.
1950. M.S. No thesis.
Brynildson, Oscar M.
1958. Ph.D. Lime treatment of brown-stained lakes and their adaptability for trout and largemouth bass. 191 p.
Budd, John C.
1950. M.S. No thesis.
Chidambaram, S.
1972. Ph.D. Hormonal regulation of pigmentation, glycemia and natremia in the black bullhead, *Ictalurus melas.* 158 p.
Cooper, Jon C.
1974. Ph.D. Olfactory imprinting and memory in salmonids. 137 p.
Dizon, Andrew E.
1966. M.S. The scoptic spectral sensitivity of the white bass, *Roccus chrysops.* 22 p.
1971. Ph.D. Ecological aspects of the evoked olfactory bulb electroencephalograph of fish with special reference to homing behavior in salmon. 168 p.
Doepke, Philip A.
1963. M.S. Arsenic distribution in a shallow lake treated with an herbicide of sodium arsenite.
1969. Ph.D. An ecological study of the walleye, *Stizostedion vitreum,* and its early life history. 202 p.
Dugdale, Richard C.
1952. M.S. No thesis.
Dunst, Russell C.
1970. M.S. The effect of stream flow upon brown trout in Black Earth Creek, Wisconsin. 34 p.
Faber, Daniel J.
1963. Ph.D. Larval fish from the pelagial region of two Wisconsin lakes. 122 p.
*Fee, Everett J.
1972. Ph.D. A numerical model for the estimation of integral primary production and its application to Lake Michigan. 169 p.
Gallepp, George W.
1974. Ph.D. The behavioral ecology of larval caddisflies, *Brachycentrus americanus* and *Brachycentrus occidentalis.* 169 p.

Gammon, James R.
1957. M.S. A comparative study of the northern pike and the muskellunge. 42 p.
1961. Ph.D. Contributions to the biology of the muskellunge. 144 p.
Gasith, Avital.
1974. Ph.D. Allochthonous organic matter and organic matter dynamics in Lake Wingra. Wisconsin. 209 p.
*Haase, Bruce L.
1969. Ph.D. An ecological life history of the longnose gar. *Lepisosteus osseus* (Linnaeus), in Lake Mendota and in several other lakes of southern Wisconsin. 224 p.
Hazelwood, Donald H.
1954. M.S. No thesis.
Helm, William T.
1958. Ph.D. Some notes on the ecology of panfish in Lake Wingra with special reference to the yellow bass. 88 p.
Henderson, H. Francis.
1963. Ph.D. Orientation of pelagic fishes. I. Optical problems. II. Sonic tracking. 132 p.
Hergenrader, Gary L.
1967. Ph.D. Echo sounder and sonar studies of the diel and seasonal movements of pelagic lake fishes. 194 p.
Hirsch, Peter J.
1977. Ph.D. Conditioning the heart rate of coho salmon *(Oncorhynchus kisutch)* to odors. 82 p.
Holt, Charles S.
1962. M.S. The influence of physical characteristics of substrates of stream bottoms on repopulation of denuded areas by macroinvertebrate organisms. 61 p.
Horrall, Ross M.
1961. Ph.D. A comparative study of two spawning populations of the white bass, *Roccus chrysops* (Raf.), in Lake Mendota, Wisconsin, with special reference to homing behavior. 181 p.
*Howmiller, Richard P.
1966. M.S. No thesis.
1971. Ph.D. The benthic macrofauna of Green Bay, Lake Michigan. 225 p.
Hunt, Robert L.
1959. M.S. The role of insects of the surface drift in the diet of Brule River trout. 30 p.
Hunt, John R.
1958. M.S. Progress report on the behavior of net avoidance in fish. 20 p.
1962. Ph.D. The utilization of the nests of *Lepomis cyanellus* by *Notropis umbratilis.* 138 p.
Huver, Charles W.
1961. M.S. Variation and speciation in coregonid fishes. 27 p.
Jaeger, James W. A.
1972. M.S. The effect of different weather conditions on the feeding of northern pike, *Esox lucius.* 80 p.
John, Kenneth R.
1954. Ph.D. An ecological study of the cisco, *Leucichthys artedi* (LeSueur), in Lake Mendota, Wisconsin. 121 p.
Johnsen, Peter B.
1976. M.S. Handbook of aquatic biotelemetry.
1978. Ph.D. Contributions on the movement of fish: I. Behavioral mechanisms of upstream migration and homestream selection in coho salmon *(Oncorhynchus kisutch).* II. Winter aggregations of carp *(Cyprinus carpio)* as revealed by ultrasonic tracking.
Johnson, Waldo E.
1954. Ph.D. Dynamics of fish production and carrying capacity of some northern soft-water lakes. 51 p.

Jones, Sara E.
1947. Ph.D. An ecological study of large aquatic plants in small ponds. 166 p.
*Judd, John H.
1969. Ph.D. Effect of salt runoff from street deicing on a small lake. 145 p.
Kaya, Calvin M.
1967. M.S. Effects of temperature on nesting and gonadal development of *Lepomis macrochirus* (Rafinesque) and *Lepomis cyanellus* (Rafinesque). 49 p.
1971. Ph.D. Relation of the annual reproductive cycles of the green sunfish. *Lepomis cyanellus* (Rafinesque) to seasonal changes in temperature and photoperiod. 193 p.
Kingsbury, A. P.
1966. M.S. Discrimination of lake water odors by the white bass, *Roccus chrysops* (Rafinesque). 72 p.
Koonce, Joseph F.
1969. M.S. Estimations of phytoplankton production and biomass in a small acid bog lake. 63 p.
1972. Ph.D. Seasonal succession of phytoplankton and a model of the dynamics of phytoplankton growth and nutrient uptake. 192 p.
Kunny, Bartholomew K.
1967. Ph.D. An analysis of the distribution of the macroscopic riffle fauna in 32 small streams in the southern half of Wisconsin and some of the interdependent ecological factors affecting this fauna. 200 p.
Le Cren, E. David.
1947. M.S. No thesis.
Lenz, Andrew N.
1965. M.S. Studies on diversity and respiration of periphytic bacteria in a thermal river system. 23 p.
Likens, Gene E.
1959. M.S. Exchange of elements across the chemocline of a meromictic lake. 30 p.
1962. Ph.D. Transport of radioisotopes in lakes. 152 p.
*Lind, Christopher T.
1967. Ph.D. The phytosociology of submerged aquatic macrophytes in eutrophic lakes of southeastern Minnesota. 118 p.
*Loeffler, Robert J.
1954. Ph.D. A new method of evaluating the distribution of planktonic algae in freshwater lakes. 205 p.
Lovshin, Leonard L.
1966. M.S. The relation of water temperature to growth of wild brook trout *(Salvelinus fontinalis)* in Lawrence Creek, Wisconsin. 48 p.
*Lueschow, Lloyd A.
1964. M.S. The effects of arsenic trioxide used in aquatic weed control operations on selected aspects of the bioenvironment. 66 p.
Lutz, Paul D.
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*McNabb, Clarence D.
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