WERE EDWARD A. BIRGE AND CHANCEY JUDAY ANTECEDENT WETLAND SCIENTISTS?

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ABSTRACT

Edward A. Birge (1851-1950) and Chancey Juday (1871-1944) were among the most influential limnologists in the late nineteenth and early twentieth centuries in the United States. They primarily studied the physics and chemistry of Wisconsin lakes and how these environmental factors affected the distribution and composition of their plankton communities. Birge and Juday published several survey papers that summarized data on the concentration of gases and the water chemistry of many lakes that varied in size and depth. Because they assumed higher plants contributed little or nothing to the dissolved and particulate organic carbon in lake water, they consciously ignored higher plants in their lake surveys. However, an examination of the data in these surveys suggests that some of the lakes sampled today would be classified as palustrine wetlands or lakes with significant lacustrine wetland areas. Like most early limnologists, Birge and Juday saw themselves as freshwater oceanographers, believing that plankton was the only important direct and indirect source of dissolved and particulate carbon in water. Because of their biases, Birge and Juday's research did not increase wetland visibility or advance wetland science.

INTRODUCTION

For my M.Sc. research at the University of Alberta, I studied the primary production of oxbow lakes of different ages (van der Valk and Bliss 1971). I aimed to test Raymond Lindeman's (1942) theory about how lake primary production changed as lakes aged. When I first designed this study, I believed I would be measuring the primary production of phytoplankton. When I scouted the oxbow lakes in September 1968, they were free of aquatic plants except for a fringe of emergents. When I went to sample them in the spring of 1969, they were full of submerged aquatic plants. I immediately had to change my sampling protocols from those of a limnologist (i.e., plankton nets) to those of a plant ecologist (i.e., quadrats and clippers). I initially failed to recognize that what I would be studying was the primary production of wetlands, not lakes. However, I was not, of course, the first to fail to distinguish wetlands from lakes.

Unknowingly, I had become an antecedent wetland scientist who studied wetlands but did not know it (van der Valk 2017, 2020). Many people in many disciplines were antecedent wetland scientists—that is, people whose research or other activities contributed to making wetlands more visible and to developing wetland science before it became a distinct discipline in the 1970s.

Along with Stephen Forbes (van der Valk 2018a), Edward A. Birge (Figure 1) and Chancey Juday (Figure 2) are among North America's most important and influential early limnologists (Elster 1974; Egerton 1987, 2014). Forbes studied shallow lakes in Illinois that were mostly palustrine wetlands; thus, he was an antecedent wetland scientist (van der Valk 2018a).

In this paper, I will examine some of Birge and Juday's surveys of Wisconsin lakes to determine if they included any wetlands. If Birge and Juday's research on lakes contributed to raising the visibility of wetlands or to our understanding of their ecology, they would be both pioneering limnologists and antecedent wetland scientists.

However, before examining their lake survey papers, I will briefly explore the relationship between limnology and wetland science.

LIMNOLOGY VERSUS WETLAND SCIENCE

François Alphonse Forel (1841-1912) is universally considered the founder of limnology (Egerton 1962, 2014; Vincent and Bertola 2012). Although trained as a medical doctor, he devoted his adult life to studying Lake Geneva (also known as Lac Léman [Forel 1892]) in Switzerland. Forel studied lakes as a branch of geography: "Geography is the science of the Earth in

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its threefold composition of lithosphere, hydrosphere, and aerosphere. The special study of the hydrosphere is hydrography. Liquid water appears in three ways upon the Earth -- in the sea, in lakes, and in rivers; and hydrography is correspondingly divided into the three departments -- Oceanography, which is occupied with the unlimited, united, and all-embracing ocean. Limnology, which is concerned with the scattered and isolated portions of the hydrosphere occurring upon the land as lakes. Rheology, which studies the running water of the land in springs, brooks, streams, and rivers" (from Forel's [1901] Handbuch der Seenkunde as translated by Mill [1901]). For Forel, limnology was oceanography in miniature (Mill 1901; Vincent and Bertola 2012).

Initially, limnology was concerned with geology (lake formation, siltation), chemistry (water and substrate), and physics (seiches, waves, energy budgets). However, the view that limnology was a branch of geography gradually changed as biological studies of lakes became more common (Strom 1929). Limnologists by the late 1920s were studying the geology, physics, chemistry, and biology of freshwater aquatic systems. In other words, what had previously been called hydrobiology or freshwater biology, i.e., the study of organisms living in fresh water, was now an integral part of limnology. By this time, limnology had also become the study of all freshwater systems, not just lakes. Although rarely mentioned in the 1920s and 1930s, this presumably included freshwater wetlands. In effect, limnology had become a branch of ecology, which is still the case. According to the Association for the Sciences of Limnology and Oceanography (ASLO) Website (in August 2022), "Limnology is the study of inland waters - lakes (both freshwater and saline), reservoirs, rivers, streams, wetlands, and groundwater - as ecological systems interacting with their drainage basins and the atmosphere." The first American limnological society, ASLO, was founded in 1948 as the American Society for Limnology and Oceanography.

Unlike limnology, there is no founder of wetland science. A wetland scientist studies the geology, hydrology, chemistry, and biology of wetlands. Although there have been many words in English and other languages for various kinds of wetlands (marsh, swamp, slough, bog, mire, fen, etc.), wetland as a generic term encompassing all types of shallow aquatic systems dominated by submerged, floating-leaved, or emergent higher plants, also called hydrophytes or macrophytes, entered the scientific literature only in the 1940s and 1950s. One of the earliest American antecedent wetland scientists to begin using the term in his publications was William T. Penfound (van der Valk 2022). Both limnologists and wetland scientists study aquatic ecosystems. However, wetland scientists study aquatic ecosystems dominated by wetland plants, also called hydrophytes or macrophytes. Is wetland science just a subdiscipline or branch of limnology? Answering this question requires a closer look at the definition of a wetland.

The US Fish and Wildlife Service developed a national wetland classification in 1953 (Martin et al. 1953) and used it for a national wetland inventory (Shaw and Fredine 1956). According to Shaw and Fredine, "Wetlands are lowlands covered with shallow and sometimes temporary or intermittent waters. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but the permanent waters of streams, reservoirs, and deep lakes are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist-soil vegetation." For Shaw and Fredine, a wetland has two defining characteristics, "moist-soil vegetation" and "shallow water," the latter, at least, temporarily or intermittently. Although water chemistry plays a role in this classification, it is of secondary importance. There are freshwater and saline wetlands in both the interior of the U.S. and along its coasts.

The current wetland definition and classification system in the U.S. is found in Cowardin et al. (1979). Wetlands are now defined as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water

or covered by shallow water at some time during the growing season of each year." Five wetland systems are recognized in Cowardin et al. (1979): marine, estuarine, riverine, lacustrine, and palustrine. However, all wetlands have three interrelated attributes: shallow water or saturated soils, hydric vegetation, and hydric soils. Again, water chemistry is only of secondary importance.

Thus, wetland science is both broader and narrower in scope than limnology. It is broader because it includes the study of inland and coastal freshwater, brackish, and saltwater wetlands. Limnology, at least in the USA, deals only with inland aquatic systems. In another sense, wetland science is narrower in scope than limnology because it deals with freshwater and marine systems normally dominated by hydrophytes or wetland plants. Although the two disciplines overlap, they have become different sciences. Wetland science's development has been shaped by several unique concerns, including the importance of wetlands as waterfowl and wading bird habitats (van der Valk 2018b), aquatic weed management and control (van der Valk 2022, 2024), and human health problems (Finlayson et al. 2015; van der Valk 2022). Some wetlands do not have, or have only limited areas, of standing water, most notably peatlands. Wetlands with saturated soils have never been of interest to limnologists. Because angiosperms and bryophytes dominate wetlands, as they do most terrestrial ecosystems, sampling techniques and theories from terrestrial ecology have played a larger role in the development of wetland science than limnology. Finally, some wetlands are legally protected ecosystems in parts of the world. As a result, many wetland scientists are involved in delineating and regulating wetlands. In short, these two aquatic sciences have developed along separate lines and today have separate professional societies, journals, textbooks, career opportunities, and academic programs. The first American wetland society, the Society of Wetland Scientists, was founded in 1980, more than 30 years after ASLO.

EDWARD A. BIRGE (1851-1950) AND CHANCEY JUDAY (1871-1944)

Edward A. Birge was born in Troy, NY, where he went to grade school and high school. From 1869 to 1874, he attended Williams College. From 1876 to 1878, he was an instructor at the University of Wisconsin. Birge did his postgraduate studies with Louis Agassiz in Cambridge, MA, and received a Ph.D. in zoology from Harvard in 1878. Birge became a professor at Wisconsin in 1879 but soon left for a postdoctoral year at the University of Leipzig. He spent the rest of his academic career at Wisconsin: professor and chair of zoology (1879-1911), dean of the College of Letters and Sciences (1891-1918), acting president (1900-1903), president (1918-1925), and president emeritus till his death in 1950. Birge was also the director of the Wisconsin Geological and Natural History Survey.

Chancey Juday was born in Millersburg, Indiana, and attended Indiana University (A.B. 1896 and A.M. 1897). He joined the Wisconsin Geological and Natural History Survey in 1900 but left after only a year. Juday then held positions for the next few years at universities in Colorado and California. In 1905, he rejoined the Wisconsin Geological and Natural History Survey as a biologist and remained with the Survey until 1931. In 1908, he was appointed a lecturer in limnology in the Department of Zoology at Wisconsin. He remained in the Zoology Department till his death, rising to the rank of professor. Juday taught the first limnology course and was the major professor of Wisconsin's first generation of limnology graduate students.

At Wisconsin, Birge initially studied the effects of depth, light, temperature, and water currents on the distribution of planktonic crustaceans in Lake Mendota. However, Birge's later research focused primarily on the physics of lakes, i.e., heat budgets, wind-generated currents, and light penetration, while Juday's focused on lake chemistry and productivity. They collaborated throughout their careers and mostly published their research jointly. When Birge retired as president of the University of Wisconsin, Birge and Juday established the Trout Lake Limnological Laboratory in northeastern Wisconsin, a region with numerous lakes. Juday was the director of the Trout Lake Station from 1925 to 1941. For more detailed accounts of the lives and the numerous contributions to limnology of Birge and Juday, see Brooks et al. (1951), Mortimer (1956), Sellery (1956), Frey (1966), Beckel (1987), Magnuson (2002), and Frey (2012).

For Birge and Juday to be antecedent wetland scientists, it is necessary to show that they studied wetlands as currently defined by Cowardin et al. (1979). Birge and Juday did not define what they meant by "lake." According to David Frey, one of Juday's graduate students in the 1930s, Juday, in his limnology course at Wisconsin, also did not define "lake." "They [lakes] were the kind of waterbody that Birge & Juday were studying in Wisconsin" (Frey 1990). The lakes Birge and Juday studied, like all lakes, had two common wetland attributes: standing water and hydric soils. However, for any lakes to be classified as wetlands, they also had to have wetland plants or hydrophytes. Thus, it is direct and indirect evidence of the presence of hydrophytes, for which I looked in Birge and Juday's lake survey papers. If some of their "lakes" were, in reality, wetlands, how did their research contribute to our understanding of wetlands and the development of wetland science?

LAKE SURVEYS

In 1911, Birge and Juday published a monograph on the dissolved gases in lakes and their biological significance. They sampled 156 lakes, 151 of them in Wisconsin. These lakes ranged from 0.05 to 39 km2 in area and 3 to 72 m in depth. Birge and Juday (1911) do not provide any quantitative information on the area of each lake covered with wetland plants. However, they note (p. 48) that in shallow lakes and larger lakes with sizeable areas of shallow water, wetland plants are abundant and a significant source of organic matter for these lakes. Birge and Juday were primarily interested in the plankton communities of the lakes and how they affected oxygen and carbon dioxide concentrations. They were mainly oblivious to the presence of wetland plants and their potential significance for dissolved gases. In the final chapter that discusses unknowns and future research directions, wetland plants are not mentioned. Nevertheless, it is clear that some of their small lakes were palustrine wetlands and that many larger lakes had considerable areas of lacustrine wetlands.

In 1927 and, in an expanded version, in 1934, Birge and Juday published papers on particulate and dissolved organic carbon in the lakes of the Highland Lake District (Figure 3) of northeastern Wisconsin. Most of the carbon in all these small lakes is dissolved organic carbon, and phytoplankton contribute only a small percentage of their total organic matter (Figure 4). "The seven lakes with the smallest amount of organic carbon are those with no inlet or outlet and with little or no marsh adjacent to them. … At the other extreme are 10 lakes whose organic carbon exceeds 10 mg. per liter of water" (Birge and Juday 1927). The latter included lakes that receive large amounts of dissolved carbon from surrounding wetlands. These lakes were either in the bog's center or received water from marshes. Birge and Juday (1934) note that the amount of dissolved organic matter from wetland sources (bogs or marshes) in a lake is evident from the color of its water. They also note that many small lakes in northeastern Wisconsin had "shallow waters [that] pass almost insensibly into boggy margins" (Birge and Juday 1934).

Birge and Juday (1927, 1934) did not sample wetland plants. Nevertheless, they concluded that higher plants, as they called them, do not contribute significantly to the organic carbon in small lakes (Birge and Juday 1934): "In the series of diagrams representing the composition of various elements of the organic content of these lakes [Figure 4], none is found for the higher plants, those growing from the bottom of the lake. The omission is intentional since additions from this source to the organic content of the water may be neglected [emphasis added]. These plants contain only a small amount of organic matter, relatively to the total volume of water in the lake. This is especially the case in northern lakes, few of which have large weed beds. Moreover, such plants, as they die, fall to the bottom, where they accumulate and their organic matter returns to the water, in small part by direct solution from the lake mud, but chiefly in the form of lower products of decomposition." However, Birge and Juday (1934) contradict themselves in the summary: "Total organic matter has two sources, external and internal to the lake. Internal sources are plankton (the main source), mud on the bottom, higher plants [emphasis added], etc." In short, Birge and Juday never bothered to determine if wetland plants growing in small lakes contributed dissolved or particulate organic carbon to them, even though they suspected this might be the case.

Beckel (1987) described Birge and Juday's science thus: "If enough data are gathered, the data will speak for themselves." Unfortunately, Birge and Juday did not collect relevant data on the distribution and abundance of wetland plants in Wisconsin lakes. They did acknowledge that wetland plants occurred and sometimes significantly impacted a lake's water chemistry. However, because they were so focused on plankton, they failed to appreciate the importance of wetland plants in small, shallow lakes, i.e., wetlands.

CONCLUSIONS

Were Birge and Juday antecedent wetland scientists? Although they were familiar with bogs and marshes, they avoided sampling them in their lake surveys because they did not consider them lakes (Frey 1990). Nevertheless, their lake survey data show that some of the lakes they sampled would now be classified by Cowardin et al. (1979) as palustrine wetlands, and others had large lacustrine wetland zones. Despite their strong bias towards plankton, they did acknowledge, when it was apparent, that wetland plants were important organisms in some lakes and that these plants affected lake water chemistry, e.g., the amount of dissolved organic carbon. Thus, they recognized that some lakes differed because they had abundant wetland plants, mostly submerged aquatics.

As previously noted, Birge and Juday (1911, 1927, 1934) never defined a lake. The distinction between wetlands and other kinds of aquatic systems, like deepwater lakes, was not formalized until 1953 (Martin et al. 1953), after both Birge and Juday had died. Reading Birge and Juday's papers, I found it striking to me that they consistently minimized the presence and role of wetland plants in lakes. They never identified which species were present or quantified how abundant or widespread these species were. Like other early limnologists, Birge and Juday saw themselves as freshwater oceanographers. Consequently, their research focused on planktonic communities in open water and the physical and chemical factors controlling their composition and distribution. Only the deeper parts of lakes were important to them, and wetland plants were not commonly found there.

Both Birge and Juday were trained as zoologists and worked in a zoology department. Being zoologists may be the ultimate reason for their lack of interest in higher plants in lakes. Their research contrasts sharply with their contemporary in England, W.H. Pearsall (van der Valk 2023). Pearsall, a botanist, studied in detail the composition and distribution of wetland plants in the lakes of the English Lake District (Pearsall 1920, 1921).

The different biases implanted in students trained in zoology and botany were made evident when I was a graduate student at the University of Alberta. I simultaneously took two introductory ecology courses in plant ecology and animal ecology. Both courses held labs on Saturdays, the plant ecology course in the morning and the animal ecology course in the afternoon. Both labs one Saturday visited the same site. In the plant ecology lab, the site was used to illustrate the importance of a moisture gradient on the distribution of plant species. In the animal ecology lab that afternoon, the site was used to illustrate the impacts of winter grazing by rabbits and deer on the distribution of plant species. The instructor never mentioned grazing in the plant ecology lab, nor did the students notice it. The zoology instructor did not mention the obvious moisture gradient in the animal ecology lab, nor did the students notice it, except for me. It is often said that we see what we want to see. In science, however, we often only see what we are trained to see.

Birge and Juday's lake research did little to increase the visibility of wetlands or stimulate wetland research. Consequently, they were not antecedent wetland scientists. They were anti-antecedent wetland scientists because they viewed only deepwater lakes as worthy of study. This anti-wetland bias would persist in American limnology until the work of Robert G. Wetzel, a renowned American limnologist, in the 1970s and 1980s (e.g., Wetzel 1979). Wetzel's studies of the importance of littoral zones in lakes stimulated numerous studies on the significant role of wetland plants in lakes (Carpenter and Lodge 1986, Schindler and Scheuerell 2002). In 1978, Wetzel contributed a paper on the products of litter decomposition of a wetland plant to a major symposium on freshwater wetlands (Good et al. 1978). When Wetzel became president of ASLO in 1980, he invited wetland

scientists to join the Society and to publish in its journal, Limnology and Oceanography. He had few takers. Like most wetland scientists at the time, I chose to join the newly formed Society of Wetland Scientists, not ASLO. Nevertheless, his studies of the littoral zone of lakes (lacustrine wetlands) marked a significant shift in the attitude of limnologists toward wetlands and their significance.

DECLARATION OF ORIGINALITY

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REFERENCES

Beckel, A. L., 1987. Breaking New Waters, a Century of Limnology at the University of Wisconsin - Special issue of the Transactions of the Wisconsin Academy of Sciences, Arts and Letters, Madison, Wisconsin. https://digital.library.wisc.edu/1711.dl/44N2KX6ER3XFM9A

Birge, E.A. and C. Juday. 1911. The inland lakes of Wisconsin: the dissolved gases of the water and their biological significance. Wisconsin Geological and Natural History Survey, Madison, WI. https://www.loc.gov/item/f11000157/.

Birge, E. A. and C. Juday. 1927. The organic content of the water of small lakes. Proceedings of the American Philosophical Society 66:357-372. jstor.org/stable/3301073

Birge, E. A. and C. Juday. 1934. Particulate and dissolved organic matter in inland lakes. Ecological Monographs 4:440-474. doi.org/10.2307/1961650

Brooks, J. L., G. L. Clarke, A. D. Hasler, and L. Noland. 1951. Edward Asahel Birge (1851-1950). Archiv für Hydrobiologie 45: 235-243. Available through Google Books.

Carpenter, S.R. and D. M. Lodge. 1986. Effects of submersed macrophytes on ecosystem processes. Aquatic Botany 26:341-370. doi.org/10.1016/0304-3770(86)90031-8

Cowardin, L. M., Virginia Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Fish and Wildlife Service, US Department of the Interior, Washington, DC. http://www.openarchives.org/OAI/2.0/oai_dc/ http://www.openarchives.org/OAI/2.0/oai_dc.xsdBeckel

Egerton, F. N. 1962. The scientific contributions of François Alphonse Forel, the founder of Limnology. Schweizerische Zeitschrift für Hydrologie 24:181–199. doi.org/10.1007/BF02503034

Egerton, F.N., 1987. The Wisconsin Limnological Community. pp. 85-122. In A. L. Beckel (ed.) Breaking New Waters, a Century of Limnology at the University of Wisconsin, Special issue of the Transactions of the Wisconsin Academy of Sciences, Arts and Letters. digital.library.wisc.edu/1711.dl/44N2KX6ER3XFM9A

Egerton, F.N. 2014. History of Ecological Sciences, Part 50: Formalizing Limnology, 1870s to 1920s. Bulletin of the Ecological Society of America 95:131- 153. https://api.semanticscholar.org/CorpusID:84937896

Elster, H-J. 1974. History of Limnology. Internationale Vereinigung für Theoretische und Angewandte Limnologie: Mitteilungen 20: 7-30. doi.org/10.1080/05384680.1974.11923880

Finlayson, C. M., P. Horwitz, and P. Weinstein, eds. 2015. Wetlands and Human Health. Springer, Dordrecht, The Netherlands. doi.org/10.1007/978-94-017-9609-5

Forel, F.A. 1892. Le Leman, Monographie Limnologique - Tome Premier. Librarie de l'Université, Lausanne, Switzerland

Forel, F.A. 1901. Handbuch der Seenkunde. Allgemeine Limnologie von Dr. F. A. Forel. (Bibliothek geographischer Handbücher herausgegeben von Prof. Dr. Friedrich Ratzel.). J. Engelhorn, Stuttgart, Germany. Available through Google Books.

Frey, D.G. (ed.). 1966. Limnology in North America. The University of Wisconsin Press, Madison, WI. Available through Google Books.

Frey, D.G. 1990. What is a lake? Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen,24:1-5. doi.org/10.1080/03680770.1989.11898686

Frey, D. G. 2012. The Birge-Juday era. LAKELINE, Winter 2012, 31-33. www.nalms.org/wp-content/uploads/2018/09/32-4-8.pdf

Good, R. E., D. F. Whigham, and R. L. Simpson, eds. 1978. Freshwater wetlands: Ecological Processes and management potential. Academic Press, New York, NY. Available through the HathiTrust.

Lindeman, R. L. 1942.The trophic-dynamic aspect of ecology. Ecology 23:399-417. doi.org/10.2307/1930126

Magnuson, J. J. 2002. Three generations of limnology at the University of Wisconsin-Madison. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen 28:856-860. doi.org/10.1080/03680770.2001.11901835

Martin, A. C., N. Hotchkiss, F. M. Uhler, and W. S. Bourn. 1953. Classification of wetlands of the United States. U.S. Fish and Wildlife Service, Special Science Report--Wildlife 20. Washington DC. www.openarchives.org/OAI/2.0/oai_dc/ http://www.openarchives.org/OAI/2.0/oai_dc.xsd"

Mill, H. R. 1901. Prof. Forel on Limnology. Geographical Journal 17: 296-298. https://archive.org/download/crossref-pre-1909-scholarly-works/10.2307%252F1775

Mortimer, C. H. 1956: An explorer of lakes. In G. C. Sellery (ed.): E. A. Birge, a Memoir. University of Wisconsin Press, Madison, Wisconsin. doi: 10.1126/science.124.3225.728.

Pearsall, W.H. 1920. The aquatic vegetation of the English Lakes. Journal of Ecology 8:163-201. doi.org/10.2307/2255612

Pearsall, W.H. 1921. The development of vegetation in the English Lakes, considered in relation to the general evolution of glacial lakes and rock basins. Proceedings of the Royal Society, B 92:259-284. doi.org/10.1098/rspb.1921.0024

Schindler, D. E. and M. D. Scheuerell. 2002. Habitat coupling in lake ecosystems. Oikos 98177-189. doi.org/10.1034/j.1600-0706.2002.980201.x

Sellery, G. C. 1956. E. A. Birge, a Memoir. The University of Wisconsin Press, Madison, Wisconsin. Available through the INTERNET ARCHIVE.

Shaw, S. and G. Fredine. 1956. Wetlands of the United States, their Extent and their Value to Waterfowl and other Wildlife. Circular 39, Washington, DC. Available through Google Books.

Strom, K.M. 1929. The Study of Limnology. Journal of Ecology 17:106-11. doi.org/10.2307/2255915

van der Valk, A.G. 2017. Antecedent wetland ecologists – German and Austrian in the nineteenth Century. Wetland Science and Practice 34:112-117. doi.org/10.1672/UCRT083-259

van der Valk, A.G. 2018a. Stephen A. Forbes, Antecedent wetland ecologist. Wetland Science and Practice 35:18-24. doi.org/10.1672/UCRT083-256

van der Valk, A.G. 2018b. Assisting nature: Ducks, "Ding" and D.U. Wetland Science and Practice 35:60-67. doi.org/10.1672/UCRT083-253

van der Valk, A.G. 2020. How I became a wetland ecologist. In Douglas A. Wilcox (editor), History of Wetland Science: A Perspective from Wetland Leaders. Amazon Print-on-Demand.

van der Valk, A.G. 2022. Naturalistic control: W. T. Penfound, T. F. Hall, and A. D. Hess and malaria control in Tennessee Valley Authority Reservoirs. Wetland Science and Practice 40:12-18. doi.org/10.1672/UCRT083-61.

van der Valk, A.G. 2023. Beginnings of wetland science in Britain: Agnes Arber and William H. Pearsall. Wetland Science and Practice 41:10-18. doi.org/10.1672/UCRT083-55

van der Valk, A.G. 2024. The world's most troublesome weed: Water Hyacinth and the development of wetland science. Wetland Science and Practice 42:177-184. doi.org/10.1672/ucrt083-602

van der Valk, A.G. and L.C. Bliss. 1971. Hydrarch succession and net primary production of oxbow lakes in central Alberta. Canadian Journal of Botany 49:1177-99. doi.org/10.1139/b71-167.

Vincent, W.F. and C. Bertola. 2012. François Alphonse Forel and the oceanography of lakes. Archives des Sciences 65:51-64. https://science.cen.ulaval.ca/warwickvincent/PDFfiles/295a.pdf

Wetzel, R.G. 1979. Role of the littoral zone and detritus in lake metabolism. Archiv für Hydrobiologie, Ergebnisse der Limnologie 13:145-161. Available through Google Books.

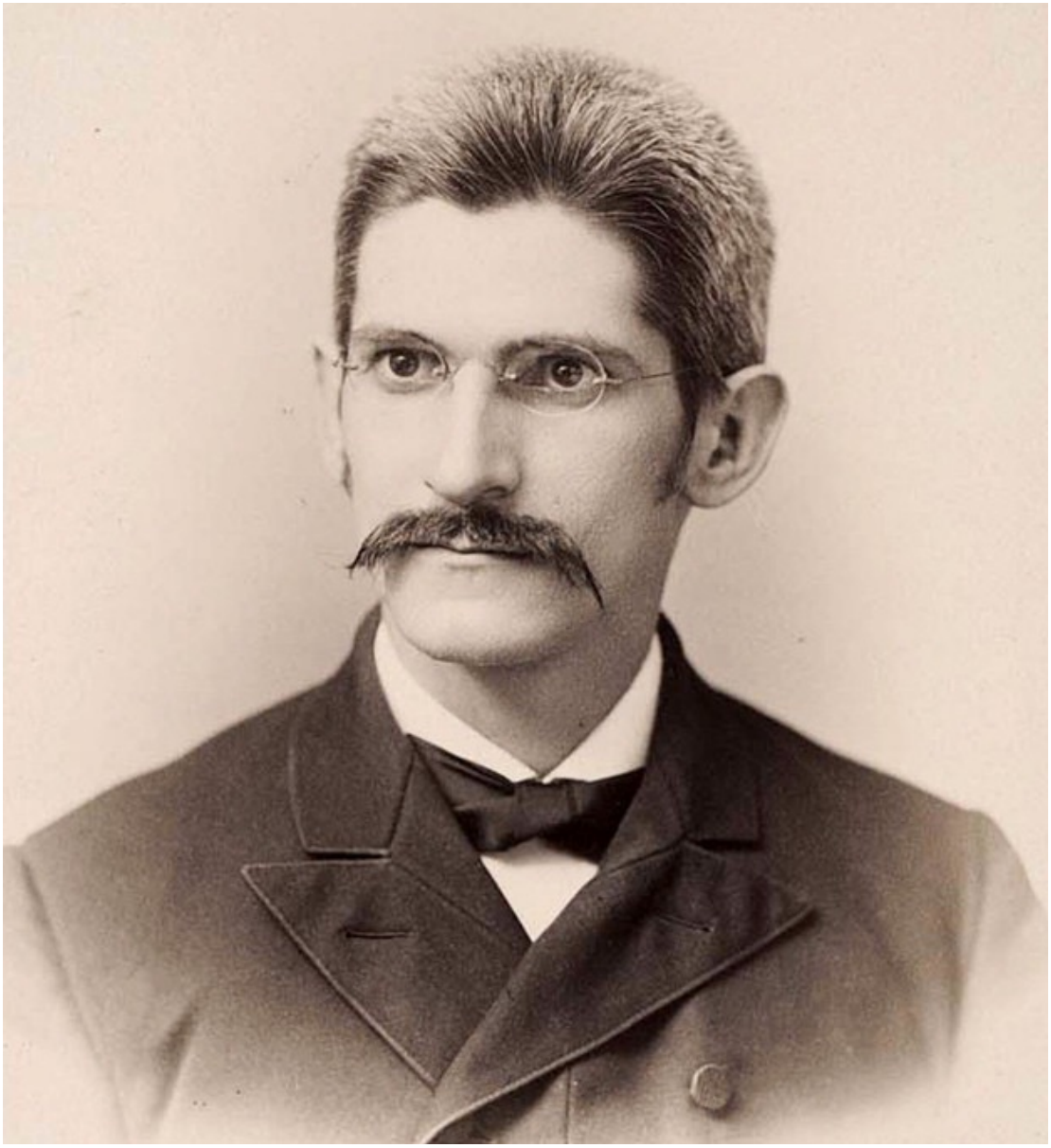


Figure 1. Edward A. Birge. (Photo: Wikimedia Commons)



Figure 2. Chancey Juday. (Photo: University of Wisconsin Digital Collections Center)

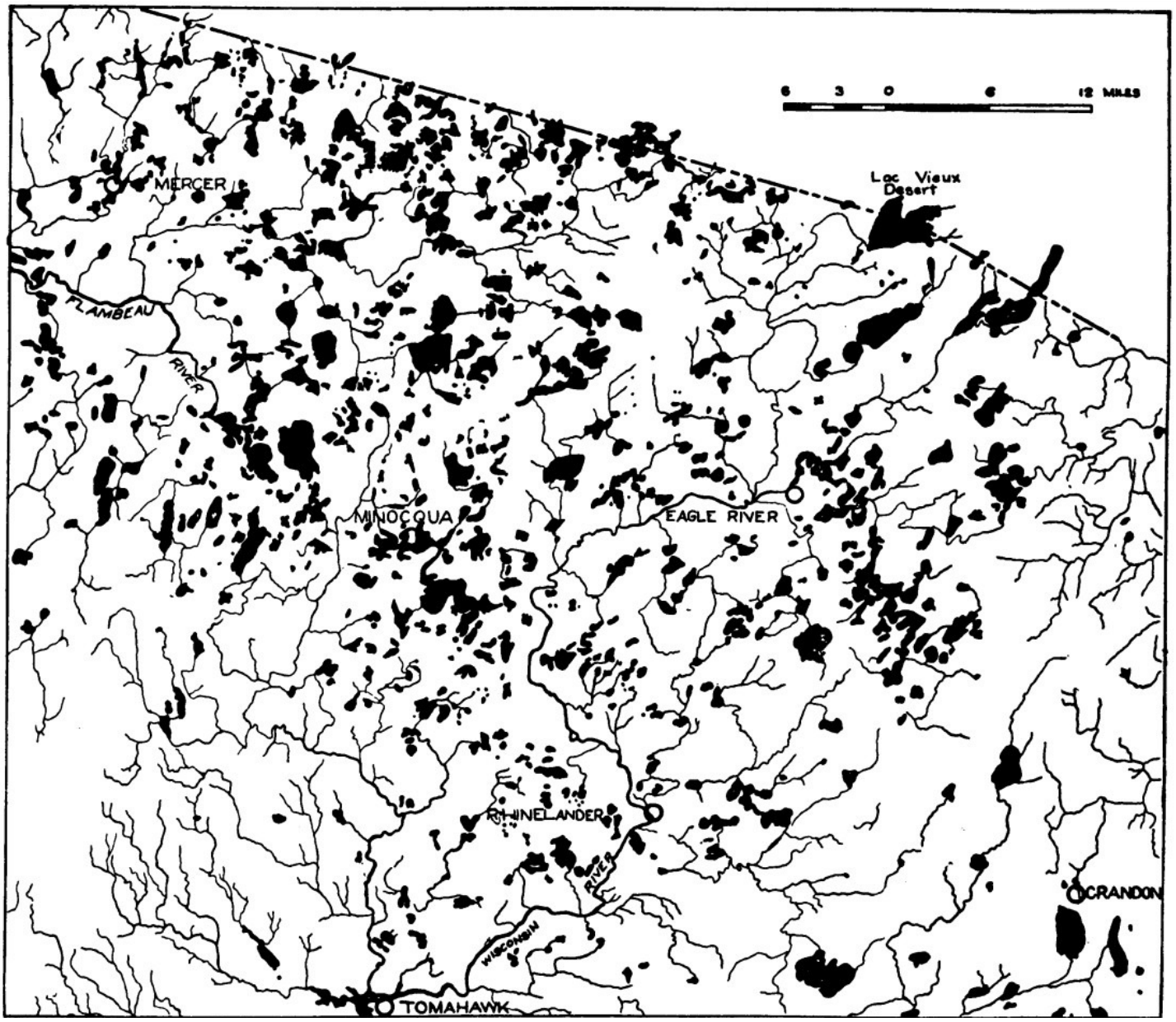


Figure 3. Sketch map of the Highland Lake District of northeastern Wisconsin. Many lakes were too small to be shown at this scale. (Photo: Birge and Juday 1934)

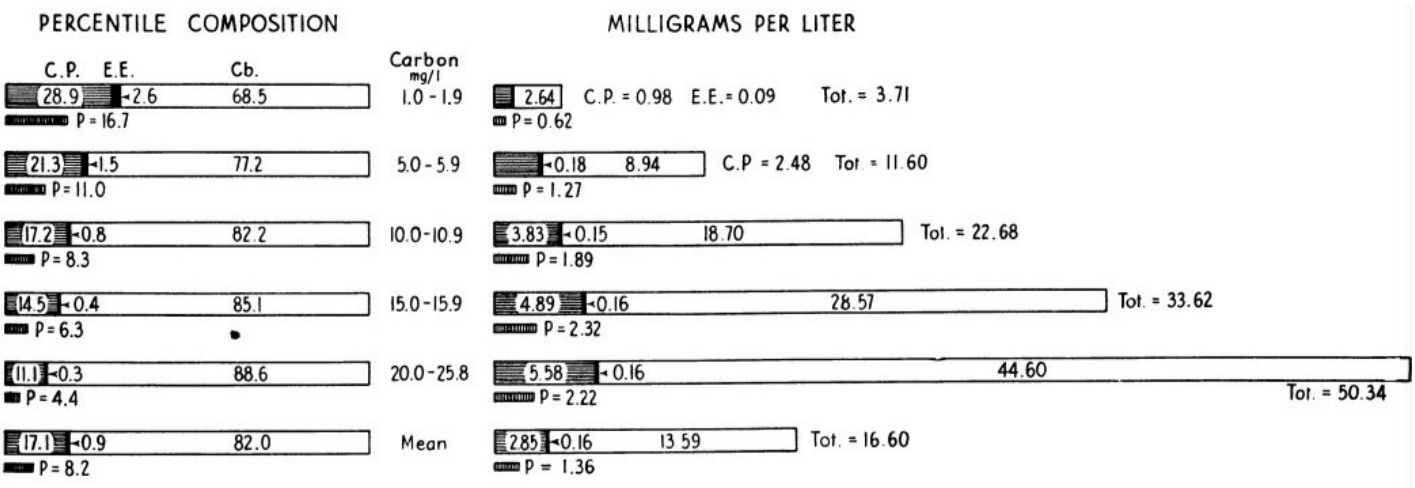


Figure 4. Mean organic content (mg/l) of five types of lakes and the weighted overall mean of all lakes in the Highland Lake District of Wisconsin. C = carbon, Cb = carbohydrates, C. P. = crude protein, E. E. = ether extract of fats, and P = plankton. (Photo: Birge and Juday 1934)