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THE SEARCH FOR SECURITY

David J. Behling

What is security? Perhaps the greatest insight into security is in the Latin definition of the word *securus,* meaning "without care." Viewed positively, security is a good and productive force—peace of mind, freedom from anxiety, freedom from uncertainty, freedom from fear. With a sense of security, we are able to concentrate on the productive aspects of life and living. Viewed negatively, insecurity is a bad and unproductive force characterized by doubt, apprehension, worry, fear, anxiety and other destructive and debilitating feelings.

All people want security. But as society has advanced the nature of man's search for it has changed. Primitive man's chief concern was the elemental protection of his life from hunger, from weather, from beasts and his other enemies. Advancing civilization brought a lessening of some sources of insecurity, but an increase in others, including pestilence, famine and despotic rulers. With the industrial revolution, man made further progress.

It's a fact—perhaps not too well known, but still a fact—that any great degree of economic security, or any great development of the insurance business that does much to provide economic security, is nearly impossible except at times and in places characterized by a considerable economic and industrial development, a general respect for law and order, a basically sound currency, and reasonable stability of government. Favorable concurrences of these conditions have obviously not existed for too long, and the Roman historian Livy, may not have been thinking of insurance when he wrote some 2,000 years ago words that have been translated to say, "Nothing stings more deeply than the loss of money—and security."

On the other hand, maybe Livy did have insurance in mind when he expressed in those words man's need for economic security, for he may have known that almost 2,000 years before his time the Code of Hammurabi had shown the essentials of insurance to be known to Babylonian traders. Hammurabi had also provided that if a man were robbed and the criminal not apprehended, the government would "render back to him whatsoever of his that was lost,"—a sort of very early Social Security Act.

Also, Livy may have known that some 900 years before his time the merchants of the island of Rhodes had added important refinements to marine insurance when they devised the Rhodian Sea Law. Storms and pirates were taking their toll of trading vessels, not to mention imagined losses to ship-gulping sea monsters or to sailing off the edge of the world into the surrounding void. The Rhodians designed a system whereby when a ship failed to return, each merchant absorbed a portion of the loss rather than allowing the unlucky individual owner to be ruined.

This early insurance, whatever economic security it created in the specific situations it covered, did not perceptibly increase the security of the great majority of people. Yet we owe a great debt to the merchant chiefs of the Mediterranean, for they formalized the voluntary mutual assistance and risk-sharing principles on which all insurance is based.

The Greeks, whose reverence for human life exceeded that of any people who preceded them, were the first to apply these principles to men's lives. Their burial societies, not only met the burial expenses of deceased members, but also provided for at least some of the temporary financial needs of their widows and orphans.

The business-like Romans left evidences that they had developed rather complex forms of commercial insurance, and that they gave continuity to the concept of life insurance through their payments to the survivors of soldiers. As a matter of fact, some 2,000 years ago the Roman, Ulpianus, for that purpose provided a table of life expectancy so accurate that only slight changes have been made since then.

Although the Greeks and Romans did make great strides in the discovery of insurance principles and in the wider application of these principles to more people, they brought increased security to only a very small fraction of the population. In the time of adversity, like the death of the family's breadwinner, the great majority still had to depend for their economic necessities on the uncertain good will and generosity of their relatives and friends, who themselves might or might not have resources to share.

The snail's pace development of man's cooperative efforts at achieving economic security halted altogether with the fall of Rome to the barbarians and the advent of the Dark Ages. The feudalism of those days has been described as a compulsory form of security: in return for his loyalty and labor for his ruler a man hoped to obtain protection and the necessities of life for himself and his family. This was not an ennobling form of security—and it existed only at the whim of the lord of the manor and only so long as the latter remained as strong or stronger than his rivals. This rather insecure form of security may still compare favorably with the present situation of a significant proportion of mankind living in countries not yet showing any considerable economic and industrial development, respect for law and order, soundness of currency, or stability of government.

The Renaissance marked the rebirth of mutual assistance efforts on the part of western man. The merchant and citizen guilds, later the friendly societies of England, other groups in other places, all used insurance concepts to protect the security of their members.

The great fire of London in 1666, while destroying five-sixths of the city, had two beneficial side effects upon man's security. One, it destroyed that section where the plague that periodically swept the city was concentrated, and which has been credited with controlling the future outbreaks of the disease. Two, fire insurance sprang into being from the city's embers, enabling men to protect their homes from the financial consequences of the disaster of fire. This is an-another example of the fact that out of mankind's greatest disasters have often arisen humanity's means of salvation.

It was then, too, that life insurance policies and annuities entered the scene, usually being offered to the public by companies underwriting both fire and life risks. So pertinacious were the agents who solicited for these companies that an outraged poet of the day complained:

> By fire and life insurers next
> I'm intercepted, pestered, vexed
> Almost beyond endurance.
>
> And though the schemes appear unsound,
> Their advocates are seldom found
> Deficient in assurance.

Among the numerous complaints were some whose titles seem absurd even to our speculative generation of the 1960's:

> Assurance of Female Chastity
> Assurance From Lying
> Insurance from Death by Drinking Gin
> Insurance Against Going to Hell

But out of this great misconception of the true purpose of insurance—and it wasn't humorous at that time—came the clearing of the way for legitimate life insurance underwriting.

It is quite true that often in those early days of insurance, fire and particularly life policies were either woefully underpriced or overpriced by reason of misconceptions as to the principles involved. Efforts to clear up these misconceptions led to actuarial science, dealing with the mathematics of life contingencies—that is, the probabilities of life and death which were long greatly misunderstood. As a matter of fact, they are still surprisingly mysterious, despite the fact that all the really basic principles of actuarial science had been developed and presented in text books by the time I studied the mathematics of life insurance at the University exactly forty years ago.

This reference to my early insurance student days reminds me of what probably ought to have been the frightening story I read at the time about a life insurance man who was such a complete insurance man that he filled many notebooks with statistical observations of phenomena concommitant with life and death, attempting to analyze each and thus extend the frontiers of his understanding and knowledge of insurance.

In today's terminology we would very likely say that this had a psychosomatic effect on him, for at a really not advanced age he discovered one day while analyzing his notebooks that he had been sleeping longer each night than the night before—fifteen minutes longer, to be precise. This continued. The time arrived when he slept for 23 hours and 45 minutes. On awakening he hastily called his wife, children and grandchildren about him, gave them such advice as the wisdom of a lifetime suggested, and bade them an affectionate farewell. At the end of fifteen waking minutes, he promptly fell asleep again, slept for precisely 24 hours—and then quietly expired.

To my youthful mind that was a highly admirable example of complete absorption in one's chosen vocation. Now that I am older, I confess that I feel happy to observe that my sleep habits show no such disquieting regularity to which my wife will attest.

Actuarial science, as I have indicated, was a mature science when I came to it, and I promptly became convinced that the life insurance problems of the future could be solved by the experience and wisdom of the past. These have supplied the basic and immutable principles; but the actual developments and innovations in my lifetime were to be so extraordinary that no one would then have conceived them to be possible of accomplishment in a short forty years.

No one forty years ago would have guessed to what extent new policies could be developed to provide new comprehensive programs of life insurance and annuity benefits, "new" even if the elements of each program were as old as actuarial science. No one would have foreseen the development of new uses for life insurance in the business world, such as to protect businesses in the event of death of key executives, or to provide necessary additional security for loans, or to assure orderly continuance of partnership businesses after the death of one partner, or to assure Uncle Sam his estate tax, with a sufficient amount left for the deceased's family.

During the past forty years there have been extraordinary changes in the methods by which life insurance is presented to the purchaser, enabling him to analyze his financial situation and buy the particular policies that fit into a logical program of protection for the insurance needs of his family. This valuable programming approach, together with other improved procedures and strengthened standards of competence, have happily changed the public image of life insurance agents from that of rather ineffectual but annoyingly high-pressure salesmen, failures in other lines of endeavor (all too generally true in fact forty years ago) to now, in many cases, trusted confidential advisors of quasi-professional or professional stature, with their own designation—that of Chartered Life Underwriter, which is equivalent to the CPA in accounting.

The life insurance business is usually counted among the very conservative institutions in our economic and social life. It must be conservative, because it is a trust sort of operation in which, above all else, policyowner's reserves must be safeguarded and adequate funds maintained to assure claim payments to all those who will suffer the losses insured against. While the insurance man's need to be conservative may somewhat too often condition him to oppose desirable, even inevitable change, it is extremely difficult in the modern business world for any insurance or other business organization to maintain the status quo for any length of time. In fact, an obsession with security through the maintenance of the status quo is the enemy of long term growth and even of existence. It must be replaced by an intense desire to respond to new situations arising in a changing world. Insurance history provides many happy examples of such response.

During the early days of life insurance in this country, that is in the 1800's, policies became null and void if the insured traveled too far from home, into the then unhealthy or dangerous regions of the southern and western states, or into less settled parts of the world or if he engaged in a duel, or even if he left the earth in a hot air balloon! In the days when horses and wagons were the usual means of land transportation, railroad engineers, firemen and conductors had to pay extra for life insurance protection, and anybody with nerve enough to serve as brakeman on a freight train just couldn't get insurance at any price. Similarly, it was years after Kitty Hawk before aviators and their passengers could get life insurance covering them in flight.

In contrast, one week before Major Gordon Cooper blasted off on his twenty-two orbit space flight in 1963, the Aetna Life Insurance Company issued a $100,000 life insurance policy to Cooper and to each of the six other original astronauts. Their life insurance protection for their families was good anywhere on earth or in outerspace. Yes, even on the moon, if and when some of those men do get there.

A great many other details of the life insurance business and its history might interest you. I must, however, move into the final phase of my discussion of the part that life insurance plays in man's search for security—in helping him achieve economic security.

Does this economic security mean protection against change in man's economic condition, to enable him to maintain the status quo? Not by any means. We must not forget the paradox that an obsession with security through the maintenance of the status quo is the enemy not only of all progress, but also ultimately of security itself.

Even if it seems to raise another paradox, let me try to explain how insurance, by protecting the status quo against certain risks, can enable a prudent man to incur other risks in order to progress far beyond the status quo. A few examples may indicate what I mean.

Life insurance has provided many a man's widow and orphans with their main or only means of self-respecting subsistence. Often it alone has enabled the members of the bereaved family to remain in what may be called their own world, something near to the kind of life they have been used to, with some of the comforts and amenities of our civilization in addition to the necessities of life, and with the right kind of opportunities for the bringing up and the education of the children. That is one side of the life insurance coin; the other is that the ownership of an adequate amount of life insurance enables a prudent man to incur larger financial obligations and to take greater financial risks for the furtherance of his career and, if he is successful, for the ultimate benefit and satisfaction of his family. He can do so in reliance on life insurance to pick up his financial responsibilities to his family if death interrupts his attainment of his business or professional objectives.

Then, too, the tendency of recent decades toward early marriages and having children young gains with life insurance a measure of economic prudence. The parents of a young girl can even prepare for this by buying insurance on her life with the provision that if and when she marries she can transfer it on to the life of her bridegroom.

Insurance provides a bulwark against these hazards to economic security, bulwarks it would be unthinkable to be without, for economic misfortune rarely if ever affects only the few persons whom it directly strikes. If there is no method of relieving the financial consequences of individual catastrophe, society as a whole suffers both from the nonpayment of the liabilities of the insolvent and from the interruption of the productive activities of all concerned. And the other side of the coin is that in the absence of the security that insurance can promise, man would not dare to invest either his money or his efforts in the business and personal activities and operations which make the modern world what it is and lead to the great developments which the passing decades observe.

I should like to conclude with a short commentary on the life insurance business' own quest for security. How can the insurance business insure itself? I do not at this point have in mind the technical, but nonetheless important, matter of protection through reinsurance against too large claims or catastrophic aggregations of claims. What I am thinking about is the long term security of the insurance business. This will come from its adaptability to change, from the new protections it provides against the financial consequences of the new hazards and perils which our country's developing economic and personal life incurs; from the extent to which the security provided by insurance to business and industry, and individuals, makes it prudent for business and industry, and individuals to exercise the boldness and adventurousness which a good pace of economic and personal progress will always require.

For all business—in fact for man himself—there can be no security that is not grounded on courageous and wise adaptation to the new situations that our changing world will bring. Man's search for security will continue to be a major personal and governmental preoccupation, but its pursuit ought not to obscure all other values, and especially those on which security itself depends.

The words of Somerset Maugham as he watched the fall of France in the first year of World War II are arresting—

> "Those who value security above freedom will lose their freedom, and having lost their freedom, they will lose their security also."

THE GREEK REVIVAL IN RACINE

*Mary Ellen Pagel**

The Greek Revival style in architecture made its American debut in 1798 with Benjamin Henry Latrobe's design for the Bank of Pennsylvania at Philadelphia. Latrobe's use of forms and details derived from ancient Greek architecture was not without European precedent; indeed, in his native England buildings in the Grecian mode had been constructed as early as the 1750's. But in no European nation was the style to prove more popular and enduring than in the young United States. Its aesthetic merits, its ready adaptability to various functions and building materials, its evocation of the ideals of Greek democracy—all these endeared it to Americans. And so it happened that within a decade of the completion of Latrobe's Philadelphia bank, the Greek Revival gained wide currency in eastern architectural circles and, in most sections of the new nation during the first half of the 19th century, was a predominant style in which both professional architects and amateur designers clothed public and residential buildings and, to a lesser extent, commercial and religious structures as well. As Hugh Morrison has observed: "From 1820 on, the Greek temple became the highest architectural ideal for a generation of Americans."[1]

A sketch of Racine, Wisconsin made in 1841 (just seven years after pioneer settler Gilbert Knapp had erected Racine's first building) reveals that the tastes of the city's early residents were not at odds with this pattern. (Fig. 1). Their fondness for classical architectural forms is evident in the modestly Grecian houses at left and right and in the more monumentally treated county courthouse near the center of the drawing.

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* Department of Art and Office of Planning and Construction, University of Wisconsin Center System.

[1] *Early American Architecture from the First Colonial Settlement to the National Period* (New York, 1952), 575.

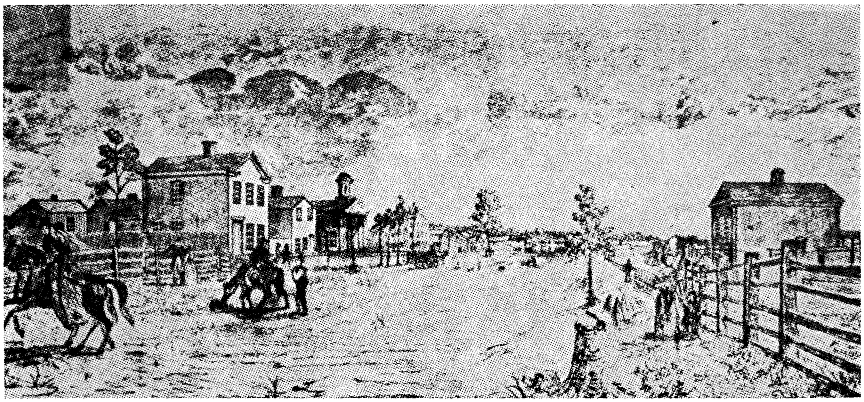

FIGURE 1. Corner of Seventh and Main Streets, Racine, in 1841 (drawing reproduced courtesy the Racine County Historical Museum).

Work on Racine's first courthouse (Figs. 1, 2) began in 1839 under the supervision of William H. Waterman and Roswell Morris, local contractors who were responsible, it appears, not only for construction but also for design.[2] Completed in 1840. their courthouse was a chaste white frame building with a symmetrical, temple-like façade of four Doric columns. A domed octagonal cupola crowned the building's low-pitched gabled roof-line. In plan and in front elevation the now-destroyed courthouse conformed to a type held in high regard across America during the three decades preceding the Civil War. Among its relatives number such eastern courthouses as those at Hillsboro, North Carolina (1845) and Waynesburg, Pennsylvania (1850)[3] and such midwestern examples as the Third LaSalle County Court House at Ottawa, Illinois (1842; razed),[4] the Milwaukee County Court House (1836; razed),[5] and

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[2] Fanny S. Stone (ed.), *Racine, Belle City of the Lakes and Racine County, Wisconsin* (2 vols.; Chicago, 1916), I, 96. For the courthouse see also: *The History of Racine and Kenosha Counties, Wisconsin* (Chicago, 1879), 367; Eugene W. Leach, *History of the First Methodist Episcopal Church, Racine, Wisconsin, with a Preliminary Chapter Devoted to the City of Racine 1836 to 1912* (Racine, 1912), 19, 31; Rexford Newcomb, *Architecture of the Old Northwest Territory: A Study of Early Architecture in Ohio, Indiana, Illinois, Michigan, Wisconsin and Part of Minnesota* (Chicago, 1950), 133.

[3] Illustrated in Talbot Hamlin, *Greek Revival Architecture in America: Being an Account of Important Trends in American Architecture and American Life prior to the War Between the States* (London, New York, and Toronto, 1944), Plates L and LXXVII, respectively.

[4] Newcomb, 101 and Plate XLI.

[5] Harry H. Anderson, "The First County Court House," *Historical Messenger of the Milwaukee County Historical Society*, XXI (December, 1965), 100–109.

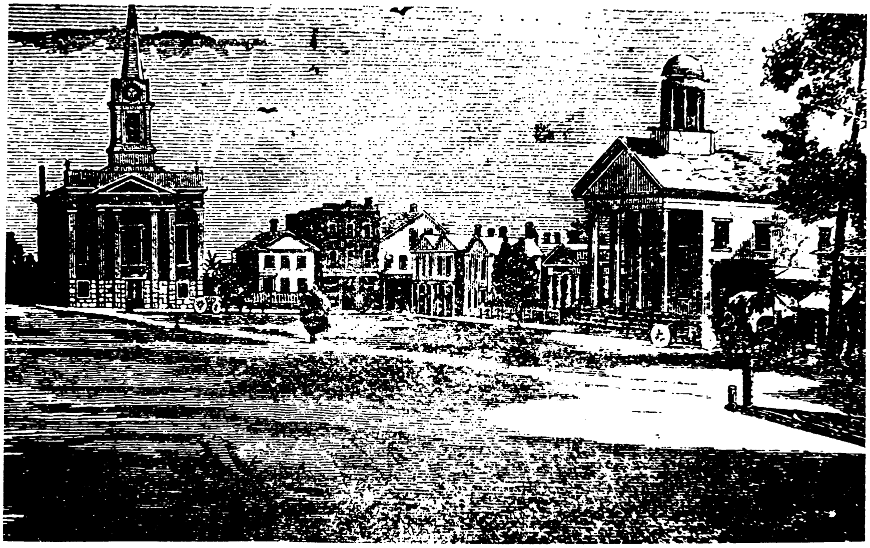

FIGURE 2. The Racine public square c. 1860. First Baptist Church is at left, the first Racine County Courthouse at right (drawing reproduced courtesy the Racine County Historical Museum).

the well-known Iowa County Court House at Dodgeville (1859), Wisconsin's last important remaining example of the type.[6]

Enjoying concurrent and equally widespread popularity were residential designs of the types represented at far left and far right in the sketch of 1841. Rectangular, two-story structures with gently sloping gabled roofs, these unpretentious homes lacked the colonnaded entrance porticoes of more elaborate Greek Revival buildings but retained the compact silhouette, geometrical clarity, and, in greatly simplified form, the classical details of the style. Familiar Wisconsin examples include the York house near Zenda and the diminutive Christophel house in Milwaukee—both mentioned by Richard W. E. Perrin,[7] the brick residence at 922 North Cass Street in Milwaukee, and the so-called Old English House on Third Avenue in Kenosha. The two early specimens in Racine, which, according to local historian Eugene W. Leach, may have belonged to H. J.

[6] Robert M. Neal, "The History of the Court House," *Centennial Story: The Iowa County Courthouse 1859–1959* (Dodgeville, Wisconsin, 1959) and Richard W. E. Perrin, *Historic Wisconsin Buildings: A Survey of Pioneer Architecture* (Milwaukee Public Museum Publications in History No. 4; Milwaukee, 1962), 30, 33.

[7] *Historic Wisconsin Buildings,* 30, 35.

FIGURE 3. 1108 Douglas Avenue before recent renovation (photograph by Todd Dahlen and Peter Vallone).

Smith (house at left) and to Paul Kingston (right),[8] have not survived, but similar residences still stand in the city.

At 1108 Douglas Avenue (Fig. 3), for example, is a home closely resembling the lost Smith house. Designed and built in 1855 by

[8] Leach, 6.

Charles Fountain, it served briefly (1862–63) as the first Dominican convent in Racine.[9] Passing again to private ownership in 1863, it has remained in use as a residence since then and had undergone only minor remodelling and modernization on the interior until 1967, when the exterior was renovated.[10] Here, just as in the Smith dwelling, one finds a two-story plan, a façade with three regularly spaced windows on the upper floor, and, below, the entrance placed to the left. The recessed entryway, with pilasters and narrow sidelights flanking the door, small transoms and an entablature above —in the Fountain house the lone decorative element in an otherwise plain façade—occurred in Neo-classical structures both humble and sumptuous, both private and public. Variations on the common theme appeared in Racine's first prominent hotel (the Racine House, 1837),[11] the city's first brick residence (the Ives house, c. 1840),[12] the mid-19th century Fratt mansion,[13] and the Cooley–Kuehneman house of c. 1851–54 (Fig. 10)—among numerous examples. This distinctive doorway treatment seems to have been popularized by Asher Benjamin, [14] whose widely circulated architectural handbooks served as design sources and practical guides for 19th century American builders.

Returning to the drawing of 1841, one finds that the Kingston home at far right, while similar to those just considered, presents a more ornamental façade, with simplified Doric pilasters at the corners and a fully-defined pediment above the second story windows. Like structures in present-day Racine include the attractive gray and white frame house at 1201 College Avenue (Fig. 4). Erected c. 1852–60, the home has been enlarged by additional construction at south and east but retains a sturdy, straightforward ante-bellum flavor.[15]

A late 19th century photograph of the one-time residence (now the local American Red Cross headquarters) at 745 Wisconsin Avenue suggests that it, also, was originally of this pedimented

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[9] Sister Mary Hortense Kohler, *The Life and Work of Mother Benedicta Bauer* (Milwaukee, 1937), 204–205.

[10] Mary Ellen Pagel (ed.), *Pagans and Goths in Nineteenth Century Racine: Architecture of the Classical and Gothic Revivals* (mimeographed; Racine, 1964), 7–8 and an unpublished report in the author's collection written in 1964 by Carol Haberman and Karen Nielsen of the University of Wisconsin–Racine Center.

[11] Leach, 18.

[12] *Ibid.*, 27.

[13] The Historic American Buildings Survey, *Wisconsin Architecture: A Catalog of Buildings Represented in the Library of Congress, with Illustrations from Measured Drawings* (Washington, D. C., 1965), 68.

[14] Newcomb, 79 and Hamlin, Plate XCIV.

[15] Pagel, 8 and an unpublished report in the author's collection prepared in 1964 by Judy Sorensen and Barbara Monefeldt of the UW–Racine Center.

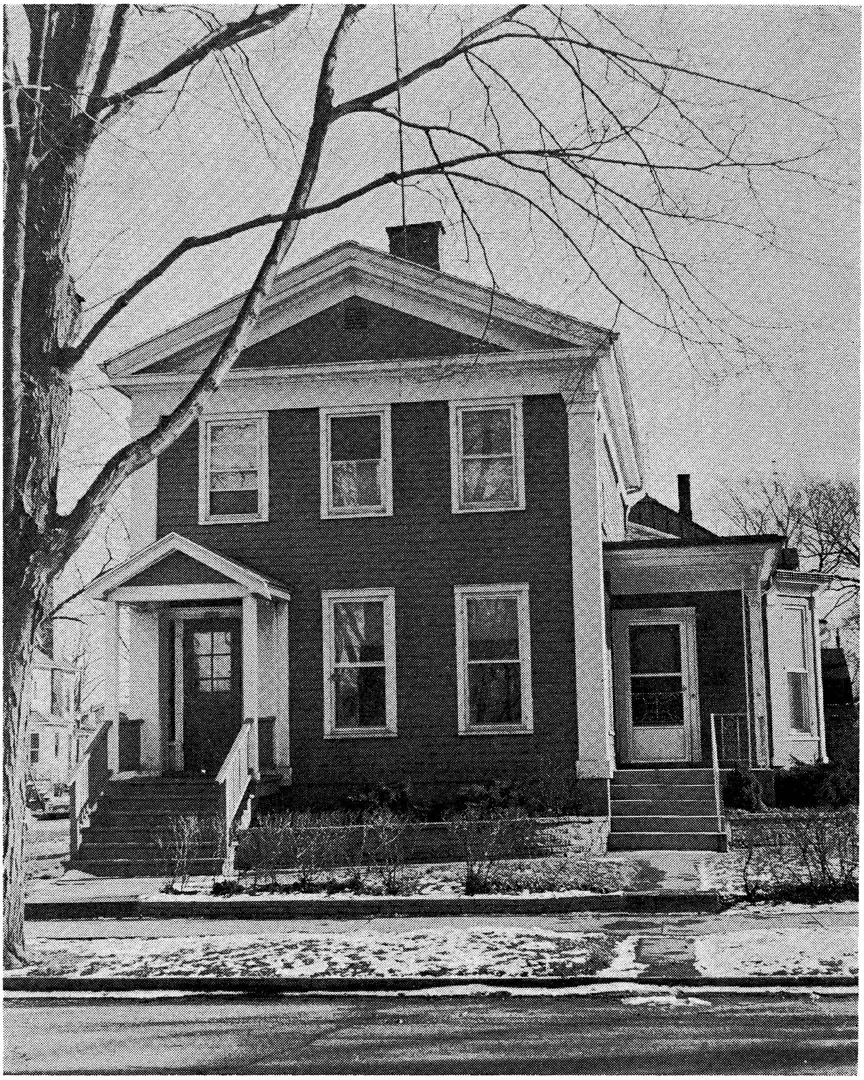

FIGURE 4. 1201 College Avenue (photograph by Todd Dahlen and Peter Vallone).

type (Fig. 5). The dainty Victorian veranda which decorated the home when it was photographed c. 1872–92 was, in all probability, a post-Civil War addition, but the wing at right with the stout Doric columns may have been part of the original design. Recent remodelling has removed both the veranda and the sturdy colonnade

FIGURE 5. 745 Wisconsin Avenue in 1872–92 (photograph from the Racine County Historical Museum).

and given the building its present facade (Fig. 6). Although there is evidence that a structure, possibly a residence, stood on this site as early as 1851, the precise date of the existing building, like its original appearance and the name of its designer, is still to be established.[16]

Uncertain, too, are the identities of the architects of Racine's best-known Greek Revival houses—the charming residence at 1247 South Main Street (Fig. 7) and its celebrated neighbor at 1135 South Main (Figs. 9, 10), both of which have been recorded by the Historic American Buildings Survey of the U. S. Department of the Interior.[17] Earlier of the pair, 1247 South Main (first the Hunt house; later called Westbourne; now the Harold C. Jensen residence) dates from c. 1842–48 and is among the city's oldest

[16] An unpublished report in the author's collection written in 1964 by Ruth Jensen and Elizabeth Maroda, then at the UW–Racine Center, states that the property in question was sold in 1851 by Alexander Bishop to Jacop Soatwall for $2,000, a sum considerably in excess of amounts then asked for unimproved lots in the neighborhood. The property increased in value in subsequent sales, having been reacquired by Bishop in 1852 for $2,500, sold by Bishop to Walter Cooley for $3,714 in 1855, and by Cooley to Hamilton Utley for $6,500 in 1870. See also Pagel, 6–7.

[17] *Wisconsin Architecture,* 68, 69.

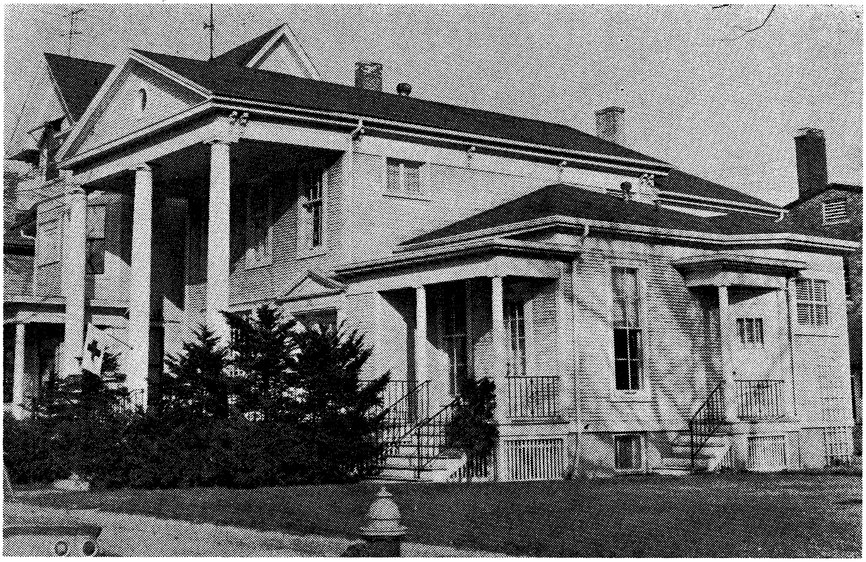

FIGURE 6. 745 Wisconsin Avenue in 1964 (photograph by Todd Dahlen and Peter Vallone).

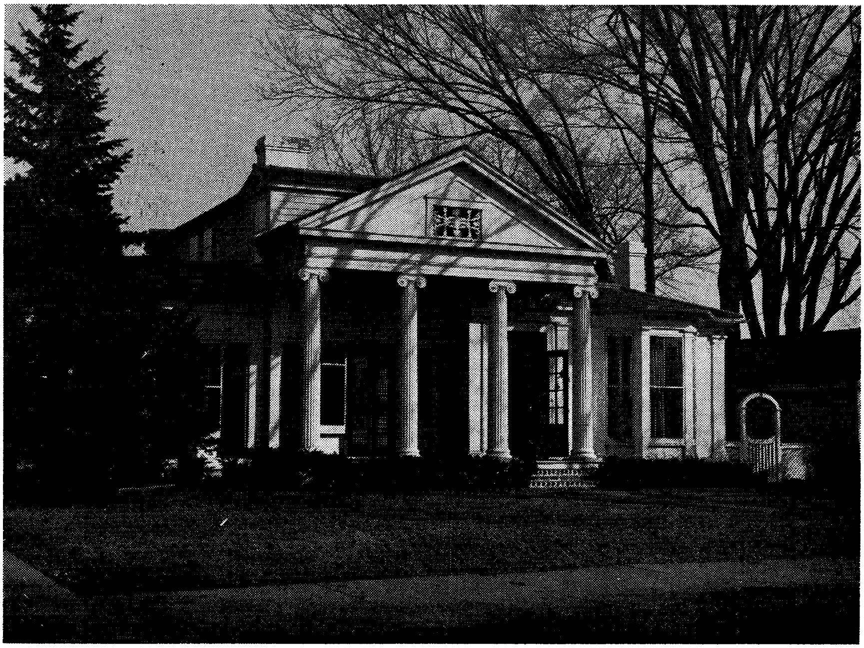

FIGURE 7. 1247 South Main Street (photograph by Todd Dahlen and Peter Vallone).

extant homes. Tradition holds that it was built by William Hunt as a gift for his wife and that the designer-builder was a local carpenter.

In this connection, it is interesting to take note of a house mentioned and illustrated some five decades ago by Racine historian E. W. Leach (Fig. 8). In his day the house was standing at 416 Lake Avenue. He noted that it had been built "about 1840" by a carpenter named Chadwick and that it was still called the Chadwick house.[18] Writing a few years later, Mrs. David H. Flett repeated this information and added that the home originally stood on Main Street.[19] Early city directories reveal that one Reuben Chadwick, cabinet maker, was residing at 141 Main Street by 1850,[20] but available evidence allows no more than speculation as to his identity with the carpenter named by Leach and Mrs. Flett. The question of the attribution and dating of the now-destroyed Chadwick house assumes particular interest for students of the Hunt–Jensen home

[18] Leach, 29.

[19] "Notable Pioneer Homes" in Stone, I, 402.

[20] *The Racine Register, Business Directory, and Advertiser* (Racine, 1850), 25. The first Chadwick specifically described as a carpenter in city directories was Ellis Chadwick, living with William Chadwick, woodturner, on Main Street, in 1868; see Richard Edwards, *Edwards' Annual Directory of . . . the City of Racine for 1868–69* (Racine, 1868), 61, 62.

FIGURE 8. The Chadwick house c. 1912 (photograph from the Racine County Historical Museum).

because of the obvious and striking similarities between the two structures. So close are they in proportions and details that one is tempted to suppose that the same hand drew both plans or that, at the very least, a single source—to be discovered, perhaps, in a 19th century builders' guide—inspired them.

The Hunt–Jensen house has been moved several times during its long history, but despite the transfers, it survives in good condition and preserves a substantial portion of its original design. It remains an excellent example of the Greek Revival temple-house, with the characteristic front portico of columns, here of the decorative Ionic order. Typical, too, are the near symmetry of plan and façade, the wood construction and siding, the uniformly white, smoothly surfaced exterior, and the air of tranquility, dignity, and comfort.[21]

The house presents many noteworthy details—among them the pedimental ornament on the facade. Architectural historian Talbot Hamlin has stated that pierced grilles of this type, executed in wood (as in this case) or in cast iron, were one of several distinctly American contributions to the Greek Revival decorative vocabulary and were "common in frieze and attic windows all over the country."[22] The Hunt–Jensen grille, the sole surviving instance in Racine, is not unlike the window grilles in Johnathan Goldsmith's cottage at Painesville, Ohio (1841), which, Hamlin found, had been borrowed from a plate in Minard Lafever's *The Modern Builders' Guide*.[23] As we know, Lafever's books were quite as popular among 19th century craftsmen as those of Asher Benjamin.

Called "perhaps the best remaining example of the Greek Revival in Wisconsin" by the writers of the Historic American Buildings Survey,[24] the William F. Kuehneman house (Figs. 9, 10) was built for Eli R. Cooley, hardware merchant and third Mayor of Racine. It can be dated between 1851, when Cooley acquired the property, and 1854 when he sold it to Elias Jennings at a marked increase in price.[25] The simple, beautifully proportioned home consists of a two-story central block with a projecting porch of four slender Doric columns and symmetrically disposed one-and-one-half-story

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[21] For the Hunt–Jensen house see also: Alexander C. Guth, "Historic American Buildings Survey," *Wisconsin Magazine of History,* XXII (September, 1938), 31–32; Newcomb, 130; Writers' Program of the Work Projects Administration in the State of Wisconsin, *Wisconsin: A Guide to the Badger State* (revised ed.; New York, 1954), 280. Pagel, 5–6; "Racine," *Wisconsin Architect,* XXXIV (April, 1966), 16; and an unpublished report in the author's collection prepared in 1964 by Frank Chud and Thomas Fuhrer, UW–Racine Center.

[22] Hamlin, 354.

[23] *Ibid.* and Plate XCIII.

[24] *Wisconsin Architecture,* 69.

[25] Lucy Colbert, "Century-old Home Cited for Its Beauty, History," Racine *Journal–Times Sunday Bulletin,* October 14, 1956, sec. 2, 1 and an unpublished report in the author's collection written in 1964 by Lynn Meier and Marilyn Francis, UW–Racine Center.

FIGURE 9. 1135 South Main Street (photograph by Todd Dahlen and Peter Vallone).

wings. Both exterior and interior have been carefully restored and maintained by the present owner.[26]

The gifted designer has not been identified with certainty, but critics have suggested that Lucas Bradley (1809–89), Racine's first architect, drew the plans. Born and educated in Cayuga County, New York, Bradley worked as carpenter-architect for a brief period in St. Louis, visited Racine in 1843, and settled there permanently the following year. His two documented buildings in the Greek Revival style—Second Presbyterian Church in St. Louis (1839–40; razed)[27] and First Presbyterian Church of 1851–52 in Racine (Fig. 13) give evidence that he was a master of the first rank and, fur-

[26] Much has been written about the Cooley–Kuehneman house. Additional sources include: Newcomb, 130; Perrin, *Historic Wisconsin Buildings,* 28–29; Pagel, 3–4; *Wisconsin Architect,* XXXIV, 15. Perrin also discusses the home in his *Historic Wisconsin Architecture* (Milwaukee, 1960), 11 and his "Greek Revival Moves Westward: The Classical Mold in Wisconsin," *Wisconsin Magazine of History,* XLV (Spring, 1962), 201.

[27] John A. Bryan, *Missouri's Contribution to American Architecture* (St. Louis, 1928), 11, 27; by the same author, "Outstanding Architects in St. Louis between 1804 and 1904," *Missouri Historical Review,* XXVIII (1933–34), 85; Hamlin, 252; Newcomb, 135.

FIGURE 10. 1135 South Main Street, detail, entrance (photograph by Todd Dahlen and Peter Vallone.

ther, offer stylistic parallels with the Cooley–Kuehneman house.[28] This home, in turn, resembles a second residence in the area, as Perrin has pointed out:

> "A few miles northwest of Racine on the Nicholson Road, in the Town of Caledonia, Racine County, is another Temple house which might be called a country cousin of the Kuehneman house. The central Doric tetraprostyle portion resembles the Kuehneman house so very much that it could be concluded that either the same architect or the same architectural handbook played a part in its design. This house is believed to have been built by John Collins of New York State in about 1853."[29]

Less appealing to church architects than was the contemporary Gothic Revival style, the Greek Revival was, nonetheless, employed for religious buildings. And Racine's Neo-classical churches, like its Grecian homes, range from the modest to the majestic. Representing the former extreme is the tiny building at 806 Superior Street (Fig. 11). Erected for the First Scandanavian Baptist Church c. 1859, the structure is remotely Grecian in the pediments and pilasters of its facade and in its boxy, compact shape. The now-anonymous designer apparently felt constrained to modify the pagan implications of the Greek Revival style and punctuated the side elevations with Gothic lancet windows. One finds this curious combination of classical and Gothic motifs in several other early Wisconsin churches, including St. Peter's Church (1839), formerly in Milwaukee and now on the grounds of St. Francis Seminary, St. Augustine Church at New Diggings (1844), and the Moravian Church at Green Bay (1851).[30] Even closer in form and spirit to the little Racine church, though lacking Gothic aisle windows, are the Painesville Chapel in Franklin (1832)[31] and the Congregational Meetinghouse at Cato (1857).[32] Racine's Scandinavian Baptists occupied their church until 1903. In 1887 they had built a

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[28] For Lucas Bradley see also: Racine city directories 1850–88; *The History of Racine and Kenosha Counties, Wisconsin,* 375, 568; obituaries in the Racine *Daily Times,* January 10, 1889 and in the *Racine Journal,* January 16, 1889; Stone, I, 401; Alexander C. Guth, "Early Day Architects in Wisconsin," *Wisconsin Magazine of History,* XVIII (December, 1934), 143; Henry Steketee, "Architect Given Praise for Planning Racine Church," Racine *Journal–Times Sunday Bulletin,* February 19, 1939, 5; the Rev. Sydney H. Croft, "A Hundred Years of Racine College and DeKoven Foundation," *Wisconsin Magazine of History,* XXXV (Summer, 1952), 251, 253; Henry F. Withey and Elsie R. Withey, *Dictionary of American Architects (Deceased)* (Los Angeles, 1956), 73; *Dictionary of Wisconsin Biography* (Madison, Wisconsin, 1960), 45–46; George Miller, "Cite Architecture of Six County Buildings," Racine *Journal–Times Sunday Bulletin,* October 23, 1960, sec. 1, 3; Pagel, 2, 12; sources cited for First Presbyterian Church (below). There also exist a number of unpublished papers dealing with Bradley and his work in the collections of Beloit College, the Racine County Historical Museum, the Racine Public Library, and the author.

[29] *Historic Wisconsin Buildings,* 29.

[30] These three churches are discussed and illustrated in *Wisconsin Architecture,* 71, 62, and 46, respectively.

[31] *Ibid.,* 44.

[32] Perrin, *Historic Wisconsin Buildings,* 34, 40.

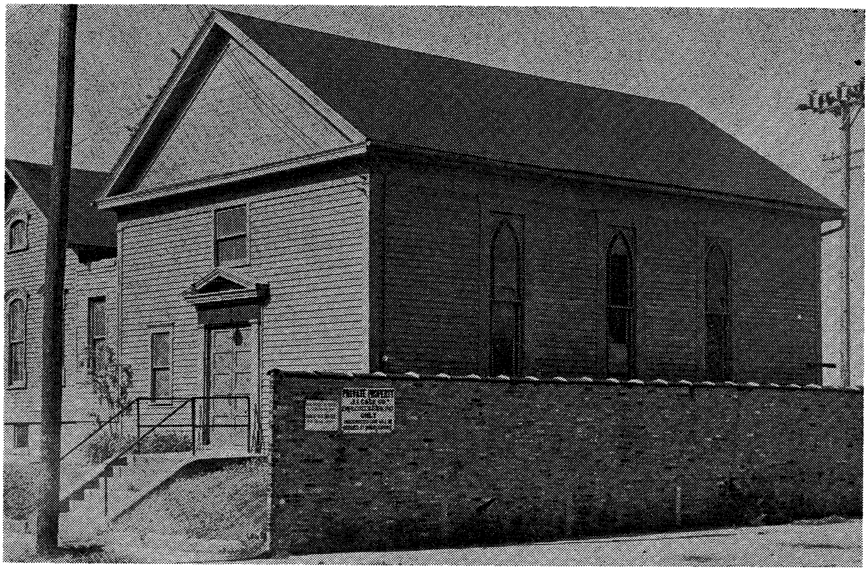

FIGURE 11. 806 Superior Street (photograph from the Racine County Historical Museum).

parsonage nearby, and during this century the two small buildings were joined and put to residential use.[33]

More architecturally pretentious was the city's First Methodist Church of 1844–45 (Fig. 12). Pilasters defined and divided its façade and acted as visual supports for the heavy pediment above. The rectangular forms of the centralized entry echoed the building's shape, its geometrical ornamentation, and its squat, squared belfry.[34] In several of these features First Methodist calls to mind the church at Streetsboro, Ohio, illustrated by Hamlin,[35] and, among Wisconsin specimens, the First Baptist Church at Merton (1845)[36] and the Muskego Meetinghouse (formerly the Free-Will Baptist Church) at Prospect (1859).[37] Mid-19th century Racine boasted at least two more houses of worship of this type—First Baptist Church completed in 1848 (Fig. 2)[38] and the Universalist

[33] Pagel, 9 and an unpublished report in the author's collection written in 1964 by William Adams, Don LaFave, and Dennis Zwaga, UW–Racine Center.

[34] The history of First Methodist is discussed in *The History of Racine and Kenosha Counties, Wisconsin,* 382–383 and in Leach, 82–83.

[35] Plate LXXXII.

[36] *Wisconsin Architecture,* 55.

[37] Perrin, *Historic Wisconsin Buildings*, 34, 40.

[38] *The History of Racine and Kenosha Counties, Wisconsin,* 384–386; Leach, 8; Stone, I, 359–360.

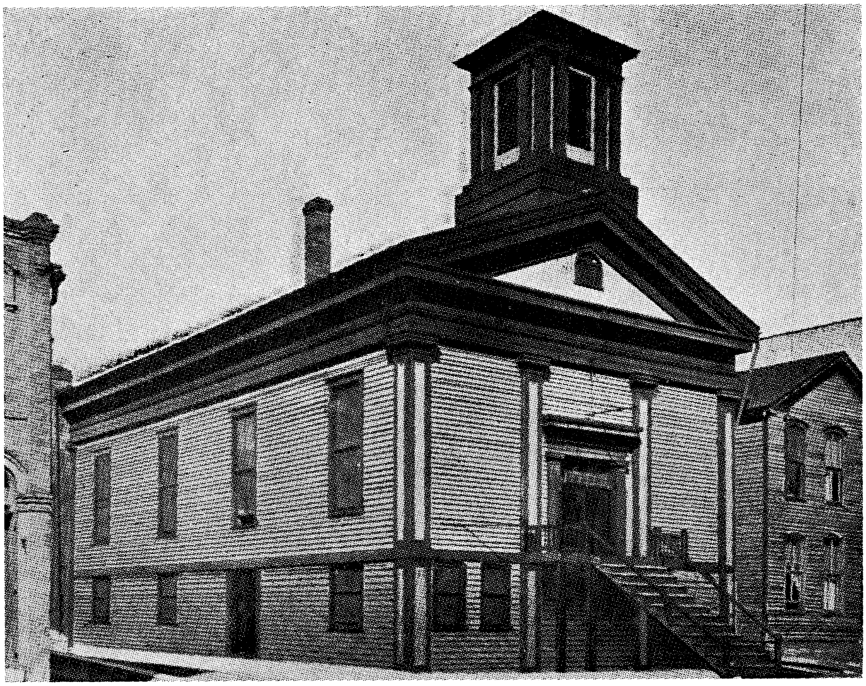

FIGURE 12. First Methodist Church (photograph from the Racine County Historical Museum).

Church of 1851–52.[39] Regrettably, neither these buildings nor First Methodist come down to us.

Greek Revival church design in Racine culminated in the greatly-admired First Presbyterian Church at Seventh Street and College Avenue (Fig. 13), praised by Rexford Newcomb for its "sincere and highly refined design"[40] and described by Perrin as "perhaps the finest example of brick church architecture in the Greek Revival Style."[41] First Presbyterian's members had built their first church in 1842 and, to accommodate a growing congregation, enlarged this simple wood-framed structure the following year. Five years later they passed a resolution calling for a new church and appointed church member and architect Lucas Bradley to the building committee. Fund-raising continued through 1850, with the lot purchased in December of that year. In 1851 church historian Stephen Peet wrote: "Measures have been taken and a subscription

[39] *The History of Racine and Kenosha Counties, Wisconsin,* 387–388, 391; Leach, 20, 30; Stone, I, 376.

[40] Newcomb, 135.

[41] *Historic Wisconsin Buildings,* 55–56.

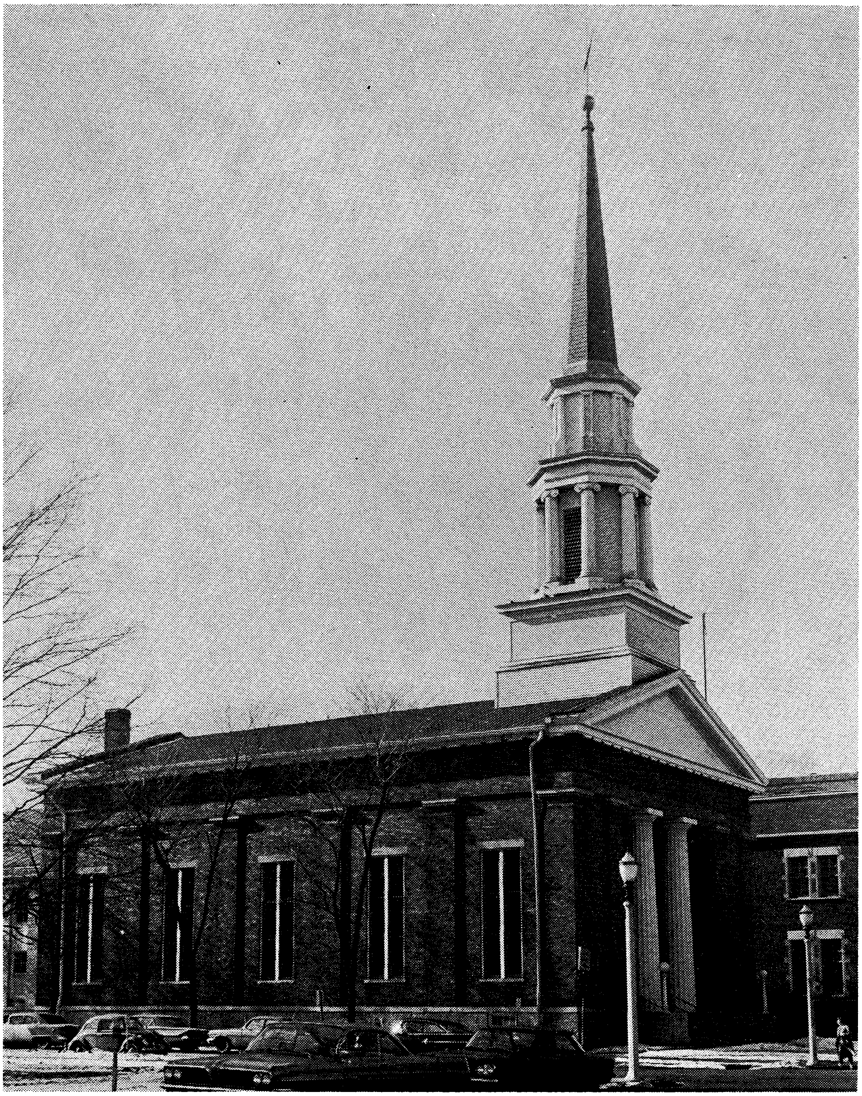

FIGURE 13. First Presbyterian Church (photograph by Todd Dahlen and Peter Vallone).

raised, amounting to near $8000, towards a more commodious house, to be erected the coming season."[42] By March Bradley had been awarded the contract, and on May 6 the cornerstone was laid.

[42] *History of the Presbyterian and Congregational Ministers in Wisconsin* (Milwaukee, 1851), 152.

Specifications called for a building of the Grecian–Doric style, and this Bradley provided in a design stongly reminiscent of his earlier Presbyterian church in St. Louis. Once again Doric columns dominated the monumental facade and were surmounted by an entablature of the same order. Crowning both compositions were spires with engaged columns of the Ionic order—spires less indebted to Greek precedent, of course, than to those of British architects Sir Christopher Wren (1632–1723) and James Gibbs (1682–1754).[43] That Bradley's design is both derivative and eclectic detracts in no way from its success.[44]

First Presbyterian was dedicated on June 10, 1852, and within a few months, work on the closely related First Congregational Church (now St. George Serbian Orthodox Church) at 826 State Street was underway (Figs. 14, 15). Two years earlier a dissident portion of First Presbyterian's membership had broken away to found First Congregational, and in February, 1851 they had dedicated their original church—according to Peet, an example of "the Swiss Cottage and Gothic Style . . . with 5 pointed arch windows on each side and one in front between two large porches, which terminate in 4 pointed buttresses."[45] This church perished in a fire later the same year. Completion of the Congregationalists' second church was signalled by dedication services on November 17, 1854. The building clearly owed a great deal to Bradley's design for the pilasters adorning the façade and dividing the side elevations the pilasters adorning the facade and dividing the side elevations into bays, the Ionic order decorating the octagonal spire—all looked back to the older church.

Good fortune has marked First Presbyterian's subsequent history: the church has seen few major alterations, and, by and large, modifications have been carried out in the spirit of the original fabric. First Congregational has been less fortunate: lightning destroyed the spire in 1912; fire forced abandonment and sale of the building in 1948; and for the next nine years it served as a

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43 For the combination of Wren–Gibbs and Greek Revival elements in American church design see Hamlin, 344–345.

44 Like the Cooley–Kuehneman house and architect Bradley, First Presbyterian Church has received considerable attention from writers. Sources, in addition to those already cited, include: *The History of Racine and Kenosha Counties, Wisconsin,* 384; Stone, I, 375–376; "Church to Observe 75th Year; Presbyterians Here to Hold Anniversary Week," Racine *Journal–News,* October 12, 1927, 1, 11; Guth, *Wisconsin Magazine of History,* XXII, 21–22. Henry Steketee, "Church to Mark Its 100th Year," Racine *Journal–Times Sunday Bulletin,* January 29, 1939, 1, 5; "To Dedicate Presbyterian Parish Hall," Racine *Journal–Times,* June 1, 1942, 9; Perrin, *Historic Wisconsin Architecture,* 11; Perrin, *Wisconsin Magazine of History,* XLV, 201; Pagel, 1–2; *Wisconsin Architecture,* 67; *Wisconsin Architect,* XXXIV, 17.

45 Peet, 153.

FIGURE 14. First Congregational Church (now St. George Serbian Orthodox Church) before 1912 (photograph from the Racine County Historical Museum).

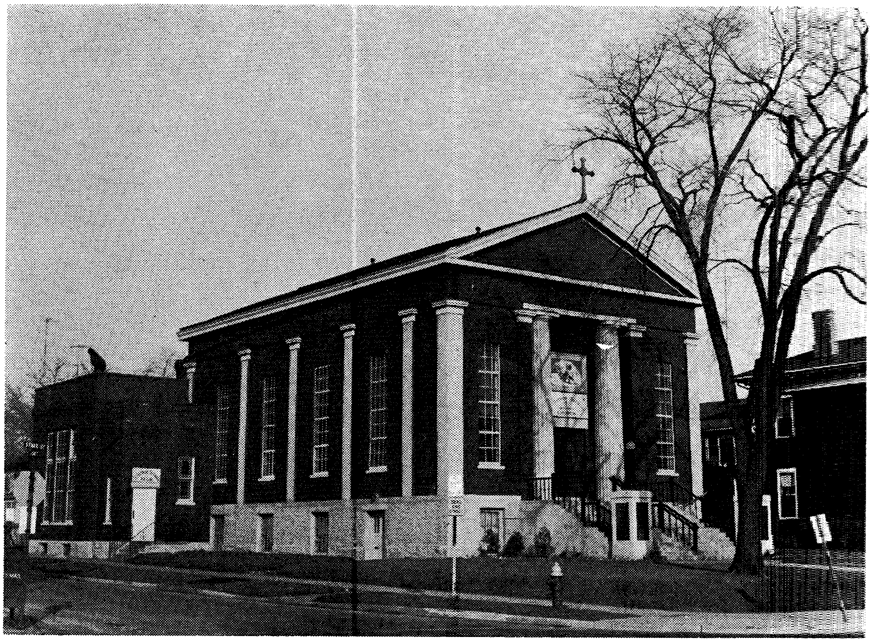

FIGURE 15. St. George Serbian Orthodox Church in 1964 (photograph by Todd Dahlen and Peter Vallone).

dance hall. In 1957 it was acquired by the present owners and has since undergone extensive remodelling and restoration.[46]

The Greek Revival chapter in Racine's architectural history came to a close within a decade after First Presbyterian and First Congregational were dedicated. Here, as elsewhere in the United States during the 1860's, long-prevailing classical tastes surrendered to the rising picturesque current—expressed in the rich, complex, decorative forms of the Italian Villa, Gothic Revival, and Second Empire styles.

A sequel to the ante-bellum Greek Revival story was written by the Academic Reaction in architecture of the late 19th and 20th centuries, when Grecian forms and details once again found favor among American designers and their patrons. In Racine this resurgent classicism was heralded by the home at 820 Lake Avenue (Fig. 16), designed c. 1885–87 by James Gilbert Chandler of Racine for the McClurg family (and, since 1938, home of the local

[46] For First Congregational–St. George Serbian Orthodox see also: *The History of Racine and Kenosha Counties, Wisconsin,* 394–396; *First Congregational Church, Racine, Wisconsin, 1851–1911, Celebrating Sixty Years of Church Life* (Racine, 1911), 1–6; Stone, I, 365–366; Lucy Colbert, "Historic Landmark Becomes New St. George Serbian Church," Racine *Journal–Times Sunday Bulletin,* October 5, 1958, sec. 2, 1, 18; Pagel, 2–3; and an unpublished report in the author's collection prepared in 1964 by Peter Charnon and James Gilmore, UW–Racine Center.

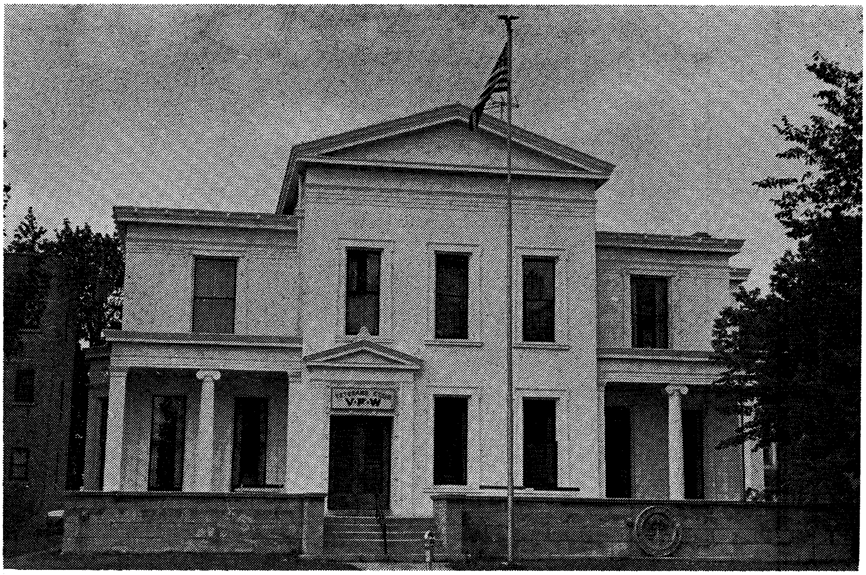

FIGURE 16. 820 Lake Avenue (photograph by the author).

chapter of the Veterans of Foreign Wars).[47] Its decorative details remind one of Minard Lafever's conceptions,[48] but its grand scale reflects the tastes of this new classical era. Popularized by the structures at the World's Columbian Exposition of 1893 in Chicago, the Academic Reaction enjoyed a long lifespan in this country, flourishing for some forty years. Typically, Racine's last prominent buildings in the classical vein—City Hall and the Main Post Office—were erected in 1930–31.

In chronology, in many aspects of design and technology, in the amateur-craftsman status of most of its designers, the Greek Revival in pre-Civil War Racine had also conformed to typical midwestern patterns. At the same time, Racine's case takes on more than ordinary interest, for alongside the city's characteristic Neoclassical structures had been built a number of the outstanding Greek Revival buildings in the Old Northwest. Fortunately, several important examples have survived the years in estimable states of preservation: the Hunt–Jensen house, the Cooley–Kuehneman house, and First Presbyterian Church are cases in point and rank among the great treasures of Wisconsin's architectural past.

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[47] Stone, I, 391–392; "V. F. W. Opens Veterans Club for 25th Anniversary," Racine *Journal–Times Sunday Bulletin,* October 18, 1950, 4; and unpublished papers in the author's collection written by Marilyn Francis in 1964 and by Daniel J. Moriarity in 1966.

[48] Compare Hamlin, Plates XCII–XCIV.

RATTLESNAKES IN EARLY WISCONSIN

A. W. Schorger

The first mention of rattlesnakes *(serpens sonnettes)* in Wisconsin was by Hennepin (1903:222) during his voyage on the upper Mississippi in 1680. Le Sueur (1902:184) in 1700 reported it was dangerous to enter the caverns near Lake Pepin because of rattlesnakes. He saw some which were six feet long, but generally they did not exceed four feet.* According to Owen (1852:57) they inhabited the bluffs below Lake Pepin.

While descending the lower Wisconsin River in 1814, Anderson (1882:192) allowed his men to stop at sand banks to collect turtle eggs and kill rattlesnakes. These he thought beautiful with their bright golden color crossed with black markings. In descending the same stream, Marryat (1839:105) considered it dangerous to wander far from the bank because of the rattlesnakes. He believed that there was probably no place in America where the two species of rattlesnakes were larger and more numerous than in Wisconsin. Brunson (1872, II:172) in 1843 made an overland trip from Prairie du Chien to La Pointe, his route running to Cashton, Tomah, Black River Falls, and Chippewa Falls (McManus, 1919). Before reaching the Black River his party saw both species of rattlesnakes, and between the Black and Chippewa Rivers, a few "massasaugers" only. They saw none beyond the Chippewa.

SPECIES

Wisconsin has only two species of rattlesnakes, the timber rattlesnake *(Crotalus horridus horridus)* and the massasauga *(Sistrurus catenatus catenatus)*. The timber rattlesnake, also known as the banded, yellow, mountain, and rock rattlesnake, is rarely found far from rock outcrops, and in Wisconsin rock rather than timber would be a more appropriate name. Although Pope (1930:282) reports western diamondbacks *(Crotalus atrox atrox)* in Vernon County in 1928, these were probably timber rattlesnakes with aberrant markings, or the progeny of an escape.

* Evidently the lengths are estimates. The French foot was 12.789 inches.

The massasauga* was also known as the prairie, and spotted rattlesnake. Its habitat is marsh, low prairie, and the low banks of streams. Bunnell (1897:323) records that in the region of the upper Mississippi the massasauga was quite local in distribution, being found in the swampy meadows along creeks; it occupied the bottoms of the Mississippi River only above flood level. Less resistant to the ecological changes produced by man than the timber rattlesnake, it is now the rarer of the two species. The *Sistrurus catenatus kirtlandi* Holb., a dark form said to have occurred in Walworth County (Higley, 1889:161), is a synonym.

SIZE

The maximum length of the timber rattlesnake is six feet two inches (Klauber, 1956:149). George Knudsen has informed me that he captured a specimen near Gotham in the spring of 1965 which was four feet five inches. Breckenridge (1944:159) mentions a "very large rattler," taken in southeastern Pierce County in 1929, which was four and one-half feet long, with fifteen rattles and a button. A supposed diamondback, killed near Viroqua in 1928, was four feet, ten and one-half inches (Pope, 1930:282). The largest rattler ever captured by Elmer Keitel in Sauk County was close to five feet. Even a snake four feet long is considered large (MacQuarrie, 1941:83). The longest rattler found by Messeling (1953:23) was four feet three inches, and the greatest number of rattles 23. A rattler five feet long with 26 rattles was once reported from Alma (Alma, 1878.2). The number of rattles is indicative only of age. A new rattle is grown each time that the skin is shed, which may be two or three times a year.

The massasauga is much smaller, the maximum length being 37.5 inches (Klauber, 1956:144). The usual length is about 24 inches. A female captured near Nelson, Buffalo County, was 23 inches (Breckenridge, 1944:152). Two specimens from Portage were 22 and 26.5 inches (Pope, 1926).

ABUNDANCE

The data available give only a faint idea of the abundance of rattlesnakes in the last century. At Dodgeville, 48 timber rattlesnakes, all but one being young, were once found under a large rock and killed (Dodgeville, 1878). Two parties killed 42 at Devil's Lake (Reedsburg, 1872). On the ridge near Ash Creek, town of Orion, Crawford County, 38 were killed at a den (Richland, 1869).

* Derived from a branch of the Chippewa living on a stream of this name on the north shore of Lake Huron. There are many variants in the spelling. According to F. W. Hodge (Handbook of Indians north of Mexico) the proper spelling is missassauga.

Three men killed 66 rattlesnakes in a meadow in the town of Harmony, Vernon County (Viroqua, 1882). During a rattlesnake and spermophile hunt at Gilmanton, 99 snakes were killed (Alma, 1962). The Cooke family, which settled near Gilmanton in 1856, kept a careful record of the number: 150 rattlesnakes killed during the first year (Cooke, 1940:286). Messeling (1953:23) stated that he collects annually for the bounty about 1000 rattlesnakes, counting old, young, and unborn.

Massasaugas, in 1835, were abundant in the marshes which then existed on the site of the city of Milwaukee. Of that time Olin (1930:214) wrote: "The first day we mowed we killed any quantity of rattlesnakes. I will not say a thousand for fear some one will think it a snake story." In 1845, they "swarmed" on the prairie of northeastern Walworth County (Burlington, 1882). When Rodolph (1900:354) settled in the town of Gratiot, Lafayette County, snakes were more abundant than he had ever seen them elsewhere. He killed hundreds of rattlesnakes. Conrad Colipp when he came to Portage in 1849 killed "thousands in the spring and summer, often averaging a few hundred a day" (West. Hist. Co., 1880:885), in which case he must have done little else than kill snakes. While breaking prairie near River Falls, two men killed 39 rattlesnakes in one day (River Falls, 1873).

The following data on the number of snakes bountied in Crawford County, furnished by Milo C. Cooper, County Clerk, show that the timber rattlesnake is still by no means rare:

Year 1964:	4,382	mature snakes
	6,086	young or unborn
Year 1965:	4,086	mature snakes
	7,952	young or unborn.

YOUNG

The young are born in early fall from eggs held within the female. A timber rattlesnake, four feet in length, killed on the lower Wisconsin River on August 14, 1820, was opened by the Indians, who removed eleven young (Schoolcraft, 1821:363). A massasauga found at Portage on July 12, 1926, contained ten embryonic eggs (Pope, 1926). A female taken near Nelson, Wisconsin, gave birth on August 6, 1933, to eight young which were slightly under eight inches in length. A second female taken in the same locality on July 22 contained five young about 6.75 inches long (Beckenridge, 1944:152). The young when born have a button on the end of the tail. Rattles develop later. For September 9, 1875, there is a report of nine young massasaugas on display in Watertown (Watertown, 1875). Four young were said to have entered the mother's mouth when closely pursued, and to have been killed simultaneously with the mother. Carver (1838:297). who was in Wisconsin in 1766, affirms that he once killed a female containing seventy fully formed young which entered her mouth when pursued. That the female swallows her young when in danger is an old and persistent myth.

HABITS

In denning, the timber rattler is not exclusive in its associations. It is recorded for Licking County, Ohio: "Dens were found containing very discordant materials, twenty or thirty rattle-snakes, black-snakes and copper-heads, all coiled up together" (Howe, 1847:297). At the mouth of a den in Richland County in May, 1874, rattlesnakes and bull snakes *(Pituophis)* were living together (Richland Center, 1874). Messeling (1953) found in southwestern Wisconsin the same den occupied by seven or more species of snakes, along with skunks and raccoons. In a den in Sauk County, opened by blasting, Elmer Keitel found 35 snakes, rattlers, bull snakes, garter snakes, and other species, well intermingled (MacQuarrie, 1941:83).

George Knudsen has informed me that in Wisconsin the massasauga winters in decayed stumps, foundations of deserted buildings, mammal burrows, and piles of old slabs. In Pennsylvania it is said to hibernate in fissures in the earth, burrows of mammals, beneath heavy moss, and under overturned trees (Miller, 1938:17).

Rattlesnakes disperse in summer. According to Klauber (1956: 402), they sometimes wander two miles from the den, but usually less than a mile. Experts in Wisconsin think that the timber rattlesnake usually travels less than 1000 feet from the winter den.

Neither species always gives warning by rattling, nor is it necessary to be within two or three feet of the reptile to produce it. Messeling (1953:22) reports that about half the time the rattlesnake gives no warning before striking, and he has known them to rattle when distant twenty feet. The rattle of the massasauga is weak. When McKenney (1868:181) was at Portage, he likened the sound to the ticking of a watch. The rattle is more like the buzz of an insect.

Rattlesnakes are excellent swimmers. When Pond (1908:335) descended the Wisconsin in September, 1740, he wrote: "As we Descended it we saw Maney Rattel Snakes Swimming across it and Kild them." At the large den on Mount Trempealeau, the yellow rattlesnakes swam from it in spring and returned by the same method in fall (Brunson, 1855:114).

Rattlesnakes can climb well. They have frequently entered buildings in Wisconsin, even reaching the second floor. Audubon started considerable controversy when he painted a rattlesnake in a tree containing the nest of a mockingbird. Examples of these snakes in trees and shrubs are not rare. Many times Keitel has found timber rattlesnakes in trees where presumably they had gone for birds (MacQuarrie, 1941). George Knudsen, who has caught many hundreds of timber rattlesnakes, has never found one in a tree.

A peculiar habit which does not appear in the scientific literature is the rattlesnake's tendency to go over an obstruction rather than around it. Pope (1923:25) kept some timber rattlesnakes in a cage two feet high. When the lid was removed and a snake could place its head over the edge, it could draw up its body. Garland (1917:33), lived on a farm near Onalaska, La Crosse County, where timber rattlesnakes were plentiful. One of the largest ever seen on the farm was killed in the act of climbing over a barrel in the farmyard. He wrote: "I cannot now understand why it tried to cross the barrel, but I distinctly visualize the brown and yellow band made as it lay an instant just before the bludgeon fell upon it, crushing it and the barrel together." Thomas Harry, who came to Racine County in 1849, saw massasaugas crawl over his men resting on the ground while breaking the prairie (Lake City Publ. Co., 1892:264). Two Germans hired to dig and curb a well on the old Frost farm near the outlet of Lake Monona, at Madison, reported a rattlesnake approaching from behind, had crawled up the back and over the shoulder of one of the men, presumably reclining, to disappear in the tall grass (Brown, 1934:8). There are several instances of rattlers crawling to the tops of beds in log cabins.

FOOD

Rattlesnakes feed principally on small mammals and birds. Little specific information exists on the food in Wisconsin. A large timber rattler captured in Pierce County had swallowed a fully grown gray squirrel *(Sciurus carolinensis)* (Breckenridge, 1944:159). The white-footed mouse *(Peromyscus)*, cottontail *(Sylvilagus)*, and young woodchuck *(Marmota)* (obtained by entering the burrow), are mentioned by Jackson (1961:117, 129, 219). Messling (1953: 21) lists gophers *(Citellus)*, mice, small birds, frogs, and blackberries. The inclusion of blackberries is inexplicable unless present in the prey. The very young feed on flies. According to Hoy (1883) the massasauga subsisted almost exclusively on meadow voles *(Microtus)*. Other writers think frogs the common food. George Knudsen has known them to eat frogs, voles, short-tailed shrews *(Blarina)*, and small snakes.

ENEMIES

Rattlesnakes have few natural enemies. There is an old tradition of enmity between the white-tailed deer and the rattlesnake, although few encounters have been observed. This may be because of the largely nocturnal feeding habit of the rattlesnake, especially in hot weather. Seton (1929:288) mentions a hunter seeing in Coahuila, Mexico, a deer cut a rattlesnake to ribbons by jumping upon it several times with all four feet. A doe attacked a rattlesnake in Pennsylvania in the same way (Aldous, 1938). McDowell (1950:46) would not commit himself on the question of whether or not deer would kill snakes, but he did affirm that deer in pens showed the greatest terror towards snakes of all kinds. A piece of rope manipulated to simulate a snake would prevent a buck from charging when a club would not. Bunnell (1887:329) mentions that a deer would leap high into the air and, with its four feet bunched, come down on the rattlesnake. Keitel (MacQuarrie, 1941:83) felt certain that deer attack rattlers, although he never witnessed the act. He had, however, found many snakes with gouges in the backs which could have resulted only from the hoofs of a deer.

Badgers in South Dakota, according to Jackley (1938), will attack and eat rattlesnakes, especially during hibernation. A similar observation has not been made in Wisconsin, where badgers were once plentiful and are still not rare.

It is probable that birds are minor enemies. Bunnell (1897:326, 329) states that while rattlesnakes of all sizes were being killed at a den at Homer, Minnesota, "falcons or swift hawks of the Mississippi bluffs" would swoop down and bear off writhing snakes. The peregrine falcon *(Falco peregrinus)* is not known to capture snakes. Raptors, however, are greatly attracted to sick or injured animals. Bunnell also mentions eagles and hawks as enemies.

In 1873, a man hauling stone from a bluff at Trempealeau observed a domestic turkey gobbler battling four rattlesnakes, two old and two young ones. He killed the young snakes, but the old ones escaped. The turkey was completely exhausted (Trempealeau, 1873). Several accounts in the literature report wild turkeys attacking, if not killing, rattlesnakes.

Man has been the greatest enemy of the rattlesnake since the first European set foot in Wisconsin. He also imported an able assistant, the hog. Keitel has said that although he has never seen a pig killed by a rattler, he has often seen a hog kill and eat one (MacQuarrie, 1941:83). James Allen Reed, when he settled at Trempealeau in 1840, found the place so infested with rattlesnakes that it was called "The Rattle Snake Hills." The Winnebago called it Wa-kon-ne-shan-ah-ga, meaning "the place of the sacred snakes on the river." Bunnell (1897:184, 327) informed Reed of a breed of hogs noted for their skill in hunting snakes, some of which Reed brought from Prairie du Chien. In a short time the number of rattlesnakes was greatly reduced. Bunnell mentions that a hog, lean from a scanty winter diet, rushed among the numerous snakes at a den. After killing several, the hog instead of eating them staggered away and took refuge in a mud hole. On recovery, she showed no further interest in rattlesnakes. The hog's lack of fat had enabled the snakes to inject their venom into the blood vessels, although it is generally assumed that hogs are immune to the venom since the normal layer of fat prevents the fangs from reaching the circulatory system.

It was not uncommon in Grant County at one time to find a rattler under an unbound bundle of wheat, or for a man loading the wheat to find that a snake had been pitched to him along with the bundle. When hogs became numerous, the snakes were largely destroyed (Holford, 1900:49). Green River, in northern Grant County, was once a good trout stream where the timid were warned not to frequent its banks until the hogs had exterminated the snakes (Platteville, 1854).

The Norwegian settlements in Dane, Jefferson, and Waukesha counties were visited by Lovenskjold (1924:88) in 1847. He wrote: "In some places, especially where there are large sloughs, there are poisonous snakes, but they are reduced in number year by year, as the land is being cultivated. Their worst enemy is the hog, and as the settlers keep large numbers of hogs because it costs but little to feed them in the summer, they devour the snakes wherever found."

Killing and eating rattlesnakes is not confined to the semi-feral animals which comprised the stock of the first settlers.

Lethal Effects of the Venom

Many writers on Wisconsin have expressed surprise, in view of the abundance of rattlesnakes, that so few people have been bitten and that only a very small number have died. Of 70 Wisconsin cases which I have found in the literature before 1880, only 12 people were reported to have died. Nearly all the deaths occurred in areas occupied by the timber rattlesnake. The massasauga is so small that the amount of venom injected was rarely fatal. Some of the fatal cases are mentioned under the counties. Of the people bitten 30 were men, 29 children, and 11 women. The fatal cases comprised 5 men, 4 children, and 3 women. Six people were hospitalized for snake bites in Wisconsin in 1958 and 1959, with no deaths (Parrish, 1965). No fatalities occurred in Wisconsin during the ten-year period 1950–59, although the estimated number of snakebites was 15 annually.

Probably few large domestic animals fall victim to rattlesnakes. If the venom rarely kills a human being, the chances of horses and cattle dying are slender. Fonda (1868:281) relates that during the removal of the Winnebago, just before making camp on the main Baraboo ridge on May 15, 1848, his horse was bitten on the nose by a rattlesnake. He thought that the horse, its head swelled to twice normal size, would certainly die. An old Frenchman offered to cure it. The next morning the horse was well, but he learned that all the Frenchman had done was to look at the horse and talk to it.

Information on the circumstances under which an animal died is meager, no mention being made of a snake having been seen or killed. In four cases where cattle were found dead, the deaths were attributed to snake bite. A colt 18 months old was found dead in the road soon after being bitten by a snake (Alma, 1877.2). A mule recovered from a bite, supposedly as a result of treatment with snakeroot (Augusta, 1878.1). One horse nearly died from a bite (Baraboo, 1871), and another succumbed twelve hours after being bitten (Prescott, 1866). A horse, bitten beside the Platte River in Grant County, swelled to an enormous size, but was cured with sage tea and milk (West. Hist. Co., 1881). Cooke (1940:286) says that when a fine horse was bitten on the nose, his father made it drink a quart of whiskey and it recovered.

Antidotes

The early remedies were based on folklore. Most of the physicians of the period were on the same medical level as the country people, their treatments doubtfully efficacious. Often it is surprising that the patient survived the treatment rather than the snake's venom. By far the most popular treatment was the internal use of alcohol. Its general use must have been intensified by the report of Dr. Burnett (1854), who declared that because the venom was a depressant, the best antidote was alcohol, a powerful stimulant. His findings were widely copied. Many statements testify to the fact that regardless of the amount of alcohol taken, intoxication did not follow.

Some of the numerous external antidotes used in Wisconsin were: salt and onions; a mixture of gunpowder, salt and egg yolk; gall of any species of snake; black mud and tobacco; clay; tobacco applied to the wound and also eaten; freshly killed chicken; tincture of iodine; ammonia; whiskey, saleratus (sodium bicarbonate), and cornmeal; and alum taken internally. Dr. Ward's treatment for a child bitten at Madison was a poultice of wood ashes and copious draughts of whiskey punch. Since the child recovered, the treatment was recommended highly (Madison, 1855). The various snakeroots, of which *Polygala senega* was so popular elsewhere, were rarely used. Sometimes a slit was made in the wound, or a large piece of flesh cut from it, and suction applied by mouth. While at Portage, McKenney (1868:188) was told that the Indians obtained immunity by rubbing over their bodies the dried, powdered flesh from the neck of the turkey vulture.

A man at Fennimore, bitten by a massasauga while binding grain, underwent heroic treatment. When questioned by Bishop Kemper, he replied that after reaching the house he drank half a pint of alcohol and camphor, then a quart of whiskey, followed by a quart of pure alcohol, and all this with no symptoms of intoxication. The following morning he drank a pint of alcohol and swallowed a quarter pound of finely cut tobacco boiled in milk (Lancaster, 1866). In a way, it is disappointing that he did not die.

The use of a tourniquet is of no value. If incision and suction are employed immediately, about 40 percent of the venom can be removed, but they are useless if more than one-half hour has passed since the snake bite. The only really effective treatment is with antivenin (Hyde, 1964).

Range

The formal papers on the reptiles of Wisconsin give only occasional places where rattlesnakes have been found. Most of my data on distribution has come from newspapers. Unfortunately the information is often insufficient to determine the species. Usually it is possible to determine species from the dimensions given for the snake, or from the habitat. Because the timber rattlesnake never occurred east of the longitude of Madison, any rattlesnake mentioned east of this line was the massasauga. Approximately 275 references to rattlesnakes, mostly before 1880, have been accumulated by the author. To cite all the references to the several counties would be superfluous. Only a few locations are spotted on the map (Fig. 1), but every reference is included for the border of the range. Maps showing the recent distribution occur in Knudsen (1954.1) and Spaulding (1965).

Adams.—A timber rattlesnake with eight rattles was killed on the west side of Hixson Bluff (Friendship, 1869), now known as Rattlesnake Mound, about five miles south of the village of Adams.

Buffalo.—Ira Nelson came to the town of Nelson in 1855. Among the first deaths was that of his daughter, who died from the bite of a rattlesnake (Curtiss–Wedge, 1919:98). Records of the timber rattlesnake exist for the towns of Alma, Dover, Gilmanton, Glencoe, and Mondovi. One killed in a field in Little Bear Creek Valley was reported to be six feet in length and four inches in diameter. The species was considered "quite scarce in this county" (Alma, 1874). A rattlesnake five feet long was killed in a vacant lot in the village of Alma (Alma, 1878.1), and one in a woodshed (Alma, 1878.4).

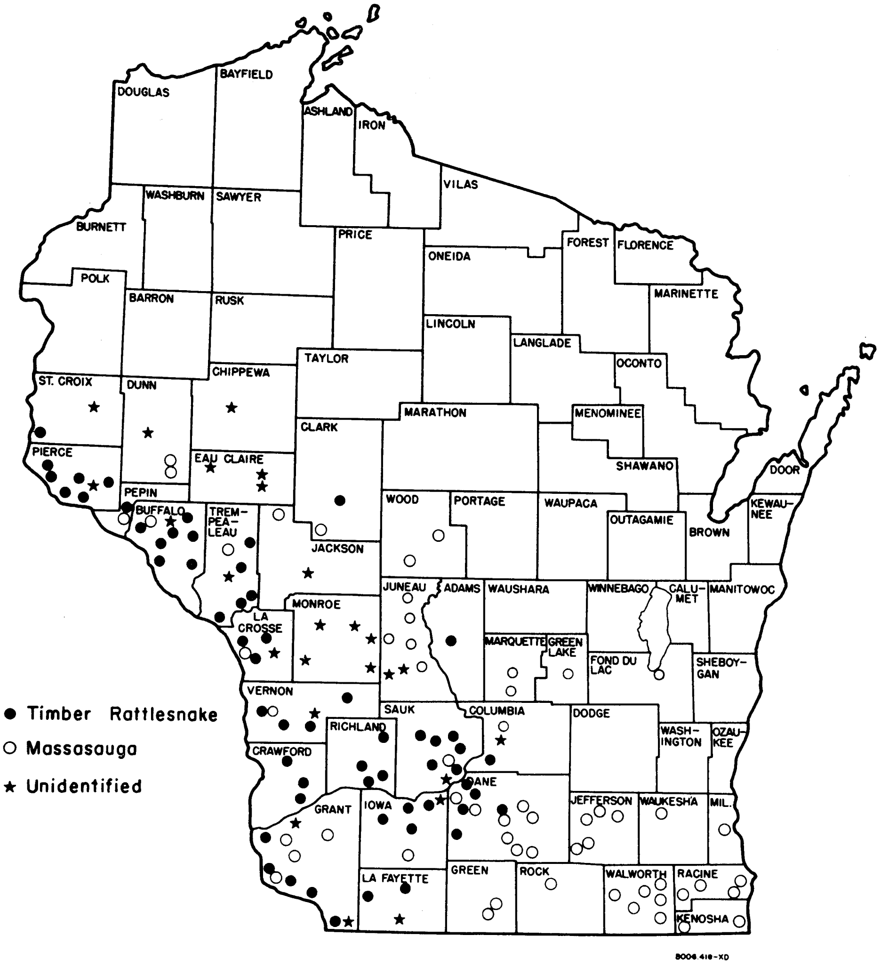

FIGURE 1. Range of the Timber Rattlesnake and Massasauga.

Seventeen rattlesnakes were killed in an oatfield, in a space of 10 acres, near Mondovi (Mondovi, 1877.1).

Two specimens of the massasauga were taken at Nelson, town of Nelson (Breckenridge, 1944:152).

Chippewa.—Records for the town of Eagle Point show several persons to have been bitten, probably by massasaugas (Chippewa Falls, 1872, 1876).

Clark.—Only one reference was found. On September 17, 1880, an "enormous" rattlesnake, 44 inches in length, was killed in Neillsville (Neillsville, 1880), the only one ever seen in the vicinity. The length shows that it was a timber rattlesnake.

A road-killed massasauga was found in the town of Dewhurst by George Knudsen. It is quite common in the southwestern part of the county.

Columbia.—Massasaugas were numerous, with many accounts of them by travelers who crossed at Portage. In 1926, Pope (1926) obtained two specimens which had been captured near by. One, killed on October 9 along the canal in Portage (Portage, 1869), gives some indication of the lateness of hibernation. Another was killed in a barn in Portage (Portage, 1870).

The timber rattlesnake occurred along the Wisconsin River. On September 26, 1886, a woman thrust her hand into a rock cavity in the town of Westpoint, expecting to find nuts stored by squirrels, and was bitten on a finger by a rattlesnake four feet long but with only one rattle (Prairie du Sac, 1886). Another killed in the same town had ten rattles (Prairie du Sac, 1877). A man was bitten in the Baraboo Bluffs in the town of Caledonia (Portage, 1878).

During a period of high water, while men were working on an improvement of the Wisconsin River at the mouth of the Baraboo River, town of Caledonia, they killed 14 rattlesnakes. Other people killed 12 in the same locality (Prairie du Sac, 1880).

Crawford.—Timber rattlesnakes have been found near Steuben (Pope and Dickinson, 1928:71), and in the towns of Utica and Wauzeka (Messeling, 1953).

Dane.—The timber rattlesnake occurred from Madison westward. James A. Jackson (1944:27). who came to Madison in 1853, encountered while walking in the woods, locality not stated, a coiled rattlesnake, sounding its rattle. Alvin R. Cahn, a student in zoology in the University in 1914–1917, told me that while canoeing along Maple Bluff, he found about a "peck" of rattlesnake bones in a cavity exposed by a fall of rock. Apparently a slippage of rock at some time had closed the cavity in which the snakes were hibernating. In the western part of Section 3 town of Dane, is Rattlesnake Bluff, so called from the former abundance of rattlesnakes (Cassidy, 1947:200). Following the battle of Wisconsin Heights in 1832, a wounded soldier was laid on the ground at night at East Blue Mounds, where the rattlesnakes gave warning (Parkinson, 1856: 361). In 1879, six large "yellow" rattlesnakes were killed at Black Hawk Bluff (Lookout), town of Roxbury. There are other records for the towns of Black Earth and Vermont.

The marsh which formerly covered most of the area between the Yahara River and the capitol at Madison, contained massasaugas.

Several adults and children were bitten, but none died. On May 24, 1881, a large massasauga was killed in front of the post office in the village of Black Earth (Black Earth, 1881). This species occurred also in the towns of Burke, Cottage Grove, Dunkirk, Mazomanie, Oregon, Rutland, Springfield, Sun Prairie, and Westport. They were killed in the county at least as late as 1892 (Madison, 1892, 1892.1).

Dunn.—With one exception, the records are for the southeastern part of the county, and must pertain to the massasauga. Davis (1911:170) making a preliminary railroad survey in 1857, at Elk Creek found abundant a "variety of prairie rattlers." Near Falls City, town of Spring Brook, 35 rattlesnakes were once killed, the heavy rains having driven them from the swamps (Menomonie, 1879). When Eugene Wiggins arrived at Falls City in 1855, these snakes abounded (Curtiss-Wedge, 1925:238). A man from Menomonie, hunting prairie chickens, shot a rattlesnake which was pointed by his dog (Menomonie, 1877).

Eau Claire.—A rattlesnake was killed in Augusta in 1870 (Augusta, 1870) and later two people were bitten near this village (Augusta, 1878, 1880). A child and a woman were bitten at Eau Claire (Eau Claire, 1859, 1872). There were no fatalities.

Fond du Lac.—Haas (1943:38), after he purchased a farm in the town of Marshland in 1847, wrote that he had not met anyone who had seen a rattlesnake. A large one, however, was killed a mile east of Fond du Lac in June, 1875, undoubtedly a massasauga. There was the comment: "This is a rare occurrence, as a rattlesnake is seldom found in this section of the state" (Fond du Lac, 1875).

Grant.—Timber rattlesnakes, especially, were abundant. On August 24, 1845, on an island at Potosi, when a member of Moore's (1946:39) party killed a rattlesnake he was informed that the woods were full of them. There are several place names. Snake Diggings took its name from a cave at Potosi which contained rattlesnakes. A creek and a mound in the town of Hazel Green bear the name Sinsinawa,* meaning rattlesnake. Rattlesnake Creek rises in the northern part of the town of Bloomington and enters Grant River 2.5 miles south of Beetown. An early account reports

* The origin of the name is uncertain. The word does not occur in the languages of the Sioux, Chippewa, Winnebago, Fox, Sauk, or related Kickapoo. The Fox occupied the area prior to commercial lead mining. Very probably it is a corruption of the Menomini name for the rattlesnake, sinâwäta. Schoolcraft (il. c. p. 346) used the spelling Sissinaway for the mound. Mr. Buford Morrison of the Horton Agency, Horton, Kansas, obtained the name Shen-weh-ah-gat from the resident Kickapoo. Mr. Bernhard Richert of the Shawnee Agency, Shawnee, Oklahoma, has informed me that the Sauk and Fox word for rattlesnake is Na'-to-we'-wuh, and Kickapoo, Na-to'--we'-a.

going from Beetown to Cassville, down Rattlesnake Valley and across the Massasauga (Lancaster, 1844).

The timber rattlesnake has been reported from the towns of Cassville, Hazel Green, Potosi, Waterloo, and Wyalusing.

The massasauga was found in the towns of Cassville, and Fennimore, and must have occurred in others. Doubtless it was a snake of this species which bit a farmer on Balke's Prairie, town of Bloomington (Lancaster, 1848). Undetermined species are mentioned for the towns of Marion, South Lancaster, Wingville, and Woodman.

Green.—Massasaugas, in 1836, raised their heads through the puncheon floor of the cabin of David Bridge, town of Jefferson. A Mr. Chadwick plowed a furrow 20 inches wide from his cabin to the schoolhouse so that his children would not become lost in the prairie, and: "On this furrow the children walked until the snakes, pleased with the soft ground, took up their abode there, and then they walked in the high grass by its side" (Bingham, 1877:167, 171). In 1875 A. W. Goddard, in Monroe, advertised for sale mens' heavy brogans which were proof against rattlesnakes (Monroe, 1875).

Green Lake.—When Richard Dart came to Green Lake in 1840, rattlesnakes were plentiful (Dart, 1910:255).

Iowa.—Timber rattlesnakes have been found in the towns of Arena, Dodgeville, Highland, and Wyoming, where they are still common locally. Specimens of the massasauga have been collected at Mineral Point (Pope and Dickinson, 1928:70).

Jackson.—Three people, two of them children, were bitten near Black River Falls (Black River Falls, 1867, 1871). Robert Ellarson has informed me that the massasauga is still common along Hall Creek, northwest of Merrillan.

Jefferson.—The massasauga has been recorded for the towns of Lake Mills, Milford, Sumner, and Watertown. One was found under a bed in Thure Kumlien's cabin near Bussyville (Main, 1943:38). S. W. Faville informed Hawkins (1940) that about 70 massasaugas were killed about 1850 at a rocky den within a mile or two of Faville Grove as they were coming out of hibernation.

Juneau.—Except for the southwestern corner, the remainder of the county was distinctly habitat of the massasauga. It occurred in the towns of Lemonwier, Lisbon, Orange, and Necedah. Bertha Thomson (1933:418) wrote of the vicinity of Necedah when a child: "The rattlers were usually in the leaves, or old stumps and logs, where the blueberries grew." Robert Ellarson found a dead massasauga in the road in the town of Finley, near the county line. It is common along the Yellow River.

Rattlesnakes, species undetermined, occurred in the towns of Lindina and Plymouth.

Kenosha.—A boy, about 20 months of age, living south of Kenosha, was bitten on the foot by a "prairie" rattlesnake and recovered (Southport, 1842). A. M. Jönsson wrote on December 9, 1843, from the town of Wheatland that the rattlesnakes were by no means as large and venomous as they were thought to be in Sweden (Stephenson, 1937:119).

La Crosse.—Both species occurred, but little is recorded of their distribution. Haines (1848) in September, 1848, killed an "enormous" rattlesnake on a bluff of the Wisconsin shore opposite the mouth of Root River, Iowa. In 1852, Ethan Roberts was told of the attractiveness of the county, including "the large yellow rattlesnakes in the rocks and of massasaugas on the marshes" (Western Hist. Co., 1881.1:465). Although the timber rattlesnake was common, the only localities mentioned are La Crosse and Green's Coulee near Onalaska (Garland, 1917:32, 33, 49). Larson (1942:25), living on a farm in Jostad Coulee in the northern part of the town of Hamilton, never saw more than three rattlesnakes.

Lafayette.—Rodolph (1900:354) settled in the town of Gratiot in 1834. He wrote: "Another annoyance was the great abundance of snakes, particularly rattlesnakes. I have never before or since even in Florida or Louisiana seen anything like it." Brunson (1900: 290) mentions that in winter a rattlesnake in a cave in West Platte Mound, near the county line in the town of Belmont, was crawling about as in summer. A rattlesnake three feet long with six rattles was killed near Darlington (Darlington, 1873). Smith (1838:25) traveled south from Mineral Point to the Pecatonica, where, probably in the town of Willow Springs, he found on the banks of the river a "brown and yellow" rattlesnake "*(Crotalus horridus)*" between four and five feet long, killed an hour or so previously.

Marquette.—On August 14, 1817, on ascending the Fox River and arriving at Buffalo Lake, Keyes (1920:351) was informed that rattlesnakes abounded in the country. Muir (1913:110) came to the county in 1849, and while living on the farm at Fountain Lake (now Ennis) in the town of Moundville, saw only one rattlesnake. He mentions seeing a copperhead, a species never known to occur in Wisconsin.

Milwaukee.—In the early days hundreds of massasaugas were killed on what was then a marsh at the foot of Mason Street in

Milwaukee (Olin, 1930:214). According to Haas (1943:38), they were common in the Milwaukee region. Mrs. Carpenter (n.d.) arrived in 1845. In going to school at Brookfield in the warm days in spring it was common to see massasaugas on the ends of the logs forming the corduroy road across a long swamp.

Monroe.—Cases of snakebite were reported from the towns of Glendale, Lafayette, Le Grange, and Oakdale. A woman in the town of Leon killed at her doorstep a rattlesnake with nine rattles (Sparta, 1881).

Pepin.—In the town of Frankfort, timber rattlesnakes occurred in the bluffs, while massasaugas abounded in the bottoms between Dead Lake, at the northeastern corner of the town, and the Chippewa River (Curtiss–Wedge, 1919:1031).

Pierce.—There are sixteen references to rattlesnakes in the county. The timber rattlesnake occurred in the towns of Clifton, Hartland, Isabelle, Oak Grove, Trenton, and Union. The locality and species of rattlesnake found along Rush River in a cabin belonging to Harvey Seely are uncertain (River Falls, 1859.1). At that time, a Harvey G. Seeley lived in the town of Salem, the only clue to the locality.

Racine.—The massasauga was formerly numerous. Two specimens collected by Dr. Hoy at Racine, about 1858, are in the U.S. National Museum (Pope and Dickinson, 1928:70). There are records for the towns of Burlington, Dover, and Mount Pleasant.

Richland.—Timber rattlesnakes were numerous in the northern part of the town of Orion and in the town of Buena Vista. In 1889 they were plentiful in the Pine River Valley (Dodgeville, 1889). Jackson (1961:117) killed one near Gotham, where it still occurs. One said to have been five feet in length was killed in the town of Westford (Reedsburg, 1874).

Rock.—The massasauga must have been more numerous than the single record indicates. When Sayre (1920:424) came to Fulton in 1849, his fear of rattlesnakes vanished after killing one at the bridge at Stebbinsville, a discontinued post office in the northern part of the town of Porter.

St. Croix.—The northern limit of rattlesnakes was in this county. Breckenridge (1944:154) in 1939 examined two sets of rattles of the timber rattlesnake in the possession of a farmer in the town of Troy, and taken years before. A man in Emerald captured a rattlesnake which refused food of any kind during its captivity of eleven weeks (Hudson, 1880).

Sauk.—Both the timber rattlesnake and massasauga were common at the time of settlement (Bühler, 1923:326; Canfield, 1870: 40). The timber rattlesnake was especially numerous at Devil's Lake and along Honey Creek, town of Honey Creek. The first year that the Philip P. Grubb family lived in the town of Freedom, they killed over 60 rattlesnakes (Cole, 1918:583). J. B. Fowler, on August 3, 1877, shot a rattlesnake five feet three inches long. His attention had been called to the snake by his cattle circling the place where the snake was coiled (Baraboo, 1877.1).

The massasauga occurred on the prairies, and especially along Otter Creek. In the town of Sumpter Knapp (1947:14) was taught how to tear down an old rail fence and kill rattlesnakes.

Trempealeau.—There are 18 early references to rattlesnakes in the county. The timber rattlesnake was particularly abundant at Mount Trempealeau. It is recorded for the towns of Caledonia, Gale, Pigeon, and Preston. The snake mentioned for Tamarac (Trempealeau, 1873.3) may have been the massasauga. The latter occurred in the Trempealeau Valley, but there were no timber rattlesnakes (Heuston, 1890:52–54).

Vernon.—In 1859, both species occurred in the town of Harmony (Button, 1955:112). The timber rattlesnake was recorded for the towns of Forest, Liberty, and Sterling, but most frequently from the town of Kickapoo.

Walworth.—The massasauga was abundant in the town of East Troy (Burlington, 1882). Dwinell (1874), who settled on Spring Prairie, town of Spring Prairie, in 1836 killed seven rattlesnakes the first summer. They disappeared about 1850. During the harvest season, 18 were killed on a farm in the town of Bloomfield (Lake Geneva, 1876). It is mentioned also for the towns of Delavan and Lafayette. Specimens have been taken in the town of Richmond (Pope, 1930:277).

Waukesha.—Unonius (1950:297) killed two rattlesnakes while cutting wild hay at Pine Lake, town of Merton. He remarked that the warning was feeble; people and stock, however, were seldom bitten.

Wood.—On July 30, 1874, six rattlesnakes of the "black species," with four to seven rattles, were killed in the large marsh west of Wisconsin Rapids (Grand Rapids, 1874). A few days afterwards one entered the house of Silas Paine, although previously they were unknown except along the Yellow River.

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THE WILD HONEYBEE IN EARLY WISCONSIN

A. W. Schorger

It is not known exactly when the honeybee *(Apis mellifica)* was brought to North America. The literature indicates that it was introduced first into Massachusetts, but the earliest records are for Virginia. Williams (1844) listed honey and beeswax among the commodities produced and available in Virginia, and gave their prices as of 1621. Evidently bees had been brought in some time previously. A letter of December 5, 1621, from the Virginia Company of London reported that beehives, peacocks and pigeons were being sent to the colony for preservation and increase (Kingsbury, 1933). Swarms escaped to use hollow trees as hives, and by the end of the 18th century honeybees were well established beyond the Mississippi.

Unfortunately we do not know the rate at which bees spread westward. Bradbury (1817) wrote that in 1810 they were found in eastern Nebraska, and that they had moved 600 miles westward in 14 years, approximately 40 miles a year. At this rate of progress bees would have advanced from the coast of Virginia to the Mississippi in 20 years, which is improbable. In 1754 there were swarms of bees at the forks of the Ohio (Pittsburg) (J.C.B., 1941), and in 1782 bees were kept by the Moravian Indians at Gnadenhutten on the Muskingum (Zeisberger, 1885, I:80). Although in 1776 wild bees were reported to be abundant at Detroit (Hamilton, 1908), Zeisberger (1885, II:316) wrote in 1793 that no bees were found in the woods at Fairfield on the Thames (near Detroit) and bees brought there by an Indian from the Huron River, Ohio, swarmed twice. The dates available show poor coincidence with longitude. In 1804, two men from the Moravian Mission near Anderson, Indiana, went with a Cherokee squaw to fell some bee trees which she had found (Gipson, 1938). The U.S. Factory at Chicago paid to the Indians thirty nine cents per pound for beeswax in 1805 (Peake, 1954). Flagg (1912) wrote from Edwardsville, Madison County, Illinois (a prairie state), September 12, 1818, that more wild honey was available in the territory than elsewhere in the world. Bees progressed slowly in the virgin forest, but rapidly at the margins of grasslands.

The date of the appearance of the honeybee in Wisconsin is uncertain. The U.S. Factory at Prairie du Chien purchased "wax, tallow, etc." to the amount of $70.88 during the first half of 1818 (J. W. Johnson, 1911). An 1825 inventory of the trading post at Fond du Lac (Superior) appraised 10 pounds of wax at $2.00 (Anon., 1911). Although neither record indicated the source of the beeswax, it probably came from near the Mississippi. The first mention of wild bees in Wisconsin was in 1828. In January of this year Fonda (1859) and a Frenchman, carrying mail from Chicago to Green Bay, discovered in southeastern Wisconsin a bee tree, revealed by the claw marks of a bear and cut it down. Fonda ate so much of the honey that he became ill. Subsequently he could not eat honey without a feeling of nausea. In the same year honey was so abundant in Grant County (Hollman, 1922) that bees must have colonized the region before 1800.

COLLECTION OF HONEY BY INDIANS

The Indians had collected honey long before the first white settlers came to southern Wisconsin as shown by their ladders and bee trees which had been cut. Except in the Lead Region, the tide of immigration was unimportant until about 1840. The Indians were on hand to exchange honey for pork and flour.

The Potawatomies in Walworth County used crude ladders to reach the cavity containing the honey and opened it with hatchets (Dwinnell, 1874). The earliest settlers in Waukesha County found a great number of Indian ladders made from tall young trees, their branches cut off to leave prongs eight to ten inches long which served as rungs (Western Hist. Co. 1880.3:626). At times the Indians sought assistance from the whites. Joseph H. Stickney came to Waukesha County in 1839. His daughter described the procedure (Martin, 1925): "My father said when an Indian came of an errand, he never failed to make his want known; he would continue to act it out in pantomime until you caught his meaning. Sometimes it was a bee-tree he had found, and he wanted the white man to go with him with an axe and chop the tree down. First he made the white man understand what he had found; he attracts his attention, then bends over and imitates the bee as he flies from flower to flower, buzz, buzz, buzz; then he points, as away the bee flies with his load to his home in the distant tree, then he says, 'armo sispoquet'*; 'sispoquet' meant bee sugar or honey. Then father gets his axe, the Indian shows him the way to the honey the Indian divides with him; then taking his half, vanishes among the trees of the forest."

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* The Potawatomi were closely related to the Chippewa, in whose language honey was *amo sisibakwat.*

Collection of Honey by Whites

Cane sugar was an expensive item for the early settlers, and maple sugar could be made only in particular areas. The cheapest and most available sweetening was honey. In fact the only readily marketable products were deer skins, furs, ginseng, honey, and beeswax. Many of the settlers from the east were experienced bee hunters and some became professional collectors of honey. Greening (1942:213) wrote at Mazomanie in 1847: "Parties go bee hunting for months together in Summer, they take wagons and a pair of oxen, an ax and coffeepot, and that's all except barrels for the honey. When they come to a prairie they turn out the cattle, and watch the flowers till they see a honey bee, catch it, put it into a box, for its humming to attract other bees, then they let it go and watch in what direction they fly, and then search all the hollow trees on that side, find the tree, chop it down, smother the bees and take the honey, barrel it up, then *ditto,* several times a day perhaps. They shoot for meat, roast corn in a frying pan for coffee, barter honey for flour from settlers, bake it in a pan, and sleep in their wagons at night."

The use of the box as described above is incorrect. The box contained honey which the bee consumed to the limit of its capacity. When released, it flew directly to the bee tree. The standard procedure in Sauk County for locating a bee tree is given by Brown (1946): "In the spring when the plum and apple trees were in bloom he [Uncle Isaih] took a small box, put some honey in it and caught a dozen bees or so and put them in the box, leaving a small crack that would allow one bee to escape at a time. When ready to 'hunt,' he would open a small slide and let out one bee. It came out laden with honey to be carried to the tree. When it first escaped, it flew around in spirals until it reached a height of twenty or thirty feet. Then it darted away in a straight line for the bee tree . . . After Uncle Isaih had followed the direction taken by the bee, until he was no longer sure of the direction, he opened the slot and let out another bee which repeated the operation." Bees were released until the tree was found. Occasionally an entire day was consumed in locating the tree, but the reward might be as much as 100 pounds of honey.

The finder of a bee tree carved his initials on the tree. Under unwritten pioneer law, this was a claim to ownership usually respected. Unonius (1950), writing of Waukesha County where he arrived in 1841, said that the finder could not cut the tree without the consent of the owner; but if the owner cut the tree, he had no right to the honey. With the influx of Europeans, the traditional custom broke down and honey was taken without regard to ownership.

Abundance

It has been said that "Wisconsin was one extensive apiary" (Cole, 1930). This was true only of the southern two-thirds of the state. An early observation in the middle west was that bee trees were most numerous in the woods bordering the prairies. The reason for this lay in the profusion of flowers which existed on the prairies from early spring until autumn. Honey could be obtained from forest trees such as basswood and maples only during spring. Sufficient honey usually could not be collected to more than last the bees until the next flowering season. When clearings were made in the woods and crops such as buckwheat and white clover were raised, bees appeared. About 70 percent of the bloom in the forests occurs before June 15, while on the prairie at least 25 percent of the bloom occurs after August 15 (Curtis, 1959). The finding of bee trees by the early settlers is accordingly of ecological significance since it shows the presence of prairie or oak opening. Evidence for this is found in the title of the book by James Fennimore Cooper, *The oak openings; or, the bee-hunter* (1848).

In October 1834, E. Johnson (n.d.) and companions cut 31 bee trees in four days near the "Big Spring" between Dodgeville and Helena. After the honey was divided among the participants, he kept of his share a sufficient amount to supply his family for a year, and sold the remainder in Dodgeville for $75.00. A man in Grant County found 75 bee trees between Lancaster and Beetown (Western Hist. Co. 1881). Perkins (1842), living at Burlington, stated that thousands of swarms were destroyed annually by the Indians and whites and advised how the bees could be housed and saved. In 1841 the inhabitants of Milwaukee County petitioned the legislature to pass a law relating to wild bees. This petition could not be found. It evidently sought to protect the bees from destruction when a tree was cut; however, "the committee had not deemed it necessary to take any action upon the subject, and asked to be discharged from its further consideration" (House Journ. 1841).

The census of 1840 recorded 1,474 pounds of beeswax produced in the state. Grant County led with 399 pounds. Probably nearly all of this wax was obtained from wild bees. The census of 1850 gave a combined production of 131,005 pounds of honey and beeswax, indicating that bee culture was then well under way. (The data are for the year prior to that in which the census was taken).

Bee Culture

An apiary in pioneer times usually began by the capture of a swarm of wild bees. The simplest hive was a section of hollow tree boarded at the top and bottom. As late as 1863, mention is made of the transfer of a colony of bees from a hive of this kind to a "patent" one (Madison, 1863). The wild bee was the so-called German, or black bee. Perkins (1842) wrote: "I wished to purchase some swarms and made considerable inquiry but notwithstanding the vast number of swarms which have been taken, yet from the reckless manner [in which] they have been destroyed, and the bad management of those kept, there is scarcely a swarm to be bought in the country." Adam Grimm (1927), settling near Jefferson in the spring of 1849, found the country full of wild bees and soon formed an apiary. These bees were black and vicious. L. Teetshorn (Watertown, 1875) was convinced that the "native or black bees" were superior to the Italian and was limiting his apiary to them.

In 1847, Raeder (1929) found that bee keeping was thriving in southeastern Wisconsin. A year later Ficker (1942) was in Mequon, Ozaukee County, where bees were kept. They were considerably more productive than in Germany. Many kinds of patented beehives were offered at Watertown in 1849 (Watertown, 1849). A year earlier Mellberg recorded in his diary at Lake Koshkonong, "Hived a swarm of bees for Mrs. Devoe" (Barton, 1946). A beehive was robbed at Kenosha in 1851 and thrown into the river (Kenosha, 1851).

There was considerable early discussion of the relative values of the German and Italian bees. The opinion prevailed that the latter were the more docile and superior in the production of honey. I. S. Crowfoot began an apiary in the town of Hartford, Washington County, in 1856, and is said to have been the first to introduce the Italian bee. He had as many as 900 hives at one time (Western Hist. Co., 1881.1). The earliest specific date that has been found for the Italian bee is 1864, when J. W. Sharp, Door Creek, Dane County, offered Italian queens at $5.00 each (Madison, 1864).

The leading bee keeper was Adam Grimm (1927) of Jefferson. He died in 1876, and on his tombstone is carved a straw beehive. He had gone to Italy in the fall of 1867, returning in the spring of 1868 with hundreds of Italian queens. Some were sold subsequently at $20.00 each. In January, 1871, he shipped 365 swarms to Utah (Grimm, 1871). Only a few people were keeping Italian bees at the time. Grimm began the season of 1870 with 600 swarms which increased to 903 during the summer. His production of honey during the year was 22,725 pounds, which was about one-tenth of the total production in the state (Anon., 1871). Dr. Maxson of Whitewater had 100 hives of imported Italian bees in 1874. Thirty hives were taken to the Bark River woods, where, in three days, they produced 700 pounds of honey (Whitewater, 1874). This would be at the rate of 7.8 pounds of honey per hive per day.

DISTRIBUTION

The places where bee trees were found are shown on the map (Fig. 1). Below, by counties, is the information that has been found.

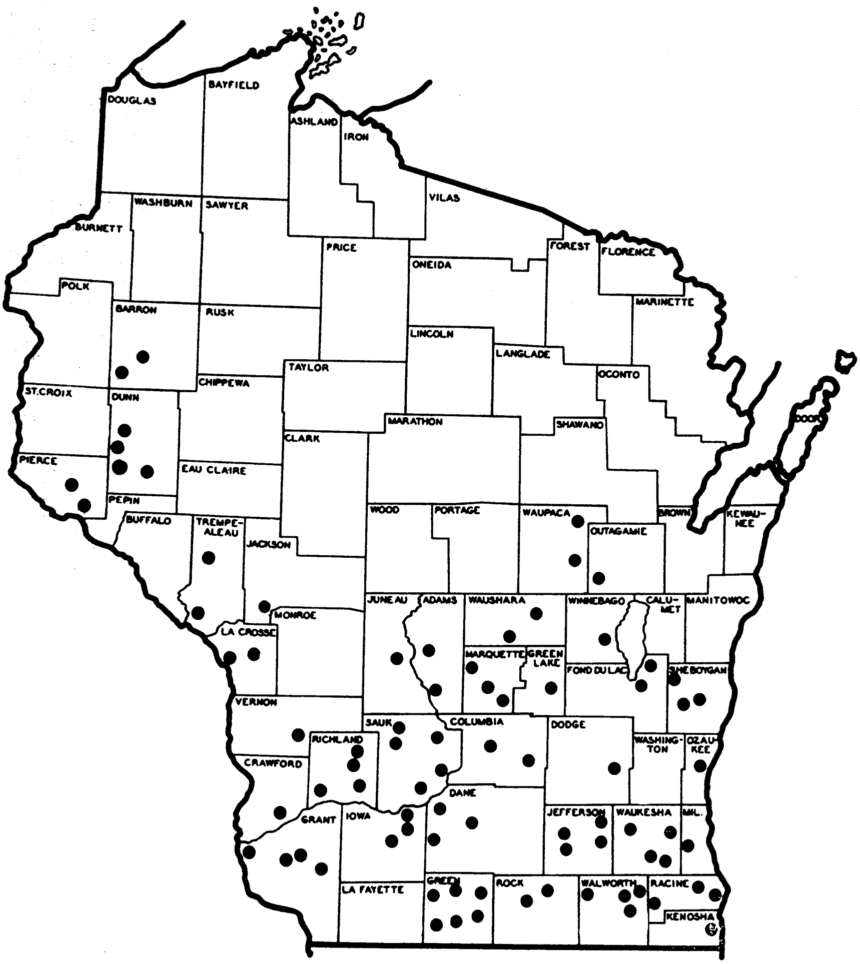

FIGURE 1. Locations of early wild honeybee trees.

Adams.—Two men cut down a tree in the town of Springville from which 250 pounds of honey were obtained (Friendship, 1870). Bee trees must have been found previously for the above amount of honey was viewed as a record. Another tree, found by James Needham, yielded 125 pounds of honey (Friendship, 1876).

Barron.—Apiaries were started in the towns of Vance Creek and Arland, at unrecorded dates, by the capture of swarms of wild bees. J. P. Carlson began raising bees in the town of Prairie Farm about 1884 (Gordon, 1922).

Clark.—Although wild bees were undoubtedly present, no record has been found. John R. Sturdevant, Neillsville, is credited with having introduced the first swarm of bees into the county (Lewis Publ. Co., 1891).

Columbia.—An early settler, staying at the cabin of William Rowan at Poynette in 1837, reported "We had good coffee and plenty of honey" (Butterfield, 1880). Beyond a doubt, only wild honey was available at that time and place. A tree found in the town of Fountain Prairie contained 65 pounds of honey (Portage, 1878).

Crawford.—In November 1830, Johnson (n.d.) found a colony of bees in the root of a tree on the west side of the Kickapoo River, town of Wauzeka.

Dane.—The fall of 1829, Johnson (n.d.) hunted for bee trees at Blue Mounds. He took the honey, along with onions and potatoes which he had raised, by ox team to Fort Winnebago for sale. Rose Schuster Taylor (1945), born in 1863, daughter of Peter Schuster who settled near Middleton in 1855, wrote: "Wild bees deposited their delicious honey in hollow trees. We gathered it on cold days when the bees could not fly and could not sting us since such bees were truly wild. Many pounds of wild honey were added to our supply which was used as a sugar substitute in sweetening as well as for corn bread and griddle cakes. White sugar cost 15 cents a pound, and brown sugar was only a little less." The early hunting for bee trees at Mazomanie has been mentioned.

Dodge.—In the town of Herman, in the fall of 1848, Reuben Judd "took over thirty swarms of wild bees" (Western Hist. Co., 1880).

Dunn.—Two men, after an absence of eight days, returned to Durand with over 500 pounds of strained honey obtained along Wilson Creek in the center of the county (Durand, 1863). In 1864 Mrs. Thomas Huey came to the home of O. Cockeram, town of Lucas. Mrs. Cockeram "had some honey for supper which they told us had been gotten out of a tree in the woods, which we thought very wonderful then" (Curtiss–Wedge, 1925). That year wild honey was reported to be very abundant and bee hunters were prospering. Honey cost 30 cents a pound (Menomonie, 1864). In 1879, in the town of Dunn, many swarms of wild bees were found in the woods (Menomonie, 1879). A year later bee trees were found in the town of Weston, the woods along Knights Creek being mentioned (Menomonie, 1880).

Fond du Lac.—Government surveyors in the town of Calumet in 1834 noted that numerous trees had been cut by the Indians to obtain honey. Reuben Simmons, who settled in the town of Empire in 1840, took butter, eggs, and honey, presumably wild, to Green Bay (McKenna, 1912). At this time the Indians brought honey for sale or exchange (Western Hist. Co., 1880.1). Titus (1936) adds that the settlers obtained maple sugar and honey from the woods.

Grant.—Beetown, nine miles southwest of Lancaster, is said to have obtained its name in 1827 when a large bee tree blew down, exposing lead ore, one piece of which weighed 425 pounds (Western Hist. Co., 1881). Another version derives the name from local mining activity (Lancaster, 1845). Hollman (1922) brought his family to his cabin near Platteville April 9, 1828). Some men suddenly left the cabin which was in a filthy condition: "in the other corners were troughs full of honey in the comb, and kettles and pans full of strained honey, which had been procured by the miners from 'bee trees' found in the vicinity."

James Grushong came to the Hurricane district, town of South Lancaster, in 1836 when bees were so numerous that a bee tree could be found almost anywhere (Western Hist. Co., 1881). About two gallons of honey were obtained from a cave in the bluffs bordering the Mississippi, just below the entrance of the Wisconsin (Platteville, 1841). Holford (1900) wrote: "Little sugar did they have to buy; the wild bees of the woods had laid up in many a hollow oak an abundant store of sweets gathered from the incredible profusion of prairie flowers."

Green.—The county seems to have been well supplied with wild honey. John Dougherty established a trading post at the "diggings" near Exeter in 1831. After the Black Hawk War was over he returned to the mines and "found his merchandise, which had been left buried in the ground much injured by moisture; but a barrel of metheglin which had been made early in the spring 'to keep' was found so much improved that all present drank immoderately, forgetting, until intoxication came, the unusual strength of its ingredients." There were enough bee trees around Monroe to furnish sufficient honey for the inhabitants. In 1843 John Adams, while looking for a bee tree in the town of Adams, discovered the Badger Diggings. Honey Creek, which rises near Monroe and flows into the Pecatonica, got its name from the felling of a bee tree to form a bridge (Bingham, 1877).

Sylvester Hills came to the town of Albany in 1838. The sweets required for the family were provided by maple sugar and wild honey. T. B. Sutherland, who came with his family to the town of Sylvester in 1843, mentioned the cutting of an oak to get the honey in it (Union Publ. Co., 1884). According to Hiram Brown, town of Albany, wild honey bees were quite plentiful between 1842 and 1850. He wrote that in 1838, a "swarm of my bees" settled in the hollow limb of an oak which was later cut to obtain both bees and honey (Butterfield, 1884).

Green Lake.—In 1840 the family of Richard Dart (1910) settled near the Twin Lakes, town of Green Lake. He wrote: "We also had splendid wild honey from the bee-trees."

Iowa.—The large number of bee trees found in 1834 has been mentioned (Johnson, n.d.). Foster (c. 1840) wrote from Helena: "Some make a business of hunting for honey, furs and deer." The Jones family came in 1857 to the town of Arena, where "bee trees were eagerly sought by the younger generation and bee keeping was carried on as a side line by some of the more enterprising farmers" (Jones, 1938).

Jackson.—Robert Douglas settled near Melrose in 1839. An Indian brought him honey in the comb, obtained from a bee tree (Polleys, 1948).

Jefferson.—Much attention was given in this county to hunting for wild honey and bee keeping. William Ball was a noted bee hunter at Jefferson in pioneer days. Buck (1876) reported that he would find from one to three swarms a day, and that "fifty-two swarms were taken up by us, upon the town site alone." Cartwright (1875), in the early 1850's, lived in the town of Sullivan in the Bark River woods. Here, "Bees thronged in multitudes of swarms, and their honey was very abundant. I commenced with my neighbor, Mr. Thomas, to hunt bees and we were very successful." A bee tree was found in which a bear had made an unsuccessful attempt at gnawing an opening. The tree when cut yielded over 160 pounds of excellent honey.

The Coes settled in 1839 in the town of Ixonia where a man named Smith was a very successful bee hunter (Coe, 1908). Hart (1925–26) was born at Ft. Atkinson in 1840. Expert bee hunters could find honey in the Bark River woods. The wife of Charles

Rockwell, one of the pioneers of Ft. Atkinson, in the spring of 1838 traded pork and flour for the honey brought by two Potawatomies (Western Hist. Co., 1879).

Juneau.—In the early days, according to Kingston (1879), wild honey could be obtained in any desired quantity. He wrote: "As an instance of the abundance . . . it may not be out of place to state that Zach. Sheldon came up from Portage City in the fall of 1851, and at the end of a four weeks' bee hunt, took home eight barrels of strained honey."

Kenosha.—In the fall of 1836, Kellogg (1924) came to the farm of relatives near Kenosha. He was served biscuits and honey as his uncle had found a bee tree. Quarles (1932) wrote from South Port (Kenosha) on February 14, 1839, that 60 to 70 pounds of strained honey were obtained from a tree.

La Crosse.—Manly (1927) and a trapping companion went down the Black River into the Mississippi, then down to Prairie du Chien (his chronology is awry and instead of May, 1847, it must have been 1844). On the way they found two bee trees. About 1865, when Hamlin Garland (1917) was a small boy, he was taken on a visit to his grandparents in West Salem. Hot biscuits and honey were served. "I am quite certain about the honey," he wrote, "for I found a bee in one of the cells of my piece of comb and when I pushed my plate away in dismay grandmother laughed and said, 'That is only a little baby bee. You see this is wild honey. William got it out of a tree and didn't have time to pick all the bees out of it'." In 1889 he visited the farm, at adjacent Neshonoc, of his uncle, William McClintock, who was an expert in tracking wild bees.

Marquette.—In the fall of 1865, James L. Jones of Packwaukee, took 103 pounds of honey from a tree (Montello, 1865). John Muir (1913), who came to Marquette County in 1849, wrote that honeybees were not seen until several years later. They were probably overlooked. In 1860 his parents moved to the Hickory Hill farm, town of Buffalo. After hearing men on the farm talk of "lining" bees with a box containing honey, he tried it, and traced bees to a hollow, bottom log in a fence. Someone had chopped a hole in the log and removed the honey. In May, 1879, Christopher Kellogg of Buckhorn found a bee tree, hived the bees, and took 25 pounds of honey (Westfield, 1879).

Milwaukee.—Honey Creek rises in Sec. 26, town of Greenfield, and flows north into the Menomonee. As early as 1841 the legislature was petitioned to protect the wild bees in the county.

Outagamie.—Mrs. Ellen Van Tassel came to Hortonville with her parents in 1852. They easily found bee trees, so that honey was available in quantity (Ware, 1917).

Ozaukee.—Cigrand (1916) wrote: "The Indians gathered honey which was plentiful in the hollow trees of this part [Sauk Creek] of Ozaukee County. They strained the honey and then poured it into large hollow gourds, corked it and then in canoes paddled into Lake Michigan." The honey was taken to Milwaukee and sold.

Pierce.—The dates found for bee trees are so late that the swarms could have been escapes from apiaries as well as original wild bees. A bee tree found September 4, 1877, at Lost Creek, town of El Paso, yielded about 60 pounds of honey. At the same time a man was reported hunting bees (Ellsworth, 1877). A number of bee trees were found in August 1880, in the town of Maiden Rock (Ellsworth, 1880).

Racine.—Henry Trowbridge came to Racine in 1836. Wild honey was obtainable in the woods (Lake City Publ. Co., 1892). The winter of 1837–38, a man living in the town of Caledonia traded an ox for a barrel of flour. Having found a bee tree he invited his neighbors to partake of biscuits and honey (Kellogg, 1924). The abundance of bee trees at Burlington has been mentioned (Perkins, 1842).

Richland.—Johnson (n.d.) in 1840 was living in the town of Richwood, nine miles below Muscoda. At Christmas he cut down what he thought was a coon tree but it contained a swarm of bees. He sawed off a section containing the bees and placed it in the root-house where he had his bees. It seems probable that many people had swarms of wild bees at an early date. In November 1843, Samuel Swinehart and Thomas Parrish explored Pine River and feasted on the honey found in a tree. According to Israel Janney, wild bees were plentiful in 1846, and hunting them for the honey was profitable. James M. Cass came to the town of Richland in 1851. Some honey spilled in one of the wagons attracted the wild bees. The bees were followed and two swarms which were found yielded 150 pounds of honey. Honey was also plentiful in 1845 in the town of Rockbridge (Union Publ. Co., 1884.1).

Rock.—Levi St. John, who came to Janesville in 1836, wrote: "I have frequently visited their [Indian] camps, gone into their wigwams and bought honey and maple sugar of them" (Guernsey, 1856). Ogden (1838) recorded in his diary finding several bee trees, at Milton in the fall of 1838 and in the spring of 1839.

Sauk.—Honey Creek rises in the northwest corner of the town of Honey Creek and flows southeast into the Wisconsin River. It is conjectured that the name was derived from the abundant amount of honey collected by professional bee hunters (Western Hist. Co., 1880.2). Opinion differs as to the amount of honey to be found along the creek. F. J. Finn thought the supply was limitless. An early settler, under urgent pressure to pay for his land, collected, with the aid of his wife, so much honey that it brought him over $100 in sales to neighboring settlements. Mrs. Henry Keifer, who arrived in 1846 after Honey Creek had already been named, reported bee trees here and there, but not in profusion. A Mr. Jassop of Ironton is also credited with payment for 40 acres of government land with the proceeds of the sales of wild honey (Cole, 1918).

Bee trees were so common in the town of Lavalle that honey could be obtained with little difficulty. A bee hunter in the town of Ironton is reputed to have taken to market 1500 pounds of honey in a single load (Western Hist. Co., 1880.2). Edmond Rendtorff (1861) came to Sauk City in 1840. Although he found wild honey he did not know the procedure for securing it. A bee tree found on Webster's Prairie, town of Delton, contained 135 pounds of honey in the comb (Baraboo, 1869). In the fall of 1886, four bee trees were found near Cassel Prairie, town of Troy (Prairie du Sac, 1886).

Sheboygan.—In the town of Lima, in 1839, A. G. Dye frequently accompanied Indians to fell bee trees which they had found. Honey was also obtained in quantity in the towns of Russell and Lyndon (Zillier, 1912). Joseph Benedict wrote on November 25, 1845, that there was plenty of wild honey (Buchen, 1944).

Trempealeau.—A farmer near Trempealeau reported honey stolen from a tree near his home (Arcadia, 1878). Bee keeping must have been established at this time because F. A. Goodhue of Arcadia had 25 swarms for sale at $5.00 each (Arcadia, 1879). At Independence two young men found a bee tree after a search of several days (Independence, 1878).

Vernon.—In the early days at Kickapoo Center, according to Mrs. Cyrus D. Turner, the best fare was "pancakes with pumpkin butter or wild honey" (Union Publ. Co., 1884.2).

Walworth.—Honey Creek rises in the town of Troy and flows east-southeast into the Fox River. Its name was bestowed in the fall of 1835 when Jessie Weacham and Adolphus Spoor found honey which the bees had collected from the prairie flowers (Western Hist. Co., 1882). Dwinell (1874), settling in the town of Spring Prairie in 1836, found that the Indians were accustomed to collecting wild honey. In 1845, the hollow oaks in the town of East Troy contained swarms of bees which collected honey from the woods and prairies (W.H.M., 1882). Joseph Nichols was a celebrated bee hunter at Whitewater in 1837. Having accumulated about 200 pounds of honey, he drew it to Milwaukee on a hand sled and exchanged it for provisions. That year an Indian, as a reward for being fed, brought Mrs. Norman Pratt a pail of honey (Cravath, 1906).

Waukesha.—Almon Welch settled in the town of Vernon in 1837. In the fall of 1839, he and N. K. Smith found 40 swarms of bees. The honey was sold in Milwaukee for $60.00. His share went far towards paying for his claim (Western Hist. Co., 1880.3). In 1840 Charles D. Parker attended a school in the town of Muskego. As usual the teacher boarded around he reported, "but there was no butter or milk in most places. Honey was substituted for both" (Showerman, 1926). Unonius (1950) has described the method of locating bee trees by the settlers near Pine Lake. When a proper tree was found, it was left until winter. A section containing the swarm was cut off and taken home. Barker (1913) arrived in Milwaukee June 14, 1845, and the family settled in the town of Brookfield. His brother was a good hunter and supplied venison and wild honey.

The first swarm of bees owned by William Addenbrooke, town of Mukwonago, was captured in the woods about 1860. For a time he was in partnership with George Grimm, son of Adam Grimm of Jefferson. In 1879 Addenbrooke had 150 swarms of pure and hybrid Italian bees (Western Hist. Co. 1880.3).

Waupaca.—Honey Creek is a small stream emptying into the Pigeon River at Clintonville. The creek was named by N. C. Clinton, who came to the site of the town in 1855. An enthusiastic bee hunter, he found many bee trees on the banks of this stream (Wakefield, 1890). In the fall of 1883, Jim Turney found three bee trees near New London (New London, 1883).

Waushara.—The first land claim in the town of Leon was made in 1849 by a bee hunter named Worden. Evidently he was a member of the exploring party which in the fall of that year hunted game and bees near a lake which they called Lone Pine, possibly Pearl Lake. Isaac and William Warwick settled in the town of Marion in September 1848, and in the following spring they obtained a large amount of honey from a bee tree (Acme Publ. Co., 1890).

Winnebago.—Lockwood (1847) recorded in his diary on October 1, 1847, that he went with a local resident into the oak timber south of Oshkosh in search of bee trees.

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WISCONSIN PINELAND AND LOGGING MANAGEMENT

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In the second half of the nineteenth century, sawmills located in the middle and lower districts of the Mississippi Valley did not have adequate forest resources near them. They were dependent upon the northern pineries located on the rivers St. Croix, Chippewa, Black, Wisconsin, and their tributaries. The downriver firms could buy logs from independent logging contractors, but in order to make certain of their supply, some of the larger companies invested in pinelands and stumpage themselves. The purchaser of stumpage had the right to cut timber, but did not retain the land. Companies with timberlands at their disposal either expanded operations and sent men into the woods, or contracted to have their timber cut by independent loggers.

This article describes problems of absentee land ownership and the business techniques of pineland management and contract logging experienced by one of the largest sawmill firms on the Mississippi, W. J. Young & Company of Clinton, Iowa. Established in 1858, the capital of the firm totaled a little over $1,000,000 in 1882,[1] including the value of over 60,000[2] acres of pinelands located mostly in the vicinity of the Chippewa and Flambeau rivers.[3]

W. J. Young obtained the pinelands through his association with John McGraw of Ithaca, New York. Already a wealthy lumberman and timber owner, McGraw bought out Young's earlier partners, but left the management of the firm in the Clinton lumberman's hands. On becoming Young's partner, McGraw agreed to sell him approximately 31,000 acres of pinelands at $9 an acre, and to contribute a like amount of forested area to the firm as an equal partner. After McGraw's death, Young purchased his partner's

[1] *N. Y. Court of Appeals. In the Matter of the Estate of John McGraw, Deceased, and also in the Matter of the Estate of Jennie McGraw–Fiske, Deceased. Return to the Court of Appeals.* (5 vols.), v. 3, *Testimony,* pp. 1487–88, cited hereafter as *McGraw–Fiske Testimony.*

[2] *Ibid.,* p. 1080. W. J. Young & Co. Pineland Register, not paginated.

[3] W. J. Young to John Dean, Minneapolis, Minn., Mar. 24, 1880, LPB 57, p. 104. To D. A. Park, Minneapolis, Minn., Mar. 15, 1880, LPB 57, p. 101. Note: Unless otherwise stated, manuscript sources are from the W. J. Young & Co. special collection at the University of Iowa, and Young wrote his correspondence at Clinton. The notes designate the particular record, letter-press-book (LPB), or box where information is found.

interest for $7,000,000 and the pinelands were among the assets which continued under his direction.[4]

The task of looking after the pinelands was so extensive that Young had to hire an agent to manage that end of the business. Daniel Page Simons was originally from Dryden, New York, had served in the Union army over three years, and thereafter had become a timber cruiser (a person who located lands and estimated their value) and agent for large land holders.[5] Simons had charge of the W. J. Young & Company pinelands beginning November 1, 1876.[6] He arranged for the payment of taxes, guarded against trespass, and handled financial affairs with logging contractors for a salary of $100 per month.[7]

The Clinton firm did not engage in logging operations itself, but Simons made contracts with independent loggers to cut the company's timber. Simons' contracts usually stated that the logger agreed to cut, haul, bank, and prepare rollways or landings by the stream for all marketable pine timber on lands which were accurately described according to township, range, and section. All of a season's operations should take place prior to the first day of May. Logs were to be cut into lengths as directed by Young from time to time, and if he so required, the logger had to cut one fourth of the whole amount into logs 26 feet, 6 inches to 40 feet, 6 inches. Contracts specified a minimum diameter for the small end of logs, usually 12 inches in the 1870's. Logs were to be ready for driving in the spring, plainly marked, and all of the operations done in a "good and workmanlike manner."[8]

Young agreed to pay a higher price per thousand (M) feet for long logs than for shorter ones. Long logs were 26 feet or more in length. Payments were made only upon the certificate of a scaler, or person who estimated the number of board feet in logs by measuring them with a scale rule calibrated to allow for the tapering of the trunks. The logs, straight and sound, were to be scaled

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[4] *McGraw–Fiske Testimony*, v. 3, pp. 1073, 1396.

[5] *Ibid.*, p. 1505.

[6] W. J. Young to D. P. Simons, Eau Claire, Wis., June 5, 1878, W. J. Young & Co. papers, microfilm collection, Main Library, University of Iowa.

[7] See Simons' financial statements, Box 162.

[8] Contract between W. J. Young & Co., and Elias Moses, Minneapolis, Minn., Nov. 9, 1876, Box 91-A. Contact with W. F. Price, Black River, Wis., Nov. 20, 1877, Box 162; and with Philander A. Viles, Eau Claire, Wis., Nov. 13, 1877, Box 162.

by Scribner's rule, which tended to read a smaller number of board feet in logs of large diameters than did the Doyle scale.[9]

Young paid the wages of the scaler and boarded him without charge. Contractors received $1 per thousand feet on the tenth day of each month for logs banked the previous month; followed by $.50 per thousand feet on a designated day in April, and another $.50 per thousand feet when the landings were broken and the logs fully ready for the spring drive. The balance was due in two equal payments, on the tenth day of the following September and October.[10]

A logger contracted to carry out his operations for a stipulated sum per thousand feet. One of the most important variables in determining logging prices was the location of the timber in relation to the stream—the closer the distance, the easier the job, and the lower the price. If a logger underestimated his expenses he would sustain a loss. Young was not disposed to adjust his payments to cover such a deficit. In 1880 he refused to do so, saying that it would encourage others to make similar claims, and that the practice might tend to destroy the force of contracts.[11]

Of the clauses in the contracts, Young considered the most important to be the ones stating that logs should not be shorter than 12 feet, 4 inches; that as many long logs be cut as practical; and that the ends of the logs be "butted" or crosscut square. He wanted the logs trimmed smooth in the woods where it could be done cheaper than in the mill, and he would not have to run the risk of breaking machinery on immense limbs. Having said this, Young allowed Simons to add to the contracts whatever provisions he thought desirable.[12]

Young instructed Simons to make contracts with the "best" and "safest" loggers, because "good men are worth a premium." By safe loggers, Young meant responsible persons who did good work.[13] The Clinton lumberman did his part by arranging for each logging camp to receive copies of the *Northwestern News*, a temperance publication.[14]

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[9] Both rules were originally used by loggers in the northeastern states. The State of Minnesota made the Scribner rule the standard in 1854, and Wisconsin adopted it in 1871. According to the *Northwestern Lumberman* trade journal (Aug. 21, 1886, p. 3), the Doyle scale eventually replaced the Scribner rule, and beginning in 1872, *Scribner's Lumber and Log Book* actually contained the Doyle scale. See also: Robert F. Fries, *Empire in Pine, the Story of Lumbering in Wisconsin 1830–1900* (Madison: State Historical Society of Wisconsin, 1951), p. 38; and William G. Rector, *Log Transportation in the Lake States Lumber Industry 1840–1918* (Glendale: Arthur H. Clark Co., 1953), pp. 81–82.

[10] Contracts in Box 162 as cited in note 8.

[11] W. J. Young to D. P. Simons, Eau Claire, Wis., July 24, 1880, LPB 57, p. 195.

[12] W. J. Young to D. P. Simons, Eau Claire, Wis., Sept. 29, 1880, LPB 57, p. 246. To C. G. Bradley, Osceola, Wis., Jan. 8, 1864, LPB 5, p. 150.

[13] W. J. Young to D. P. Simons, Eau Claire, Wis., Mar. 1, 1879, LPH 57, p. 16.

[14] W. J. Young to E. W. Brady, Davenport, Ia., June 22, 1883, LPB 57, p. 283.

Young insisted that Simons receive a monthly report from the scalers of each of the several logging camps which might be operating simultaneously in different areas.[15] The contractors and scalers were not supposed to receive their pay until the reports were complete,[16] identifying the location of the camps by township, range, and section; and containing a record of the number of logs cut in various lengths; and the amount of board feet.[17]

From the reports, the company compiled surprisingly intricate statistics that represented the prospective stock down to the last log and its length. This information was useful because the company took orders for future delivery based on the prospective supply of logs. In the case of long timbers, moreover, the firm took orders based on the prospective supply of logs of each specific length. Before accepting an order calling for a large number of timbers for a railway bridge, for example, the company wanted to be sure of its supply of long logs.[18]

The cutting of logs into various lengths was not a haphazard undertaking, but was carefully planned. After trees were felled in the woods, the "buckers" sawed the logs into the proper lengths, which could be a few inches longer than the lumber to be sawed at the mill. It was not however, permissible to saw logs a few inches too short. Logs were always cut into sizes from which lumber could be sawed into even lengths of 12, 14, 16, 18, 20, 22, or more feet. Odd lengths of lumber were seldom sawed, and only by special order. In order to saw lumber 19 feet in length, for example, it was necessary to use a log meant for boards 20 feet long.

Young gave considerable attention to figuring out the amount of the various lengths of logs needed to match the demand of the market. He frequently suggested to the independent dealers and loggers the lengths that they should provide for the Clinton trade. He once stated that 16 feet was the best average length, but the situation was changeable each year depending upon supplies on hand. In 1863, for example, he called for more 12 and 14 foot lengths, and suggested that out of every million feet, a good proportion would be one-sixth in 12 foot lengths, one-sixth in 14 foot lengths; and that 32 foot lengths would be very convenient for long timber.[19]

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[15] W. J. Toung to D. P. Simons, Eau Claire, Wis., Mar. 1, 1879, LPB 57, p. 16.

[16] George W. Forrest, Clinton, Ia., to D. P. Simons, Eau Claire, Wis., Feb. 6, 1882, LPB 57, p. 574.

[17] W. J. Young to D. P. Simons, Phillips, Wis., Jan. 12, 1880, LPB 57, p. 78. George W. Forrest to D. P. Simons, Eau Claire, Wis., Jan. 23, 1883, LPB 57, p. 827.

[18] George W. Forrest, Clinton, Ia., to D. P. Simons, Eau Claire, Wis., Feb. 8, 1887, LPB 57, p. 324.

[19] W. J. Young to B. H. Hollway, Onalaska, Wis., Jan. 1, 1863, LPB 3, p. 514.

With estimates of the lengths of logs needed for the coming season, Young could apportion work to loggers according to a systematic plan. Young estimated the lengths of logs he needed for 1877 by averaging the amount of each length sawed at his mills during April and October, 1876. April was an early sawing month of low productivity; October was a late season time of large production. To obtain an average monthly figure for each length, Young added the amount sawed in April and October and divided by two. Then he multiplied by 12 to record the amount for a year. The total amount of the cut would vary, however, from year to year, and the important thing was the proportion of each length to be sawed. Therefore, Young figured the percentage of each length, and the proportion of each he would need, based on his estimate of the next year's total cut. The total cut for the year varied with Young's view of the lumber market, and his estimate of the number of feet of logs needed. Other factors, however, could enter into the decision to cut timber on specific tracts of land. A contract for stumpage could contain a time limit for the felling of trees, and a provision that Young would in the meantime pay the taxes. Moreover, logging operations were planned so that no small areas were left uncut; it was too expensive to send a logging force into an area a second time for an insignificant amount of timber.[20]

During the season of 1876–1877, Young's contracts for operations in the woods called for more than double the amount of board feet cut any previous year. The *Chippewa Herald* reported that Young's logging contract with Elias Moses of Minneapolis was probably the largest of its kind ever made in the West. Out of a tract estimated to contain 250,000,000 feet of timber, Mr. Moses expected to cut 20,000,000 feet the first winter; and thereafter 20,000,000 to 50,000,000 feet per year. The contract covered only the delivery of the logs to the banks, and not the driving.[21] Moses fell short of his goal for the season of 1876–1877, but his loggers did cut, haul, and bank 67,033 logs which totaled 15,079,060 feet. Allowing $2.50 for logs under 26 feet in length, and $3 for longer ones, Young paid Moses $39,099.63 in seven payments on and between February 7, and October 10, 1877.[22]

Taxes and assessments were persistent problems, particularly for absentee land owners, because local assessors might try to discriminate against them. These matters were complicated, however, and at times complaints by land owners lacked substance. Nevertheless, as an agent for absentee land owners, D. P. Simons spent

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[20] W. J. Young to D. P. Simons, Eau Claire, Wis., Nov. 11, 1881, LPB 57, p. 512.

[21] The *Chippewa Herald* as quoted in the *Clinton Age*, Dec. 8, 1876.

[22] W. J. Young to J. M. Williams, Minneapolis, Minn., Sept. 8, 1877, LPB 52, p. 651; and Oct. 11, 1877, LPB 53, p. 24.

much of his time traveling around Wisconsin townships, examining local taxation procedures, and seeking refunds or adjustments of taxes on lands that he held to be unfairly assessed. Simons stressed that lands had to be properly assessed as the only way to avoid something "like confiscation more than legal taxation." Simons explained in 1884 that town officers tended to levy a particularly high tax on the lands of non-residents, but that he had obtained a reduction of about $5,000 on lands already cut.[23]

Taxes were higher than ever in 1884, Simons said, but not over one and one-half per cent of the actual value of the land. The company reduced the valuation of some lands by removing pine, but Simons believed that tax officers tended to increase the rate on what remained. The only solution was to keep a close watch on the officials, who changed frequently, and necessitated "continued and constant care to get them half right."[24] Sometimes Simons claimed that he encountered outright corruption and he cooperated with other large interests in seeking tax reductions.[25]

The management of pinelands involved numerous negotiations of right-of-way. Young authorized Simons, for example, to allow other parties to build a dam on his land providing they paid for all timber used in construction and for any flood damage to other trees. Also, free of charge, W. J. Young & Company could use the dam to store water and increase the probability of successful drives.[26]

Simons guarded against trespass on the part of loggers who might encroach on his employer's lands, and he watched for stealing on a small scale. In 1884 Simons caught a man who had cut several choice trees and hauled them to sell to a railroad for bridge timber. The agent believed that this arrest would help discourage such happenings.[27]

Once Simons was himself caught in the middle of a trespass dispute between two of his employers. Simons was negligent and allowed Young's loggers to cross over a boundary and cut over 2,000 acres that belonged to Henry W. Sage. Sage sent another agent, Mr. Emery, to accompany Simons and survey the loss, and the lands that Young offered in exchange.[28] Simons accepted Emery's judgment of the lands, but Young became considerably

[23] D. P. Simons, Eau Claire, Wis., to W. J. Young & Co., July 19, 1884, Box 173.

[24] D. P. Simons, Eau Claire, Wis., to W. J. Young & Co., Jan. 28, 1884, Box 162.

[25] D. P. Simons, Merrill, Wis., to W. J. Young & Co., Feb. 20, 1884, Box 162, See also: Paul Wallace Gates, *The Wisconsin Pine Lands of Cornell University: A Study in Land Policy and Absentee Ownership* (Ithaca: Cornell University Press, 1943), pp. 163–164.

[26] W. J. Young to D. P. Simons, Eau Claire, Wis., Jan. 27, 1883, LPB 57, p. 831; and Mar. 3, 1883, LPB 57, 857.

[27] D. P. Simons, Eau Claire, Wis., to W. J. Young, Sept. 1, 1884, Box 162.

[28] D. P. Simons, Eau Claire, Wis., to W. J. Young, Apr. 24, 1878, W. J. Young & Co. Papers, Microfilm Collection, University of Iowa.

irked when the number of board feet that actually materialized in logs and lumber from Sage's land failed to approach the estimate.[29] The Clinton millman complained to Simons, ". . . you were in Mr. Emerys [*sic*] hands, as clay in the hands of the potter, and to our humiliation we find ourselves adrift without a pilot compass or rudder."[30]

Young suspected that Sage had written Simons about the matter, and he requested that any such letters be sent to him to be laid before Douglass Boardman, a mutual acquaintance of everyone involved, and a sort of adviser-arbiter in the dispute.[31] Young, who suspected that Sage might exercise undue influence with Simons, wrote to Boardman that the agent had showed "great weakness, and I am afraid a sprinkling of negligence—an unpardonable ignorance in treating this matter of land exchange. Emery has clearly outgeneraled him, and H. W. Sage is a good prompter."[32]

Without the backing of Simons, Young was humiliated. Since many of the logs had turned out to be of poor quality, the Clinton lumberman honestly felt that Sage asked too many acres in exchange. Young decided to settle on Sage's terms, but he wrote to Boardman that he might have some sworn experts examine the lands all over again and publish the results, along with all the correspondence in the matter, as a "precedent for lumbermen." As for Sage, Young commented, "He has tried to insult me in this whole matter, but he may realize that there is a God in Israel yet. I have no desire to retaliate on Sage but he must do right or I will tell him he has done wrong."[33] A month later the parties settled the matter and Young wrote, "Mr. S. is a curious man, but no doubt thinks he is all right, a good many kind traits but hard in a trade."[34]

Owners of large tracts of pine who held their lands for a considerable length of time could make immense profits through the appreciation of stumpage values. On November 1, 1890, W. J. Young & Company sold 41,251.26 acres to the Mississippi River Logging Company. The contract stipulated that the logging company should not cut more than 30,000,000 board feet of timber in any one year

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[29] W. J. Young to Douglass Boardman, Ithaca, N. Y., Apr. 20, 1878, W. J. Young & Co., Papers, Microfilm Collection, University of Iowa.

[30] W. J. Young to D. P. Simons, Eau Claire, Wis., June 5, 1878, W. J. Young Papers, Microfilm Collection, University of Iowa.

[31] *Ibid.*

[32] W. J. Young to Douglass Boardman, Ithaca, N. Y., June 5, 1878, W. J. Young & Co. Papers, Microfilm Collection, University of Iowa.

[33] *Ibid.*

[34] W. J. Young to Douglass Boardman, Ithaca, N. Y., July 6, 1878, W. J. Young & Co. Papers, Microfilm Collection, University of Iowa. Interestingly enough, Young thereafter had an agreeable relationship with Sage, who loaned him large sums of money personally, and arranged for him to borrow other funds from Cornell University.

until it finished paying for the land, and meantime should pay the taxes. W. J. Young & Company reserved the right to profit from one-tenth of all minerals that might be discovered. The Clinton firm received $694,887.50, or approximately $16 per acre for land valued at approximately $9 an acre in 1875.

Profits awaited the owners of pinelands whether the timber be cut or held for speculation. Surprisingly systematic procedures could increase those profits, particularly if the absentee land owner found a loyal, talented agent to stand guard and handle the administrative details for a salary of $100 per month.

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[35] Ledger F, 1890–91, p. 53. See also: Mississippi River Logging Co. papers, Box 1, 1871–99, in the Minnesota Historical Society, St. Paul.

MARY MORTIMER: CONTINUITY AND CHANGE AT MILWAUKEE FEMALE COLLEGE

Walter F. Peterson
Lawrence University

During the early years of the nineteenth century it was hardly an open question whether it was worthwhile to educate a girl or whether her fragile mind could stand it. However, under the leadership of such reformers as Emma Willard, Catharine Beecher, and Mary Lyon, ambitious women began to fight the traditional social attitudes which insisted that woman's place was in the home and that women were inherently inferior intellectually to men. Despite these obstacles, schools for young women were established by Emma Willard at Troy, New York, in 1821, by Catharine Beecher at Hartford, Connecticut, in 1828, and by Mary Lyon at Mount Holyoke, Massachusetts, in 1838.

Milwaukee Female College, during the period 1853–1873, stood as an extension of the educational concepts of the second quarter of the century, as they related to women, and as an institution caught in the currents of change in the third quarter of the nineteenth century. The key figure in this study of continuity and change is Mary Mortimer.

Born in Trowbridge, Wiltshire, England, on December 2, 1816, Mary emigrated with her family to New York five years later. Until she became of age her educational ambitions were frustrated by a tight-fisted guardian and her only formal education was a brief time in the common schools and a short span at an academy at Auburn, New York.[1] In July of 1837, when she was legally able to take possession of her share of the family estate, she entered Madam Ricord's Seminary at Geneva, New York. A friend later wrote, "It was at Geneva that she first began really to live."[2] Mary threw all her energies into her studies. She tackled Chemistry, Mental Science, Latin and Paley's *Natural Theology*. Then she turned to Algebra, Evidences of Christianity, Ancient History and

[1] William W. Wight, *Annals of Milwaukee College, 1848–1891* (Milwaukee, 1891), p. 3. Also, *Milwaukee Sentinel,* July 23, 1877, p. 2.

[2] Minerva Brace Norton, *Mary Mortimer: A True Teacher* (New York, 1894), p. 9. This volume is particularly valuable because it includes a great deal of Mary Mortimer's correspondence, all of which, unfortunately, has since been destroyed.

Astronomy. Finally there was Rhetoric, Moral Philosophy, History of Modern Europe, Geometry, French, and Butler's *Analogy.* Through concentrated effort she succeeded in completing the four year course in two years.[3]

Her deep interest in the areas of Moral Philosophy and Evidences of Christianity and her intense discussions with her teachers drove her to think earnestly about the state of her own soul. During her first year at Madam Ricord's Seminary, Mary Mortimer experienced a religious conversion and joined the Presbyterian congregation at Geneva.[4] She was also inspired by her teachers to become a teacher. Miss Thurston, a teacher at the seminary wrote, "In accordance with my advice she decided to remain in school another year and to adopt teaching as her life work. Her great desire now was to dedicate her time and talents to that employment in which she could be most useful."[5]

For the next ten years Mary Mortimer gained experience for her life's work teaching in various places in western New York. During this time she grew from a novice assistant at Geneva to a capable administrator of Le Roy Seminary, during the time when the regular principal traveled in Europe on a leave of absence. She regarded teaching as her calling and her vineyard was the education of women. In 1857 she wrote to a friend, "I shall never lose my interest in female education, to which I long ago desired to dedicate my life. I have no wish or thought of changing that dedication."[6] In 1848, while travelling through Michigan, she came to the conclusion that her calling, her vocation, should be exercised in the West. "Indications have pretty nearly decided me to remain somewhere in this western land. I trust I have been and still am watching the indications of Providence and desiring to be led in the path of duty."[7]

It was, then, only natural that when an opportunity came to establish a school in Milwaukee that she would take it. This opportunity appeared in the person of Miss Catharine Beecher. For nearly twenty years Miss Beecher had been developing a plan for women's education. In Mary Mortimer she and her sister, Harriet Beecher Stowe, were happy to find one of the "original, planning minds"[8] to help with this undertaking. Miss Beecher stated her

[3] *Ibid.*, pp. 12–13.

[4] For a detailed account of the conversion of Mary Mortimer see Walter F. Peterson, "Mary Mortimer: A Study in Nineteenth Century Conversion," *Journal of Presbyterian History,* June, 1963, pp. 80–88.

[5] Norton, pp. 23–4.

[6] *Ibid.,* pp. 176–177.

[7] *Ibid.,* p. 77.

[8] *Dictionary of American Biography,* XIII, p. 252.

philosophy in succinct fashion: "I am one who believes that 'woman's wrongs' are to be righted, not by putting her into the profession of the other sex, but in fitting her for her profession, and giving her employment in it."[9] This was to be accomplished by establishing endowed non-sectarian colleges for women in the West.[10] In a letter to Mary Mortimer, Catharine Beecher indicated what the aims of such schools should be. "First, an effort to overcome sectarianism; second, opposition to large boarding houses; third, more thorough and practical education for girls; fourth, better positions for female teachers."[11]

Mary Mortimer was selected to implement this plan and Milwaukee was ripe for the experiment. The growing city had no college, no high school and the public schools were poorly staffed, crowded and generally inadequate.[12] In 1849 she arrived in Milwaukee. With the cooperation of Mrs. Lucy A. Parsons, founder of a private seminary, the plan was put into operation. By 1851 the Normal Institute and High School of Milwaukee, a new institution with a college charter had been established. Mary Mortimer was one of four co-equal department heads and leading Milwaukee citizens were members of its board of trustees.[13] During the next two years the school acquired a new building and a new name—Milwaukee Female College.

By 1852 the "Collegiate School" had been divided into four classes but the program allowed for a great deal of flexibility. The Preparatory Class covered "an indefinite period of time, according to the health, capacity and circumstances of the pupil." The Junior, Middle and Senior classes covered the period of one year each. "The Course of Study has been arranged with a view to ordinary capacities. Those who are below this standard must acquire a fuller preparation before leaving the Preparatory Class; those who are above, can carry on the study of one or more branches more extensively than their class."[14] During the academic year 1852–1853,

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[9] Catharine Beecher, *Suggestions in Regard to the M. F. College,* undated MS, State Historical Society of Wisconsin Manuscript Collections.

[10] Catharine Beecher and Mary Mortimer spent the summer of 1852 at the home of Harriet Beecher Stowe drafting plans for the American Woman's Educational Association. This association was to further "The Plan" by securing an endowment for Milwaukee Female College and other similar schools to be established particularly in the West. This grand scheme largely failed due to the inability of the association to raise the necessary funds.

[11] Wight, p. 3.

[12] Bayrd Still, *Milwaukee: The History of a City* (Madison, 1948), pp. 216–218.

[13] *First Annual Catalogue of Officers and Pupils of the Milwaukee Normal Institute and High School* (Milwaukee, 1851).

[14] *First Annual Report of the Officers and Pupils of the Milwaukee Female College* (Milwaukee, 1853), p. 12.

2 students were enrolled in the Senior Class, 10 in the Middle Class, 32 in the Junior Class and 61 in the Preparatory Class.[15]

Milwaukee Female College, according to the Beecher plan, was to be unique in the annals of higher education. Miss Beecher proposed that the faculty be composed of co-equal teachers, instead of a principal and subordinate teachers. This was supposed to result in "increased thoroughness in the course of instruction, and, by the division of responsibility, greater security in the health of teachers."[16] In point of fact, this plan was attempted only very briefly. Catharine Beecher as a theoretician was primarily interested in the administrative organization and such peripheral aspects as the architectural appearance of the college. Mary Mortimer, however, was essentially a practical educator interested in the curriculum and instruction. After a brief experimental period Mary Mortimer came to be viewed by the faculty, the board of trustees, and also the community as the head of the school and she proceeded to direct the affairs of Milwaukee Female College.

Mary Mortimer succeeded in imparting to her students an enthusiasm for study and a strong religious impulse. Her methods, born of independence of thought and a spirit of skepticism, were rather unique for that day. Because her religious conversion had been through intellectual rather than emotional processes, Mary Mortimer was convinced of the importance of developing a skeptical, searching mind in her students. A former student recalled that this was particularly true in Bible and Mental Philosophy classes. "How often would she suffer us to lose ourselves in the labyrinth of metaphysics, and then carefully seek to guide our way into the light of truth. It seemed sometimes as though she sought to make us stronger doubters, that we might prove more sincere."[17] This teaching technique, used so effectively by Mary Mortimer, but such a far cry from the Mount Holyoke of Mary Lyon,[18] was carried directly from her academic and religious experience in New York.

With the support of the trustees, Mary Mortimer in 1852 introduced a course of study which divided the curriculum into three departments: The Department of Mathematics and Natural Sciences; the Department of Geography, History and Mental Science; and the Department of Languages, Belles Lettres and Composition.[19] While the curriculum was basically patterned after the of-

[15] *Ibid.*, pp. 5–9.

[16] First Annual Catalogue, p. 11. Also, Catharine Beecher, *An Appeal to American Women in Their Own Behalf* (Milwaukee, 1851), p. 2.

[17] Norton, p. 157.

[18] In the *Memorial: Twenty-Fifth Anniversary of the Mt. Holyoke Female Seminary* (South Hadley, 1862), p. 51, it is interesting to note that they had maintained an exact count of the number of students who had been converted prior to graduation. Nothing like this ever occurred at Milwaukee Female College.

[19] First Annual Report, p. 13.

ferings at Miss Ricord's Seminary in New York, it placed greater emphasis on history and English literature and introduced French into the offerings.

Milwaukee gave increasing support to Milwaukee Female College in terms of raw numbers. During the term beginning in 1852, the total student enrollment had been 105, but by 1856 this number had increased to 256. However, a breakdown of this total by classes would indicate that the concept of a complete collegiate education for young women received only token endorsement. Only 6 of the total number were seniors, 11 were middlers and 49 were juniors. The remaining 190 students were all in the Preparatory Class.[20] But those few students who did complete the entire course received an excellent education for that day for Mary Mortimer insisted on high standards. The senior year was brought to a close by a public oral examination to which the local clergy, professional men, and others were invited. The guests as well as the faculty committee and trustees were free to ask questions of the candidates for graduation and enter into the discussions. During one of the oral examinations a theological discussion developed "on the question of our moral capacity for doing good when evil passions have, as it were, overcome and consumed our good promptings. Here there was a terrible battle in which the class, the divines of the committee, and Miss Mortimer all seized weapons."[21]

Catharine Beecher had provided the inspiration for the establishment of Milwaukee Female College. She had also induced Mary Mortimer to become a member of the faculty, to implement her plan, and to represent her in relations with the trustees and the community. The trustees were a most competent group. Men such as Alexander Mitchell, Milwaukee's leading banker, and Increase Lapham, who had gained an international reputation as a scientist, provided stability and inspired confidence. However, the absentee direction of the institution was most unsatisfactory for both the trustees and for Mary Mortimer. Mary Mortimer was supposed to direct the college at the same time that she was supposed to be co-equal with the other members of the Board of Instruction. She also found it difficult to interpret the long, demanding, querulous letters of Catharine Beecher to the trustees.[22] Catharine Beecher proved to be an incredibly difficult woman. By 1857 the role of mediator became too much for Mary Mortimer and she took a position as principal of a female seminary at Baraboo, Wisconsin.

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[20] *Fifth Annual Catalogue*, p. 9.

[21] Wight, p. 16.

[22] Catharine Beecher to Increase Lapham, Feb. 18, 1856. Writing from Columbus, Ohio, Miss Beecher in this letter insisted on the erection of a building which the trustees did not think necessary, the importation of her own carpenters and workmen from the East and an immediate reply to a long list of questions. State Historical Society of Wisconsin Manuscript Collections.

In 1866 the trustees invited Mary Mortimer to return to Milwaukee Female College on her own terms. She now had an opportunity to introduce further curricular changes. Through the division of the Department of Geography, History and Mental Science into the Department of Moral and Mental Science, in which she was the sole teacher, and the Department of Geography and History, greater emphasis was placed on history than was usual at that time. Also, the amount of time devoted to Latin and classical literature was reduced to provide more time for English literature. It is also significant that German, as a companion to French, was introduced as a modern language.[23]

Although the curriculum of Milwaukee Female College, with its emphasis on history, English literature, and modern languages, was liberal for that day, Mary Mortimer held to the traditional, highly structured pattern and failed to anticipate the introduction of elective studies as was found at Smith College when it opened its doors in 1875.[24] However, this is not to suggest that she did not maintain widespread professional relationships. In fact, she chose as her successor Professor Charles S. Farrar, an acquaintance of some years, who had been the first chairman of the Science Department when Vassar opened in 1865.[25] In her own quiet way Mary Mortimer worked to keep abreast of Eastern educational developments and to open intellectual doors in the Milwaukee area.

Mary Mortimer was always conscious of the importance of a strong board of trustees and the relation of the board to the community. In 1872, Milo Parker Jewett, first president of Vassar College, who had moved to Milwaukee after personal differences with Matthew Vassar, was elected vice president of the board of trustees. He was to provide enlightened educational leadership for the trustees and the college until his death in 1882.[26] While Mary Mortimer "had no sympathy with so-called 'women's rights,' "[27] she did feel that leading women of Milwaukee should be on the board of a woman's college and would provide a valuable link with the community. To that end, she had three Milwaukee women appointed to the board in 1869 and this number was increased to 5 in 1872.[28]

In the spring of 1874, Mary Mortimer retired from Milwaukee Female College. During her years at the college she had contact

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[23] *Annual Catalogue,* (1866–1867), p. 14.

[24] Henry M. Tyler, "The Curriculum," in L. Clark Seelye, *The Early History of Smith College, 1871–1910* (Boston, 1923), pp. 162–164.

[25] Wight, p. 33. For Vassar curriculum in this period see Henry Noble MacCracken, *The Hickory Limb*, (New York, 1950), pp. 55–56. 58–59.

[26] *Dictionary of American Biography,* vol. X, p. 70.

[27] *Milwaukee Sentinel,* July 23, 1877, p. 2.

[28] *Annual Catalogue* (1869–1870), p. 3, and *Annual Catalogue* (1872–1873), p. 3.

with some 1,500 young women, about 200 graduating from the college.[29] At her death, in 1877, a former colleague paid a fitting tribute to Mary Mortimer. "As a teacher of young ladies, Miss Mortimer has stood in the front rank for more than thirty years and especially in the West her influence has been widely extended and deeply felt."[30] Her successor as principal of Milwaukee Female College, Professor Charles S. Farrar, may have thought it politic but his words were nonetheless true when he said, "That life was the most important in the founding and development of this institution; and whatever in the future it may become, the chief personal story will be that of Mary Mortimer."[31]

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[29] Lilian Bacon Mallory, "Milwaukee College" in J. W. Stearns, ed., *The Columbian History of Education in Wisconsin* (Milwaukee, 1893), p. 702

[30] *Milwaukee Sentinel,* November 14, 1877. p. 2.

[31] *Ibid.,* July 18, 1877, p. 8. The institution for which Mary Mortimer set a high standard of academic leadership and excellence was merged in 1895 with Downer College of Fox Lake, Wisconsin, to form Milwaukee–Downer College. On July 1, 1964, Milwaukee–Downer College and Lawrence College, Appleton, Wisconsin, merged to become Lawrence University.

A PROPOSITIONAL INVENTORY OF EXECUTIVE-LEGISLATIVE CONFLICT*

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The tradition of separation of powers in American government focuses attention on executive–legislative relations and how they are shaped by underlying doctrines. Such attention ranges from *The Federalist Papers* through the standard textbooks on American government. Yet nowhere is there set forth in a systematic way the fundamental characteristics of executive–legislative relations. This study draws upon the generally accepted wisdom to present six tentative propositions on the nature and scope of executive–legislative conflict. Milwaukee County is used to illustrate these propositions, because its relatively recent creation of a chief executive office dramatized over a short time the fundamental conflicts between the executive and legislative establishments.[1]

Since 1960 Milwaukee County has had an elective county executive. He is chosen for a four-year term at the Spring nonpartisan election. A board of supervisors wields county legislative powers. Its 24 members are elected concurrently with the executive for four-year terms. Prior to the creation of the chief executive office, the board necessarily and partially performed some of the functions granted to the new office. These were usually handled through administrative oversight activities of board committees. Perceptions of the inability of a legislative body to provide effective executive leadership contributed to demands for the creation of the chief executive office for the county.

I. *Constituency differences produce executive–legislative conflicts.* The prevailing basis for the selection of chief executive officers is through election within the political jurisdiction as a whole. Legis-

* The Research Committee of the Graduate School, University of Wisconsin, provided summer salary support for this study. Michael C. Quinn gave invaluable assistance in gathering and analyzing data used in the study.

[1] The position of Milwaukee County Executive was created in 1959, and the first incumbent was elected in 1960. In 1968 the Board was increased to 25 members.

lators are generally elected from subdivisions of political units, usually single member districts in which only one legislator is elected in each district. Milwaukee County follows the normal pattern. Its chief executive is elected by plurality vote of the entire county. Twenty-four supervisors are selected from as many districts within the county.

Nelson Polsby cites constituency differences as an important ingredient in Presidential–Congressional relations, and argues that conflict is heightened by a tendency of each participant to over-represent his constituency.[2] Similarly, Wilfred Binkley comments upon the typical presidential tactic of using messages to Congress as a device to communicate with "the larger audience, the American people."[3]

The conflict between the executive and legislative establishments is often translated into executive defense of "general" interests and legislative protection of "local" interests. As representatives of a specific area, legislators are expected to guard that area's interests. It is presumed that the executive rises above "selfish" interests and fights for programs of value to the entire jurisdiction. This point is highlighted by Don K. Price when he states that "the greater threat of political interference . . . had typically throughout all our history come less often from the President . . . than from local interest groups exerting pressure on members of the Congress."[4]

Two results are implied from the basic proposition, and these are seen in the Milwaukee County situation. One is that a shrewd chief executive can use the localized reward system in bargaining with legislators for support of the executive's general program. For example, in an effort to replace a Park Commissioner who opposed the County Executive's program to reorganize the park system, the executive nominated a south side suburbanite. This was interpreted as an effort "to curry favor from supervisors who have been lukewarm to his program."[5]

A second result is that the legislator's constituency does not tend to be particularly concerned about the issues that produce the greatest stress between the executive and legislative branches. Even if the executive's constituency supports him and his program, that support may not be translated into effective pressures upon legislative representatives. A study of Congressional representation showing that on a host of important national issues congressmen

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[2] *Congress and the Presidency,* Englewood Cliffs, N. J. (Prentice–Hall), 1964, p. 102.

[3] *President and Congress,* 3rd Ed., New York (Random House), 1962, p. 238.

[4] *Government and Science: Their Dynamic Relation in American Democracy,* New York (Oxford U.P.), 1962, p. 53.

[5] *Milwaukee Journal,* January 13, 1965.

hear nothing from their constituents illustrates this point.[6] Milwaukee County Board members have similar experiences. Several indicated that they hear very little from their constituents on the issues pushed by the executive. They were much more likely to be approached by constituents on matters of localized district concern.

This is also implied by a comparison of the votes by district on two constitutional amendments pertaining to the office of county executive and support for the executive by representatives of those districts. One provided constitutional authorization for the county executive office, instead of its statutory base theretofore, and the other granted the executive veto powers over county board enactments. They were approved by overwhelming majorities in November, 1962, and every district supported them. Moreover, there was a significant positive correlation between the level of district support for the referenda and the social rank of the districts.[7] That is, the districts ranked highest in terms of the educational achievement and income of their residents gave greatest support to the referenda. One might expect a similar correlation on roll call votes. Then representatives of districts of highest social rank would give the executive greatest support and vice versa. However, there was no such correlation.

Similarly, the county executive had no opposition in running for reelection in 1964. Yet the strong support of the executive's constituency did not increase support for his program by county board members. Analysis of roll call votes within the board after the election did not show significant differences in the pattern of support for the executive's program. Board members clearly did not receive the same signals from their individual constituencies as the county executive did from those constituencies as a whole.

In this connection the use of a nonpartisan ballot for the election of the executive and the supervisors may heighten the impact of constituency differences between the two branches. It is alleged that on the national and state levels political parties modify or cloak the separation of the executive and legislative branches. Lacking the overt participation of parties, the county may illustrate more sharply the basic executive–legislative relationship.

II. *Legislators representing a relatively large and readily identifiable minority within the political jurisdiction will tend to guard legislative prerogatives against presumed executive encroachment.* The bloc of legislators must be large enough so that, by maintaining a solid front against the often quiescent majority, it may safeguard

6 Lewis Anthony Dexter, "The Representative and His District" in Nelson W. Polsby, Robert A. Dentler and Paul A. Smith, *Politics and Social Life,* Boston (Houghton Mifflin), p. 496.

7 Based on Shevky–Bell Social Rank Index.

the group's interests. Developing expertise in using the legislative process to that end is also typical of a strong minority bloc within a legislature. This stake in the legislative process is likely to make the group antagonistic toward the exercise of executive power. Within Congress the South traditionally fit into this political role. State politics provide similar examples.

The southern half of Milwaukee County has developed a political self-consciousness consistent with its minority status within the entire county. This area contains eight of the county's 24 districts, and its spokesmen frequently defend south side interests. From one member of its county board delegation came the threat: "I won't go for one dime for swimming pools until the south side is taken care of."[8] From another: "I feel that the county executive has been neglecting the south side in making his appointments."[9] While other supervisors might complain about similar issues, it is unlikely that their complaints would stress "north side" or "west side" interests.

In 1960 the leader of the south side bloc became chairman of the county board. It was possible for him to build a majority coalition because of 1) his long tenure on the board, 2) his previous position of vice chairman of the board, and 3) the failure of his opponent to expend much energy in mobilizing support.[10] The coalition formed to select the chairman did not remain intact. Frequently, the chairman was defeated on issues he strongly supported. However, his selection meant that the board was led by the leader of a faction which had greatest fears of expanded executive authority. The extent of this opposition was reflected in several ways. Table I illustrates that on county board roll call votes on issues of concern to the executive the south side bloc provided his greatest opposition.[11] This bloc does not exhibit the same solidarity in other important issue-areas, such as welfare or appropriations. It appears that the executive issues raised special threats to the sectional interests of this minority group.

Another illustration of the bloc's antagonism toward the county executive came during the battle for ratification of the aforementioned constitutional amendments. While the county executive campaigned for approval of the amendments, the board chairman opposed them. As part of his efforts, the eight south side supervisors, joined by three other board members, issued a manifesto

[8] *Milwaukee Journal,* September 21, 1960.

[9] *Milwaukee Journal,* July 19, 1962.

[10] *Milwaukee Journal,* April 27, 1960.

[11] This was based on roll call votes in which more than one supervisor voted in the minority. Only those votes in which the executive's position was clearly known through speeches, messages to the board and/or newspaper accounts, are tabulated.

TABLE I. SUPPORT OF COUNTY EXECUTIVE'S POSITION BY COUNTY SUPERVISORS ON DIVISIVE ROLL CALL VOTES, 1960–1963 (In Percentages; Supervisors Identified By District Number; South Side Districts in Italics)

N=84

1ST QUARTILE	2ND QUARTILE	3RD QUARTILE	4TH QUARTILE
1 — 77.4	7 — 67.5	*22* — 54.9	19 — 38.3
9 — 77.1	3 — 64.1	13 — 51.8	*14* — 38.1
4 — 76.2	15 — 63.8	6 — 51.2	*24* — 37.8
5 — 71.4	18 — 61.4	*12* — 43.9	*23* — 37.7
20 — 70.7	16 — 58.2	10 — 42.8	*11* — 33.7
21 — 70.2	2 — 56.2	*17* — 40.2	*8* — 26.5

denouncing the effort to grant veto powers to the executive. One of the signers argued: "The veto is a tremendous weapon. It results in one man rule and we just aren't ready for it."[12]

Without question, executive veto powers posed a critical threat to the chairman and his followers. Given the cohesiveness of that group, it was often possible for it to pick up the necessary four or five votes from other supervisors to pass measures of special interest to the bloc. To muster sixteen votes to override a veto seemed to be an almost hopeless task.

Other issues viewed as threats to legislative prerogatives drew heavy attack from the south side bloc. These included administrative reorganization proposals, suggestions by the executive for reorganization of the board's committee structure, and appointments to county boards and commissions. These were expected to make the executive more powerful at the expense of the board. Therefore, the predominant minority bloc on the board was quick to defend its legislative interests.

III. *Institutional role playing is an important source of executive–legislative conflict.* Because of institutional pride, traditions and customary methods of operation, organizations develop sets of roles for their members designed for organizational self-preservation and the maintenance or increase of the organization's importance. Legislative bodies often are more susceptible to the manifestations of institutional role playing than other organizations. Their multimembership with an absence of hierarchical authority contributes to that result. So too does the complicated system of rules used by legislatures to carry on their business.

As William S. White notes, the Senate's censure of Joseph R. McCarthy for conduct unbecoming a Senator illustrated institu-

[12] *Milwaukee Sentinel,* September 15, 1962; *Milwaukee Journal,* October 30, 1962.

tional self-preservation.[13] Another context in which legislative role playing typically develops is when one chamber of a bicameral legislature takes action affecting the other without proper notice. The recriminations that result are reminders that legislative bodies are quick to feel alleged slights and defend against them. The antagonism is intensified if the legislature preceives an outside threat to its status and prestige.

Institutional role playing within the Milwaukee County Board was illustrated following the grant of executive veto powers. The first use of this new power occurred with a veto of an ordinance providing music in the Courthouse. The board fell one vote short of the two-thirds majority necessary to override. Thereupon, one of the board's leaders switched his vote. The action was interpreted as a victory for supervisors who "sought to establish a strong precedent" in their relationship with the executive. That two other board members supported the measure only after it was vetoed gives additional weight to the impact of institutional role playing.[14]

The final act in the Courthouse musical came a year later when funds were necessary to continue the program. A board committee voted unanimously to kill the measure. The County Executive's entrance into the committee room prompted a supervisor to remark: "He won't be able to veto it this time."[15]

Institutional role playing is intensified when members of the organization feel that their power is threatened. For example, the county treasurer brought together municipal officials to discuss property tax billing. The County Executive commended the treasurer for his initiative. The board chairman was not enthusiastic and said: "The only thing wrong with it was that the county board was not notified." The treasurer hastily apologized for his slight of legislative prerogatives.[16] Similarly, a group of supervisors threatened to boycott a ground-breaking ceremony simply because the executive's office scheduled it. The suggestion of a boycott at a ceremonial rite illustrates how quickly legislators may feel that they are being upstaged.

Institutional orientation is also exemplified by the executive. The first county executive previously served as chairman of the county board. In that capacity he occupied a middle-of-the-road position in a consensus-oriented legislative body. He presented policy goals to the board, but he tended to emphasize goals which did not sharply

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[13] *Citadel: The Story of the U. S. Senate,* New York (Harper's), 1956, pp. 126–33. See also Donald R. Matthews, *U. S. Senators and Their World,* Chapel Hill (Univ. of North Carolina Press), pp. 101–102, for a discussion of "institutional patriotism."

[14] *Milwaukee Sentinel,* May 1, 1963.

[15] Committee meeting, July 7, 1964. Three of the four members of the committee who were on the board the previous year had voted to override the veto.

[16] *Milwaukee Journal,* July 22, 1962.

divide it. He had the added advantage of speaking from within the board. As county executive his role *vis-á-vis* the board became markedly different. As policy initiator, he was no longer circumscribed by his legislative leadership role. Moreover, a county-wide constituency added impetus for the presentation of bold, far-reaching changes in county policies. Consensus was clearly more difficult to attain on these recommendations.

The change in roles is seen in a comparison of the support he received from county supervisors first as board chairman and then as executive. He was supported as board chairman in a range of 55 to 72 per cent. As executive, the range was 27 to 77 per cent. Apart from some limitations in the data, the controversial issues pushed by the county executive are an important cause of this change in support.[17] Differences between the roles of a chief executive and a legislative chairman contribute to the marked change. The strong executive pushes controversial divisive issues, because successes on those issues produce a noteworthy administration. This is similar to Polsby's argument that different conceptions of time underlie congressional–presidential relations. The President is interested in what he can accomplish in the limited time remaining in his tenure. Congressmen, especially those in leadership positions, usually expect to be around for many years. With that gauge the need for haste cannot seem pressing.[18] The executive then must force his issues against what appears to him to be a lethargic legislature.

Another ingredient of institutional role playing in executive–legislative relations is that awareness of the conflict tends to increase the conflict. Battle lines become hardened as anti-administration groups develop in the legislature. When the Milwaukee County Executive attacked his opponents in a strongly worded message to the board early in 1965, anti-executive legislators lashed back with denials of the charges and accusations against the executive. More significantly, legislators who normally supported the executive also bristled against what they considered to be unjustified attacks. Thus, in taking the battle to the legislature, the executive discovered that the opposition stiffened and allies took umbrage.

Finally, if an executive's program is enthusiastically received in the legislature, it is never long before "rubber stamp" charges are

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[17] The findings are from an analysis of divisive roll call votes (84 on issues of concern to the county executive, 1960–1964, and 327 taken at random when he served as chairman, 1956–1960). Only the votes of the 15 supervisors who served in both periods are tabulated. The data from the two periods are not completely comparable. As part of the board, the chairman votes on many measures in which he may not have strong feelings. As executive, only those issues in which he declared an interest could be tabulated.

[18] *Congress and the Presidency*, *op. cit.*, pp. 103–103.

heard. Typically, the "rubber stamp" charge is an appeal for legislative pride to assert itself against the challenge of executive domination.

IV. *The legislative committee structure tends to strengthen specific interests of legislators at the expense of the executive's general program.* Legislatures establish committees to handle their workload. Legislators generally attempt to serve on committees in which they have strong personal or constituency interests. There is a great degree of continuity within the committee system. After obtaining a preferred committee assignment, a legislator is likely to retain it throughout his legislative career. This occurs because of 1) the legislator's interest in the committee, 2) the investment he makes acquiring expertise in the committee's subject matter, and 3) the importance of seniority within the committee.

Prior to the creation of the county executive office in Milwaukee County, board committees dabbled in day-to-day administration in varying degree depending on the composition of the committee, the administrative departments under its surveillance and so on. Moreover, it has been traditional to have county board representation on some of the boards and commissions which administer county activities. For example, a supervisor is appointed chairman of the county welfare board. Supervisors also serve on a number of other administrative boards. Participation on these administrative bodies intensifies the legislator's involvement in his subject matter interests.

The impact of the board's committee structure on executive–legislative relations in Milwaukee County is most clearly seen in two committees chaired by the chairman of the board: the airport committee and the civil defense committee. Through his position on these committees, he made strong efforts to push policies antithetical to the executive's general program. The airport committee took the lead in making the airport division a separate department. This was strongly opposed by the county executive, who argued that it was inconsistent with his administrative reorganization proposals.

Warfare over civil defense in Milwaukee County has raged continuously during the past several years, and much of it was related to executive–legislative conflict. Who should appoint the civil defense director? Who should be the head of government in the event of a disaster? In both cases the alternatives presented were the county executive or the county board chairman. The executive won these battles, but only after spirited wrangling, made more complicated because of the board chairman's control of the civil defense committee.

V. *A recurring element of executive–legislative conflict is competition between each sphere in controlling administration.* This proposition is closely related to the preceding one. All of the examples presented there included efforts to control parts of the county administrative structure through the operations of legislative committees. Yet the battle to control the bureaucracy transcends the committee system. It is a central component in the relationship between the legislative and executive establishments.

The issue of controlling administration has two corollaries. The first is that legislators tend to be suspicious of administrative experts, while chief executives are more likely to respect and utilize them.[19] The legislator therefore may view fragmentation of administrative authority as a defense against the exercise of power by the bureaucratic expert. Chief executives have been the principal forces behind administrative reorganization efforts. These include the centralization of agencies, elimination of boards and commissions and increases in the executive's own staff.

A second corollary is that fragmentation of administration enhances the "errand boy" role of legislators. Legislators spend a great deal of time performing services in which they act as intermediaries between constituents and administrative agencies. The legislator may feel that he can perform the service function more effectively within a fragmented bureaucracy, where there will be more points of access. In a centralized administration he may have to negotiate for access with a chief executive who is unsympathetic to the individual demands of the legislator's constituent. Moreover, a chief executive may feel that intercession by legislators may be disruptive intrusions upon efficient administrative procedures.

Competition between the executive and legislature for control of the Milwaukee County bureaucracy has frequently occurred. On several occasions legislators have suggested that the county board or its chairman should make appointments to various county offices now made by the executive. The board was especially irked by the executive's power to choose the supervisors who represent the board on various county commissions.[20]

Attempts by legislators to make certain county administrative functions directly accountable to the board have been numerous. The use of the board's committee structure to this end has been cited. The chairman of the airport committee (the board chairman) has participated extensively in matters relating to airports which normally are executive responsibilities. For example, a threatened cutoff in federal airport funds for the county prompted him to write

[19] See David Booth, *A Guide to Local Politics*, East Lansing (Michigan State Univ.), 1961, p. 16.
[20] *Milwaukee Journal*, April 15, 1964.

to the Federal Aviation Administration explaining why funds should not be withheld. Later he and the airport director met with FAA officials to forestall the cut.[21] At no point was the county executive involved.

In another area of administration, the county board passed an ordinance requesting state legislative authorization of a county department of children's services. Included was the provision that the department's director be solely responsible to the board. As interpreted by one commentator, the supervisors would be "in the business of administration."[22]

Along with efforts to exert control over county agencies, the board has refused to enact any of the executive's administrative reorganization proposals. In brief, these proposals recommend a reduction in county agencies from more than 40 to 11. The heads of the revamped departments would be appointed by the executive with confirmation by the board. At present, many agency directors are selected by a board or commission or are covered by merit civil service provisions rather than subject to appointment by the executive.

The board has responded to the executive's requests for professional staff assistance grudgingly. For the first four years of the executive's tenure, he had just one staff aide in addition to clerical assistance. A request for a planning analyst in his office was rejected in 1961.[23] Claims that the county executive was "empire building" marked board response to this request.

These instances are actions of the legislative body to maintain or increase its control over administration. Most moves by the executive to strengthen his position in this area have been challenged by the board, often because they were interpreted as threats to its power and influence.

This is not to suggest that the executive has been completely thwarted in his effort to control the county bureaucracy. Through his budget-making authority he has had considerable leverage against administrative agencies. He has used this power effectively both at budget-review sessions and also through an executive order directing all county agencies to notify him of new programs that would affect their budgets.

VI. *The presence of a threat to the political jurisdiction from an outside source tends to reduce executive–legislative conflict.* The notion in American foreign policy that "politics ends at water's edge" is applicable also in the realm of executive–legislative rela-

[21] *Milwaukee Journal,* December 16, 1964.
[22] *WTMJ-TV Editorial,* March 23, 1965.
[23] *Milwaukee Journal,* Feb. 8, 1961. Not until 1964 did the board authorize a second staff aide.

tions. On local levels, of course, the "outside threat" may be an adjoining municipality or county, a state or federal agency or even private economic interests. Any of these may pursue policies at variance with the self-interest of the governmental unit involved.

In Milwaukee County a number of issues arising from diverse sources have demonstrated that the legislature and executive are able to put aside institutional differences at least temporarily to meet an outside threat. Executive–legislative relations were at low ebb before the shift of the Milwaukee Braves baseball franchise to Atlanta was announced in October, 1964. As the county appealed to baseball leadership for a veto of the shift, the "feud" between the executive and the board chairman was set aside. They led a delegation to a hearing before the Baseball Commissioner to plead Milwaukee's case for retention of its franchise. Subsequently, the major branches of county government maintained their newly-formed alliance to investigate what legal remedies could be pursued to retain or regain major league baseball in Milwaukee.

CONCLUSION

The creation of a new chief executive office in a political jurisdiction telescopes into very short time many of the fundamental issues involved in executive–legislative relations. As such, it exemplifies the recurring conflicts and problems involved in the separation of powers. Differing constituencies represented by an executive elected at-large as against legislators elected on a district basis produce a contrast between a generalized public interest and local public interest. When the legislature contains an influential minority bloc, it will perceive the chief executive as an especial threat to the minority interest represented.

In addition to differences in conflicting perceptions of individual or group interests, institutional role playing frequently affects the relationship between the establishments. This is seen most clearly as legislative or executive jealousies are aroused or when customary standards of behavior are ignored. The legislative committee structure produces an additional source of conflict with the executive. Insofar as legislators attain committee assignments because of their personal or constituency interest in the committee's subject-matter, it further intensifies executive–legislative conflict.

Competition for control over the jurisdiction's bureaucracy is another source of potential conflict between a chief executive and a legislature. The clash between an executive's predilection for centralization as against the legislature's acceptance of fragmentation is seen with distinct clarity in a political unit in which the legislature has, in the absence of a chief executive office, become accustomed to direct and continuing participation in the administrative process.

Finally, outside sources may mollify executive–legislative conflict. A clearly perceived threat to the political unit from an outside source may produce an armistice in the executive–legislative struggle—at least until the outside threat is removed.

Given the separation of powers between governmental establishments, friction is perhaps inevitable. This analysis is an effort to indicate the form it will take and the reasons for its occurrence. Through additional empirical examination of executive–legislative relations the propositions may be further tested and assessed.

THE HANDWRITING ON THE LAND

Robert A. McCabe

Wildlife ecology, like any other science, attempts with its tools to categorize and to predict; and like other sciences, it is only partially successful. Predicting behavior of wildlife populations and their interaction with manufacturing and industrial growth strains both the limited source material and the limited skill of one foolhardy enough to attempt such an appraisal.

Economists have numerical data with which to extrapolate growth curves for various aspects of manufacturing and industry.[1] To much lesser extent we have crude indices of wildlife population trends which can be used for prediction—at least short-term. A study of the interaction between wildlife on one hand and manufacturing on the other enjoys no basic data to draw on. The relationships are a matter of conjecture but by no means pure guesswork.

No wildlife population can materially affect a major industry, but there is a likelihood that major industries do affect wildlife. This one-way cause-and-effect relationship we will explore. This is not to imply that the effect is always negative, but it is likely to be the more common.

In a recent international symposium on *Man's Role in Changing the Face of the Earth,*[2] Dr. Paul B. Sears, as chairman of one of the sessions, began by putting on the blackboard the notation $\frac{R}{P} = f(C)$, where *R* represented resources, environment, or land; *P*, human population; and *C*, culture. This social equation said (p. 423), "The sum total of resources and the population among which the resources have to be divided are a function of the pattern of culture." Unfortunately, the impact of this formula was not pursued in the reported discussion, and only one other participant in the symposium questioned it by asking somewhat rhetorically, "What is culture?"* Apparently assuming the answer had no relevancy to the basic tenets, the questioner rushed on to even more abstract involvement.

* From Webster's unabridged 3rd new international dictionary: The total pattern of human behavior and its products embodied in thought, speech, action and artifacts and dependent on man's capacity for learning and transmitting knowledge to succeeding generations through the use of tools, language and sytems of abstract thought.

I suggest a closer look at this generalized man-resource formula, for it appears to be adequate as far as it goes, but needs to go further. The relationship of available resources and numbers of of people interacting with them is more than a function of culture. These interactions have a feedback influence on culture. Indeed numbers of people and *quantity* of resources are influenced by still another major factor, technological advance. This substitution $\left(\frac{RT}{P}\right)^{t} = C$ is offered as a better expression of culture and resource ecology. Where *R* represents resources; P, human population; *T*, rate of technological advance; *t*, time in history; and *C*, culture. What this social formula says is that culture is a function of the rate at which technology allows a given population in time to exploit its resources.

Thus these resources influence culture when technology makes them available to the population. An increase in the population increases the chance for more minds to contribute to technological breakthrough. Technology (which includes knowledge and learning) is not and was not acquired evenly in historical time but increased by fits and starts. This accounts for our use of the exponent *t* in the formula and allows us to take stock at various times in history. An increase in the number of people alone, as in the denominator of the fraction, does not necessarily mean a greater impact on *R*, the resources. In the periods prior to the Civil War, and even World War I, our expanding population, plus relatively limited technology, did not appear to be making serious inroads on the resources, but the population in the last two decades with concomitant technological advances gives us cause to stop and reflect on whether the interaction of *R* and rapidly-growing *T* fostered by an expanded *P* is not creating a negative effect on *C*.

One needs only to be aware of the comparatively advanced cultures of the Mayans, Greeks, Romans, Egyptians and Babylonians to realize that somewhere an imbalance occurred in the resources-people-technology side of the equation to cause these cultures to take on negative aspects until *C* was reduced to a low status or to zero. Admittedly, it is difficult to recognize when and to what degree negative values are introduced by man to debase our culture. In part, the difficulty occurs because we tend to lower standards instead of confronting the more arduous mastering of deterioration.

Up to a point the greater our technology, the better we are able to exploit and to increase our resource base, and the better or greater our culture becomes. Our resources, both available and as yet unknown, are in a sense finite, and when the values for *P* and *T* increase rapidly, the drain on *R* reduces its ability to sustain itself, and the result can only be a lessening of the magnitude of *C*.

To illustrate: When the number of people demanding a given manufactured product is low, and the technical know-how in gathering raw materials or disposing of associated wastes is also low, the resulting degradation of the resource used, or the resource handling the waste burden is not seriously impaired. When the demand increases, technology is stepped up to meet the demands of procurement and production, but frequently the companion technology necessary to relieve the environment of the resulting waste burden is overlooked. Industry's basic charge is to stockholders, not to the environment. I asked a very good friend of mine who sits on the board of directors for two manufacturing companies if he knew of any company that by its own free will, without public pressure, substantially reduced or eliminated stock dividends to cover costs which would free an environment of the company's own metabolic wastes. His answer: "It would not be in the interest of good business. In spite of the fact that each waste-producing industry would like to do the necessary clean-up, it cannot afford to do so." The eighteenth century Scottish philosopher David Hume[3] considered *avarice the spur of industry.* I do not agree fully with this appraisal, but if avarice be the spur of industry, then let wisdom and conscience be its bit and bridle.

In some cases pollution is so acute or extensive that not only is recreation impaired, but public health and safety are in jeopardy. The informed citizen must assume the attitude that it is in the interest of national health, that all polluters, public and private, be forced into clean-up practices. As stockholders in our future, we cannot afford to accept less.

I firmly believe that our social equation as of this time indicates an imbalance in values that is causing *C* to take on some negative characteristics. When a resource is so badly abused that the public ernment steps in (often with subsidy) to remedy and repair. The mutterings from some onlookers are concerned with "creeping socialism." If this is bad, blame "resource disregardism." And, if there is any doubt as to whether the public is aware of the seriousness of pollution, one needs only to be cognizant of the pending and recently enacted remedial legislation at both the state and federal levels.

Before we leave our equation, mention should be made of the component *space.* It is the one aspect of our resources that technology cannot physically increase. Space use will increase with population, and whatever is available will likely suffer quality deterioration.

Moving a polluting industry from one part of the country (space) to another does not, from a political or economic point of view, alter the inevitability of degradation in the U. S. A. Temporary economic gains mask but do not stay the ultimate loss to an environment which will be called upon to support more and more people.

The control of our human population growth (P) could prolong and perhaps insure the positive values of our culture (C). To exercise this control through a limited birth rate, a pill to adjust intellectual attitudes as well as reproductive physiology will be needed. Birth control implications, however pertinent here, are beyond the purview of this symposium.

I have said before,[4] and it is germane here, that society tends to default on resource jeopardy when the debasing activity is distant in either time or space. We are jarred from a complacent attitude only when our sight, hearing, sense of smell, and intelligence are offended by resource misuse or overuse, and are goaded into action by infringement on our health, economy or recreation. To act for what is *right* when it affects our *neighbor* and not ourselves is not only a biblical dictate, but evidence of conservation awareness.

The foregoing exercise in letter symbolism allows us to think about the people-resource interaction when precise, statistically significant data are lacking, and we are left with the unmeasured obvious.

Fish and other wildlife and the habitats they occupy are an important part of our state and national resource base. They are in an economic sense essential to a rapidly-growing enterprise called tourism, or outdoor recreation. No major wildlife group is completely free from infringement, but not all are affected uniformly. Without magnifying problems of particular species, the following groups are involved:

Waterfowl and water birds	Furbearers
Upland game birds	Fish
Songbirds	Amphibians
Small mammals	Reptiles
Large mammals	Invertebrates

These categories of wildlife are affected in four major ways: loss of cover, loss of food, direct killing, and impairment of productivity. The following are examples of this industry–wildlife interaction.

Fish.—In the inland aquatic environment which is limited and to a considerable extent a functional part of our industrial sewerage system, fish suffer loss of protective plant life in waterways, the death of small animal life on which they feed, are killed directly by poisons or by lack of oxygen used by oxygen-demanding pollutants, or are limited in reproducing when spawning habitat is denied them or is destroyed by siltation. Loss of biological and physical aspects of fish environments to industrial pollutants are widespread and readily documented. They remain to be corrected.

Birds.—In a zealous effort to recoup losses of cellulose fiber initiated by the period of "cut out and get out" harvesting of our virgin forests and completed by the holocausts that followed, we were oversold on reforestation. Most reforestation of softwoods is necessary and beneficial. Some of the land that could not be planted has now grown to other forest trees, making reforestation today difficult if not impossible on these lands. Forest fire control is virtually complete. The bird affected by these efforts is the sharp-tailed grouse, a bird adapted to forest openings and young forests. In pristine times fire created the openings and natural reseeding produced the young forests. Today, without fire, frost pockets, high water tables, and plant competition have maintained scattered openings for sharp-tails. Because these areas are relatively accessible, they are vulnerable to the mechanical tree planter. To stop the ponderous social, governmental, and industrial complex dedicated to covering our northland with trees is difficult but not impossible. There are encouraging signs that industry and some governmental foresters are recognizing varied uses of forests, particularly the recreational values of forests, and the sharp-tailed grouse is important to part of such activity. While the foot is on the brake, we can only hope that the vehicle will stop before it causes the demise of one of Wisconsin's handsomest native grouse.

Mammals.—The common muskrat is one of the most important furbearers in the state. Destruction of food and cover causes continual shrinkage of habitat and numbers of this animal. Aquatic habitats, particularly wetlands and marshes, are subject to sanitary land fill (dumps); industrial fill for building sites; drainage for agriculture; cesspools for villages and cities; and graveyards for automobiles, machinery, and construction debris. One by one these lowland communities, because they are not understood or appreciated, are destroyed and with them the muskrat. In some cases when the desecration is from industrial pollutants, the muskrat is poisoned directly.

What kind of yardstick shall we use to appraise natural losses against commercial gains? Whatever it is, the results may be the same, but the sad fact is that at present we are using no yardstick at all.

A University of Chicago scientist[5] grew flour beetles in a jar under controlled conditions and found that up to a point (55/per gm flour) further increase fouled their environment and caused cannibalization of the very young. Flour beetles in a jar appear to be a far cry from people and our land, but the ecology is not, John

W. Gardner, the ex-Secretary of Health, Education, and Welfare, said (*Time Magazine,* October 1, 1965):

"We are living in our own filth." The article continues: "U. S. rivers and streams, like the muddy Missouri, used to be contaminated with nothing worse than silt, some salt, and the acids from mines. Now they are garbage dumps. Raw sewage, scrap paper, ammonia compounds, toxic chemicals, pesticides, oil and grease balls as big as a human fist—these are the unsavory contents of thousands of miles of U. S. waterways.

"Industry now pours at least twice as much organic material into U. S. streams as the sewage of all the municipalities combined. Americans who once could be excused a superior attitude about sanitation after traveling abroad, now come home to find that their own drinking water may come from rivers into which steel mills pour pickling liquors, paper mills disgorge wood fibers that decay and use up oxygen, and slaughter-houses dump the blood, fat, and stomach contents of animals. Pollution has become such a problem that it is all but impossible to calculate the probable cost of cleaning up the streams. A conservative estimate: at least $40 billion over the next decade."

Although certain industries are more directly involved in adversely affecting natural resources, particularly wildlife, my mission is not to point an accusing finger. Industry, in defending itself, calls attention to municipal infractions; pesticide interests challenge the adverse effects of agricultural fertilizers; water polluters focus attention on air polluters. Each offender advertises recent improvements in its own back yard. May these improvements catch up with, neutralize, and then correct the deleterious effects on human and wild environments.

In our zeal to make life better, easier, more pleasant and more profitable we are, like flour beetles, destroying these environments while the gears of technology having writ move on.

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RADIOCARBON DATES OF WISCONSIN

Robert F. Black[1] *and Meyer Rubin*[2]

INTRODUCTION

During the last 15 years, radiocarbon dating (Libby, 1961) has done more to change the correlation and reconstructed chronology of the Wisconsinan Stage of glaciation in the upper Mississippi Valley than any other method. The classical chronology, which was dependent on correlation of events between the Lake Michigan and Des Moines Lobes, was shown to be inadequate and inaccurate and was discarded in Illinois in favor of a new radiocarbon-supported chronology for the Lake Michigan Lobe alone (Frye and Willman, 1960). Discrepancies between the new and classical chronologies are readily apparent (table 1). The new chronology has been applied to Wisconsin (Frye, Willman, and Black, 1965) and to other places. However, not all events recorded from the Wisconsinan Stage in states adjoining Wisconsin have been recognized in Wisconsin, and vice versa. Furthermore, some of the major events affecting Wisconsin, according to the variety and distribution of land forms and deposits left behind, have not yet yielded organic matter for radiocarbon dating and can only be dated relative to other events.

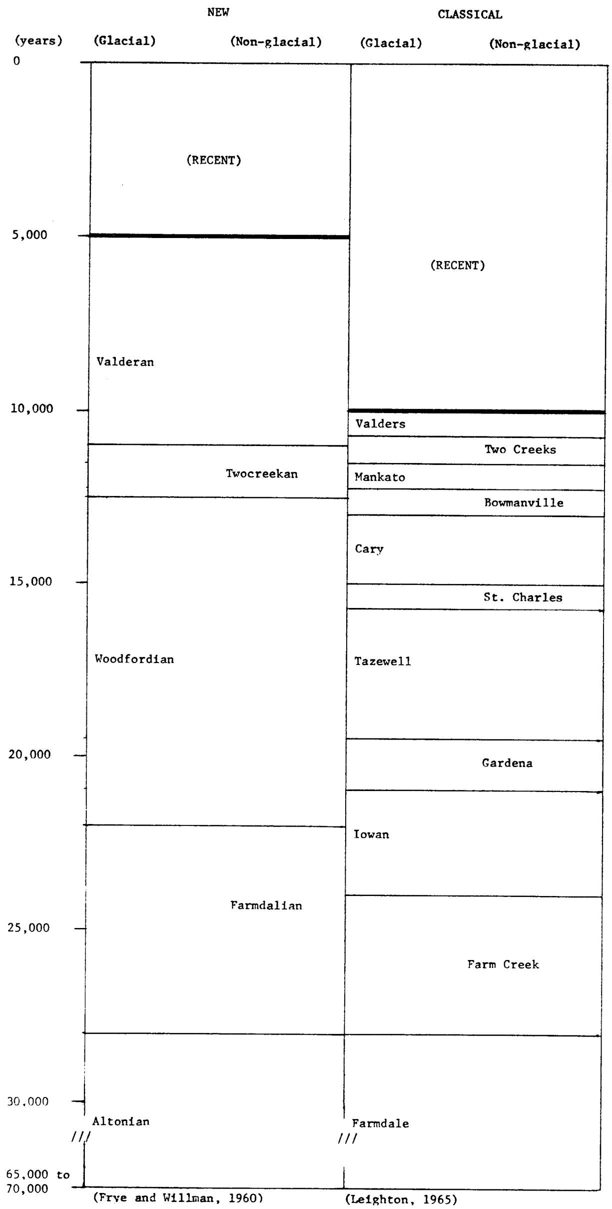
This paper lists (table 2) the radiocarbon dates older than 5,000 years from Wisconsin and discusses the significance of some in our interpretation of the glacial history of the state. Where samples have been re-dated by better methods, only the latter are given. Representative dates are shown on a map of Wisconsin (figure 1). The dates fall into natural groups (table 2) that are correlated with the new chronology even though some dates may be interpreted in different ways.

It is readily apparent that final answers on all events of the Wisconsinan Stage in Wisconsin are not yet in hand. However, no

[1] Professor of Geology, University of Wisconsin–Madison. Field work leading to this paper was supported in part by National Science Foundation Grant GP-2820, in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation, in part by the Wisconsin State Highway Commission, in part by the National Park Service, Department of the Interior, and in part by the Wisconsin State Geological and Natural History Survey.

[2] Geologist, U. S. Geological Survey, Washington, D. C.

TABLE 1



Two contrasting classifications of the Wisconsinan Stage.

TABLE 2. SOME RADIOCARBON DATES FROM WISCONSIN*

Age	Laboratory Number	County	Location	Remarks
Post-Valderan				
4,800 ± 150	L-605	Bayfield	46°57′N 91°00′W	Sand Island. Compressed peat under 14 ft. of sand in water depth of 40 ft. Equivalent to C-504 at 3,656 yrs. Dates low-water stage of Lake Superior.
4,880 ± 190	Y-238	Marinette	45°5′N 87°38′W	Sewer trench, 600 ft. or less in elevation. White oak. Dates maximum or recession of Lake Nipissing.
6,040 ± 350	W-1139	Columbia	43°31′N 89°29′W	Driftwood at 7 ft. in Wisconsin River alluvium. With W-1138, dates rapid filling of alluvium of the Wisconsin River.
6,070 ± 320	W-1138	Columbia	43°31′N 89°29′W	Beaver-cut stump *in situ* at 20 ft. in Wisconsin River alluvium.
6,340 ± 300	W-1017	Kenosha	43°33′N 87°49′W	Red oak. Dates paleosol at present lake level, under sand dune.
7,650 ± 250	SM-16	Vilas	46°9′N 89°37′W	Grassy Lake. Yellow-brown-black gytta in south center in 6–7 ft. of water; lower part of 30 ft. of sediment on sand. Total organic content is minimal date for organic accumulation in lake.
Twocreekan				
10,400 ± 600	M-343	Manitowoc	44°19′N 87°32′W	Inner part of log.
10,700 ± 600	M-342	Manitowoc	44°19′N 87°32′W	Outer part of log.
10,877 ± 740	C-308	Manitowoc	44°19′N 87°32′W	Spruce.

TABLE 2. SOME RADIOCARBON DATES FROM WISCONSIN*—Continued

Age	Laboratory Number	County	Location	Remarks
Twocreekan—Cont.				
11,097 ± 600	C-366	Manitowoc	44°19′N 87°32′W	Peat from soil horizon.
11,130 ± 350	Y-227	Manitowoc	44°19′N 87°32′W	Spruce from soil horizon. Equivalent to C-308, 365, 366, 536, 537 and W-42 and 83.
11,250 ± 120	W-42	Manitowoc	44°19′N 87°32′W	Wood from soil horizon. Equivalent to Y-141.
11,410 ± 180	W-83	Manitowoc	44°19′N 87°32′W	Wood from soil horizon. Equivalent to Y-227.
11,437 ± 770	C-365	Manitowoc	44°19′N 87°32′W	Spruce root from soil horizon.
11,442 ± 640	C-537	Manitowoc	44°19′N 87°32′W	Peat from soil horizon.
11,550 ± 300	W-698	Manitowoc	44°19′N 87°32′W	Wood from soil horizon.
11,840	L-698C	Manitowoc	44°19′N 87°32′W	Log in sediment below soil. Average of cellulose and lignin.
11,850 ± 100	L-607A	Manitowoc	44°19′N 87°32′W	Wood in soil horizon. Cellulose age.
12,000 ± 400	A-79B	Manitowoc	44°19′N 87°32′W	Wood.
12,150 ± 400	A-79A	Manitowoc	44°19′N 87°32′W	Wood from soil horizon.
12,168 ± 1,500	C-536	Manitowoc	44°19′N 87°32′W	Spruce from soil horizon.
12,200 ± 400	W-670	Manitowoc	44°19′N 87°32′W	Wood from soil horizon.
10,676 ± 750	C-630	Outagamie	44°17′N 88°20′W	Tree stump at depth of 10 ft. in varved deposits 25 ft. thick, formed in front of Valders ice. Reworked.

Table 2. Some Radiocarbon Dates From Wisconsin*—Continued

Age	Laboratory Number	County	Location	Remarks
Twocreekan—Cont.				
10,700 ± 210	Tx-44	Outagamie	44°16′N 88°27′W	Spruce at depth of 14 ft., below Lake Oshkosh sediments. Equivalent to C-800.
10,856 ± 410	C-800	Outagamie	44°16′N 88°27′W	Spruce at depth of 14 ft., below Lake Oshkosh sediments in Valders till. Reworked (average of 10,241 ± 650 and 11,471 ± 500).
11,640 ± 350	W-1110	Outagamie	45°27′N 88°14′W	Tamarack in soil horizon.
11,790	L-607B	Outagamie	44°12′N 88°27′W	Wood in till. Average of cellulose and lignin.
11,790	L-698D	Outagamie	44°17′N 88°25′W	Spruce in Valders till. Average of cellulose and lignin.
11,840	L-698B	Outagamie	44°27′N 88°14′W	Spruce in soil horizon. Average of cellulose and lignin.
11,900	L-698A	Outagamie	44°27′N 88°14′W	Spruce in soil horizon. Average of cellulose and lignin.
11,140 ± 300	W-590	Brown	44°32′N 87°55′W	Wood in Valders till and lake sand.
11,940 ± 390	Y-147X	Brown	44°32′N 87°55′W	Wood in Valders till and lake sand.
11,280 ± 100	Y-488	Winnebago	44°14′N 88°27′W	Wood from varved clay of Greater Lake Oshkosh. Equivalent to C-419 at 6,401 ± 230.
11,690 ± 370	Y-237	Winnebago	44°12′N 88°27′W	Wood in red clay.
12,060 ± 700	W-1183	Winnebago	44°13′N 88°26′W	Peat and spruce under till.
10,420 ± 300	W-820	Waushara	44°5′N 89°21′W	Peat at base of kettle.

TABLE 2. SOME RADIOCARBON DATES FROM WISCONSIN*—Continued

Age	Laboratory Number	County	Location	Remarks
Towcreekan—Cont.				
11,000 ± 400	UCLA-633	Waushara	44°10′N 89°21′W	Carbonate in gyttja at base of kettle (organic age estimated at 9,900).
11,600 ± 300	UCLA-631	Waushara	44°10′N 89°21′W	Wood at base of kettle.
12,000 ± 500	W-641	Waushara	44°5′N 88°54′W	Peat at 2–4 ft. under silt in last stage of Later Lake Oshkosh.
12,220 ± 250	W-762	Waushara	44°3′N 89°4′W	Peat at 4 ft. under lake clays.
13,700 ± 300	UCLA-632	Waushara	44°10′N 89°21′W	Carbonate in marl, 4 ft. above base of kettle (organic = 12,800 ± 400).
11,130 ± 600	W-1391	Jackson	44°23′N 91°1′W	Wood in meander scar of Trempealeau Valley.
11,611 ± 600	M-812	Sauk	43°21′N 89°56′W	Raddotz Rockshelter Sk-5. Charcoal in fire bed in stratum "R".
12,800 ± 220	WIS-48	Jefferson	42°54′N 88°44′W	Spruce at base of peat mound that formed shortly after deglaciation.
Woodfordian				
17,250 ± 300	GX-0457	Grant	42°53′N 90°34′W	Caribou bone at base of 7 ft. of loess in cave and on sandy gravel. H. Palmer, written communication.
19,250 ± 350	GrN-3624	Grant	42°33′N 90°37′W	Alkali soluble organic matter 3.7 m. below top of loess and 2.8 m. above base.

TABLE 2. SOME RADIOCARBON DATES FROM WISCONSIN*—Continued

Age	Laboratory Number	County	Location	Remarks
Farmdalian				
24,800 ± 1,100	Gro-2114	Grant	42°36′N 90°34′W	Bulk soil sample at base of loess.
Rockian				
29,000 ± 900	W-903	Walworth	42°45′N 88°33′W	Spruce in overridden outwash.
29,000 ± 1,000	W-747	St. Croix	44°57′N 92°30′W	Spruce in dark-gray clayey till on bedrock.
29,300 ± 700	GrN-2907	Grant	42°33′N 90°37′W	Spruce charcoal in paleosol at base of loess.
30,650 ± 1,640	Y-572	St. Croix	44°57′N 92°18′W	Spruce in dark-gray clayey till on bedrock.
30,800 ± 1,000	W-901	Waukesha	43°2′N 88°12′W	Spruce in overridden outwash.
31,800 ± 1,200	W-638	Walworth	42°33′N 88°31′W	Spruce in till. Equivalent to M-936 at >30,000.
Pre-Rockian				
>33,000	W-1370	Wood	44°41′N 90°7′W	Organic matter in fine mud below till.
>38,000	W-1598	Polk	45°38′N 92°13′W	Spruce and willow at depth of 175–180 ft.
>45,000	Nucl. Sci. & Eng. Corp.	Wood	44°38′N 90°8′W	Organic matter in fine mud below till. M. T. Beatty and F. D. Hole, written communication.
>45,000	W-1758	St. Croix	44°57′N 92°18′W	Peat in pond filling above Y-572.

*Excludes younger archeologic dates, those samples well above the bottom of lake deposits, and some solid carbon dates of doubtful validity. Letter prefix denotes laboratory where sample was run: W = U. S. Geological Survey; Y = Yale U.; M = U. of Michigan; C = U. of Chicago; L = Lamont; WIS = U. of Wisconsin; UCLA = U. of Cal. at L. A.; Gro and GrN = Groningen; A = Arizona; Tx = U. of Texas; and SM = Socony Mobil. See various issues of "Radiocarbon" for futher details on individual samples.

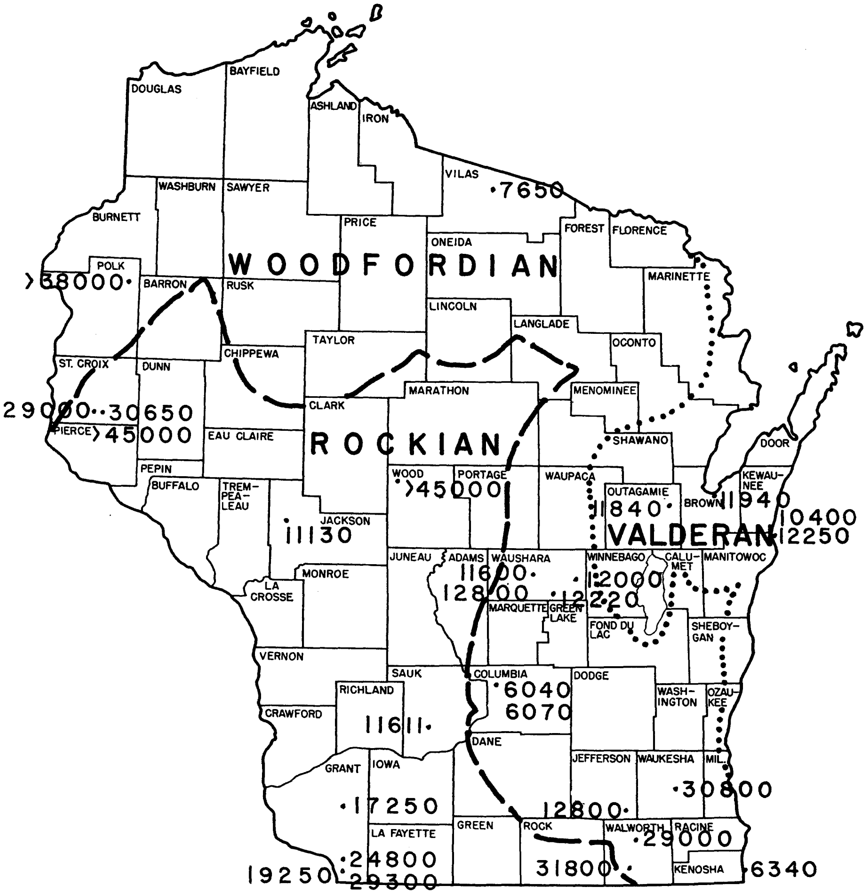


FIGURE 1.—Some representative radiocarbon dates on the county map of Wisconsin and the approximate boundaries between drifts of Valderan, Woodfordian and Rockian age.

attempt is made here to review in detail the entire Wisconsinan chronology for the state nor the events that are not recorded by radiocarbon dates.

DISCUSSION

Pre-Rockian

Four dates are indefinite but are more than 33,000 radiocarbon years old (table 2). Two samples (W-1370 and Nuclear Science and Engineering Laboratory) from the vicinity of Marshfield, Wood County, are of finely disseminated organic matter in silty-clay pond deposits (interpretation by Black of samples from power augering by T. E. Berg) on bedrock and beneath a single drift sheet that surely is Wisconsinan in age (Hole, 1943). The date of more than 45,000 radiocarbon years may be interpreted to mean that the fluctuations of the Altonian ice in Illinois (table 1) (Frye, Willman, and Black, 1965) were not represented in central Wisconsin from the time of existence of the pond to the advance of the ice that left the overlying till. The same interpretation is possible for the situation in St. Croix County. There basal till with erratic spruce dated at 29,000 (W-747) and 30,650 (Y-572) radiocarbon years also seems to have incorporated peat (W-1758) from former ponds that is dated at greater than 45,000 radiocarbon years. The wood (W-747 and Y-572) is thought to date the time the ice advance destroyed the spruce forest on a residual soil rich in chert; the older peat (W-1758) now overlies the younger wood (Y-572) in the till and is thought to represent a pond deposit overrun and picked up by the ice.

If the different kinds of organic matter were transported by the ice only once, they would imply that central and west-central Wisconsin were ice-free from more than 45,000 radiocarbon years ago until about 31,000 radiocarbon years ago. Such a situation existed in Ontario (Dreimanis, Terasmae, and McKenzie, 1966), but apparently not in northern Illinois (Kempton, 1963 and 1966). Obviously other interpretations are possible, and data are not now sufficient to reconcile them.

Similarly, the spruce and willow fragments (W-1598) from Polk County are more than 38,000 radiocarbon years old, but they tell us little about the chronology of the area. The 175–180 feet of drift overlying the sample is so poorly recorded in the well records that almost any interpretation is possible.

Rockian

The three dates of 29,000 to 31,800 radiocarbon years from spruce (W-903, W-901, and W-638) in drift of Walworth and Waukesha Counties, the two comparable dates of spruce (W-747 and Y-572) from St. Croix County, and the comparable date of spruce (GrN-2907) of the paleosol from the base of the loess in Grant County are believed to represent the time of a brief ice advance, called Rockian by Black (1960b and 1962), that occurred simultaneously from the Des Moines Lobe on the west and from the Lake Michigan Lobe on the east (Black, 1964b). This time is latest Altonian (Frye, Willman, and Black, 1965) (table 1) and is recorded also outside Wisconsin (White and Totten, 1965). The wood in St. Croix County is in the basal till which is rich in disseminated organic matter, clay, and residual chert (Black, 1959a; Black, Hole, Maher, and Freeman, 1965); the wood in Walworth and Waukesha Counties is in oxidized sandy till and in overridden gravelly outwash. All the wood is erratic and conceivably could have been picked up and transported more than once by ice or water. Hence, other interpretations are possible, but the deposits can only be younger than the included wood—not older as had been proposed decades ago (Alden, 1918).

The dated paleosol (GrN-2907 and Gro-2114) from Grant County occurs only in a few isolated thin patches which are disrupted and moved. Spruce (GrN-2907) occurs as small angular fragments of charcoal (Hogan and Beatty, 1963) and provides a more realistic date than does the bulk sample (Gro-2114). Clays in the paleosol are similar mineralogically to those in the residuum from the dolomite below (Akers, 1961), and general alteration of the mineral fragments (Hogan and Beatty, 1963) is not severe. The paucity of paleosol below the loess in southwest Wisconsin, if the area had never been glaciated, is difficult to explain. That it was glaciated now seems accepted (Black, 1960a; Frye, Willman, and Black, 1965; Trowbridge, 1966) and disagreement now is concerned more with timing—Frye and Willman and Trowbridge suggest a Nebraskan time; Black concludes that Rockian ice from east and west joined in the center of the state, with relatively thin inactive ice formed in large part by local accumulation covering the Driftless Area. Earlier glaciation is also recognized as a strong likelihood.

Positive evidence of glaciation of the Wisconsin Driftless Area (Frye, Willman, and Black, 1965) comes from some fragments of Precambrian igneous and metamorphic rocks and particularly Paleozoic chert and sandstone that rest on younger formations. Erratics of sedimentary rocks are especially abundant in the central and northern parts of the area (Akers, 1964). Sparse igneous erratics occur in isolated kame-like deposits south of Taylor in the northern part of the area and in fresh gravel on the upland beneath thick loess at Hazel Green, Richland County. Igneous erratics are also found in terraces tens of feet above the Wisconsin River. One deposit north of Muscoda contains 10-foot angular clasts in foreset beds that demonstrate a northeastward flow of water and a probable ice front. Large sand bodies in the Kickapoo River valley have come off dolomite uplands and contain glauconite above any known source. Anomalous rubbles on the upland (Akers, 1964) also have anomalous clay minerals (Akers, 1961). Thus, in an area of 10,000 square miles in southwest Wisconsin we see an absence or paucity of chert and clay residuum on bedrock, an absence of loess older than 30,000 years, and an almost complete absence of older paleosols. Moreover, shale with thin seams of unweathered dolomite (Maquoketa Formation) caps East Blue Mound, with only small fragments of the silicified Niagaran dolomite scattered on the broad flat upland (Black, Hole, Maher, and Freeman, 1965, p. 75–76). This is also an incongruous situation. No gradational processes other than glaciation seem competent to strip the Niagaran from so broad an area of shale and remove it and the chert residuum of the Paleozoic formations from all surrounding stream valleys.

A pre-Wisconsinan age for some of the peculiar features or deposits in the area can neither be confirmed nor denied (Akers, 1964; Black, Hole, Maher, and Freeman, 1965; Frye, Willman, and Black, 1965) but it is suggested (Frye, Willman, and Black, 1965; Palmquist, 1965; Trowbridge, 1966). The supposed front at Muscoda, relatively thick cherty residuum on the dolomite uplands near LaValle, Sauk County, red-brown stony drift mostly in Green and western Rock Counties, and some Windrow deposits (Black, 1964c; Andrews, 1958) still offer the most promise of being early Altonian or pre-Wisconsinan. No way yet has been found to date these isolated deposits adequately.

Farmdalian

The time of the Farmdalian deglaciation, which is recorded so well in Illinois (Frye, Willman, and Black, 1965), is represented in Wisconsin by one date only (24,800 ± 1,100 years B.P.) at the base of loess in the Driftless Area. This date is from a bulk organic soil sample which differs significantly from the date (29,300 ± 700 years B.P.) of fragmented spruce contained in it. No significant breaks in loess deposition from the dated paleosol at the base to the present surface have been found (Glenn, Jackson, Hole, and Lee, 1960; Hogan and Beatty, 1963).

Farmdalian time in Wisconsin was at least partly a time of very cold climates and accompanying permafrost and periglacial phenomena (Black, 1964a and 1965). However, dating of events is difficult as no trace of woody material has been found. Presumably, the thick outwash gravel in southeastern and southern Wisconsin was formed at this time while ice remained in the northern part of the state (Black, 1960b). The Farmdalian was a time of ice advance in Ontario (Dreimanis, Terasmae, and McKenzie, 1966).

Woodfordian

Woodfordian time is represented in Wisconsin by two dates in the Driftless Area. One, of caribou bone, is 17,250 radiocarbon years; the other, a bulk sample of loess (GrN-3624), is 19,250 radiocarbon years. Their significance and relationship to the prominent Cary (late-Woodfordian) front or the chronology of glacial events are not known.

Drift of middle and later Woodfordian age makes up the surface of more of the state than any other, yet it has no known organic remains. Early Woodfordian deposits are thought to be present (Black, 1959a) but have not been dated for lack of organic matter. Isochronous boundaries (Alden, 1918) at the front or within the Woodfordian drift sheet are exceedingly tenuous. Woodfordian time in Illinois is represented by tens of moraines and numerous radiocarbon dates (Frye, Willman, and Black, 1965). Clearly the Woodfordian in Illinois and Wisconsin is multiple and is composed of many pulsations of the ice front, some having only limited movement, but others consisting of retreats or advances up to 100 miles. The outermost Cary of presumed late-Woodfordian age is not represented everywhere in either Wisconsin or Illinois by the same pulse. Although its border from the Plains to the Atlantic Ocean has been described and mapped for decades as the break between deposits of the First and Second Glacial Epochs (Chamberlin, 1878 and 1883), we still have much to learn about it. Without a single radiocarbon date related to the advances of the Woodfordian ice in Wisconsin, and few to record its destruction, we have been dependent on morphology of forms and direction indicators to separate pulsations. These are applied with difficulty in many places but generally seem better than lithology or texture of the material involved in any one sublobe (Oakes, 1960). Lithology helps to distinguish major lobes (Anderson, 1957).

Post–Cary or late Woodfordian events which are pre-Twocreekan are much less well known in Wisconsin than elsewhere. Moraines assigned to Mankato and Port Huron in Minnesota and Michigan, for example, are presumed to be present in Wisconsin, behind the Cary front. However, the correlation of moraines in Wisconsin with type localities has not been done, and deployment of such ice in the state is conjectural.

Deglaciation of the Woodfordian ice in Wisconsin may be time transgressive, being earlier in the south than in the north. Revegetation presumably took little time after deglaciation, forest trees coming in last but perhaps even growing on stagnant buried glacial ice. A peat mound on Cary drift in Jefferson County has spruce (WIS-48) at the base dated at 12,800 radiocarbon years (Ciolkosz, 1965). In Waushara County, a date of 12,800 radiocarbon years was obtained on organic matter (UCLA-632) in marly gyttja four feet above the base of undisturbed marsh deposits (Park, 1964, p. 8), but spruce (UCLA-631) at the base of the same deposit and higher on the flank of the kettle was dated at 11,600 radiocarbon years. Three other dates on peat (W-820, W-641, and W-762) in basal pond deposits in Waushara County are 10,420, 12,000 and 12,220 radiocarbon years respectively. One

(W-1183) in Winnebago County is 12,060 years. The dates of organic matter are suggestive of transgression, but the main evidence for the time transgressive deglaciation is morphologic—that is, the widespread evidence of ice stagnation and the youthful lakes and other features in the north. The time difference may be several thousand years for all buried ice to melt out.

Twocreekan

The Twocreekan interval is named from Two Creeks, Wisconsin, where a buried soil and organic remains were recognized in lacustrine deposits along the exposed bluff of Lake Michigan (Goldthwait, 1907; Black, Hole, Maher, and Freeman, 1965). This is the most dated interval in Wisconsin, the latest dates yielding an average of 11,850 radiocarbon years (Broecker and Farrand, 1963). A number of dates (Thwaites and Bertrand, 1957) derived by the original solid-carbon method were as much as several thousands of years in error, according to re-runs by better methods. Many samples (e.g., C-308, C-365, and C-366) dated years ago have not been re-run.

The general range of Twocreekan time from 11,000 to 12,500 years proposed by Frye and Willman (1960) is distinctly longer than the interval represented at Two Creeks. There, only an incipient soil profile was formed under trees of which the oldest by tree-ring count was only 142 years (Wilson, 1932 and 1936). Several other localities in east-central Wisconsin contain the Two Creeks horizon *in situ,* and logs from it are incorporated in the overlying Valderan till. These also tend to cluster close to 11,850 years ago so the span of Twocreekan time in central and northern Wisconsin likely is less than in southern Wisconsin. This is to be expected, because deglaciation through several hundred miles of latitude of an ice lobe the size of that which occupied the Lake Michigan area during late Woodfordian time cannot be accomplished overnight.

The sample (WIS-48) dated 12,800 radiocarbon years from Jefferson County attests to the early development of the spruce forest in the southern part of the state. Similar dates (samples W-641, W-762, and UCLA-632) from Waushara County confirm that deglaciation of the Woodfordian ice from those areas, and, hence, the beginning of Twocreekan time, must have taken place about 12,000 to 13,000 radiocarbon years ago. The carbonate date (UCLA-632) of 13,700 radiocarbon years is likely too old, according to associated organic matter that has an age of 12,800 radiocarbon years.

Destruction of the Twocreekan forests by rising lake waters and by Valderan ice at about 11,850 radiocarbon years ago should mark the close of Twocreekan time rather than the 11,000 years proposed. Probably the entire area of Wisconsin was free of surface ice during Twocreekan time, and only the northeastern part was again covered by glaciers. Consequently over most of the state, the effects of Twocreekan soil formation and geomorphic processes were merged and obliterated by the same processes that continued down to the present day in all but rare situations where quick burial took place. Aggrading stream valleys retain Twocreekan material (W-1391) (Andrews, 1966), as does the rock shelter under the Natural Bridge in Sauk County (M-812) (Black, 1959b; Wittry, 1959). Man was associated with the shelter, leaving remains of his wood fires (Black and Wittry, 1959; Wittry, 1964). The climate in northeastern Wisconsin at the time was perhaps similar to that of today in northern Minnesota (Roy, 1964). Pollen analysis of Twocreekan material shows spruce forests dominated (Black, Hole, Maher, and Freeman, 1965; West, 1961).

Valderan

Distribution of the Valderan ice in Wisconsin seems limited to the northeastern part of the state bordering Lake Michigan (Black, 1966). Whereas the ice was formerly thought to extend across northern Wisconsin (Leverett, 1929) and to correlate with red clayey till in eastern Minnesota, this is clearly incorrect (Wright and Ruhe, 1965). Unfortunately we have no radiocarbon dates in Wisconsin directly reflecting either the rate of advance or retreat of the ice. Although the trees at the dated Twocreekan localities apparently were living when drowned by rising lake waters or were knocked over by the advancing glacier, the sites are too close together and the dates are too imprecise to record the date of advance; we do not yet have any dates in Wisconsin that record its retreat.

Valderan ice at one time occupied the eastern part of Lake Superior and the northern part of Lake Michigan, radiating from a cap on the peninsula between them (Black, 1966). Parts of both those lakes must have had only seasonal ice and open water from the latter part of Woodfordian time to the present. Other very local caps on Michigan's Upper Peninsula, as in the Huron and Porcupine Mountains, may have formed at the same time and survived after Lake Michigan was entirely freed of ice. That ice seems to have stopped short of Wisconsin. Buried ice from earlier glacial advances into northern Wisconsin survived through the Valderan.

Post-Valderan

No radiocarbon dates from Wisconsin record the withdrawal of the Valderan ice, and we can only infer from evidence elsewhere that it likely left the state about 10,000 radiocarbon years ago. Only one date (SM-16) (7,650 radiocarbon years B.P.) from the bottom of a kettle lake in northern Wisconsin is older than 5,000 radiocarbon years. It is a minimal date for organic accumulation, but time must also be allowed for the thaw of the buried ice to produce the kettle. Drumlins made by Valderan ice have been dropped into some lakes by post-Valderan thaw of buried ice of Woodfordian and Rockian age. The ice blocks of different sizes and depth of burial presumably melted out during a relatively long period of time—many hundreds to several thousand years. Hence, radiocarbon dating of pond sediments can provide minimal dates only for withdrawal of the Valderan ice.

The Columbia County dates (W-1138 and W-1139) of about 6,000 radiocarbon years record the rapid alluviation of the Wisconsin River valley south of Portage and are of comparable age to a paleosol (W-1017) exposed beneath dunes along the shore of Lake Michigan in Kenosha County. Although that was a time of increasing temperature and dryness, the altithermal, actual significance of the dates is not yet known.

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GEOMORPHOLOGY OF DEVILS LAKE AREA, WISCONSIN

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INTRODUCTION

Devils Lake Park in the Baraboo Range, Sauk County, presently contains about five square miles of scenic cliffs, wooded hills and Devils Lake itself (Fig. 1). Topographically the Devils Lake area is mostly a rolling upland near 1400 feet above sea level, cut by a steep walled L-shaped gorge whose floor is generally 500 feet below the summit. The north-trending part of the gorge is occupied by Devils Lake, held in on the north and on the southeast by end moraines. Within, but especially adjacent to, the Park many glacial phenomena are beautifully preserved. Ancient rocks of Cambrian and Precambrian age crop out locally in bizarre forms. The record in the rocks and in glacial and periglacial features of the Devils Lake area is especially rich. The geomorphic development of the area, resulting in the present landscape, covers many hundreds of millions of years of geologic time and is truly an intriguing story.

As a field laboratory in earth history, this area has been one of the most valuable and fascinating in the upper Mississippi Valley region. Besides being one of the most popular parks in Wisconsin, the Devils Lake area has been the locus of field trips for many hundreds of geology students each year. In spite of the great amount of study given the area by scientists over the decades, new information continues to appear.

The last major summaries of the surficial geology of the Devils Lake area are those of Salisbury and Atwood (1900), Weidman (1904), Trowbridge (1917), and Alden (1918). They are now out of print and found only in the larger libraries. However, Smith (1931), Martin (1932), Thwaites (1935; 1958), and Powers (1960), have discussed some of the prominent land forms in the

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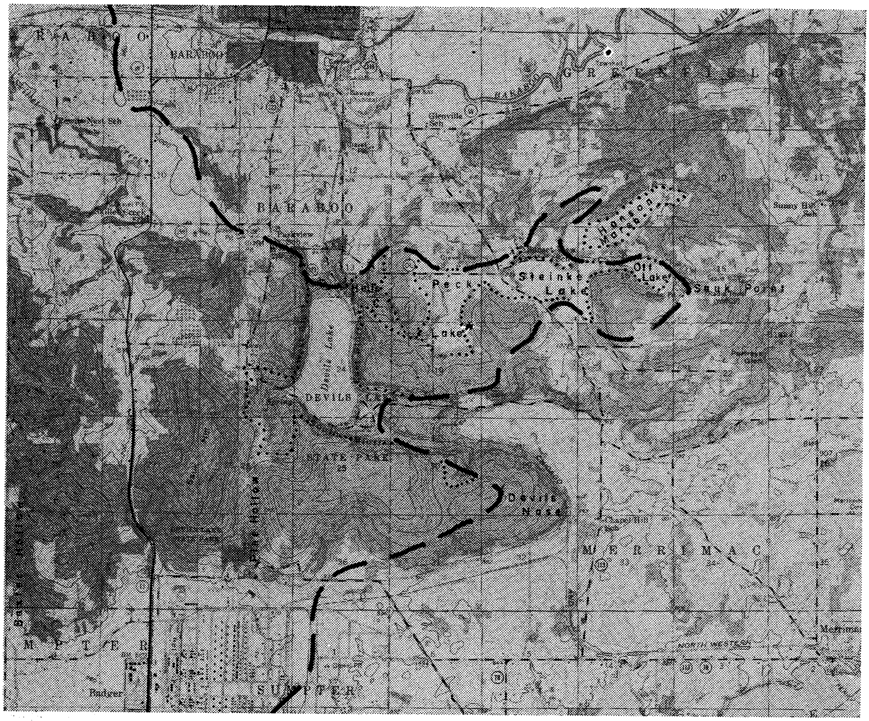

FIGURE 1. Topographic map of the Devils Lake area, showing border of the late-Woodfordian (Cary) drift and some proglacial drained lakes. Portions of the U. S. Geological Survey quadrangle maps Baraboo and North Freedom. Scale one mile to the inch.

geomorphic evolution of the Baraboo Range. For the benefit of the many Park visitors this paper outlines the geology of the area, and then describes in more detail some of the specific features to be seen. Devils Lake, the moraines, periglacial features, drained lakes, stagnant ice features, pot holes, and erratics are singled out. Many facets of the geologic history are still missing, thus making different interpretations equally viable. Hopefully this summary will accelerate the search for additional clues.

It is urged that the many striking features illustrated in the Devils Lake area be seen and appreciated, but not destroyed, by the thousands of visitors each year who come to Devils Lake Park. Pressure of man's use continues to increase each year, now to the point where even the durable rocks need protection. In their zeal, geology students particularly have contributed disastrously to the natural attrition of certain exposures of the bedrock. Every geologist who has written extensively on the Devils Lake area has emphasized the uniqueness of the glacial, periglacial and bedrock phenomena present. No other location in the midwest has such a rich variety of unique features in so small an area near major centers of population. As a tourist area and as the scientist's field laboratory, it is certainly unrivaled for hundreds of miles around. Hence, every effort must be made to preserve, not just the features in the Park, but the many glacial and bedrock features adjoining it as well for future use of all mankind. Once destroyed, they can not be replaced.

Outline of Geology

The story of Devils Lake Park must begin about a billion years ago, in middle Precambrian time, with the deposition in shallow seas of many hundreds of feet of very clean, well-winnowed quartz sand of medium-grain size. Subsequent burial in the earth's outermost crust and accompanying alteration during late Precambrian time lithified the rounded to subangular sand grains into the brittle Baraboo Quartzite in which the gap containing Devils Lake has been cut. The lithification involved little or no crushing of the sand grains—only deposition of secondary silica cement in interstices. This makes the total rock very hard yet brittle so it breaks across grains. The individual grains of sand and some pebbly and bouldery zones are still easily distinguished today.

Large joint blocks are commonplace and lead to the formation of extensive talus and jagged cliffs (Fig. 2). The characteristic pink, red, and lavender hues are attributed to finely disseminated iron oxides in very small amounts. Oscillation and current ripple marks, mud cracks, and cross-cutting stratification typical of the former marine environment are widespread in the Park.

Perhaps in part during metamorphism of the sand to quartzite and certainly afterwards the area was folded into a large basin or syncline by a mechanism not fully understood. Perhaps more than one episode of regional stress produced the minor structures now visible in the Baraboo Range. The basin is 25 miles long, 10 miles wide, and trends east-northeast. Devils Lake lies in the center of the south limb of the basin where the gentle north dips and local gentle undulations of the quartzite are readily discerned in the cliffs of the West and East Bluffs overlooking the Lake (Fig. 3). Local very gentle south dips of the quartzite are found in the cliffs two to three miles east of Devils Lake.

Fracture cleavage—a parallel splitting of the quartzite easily confused with bedding—dips northward at Devils Lake at angles greater than the bedding planes of the quartzite (Weidman, 1904; Hendrix and Schaiowitz, 1964). It too aids in the formation of joint blocks, talus, and jagged cliffs. Such fractures are considered

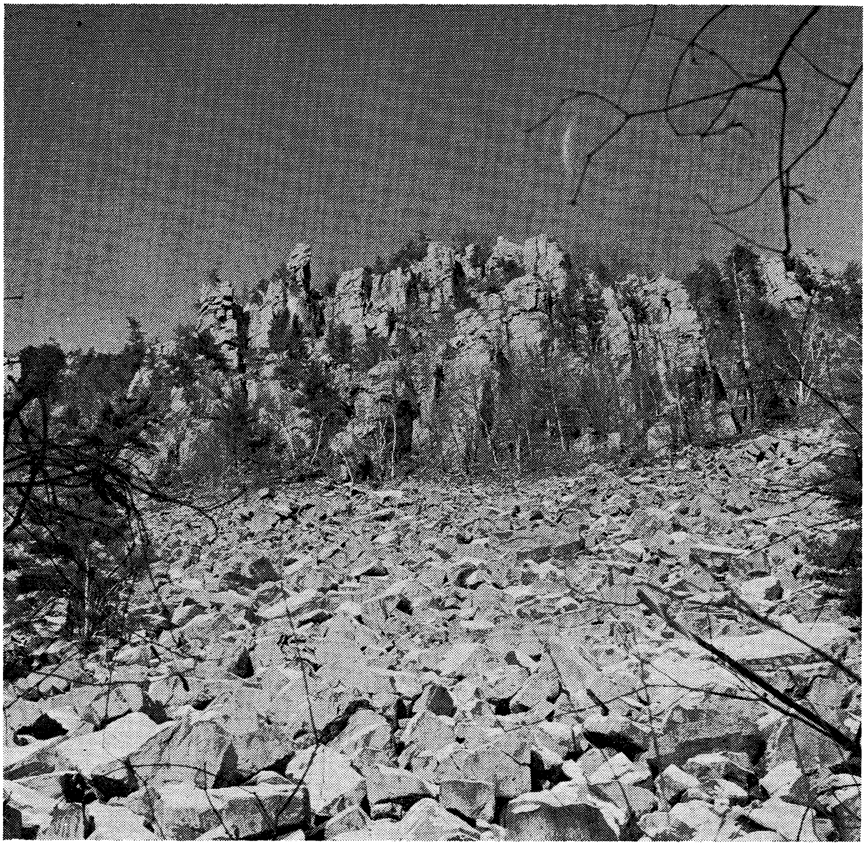

FIGURE 2. Talus surmounted by castellated cliffs of Baraboo Quartzite on the south face of East Bluff of Devils Lake.

"normal" in their orientation with respect to the stresses that are inferred to have produced the syncline (Hendrix and Schaiowitz, 1964). So are minor drag folds in thin argillites (clayey zones) at Devils Lake, but other minor structures including small folds, slip cleavage, and shears are considered "reverse" by Hendrix and Schaiowitz (1964). The normal minor features are confined to thin silty argillite layers interbedded with quartzite, whereas the reverse minor features are in thick argillite beds. Extensive exposures of the reverse structures are in Skillet Creek, about one mile northwest of Devils Lake; a small outcrop is just inside the present northwest entrance to the Park (Hendrix and Schaiowitz, 1964). (Both exposures are rapidly being destroyed by the promiscuous hammering of geology students who do not realize that more

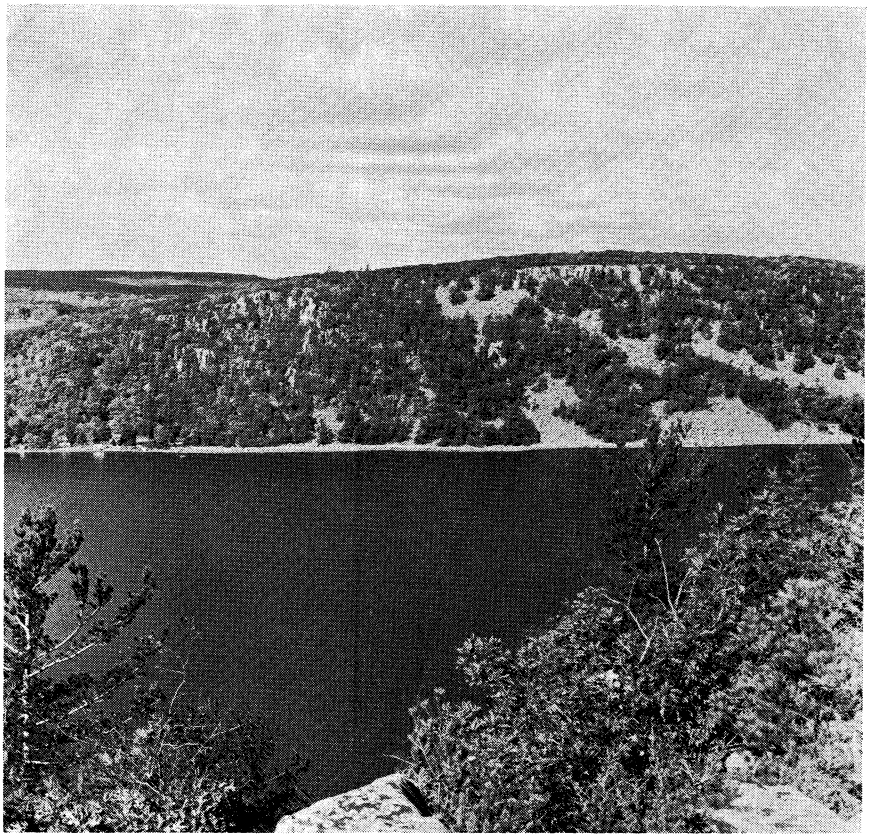

FIGURE 3. View westward of West Bluff of Devils Lake, showing talus and jointed beds of the Baraboo Quartzite dipping 10° northward.

can be seen on the weathered surface than on a fresh one. This must cease if we are to preserve these structures.)

The details of the folding mechanism of the quartzite are interesting but not especially germaine to the problem of the present day surface features in the Devils Lake area even though the resulting structures are. As pointed out, the fracturing of the rock has made frost work especially effective in the formation of pinnacles, talus slopes, and bizarre forms (Figs. 2 to 5).

The younger Seeley Slate Formation and the overlying Freedom Formation of iron-bearing slate, chert and dolomite of Precambrian age are on the Baraboo Quartzite southwest of North Freedom but have not been recognized in the Park. They were the object of a flourishing subsurface iron ore exploration program in the late

1800's (Weidman, 1904), but no mines are operating today. They do not contribute to any notable or striking surface features.

Some time after the folding and uplift of the Baraboo Range, sub-aerial erosion (Trowbridge, 1917) and probably marine shore erosion also (Thwaites, 1958) developed relief of a thousand feet between the top of the Range and the surrounding beveled Pre-cambrian igneous and metamorphic rocks. Such relief was due almost entirely to the great resistance to weathering and erosion of the quartzite.

Igneous rocks crop out in Baxter Hollow (quartz diorite); in three isolated bodies northeast, north and northwest of Denzer (rhyolite and diorite); at the Caledonia Church on Highway 78, southwest of the east nose (rhyolite); and in a larger body at the

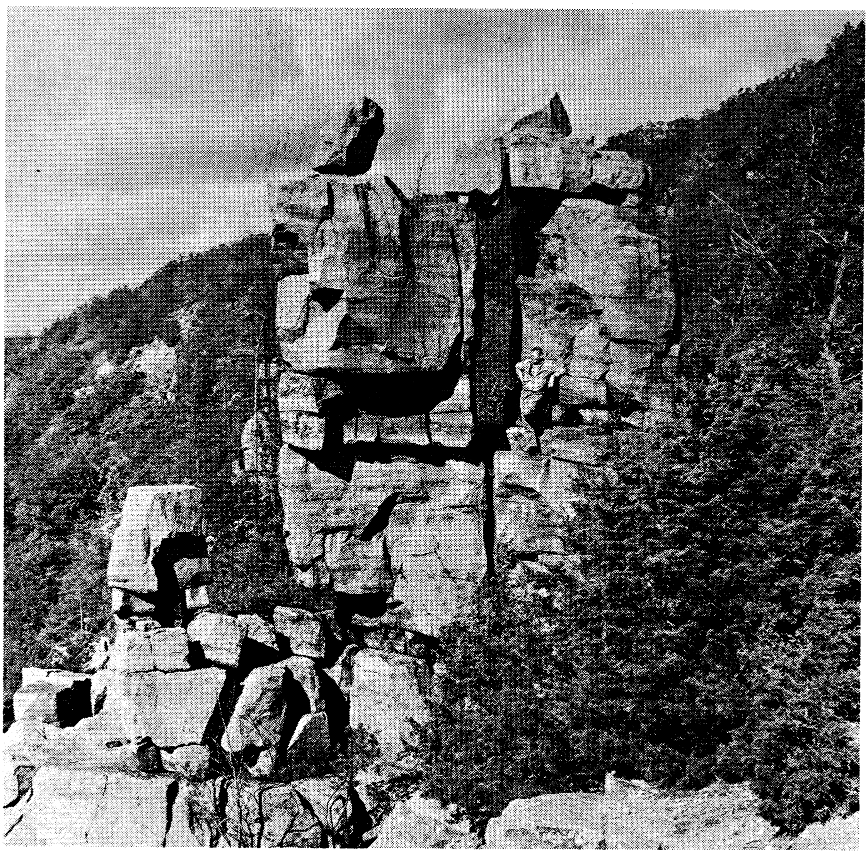

FIGURE 4. Devils Doorway on the south-facing slope of East Bluff of Devils Lake, formed by periglacial frost action from well-jointed Baraboo Quartzite.

FIGURE 5. Balanced Rock, a joint block of Baraboo Quartzite, isolated by periglacial frost action and rock falls of adjacent material. On the west-facing slope of East Bluff of Devils Lake.

Lower Narrows of the Baraboo River, on the north side of the Range (rhyolite) (Weidman, 1904). However, in most of the area surrounding the Range, the igneous rocks are buried beneath thick accumulations of sand of Upper Cambrian age (500 to 550 million years old).

During the development of the relief, beveling of the upland quartzite obliquely across the bedding produced surfaces which look smooth to the eye and have long been called peneplains (Trowbridge, 1917). The interpretation that the region was in the end-stage of one or more cycles of erosion is now discredited (Thwaites, 1958 and 1960). Nonetheless the mode of beveling of the resistant quartzite at such marked elevations above the surrounding plains is not truly understood. Certainly toward the close of the erosion cycle marine waters again inundated the quartzite.

Thick accumulations of sand were piled around the Range which for a time stood as islands in the shallow seas, shedding their characteristic pinkish rocks into the surf zone to be transported down-wind and along shore to inevitable burial (Raasch, 1958). Thus we find pebbles and boulders of rounded quartzite scattered thickly and widely through the sands lapping onto the quartzite to the south but only a short distance to the north. Quartzite pebbles are found locally from the Cambrian basal conglomerate up to the Platteville Formation of Ordovician age. The Cambrian sands not only lapped onto the flanks and filled the center of the syncline, but they also filled channels cut into the quartzite by ancient streams. The angular unconformity of the sands with respect to the beveled quartzite is striking in many places as is also the abrupt textural and compositional change in the basal conglomerate. A possible wave cut terrace lies on the northeast part of Happy Hill, six miles west of Devils Lake (Thwaites, 1958).

Gaps cut entirely through the Range are common in the narrow steeply dipping north flank. Only one is known, that with Devils Lake, in the broad south flank (Trowbridge, 1917 and Alden, 1918, p. 105–107). Some, such as at least part of Devils Lake Gap, are definitely pre-late Cambrian in age for they contain Cambrian sandstone; others likely are post-Paleozoic and still others were modified by streams as young as Pleistocene to the Recent age.

Hanging valleys in the quartzite of the south flank are anomalous also. They are broad and gently dipping in their upper reaches and plunge precipitously to the buried Precambrian surface hundreds of feet below. Some are filled partly with Cambrian sandstone so date from the Precambrian erosion cycle; some also have narrow notches cut into them that may postdate the Paleozoic. The distribution of the hanging valleys in the Baraboo Range is not known nor is their origin. Pine Hollow in the southwest corner of the Park, southwest of Devils Lake, is typical (Thwaites, 1958).

Cambrian sandstone crops out near the northeast and northwest corners of Devils Lake, in the gorge east of Devils Lake and continuing eastward to Parfreys Glen, near Koshawago Springs and along Messenger Creek southwest of the Lake to the headwaters of Pine Hollow, and in a considerable area in Skillet Creek. It has not been found in the deep valley under Devils Lake itself which is filled with glacial sediments. Cambrian sandstone also is common along Highway 12 where it crosses the south limb, and continues westward to Baxter Hollow where it produces striking cliffs.

Paleozoic sediments continued to be deposited around and over the Baraboo Range probably until Silurian or possibly Devonian time (Wanenmacher, Twenhofel, and Raasch, 1934) with erosional intervals such as that below the St. Peter Formation (Thwaites, 1961). However, in the Park only the Upper Cambrian sandstone lies on the quartzite. The oldest units exposed is the Galesville For mation of the Dresbach Group (Ostrem, 1967). It is thickbedded and mostly white or very pale yellow. It is the unit that develops striking cliffs and steep slopes in Baxter Hollow west of the Park. The next younger formation is the dolomitic, fine-grained Franconia Sandstone that forms local benches, cliffs, and crags that are greenish grey in contrast to the Dresbach. Still younger rocks are more distant from the Park today although they may have been present in the geologic past (Ostrem, 1966). Chert nodules and clay on top of the quartzite west of Devils Lake are thought to have been "let down" during weathering of the dolomitic formations of Ordovician age (Thwaites, 1958).

Peneplaination of the upper quartzite surface also has been attributed to the erosion cycles that removed the Paleozoic strata from the top of the Range. Thwaites (1958 and 1960) discards those hypotheses in the same way as he discards that for the Precambrian.

Between the time of deposition of the post-Cambrian strata and the Pleistocene, or Great Ice Age, geologic events in Devils Lake Park are obscured. The latter part of that interval, encompassing at least 300 million years, must have been largely a time for erosion as no rocks are left behind. If the interpretation is correct that the upland surface of quartzite is only the recently exhumed Precambrian surface protected during much of the time by a cover of Paleozoic sediments, then the topography of Devils Lake Park has changed considerably during the last 550 million years even though present day topography in the Park may be essentially the same as it was 550 million years ago. The small amount of Cambrian sandstone in the present Park does not make striking erosional features as it does farther west, especially in Baxter Hollow, or eastward in Parfreys Glen.

It seems clear that at least part of the Devils Lake gorge was cut by an ancient stream in Precambrian times, otherwise Cambrian sandstone would not infill it, but perhaps not all was cut then. Some writers attribute the north part of the gorge to the Paleozoic cycles of erosion (Thwaites, 1958), and the writer does not believe that an early Pleistocene time for cutting part of the gorge can yet be ruled out.

Potholes on the East Bluff are attributed by different people to the stream work associated with the cutting of the gorge during the Precambrian, the Paleozoic, the Cretaceous, or the Tertiary yet they too may only be Pleistocene (Black, 1964). However, at the east end of the Baraboo Range one pothole in a group of about 25 in the quartzite has Cambrian sandstone firmly adhering to the inside walls so it was cut indisputedly in late Precambrian or early Cambrian time. (These were called to my attention by A. C. Trowbridge.) Different kinds of potholes are present at that site, and all may not be of the same age nor are they necessarily the same age as those at Devils Lake. Several are altered by glacial ice of late-Woodfordian (Cary) age, but if all were, the evidence is obscured by post-glacial weathering.

The pebbly loam with much expandable clay on top of East Bluff must be the source for the Windrow gravel which Andrews (1958) considers Cretaceous, but again a Pleistocene age for the deposit cannot yet be ruled out (Black, 1964). The gravel has been found in and around the potholes. No way has yet been found to date the deposits or cutting of potholes satisfactorily. Their place in the history of events must await new evidence. Regardless of their age, however, loose blocks with potholes have been moved about on the upland, and angular quartzite blocks lie on top of the pebbly clay. Glacial ice must have accomplished this for blocks up to 85 tons seem to have moved upslope (Black, 1964). The area lies immediately west of the prominent Cary end moraine on the upland. This is correlative with the moraines that plug the southeast and north parts of the Devils Lake gorge. These features are perhaps only 13,000–16,000 years old (Black, Hole, Maher, Freeman, 1965). They themselves do not prove that earlier ice went no farther into the Driftless area, and much evidence has now been amassed to indicate ice did go further west (Black, 1960; Black, Hole, Maher, and Freeman, 1965; Frye, Willman and Black, 1965).

Much of the talus and the pinnacled cliffs around Devils Lake (Figs 2 to 5) are associated with the late Wisconsinan Stage of glaciation (Smith, 1949; Black, 1964; and Black, Hole, Maher, and Freeman, 1965). Whether the area was glaciated more than once is not proved but is suggested by distribution of erratics and buried organic matter (Weidman, 1904; Alden, 1918, p. 177–178; Thwaites, 1958; Black, 1964; and Black, Hole, Maher and Freeman, 1965). For example, organic matter from a depth of 130 feet in glacial deposits at Baraboo was submitted by F. T. Thwaites to Wilson (1936, p. 43) for identification; he found leaves of several dicotyledonous plants, some probably *Vaccinium,* and one species of moss, identified as *Campylium stellatum.* Thus the story of the geomorphic development of Devils Lake Park jumps quickly from the Paleozoic to the Pleistocene or even late Pleistocene.

Since glaciation, gravity and frost have moved many large blocks of quartzite down slope although the present rate is very slow. Man's unsightly activities are now most important. Railroad and other construction, and abortive attempts at farming in the last century have left their mark. Large pits for aggregates have been opened in glacial materials and in bedrock, and increasing pressure from tourists and students is showing. The need for judicious controls is painfully obvious and cannot long be withheld if we are to preserve many of the striking features.

DESCRIPTION OF SPECIFIC FEATURES

DEVILS LAKE

Probably most tourists are interested in Devils Lake itself (Fig. 6) and spend most of their time in and around it. It is well known for its trout fishing. The lake is about 1.3 miles long, 0.4 to 0.6 miles wide, and generally 30 to 40 feet deep. A shallow shelf extends southward from the north shore a distance of about 500 feet; a narrower shelf surrounds the south end. The east and west sides drop abruptly into deep water. The water is soft and clear—on the border between eutrophic and oligotrophic (Twenhofel and McKelvey, 1939).

The lake has only two small streams entering it—Messenger Creek on the southwest and the smaller creek from Hells Canyon on the northeast. The total drainage basin is only about 5.5 square miles. No streams flow out of Devils Lake. Evaporation and seepage control the losses. The water table is perched at the general

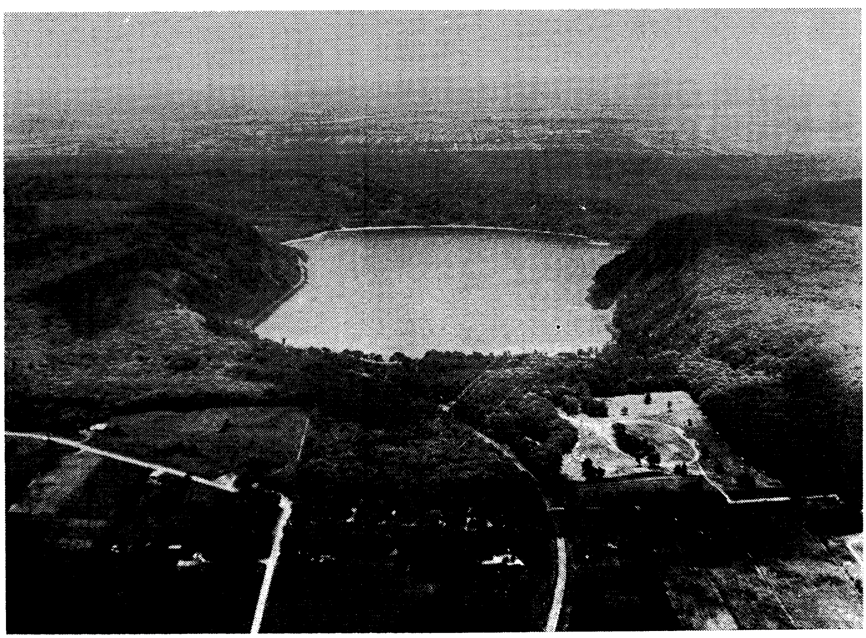

FIGURE 6. Air view looking southward of Devils Lake, its morainal plug in the foreground, the quartzite bluffs, and the distant broad flat of the Wisconsin River at the Sumpter Badger Ordnance Works.

lake level presumably by the fine sediments and organic matter in the lake basin.

The sediments around the north and south shores are mostly clean, light-yellow, medium-grain sand with some pebbles of glacial origin. These become finer and darker as water depth increases. The bottom of the lake, below about 25 feet of water, is covered with fine black muds (Twenhofel and McKelvey, 1939). Near shore a black soupy liquid or sludge is present up to about three feet in thickness. It is very rich in aerobic and facultative bacteria. The sediments below the sludge are black, porous silts and clays with 15 to 20 percent organic matter. Bacteria are not abundant below the sludge. Little or no carbonate is present. Most inorganic matter is silica. Few macroscopic animal remains are present; microscopic tests and skeletal materials are diatoms and sponge spicules, and these are not abundant.

The thickness of organic-rich sediment is not known, but is more than 10 feet. Glacial outwash sand and gravel near the south end of the lake was penetrated in a well to a depth of 383 feet without reaching bedrock (Thwaites, 1958).

MORAINES

The most important glacial feature in the Devils Lake area is the end moraine of Cary age (late Woodfordian) depicted on Figure 1. This end moraine can be traced with only minor breaks through the area, in an irregular looping course. It is an extension of the Johnstown moraine to the south and others traceable along the entire front of the Green Bay lobe and farther (Alden, 1918). The description of the moraine in the Park, initially given in detail by Salisbury and Atwood (1900, p. 93, 94, and 105–111), has stood the test of time. Because of its length, it will not be quoted here. The moraine marks the still stand of the outer edge of the ice sheet. It is only in part synchronous with the more massive till-covered outwash and deltaic deposits plugging the valley and enclosing Devils Lake on the north and on the southeast (Thwaites, 1958).

Terminal moraine plugs, such as occupy the gorge north and southeast of Devils Lake, are unusual individually but together comprise a unique situation. Having such a prominent well-defined end moraine extending for so many miles from those plugs makes the situation even more astounding. The moraine outlined in Figure 1 is certainly one of the best to be found anywhere in the world. Having it so readily accessible to centers of population with so many other features nearby makes it especially attractive. As recognized by Salisbury and Atwood (1900), the striking loops show clearly the inability of the ice to surmount topographic obstacles of negligible relief because of restricted flow over and around buttresses up ice. Nowhere are similar features so well displayed amongst so many other phenomena of intriguing historical connotation.

The uniformity of height (15 to 50 feet) and width (100 to 200 feet) of the moraine on flat surfaces and the asymmetry of the moraine on hill sides (only 10 to 15 foot abrupt faces on the uphill side and 50 to 100 foot faces on the downslope side) are in themselves very unusual over such broad distances. Furthermore the position of the moraine from its high point on Devils Nose southwestward to the level of the plain records precisely the distal slope of the ice front during at least the latter part of the deposition of the moraine. Recording of such gradients is a rare occurrence almost anywhere because of concurrent or post-glacial destruction by flowing water and mass movements. Thus, in the area of Devils Lake are numerous textbook examples of glacial features.

The moraine is but a small part of the end moraine of essentially similar age that has been traced throughout Wisconsin, from the Minnesota border near Hudson to the Illinois border south of Lake Geneva, and also from the Great Plains to the Atlantic Ocean (Chamberlin, 1883). This moraine was designated the terminal moraine of the Second Glacial Epoch (Chamberlin, 1878; 1883). He considered it to be the boundary between older and younger drift and, as such, to be the most important time break in the Pleistocene in the state. Field work in Illinois has not supported this viewpoint (Frye, Willman, and Black, 1965). Unfortunately we do not have a single radiocarbon date recording the advance of ice to this end moraine in Wisconsin. From evidence in Minnesota and Illinois, it likely was formed 13,000 to 16,000 years ago. In many places outside the Park, the moraine appears more massive than it is within the Park. Yet its massiveness commonly may be attributed to bedrock elevations on which it is found or to the overriding and pushing up of material from below (Alden, 1918).

Outside of the two plugs containing Devils Lake, the end moraine in the Park is generally only 15 to 50 feet high. Locally the front is fully 80 feet high as at the easternmost loop at Sauk Point (Fig. 1). It is accentuated there because of the high level of the Baraboo Quartzite on which it is built and the low plain stretching to the west which was occupied by outwash and a former glacial lake (Ott Lake, Fig. 1). The more massive moraines containing Devils Lake rise 90–130 feet above Devils Lake and even higher above the valley floors north and east. Their massiveness is due mostly to outwash and deltaic deposits (Thwaites, 1958, p. 150) deposited in front of the advancing ice. Only a thin local veneer of till was deposited directly on these deposits by the ice. The deepest well in the gorge, 383 feet, did not reach bedrock.

From a car, views of the end moraine are particularly good along County Highway DL northeast of Devils Lake and at the extreme northwest corner of the park where Highway 159 crosses the moraine (Fig. 7). There the abrupt steep slope to the northeast was formerly occupied by ice which built the small moraine ridge with its smooth outwash plain to the west or front of the moraine. These provide a classic example of the relationship of the ice sheet to its proglacial fluvial and lacustrine deposits. At the easternmost loop, by Sauk Point, the moraine and its relationship to the quartzite and proglacial lakes are accessible and readily discernible. Stratification and texture of outwash dipping westward, unassorted sandy till, and shear planes inclined steeply up ice to the east are especially well displayed in the gravel pit shown in Figure 8. Immediately below the pit is Ott Lake Basin, a former proglacial lake, and weathered outcrops of the Baraboo Quartzite. Retreatal moraines are also common behind the outer moraine south of the gravel pit. The abrupt interlobate junction of ice from the north

FIGURE 7. Outwash plain in front of the late-Woodfordian (Cary) terminal moraine as viewed northeastward from Highway 159, about one-half mile east of Highway 12.

and south sides of the Range is clearly portrayed in the moraines northeast of the pit.

The gravel pit (Fig. 8) at the easternmost loop of the moraine contains a wide variety of material typical of much of the moraine and associated outwash. A count of the 6- to 18-inch boulders shows:

	Percent
dolomite	30
gabbro	26
Baraboo Quartzite	16
Cambrian sandstone	12
granite	6
diabase	5
dense intermediate mafic rock	4
rhyolite porphyry	1
	100

The till zones are sandy, brown, yellow-brown, to dark red-brown. Sandy, bouldery outwash has been overridden locally. Native copper has been found in the pit and presumably had its source from Keweenaw Peninsula in Upper Michigan. Ordovician and Silurian dolomite and oolitic chert of the Ordovician Prairie du Chien Group are readily identifiable.

For hikers the views of the moraine are particularly good near the Devils Nose on the South Bluff southeast of Devils Lake, on the southern part of East Bluff (Fig. 9) extending eastward to the extreme eastern loop of the moraine at Sauk Point, and also at the north tip of the north loop. From the north loop one has a striking view of the Baraboo Valley, the city of Baraboo, and the Lower Narrows gap of the Baraboo River through the North Range. Views to the Wisconsin River Valley are superb from the south rim of the East Bluff at Devils Lake to the vicinity of Parfreys Glen. Excellent views of the plugs containing Devils Lake may be had from all of the bluffs rising above them.

Concentric moraines arc around the extreme north end of the north loop of the Cary end moraine, in section 9, north of Hanson Marsh (Fig. 1). These show beautifully the building of ridges at the edge of the ice as it struggled to maintain its position around that high point. Probably during the initial advance the ice went over the inside of the loop for erratics are to be found in it. However, their presence can also be attributed to water transportation and even gravity movement from the steep face of the ice that must have developed there. As the terrain inside the loop is precipitous,

FIGURE 8. Gravel pit at the east loop of the late-Woodfordian (Cary) end moraine at Sauk Point, looking northeastward. Stratified outwash dips gently to the left; till and drift partly bedded is inclined steeply to the right, reflecting ice push and possible shear and flowage as the ice attempted to override its moraine.

boulders could have bounced and rolled practically across the loop on a vegetation-free surface or on an ice-covered surface. At any rate the successive arcs are each slightly lower than their predecessor. The first two are separated by a gap only 60 to 100 feet across and 10 to 20 feet deep. The later ones are lower and less regular. The features at the nose of the arc are among the best developed anywhere. When coupled with the beautiful views of the Baraboo Valley to north and west and of the drained lakes and other features to the south, this can be considered truly one of the grand overlooks of the Devils Lake area.

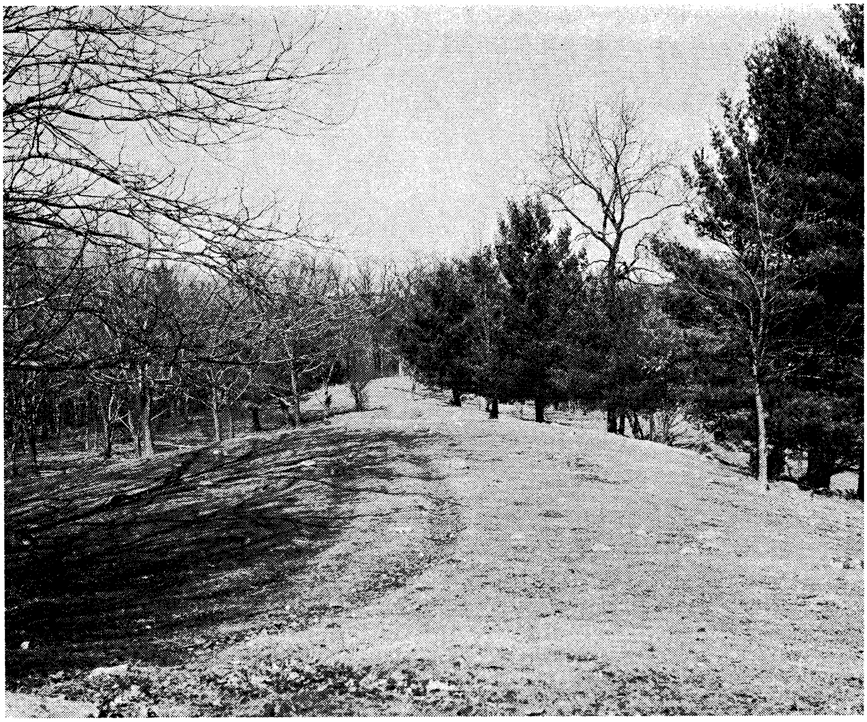

FIGURE 9. Top of the late-Woodfordian (Cary) end moraine on the East Bluff of Devils Lake, about one-quarter mile southwest of Highway 113, looking northeastward.

For additional details on the moraine, the reader is referred to the original works of Salisbury and Atwood (1900), Trowbridge (1917), and of Alden (1918). All emphasize its uniqueness.

PERIGLACIAL FEATURES

Periglacial processes are those particularly involving frost action (especially frost riving in the Baraboo area) and gravity movements. Within the Baraboo area Smith (1949) lists three groups of features attributable to periglacial processes: 1) stabilized talus, 2) block concentrations and block-strewn slopes, and 3) choked valleys and block cascades. Talus occurs in the vicinity of Devils Lake, and block concentrations, choked valleys, and talus slopes are west and northwest of Devils Lake and also on the south flank of the Baraboo Range south of the lake. Pinnacles and monuments on the cliffs of Devils Lake and wind-polished surfaces north of the lake are also considered periglacial in origin.

The talus accumulations around Devils Lake are among the most striking features of the Park (Figs. 2 and 3). They are better displayed there than anywhere else in the Baraboo Range. Other good locations are in the gorge north of North Freedom (Salisbury and Atwood, 1900, p. 67), and also along the bluffs of the Lower Narrows northeast of Baraboo. Talus is best developed on the East, West and South Bluffs of the lake. Where the Cary ice stood in the southeast gap it presumably removed much of the talus that apparently was there before. On the bluffs above the lake the talus is almost continuous laterally, being interrupted locally by dipping ledges of the quartzite. It is partly covered by irregular patches of forest. The talus on the south-facing slope of East Bluff attains maximum height and continuity of exposure. On the north-facing slope of the South Bluff the talus is covered largely by trees, and the slope is slightly less steep.

The talus is composed of heterogenous angular irregular blocks of quartzite more or less firmly wedged together. The blocks commonly are more than six feet on a side. No marked vertical zoning of large blocks is apparent. Occasional erratic boulders up to 90 feet above the lake level (Salisbury and Atwood, 1900, p. 133) may be found in the talus. During the 1930's the Civilian Conservation Corps brought in foreign material to surface trails, and the practice continues. Erratics of foreign debris should be found in the talus up to the level of the divide between Messenger and Skillet Creeks, if the interpretation of that divide as the outlet of glacial Devils Lake is correct (Trowbridge, 1917).

The maximum height of talus is about 300 feet; the maximum inclination of the slope is about 36°. The hydrographic map of Devils Lake (Juday, 1914, map 8) suggests that the talus extends 30 feet out from shore below water level. According to unpublished data of F. T. Thwaites, the talus may extend to depths of as much as 285 feet below lake level. However, its subsurface distribution is not known. Surmounting the talus at many places around the lake are nearly vertical rock bluffs, some tens of feet high and presenting a jagged appearance.

Many of the talus blocks as well as the rock surfaces and ledges above them are partly covered with lichens and show some weathering stains. No clear indications of movement are available. The vegetation seems stabilized on the slopes. Few blocks are seen on snow surfaces in winter, and isolated loose blocks in the forest at the foot of the bluffs are also relatively uncommon. The frost-rived bluffs and ledges above the talus show many loose blocks and pinnacles (Figs. 3 and 4) apparently in unstable situations, yet few seem to have collapsed in historical time. The angularity and weight of the blocks permit them to stand as relatively permanent features.

Other signs of inactivity recorded by Smith (1949) indicate that the formation of talus blocks now is an exceedingly slow process. How much of the talus originated prior to the advance of the Cary ice into the north and southeast gorges is not known. If the talus does extend many tens of feet below the surface of the lake, it seems likely it has been covered by outwash from the Cary front. In an abandoned quarry on the northeast side of Devils Lake a thin veneer of talus is separated from the bedrock by about five feet of stony soil containing small blacks and rock fragments scattered through an earthy matrix (Smith 1949, p. 202). The contrast between the talus and underlying material is striking and points, according to Smith, to a marked change in conditions of weathering when talus accumulation began.

Smith (1949) did not discuss the effects that high glacial lake levels might have had on the formation of talus in the gorge. If Trowbridge (1917) is correct that Devils Lake was up to the level of the divide between Messenger and Skillet Creeks, then the bulk of the talus in the area would have been covered by the glacial lake waters, and the lake level would have been near the base of the present cliff in many places. Would frost action which is commonly more severe at the water level of a lake have been instrumental in the formation of some of the talus? This is a question that we cannot yet answer. The lack of erratics of obvious foreign sources among the talus blocks where they surely were covered by lake waters is difficult to explain unless the talus has come down on top of such material to hide it. However, small particles could have been flushed through the coarse openings of the large talus blocks.

Around Devils Lake talus is more abundant outside the area covered by the Cary ice than inside. However, pinnacled slopes and jagged angular cliffs are just as common along the Baraboo bluffs to the east of Devils Lake and also in the Lower Narrows of the Baraboo River to the northeast of Baraboo where the Cary ice definitely overrode the surface as they are in the cliffs around Devils Lake. Talus also is abundant in the Lower Narrows. In the St. Croix Dalles area of western Wisconsin Cary ice clearly went through the gorge and the pinnacles in cliffs of basalt have developed subsequently. Pinnacles may form rapidly. As a consequence, we can not say specifically when some of the talus or the pinnacled cliffs of the Devils Lake area were produced. Some of the material must have been derived in pre-Cary times; some of the monuments such as Devils Doorway (Fig. 4), Elephant Rock and Balanced Rock (Fig. 5) possibly were produced during or immediately after Cary glaciation.

The narrow depressions (Fig. 10) along the bases of many talus slopes are peculiar. They are elongate, discontinuous channels 15 to 20 feet wide and 5 to 15 feet deep. Thwaites (1935, p. 404; 1958, p. 153) attributed them to settling of the finer sediment into interstices of the talus, but their origin is conjectural. On the hottest days cold air drains down through the talus into some depressions, and at times running water may be heard in the talus above them.

The smaller block concentrations and block strewn slopes on the south-facing flank of the Baraboo Range south of Devils Lake and the choked valley in the depression southwest of the Lake contain angular blocks similar to those in the talus slopes of Devils Lake. The blocks are distributed in elongate bodies. Locally many are covered with forests, and interstices of the large blocks are filled with soil.

The locality less than a mile northwest of Devils Lake presents a problem (NE ¼, sec. 14) (Smith, 1949, p. 204). Smith records shattered blocks and boulders of quartzite, sandstone and conglomerates occurring along a shallow valley and adjoining gentle slopes. Some of the blocks are almost buried in the soil, but others appear

FIGURE 10. Elongate depression in drift at the base of talus along the south-facing slope of East Bluff, Devils Lake.

to be largely above the ground surface. Locally the blocks are jumbled together. This area is very close to the Cary ice front where it butted against the northeast corner of West Bluff. Some glacial drainage went around the end of the bluff and may have affected this particular area. Smith concluded that this material was produced in the same way as that of the talus on the south flank of the Baraboo Range south of Devils Lake. However, the materials and history of these localities are different. Concentration of blocks by running water could not have been important or the angular blocks would have been more rounded.

A small ridge of Baraboo Quartzite juts above the level of the south fork of Messenger Creek in the extreme southeast corner of section 23, southwest of Devils Lake. The relatively flat top of the ridge reaches an elevation of about 1100 feet, but a large isolated pinnacle rises fully 20 to 30 feet above the level of the ridge, and isolated rocks and smaller pinnacles are also present to the north. The origin of these features is conjectural. They may have been formed in glacial Devils Lake, assuming it had reached this general level.

Wind work is not common in the Park. A thin accumulation of loess has been brought in by wind and deposited over the upland surface. This loess probably is latest Wisconsinan to Recent in age according to the immaturity of weathering. Such deposition is common on uplands adjacent to abandoned lake areas or glacial outwash valleys like those around the Baraboo area. The sources of the loess could well have been Glacial Lake Baraboo to the northwest and the outwash apron in the Wisconsin River Valley to the south.

Wind-polished and fluted surfaces may be seen outside the Park on quartzite knobs that rise above the early Paleozoic formations south of Baraboo. There ventifacted, furrowed surfaces suggest strong winds blew from the west-northwest. Polishing of the corners and faces of some of the upland cliffs of the Baraboo area have been attributed to wind work, but we cannot exclude water work and chemical action from such alteration.

Drained Lakes

Proglacial lakes were formed immediately in front of the moraine in several places in the Park area (Fig. 1). All of these former lakes (except Devils Lake discussed earlier) have been drained, but the sediments remain behind as mute testimony of their former existence. One unnamed lake formerly existed 1.3 miles southeast of Devils Lake on the north side of Devils Nose. Cary ice butted against the ridge leaving its end moraine which may be traced around and across the nose (Fig. 1). Where the moraine crosses the gully in the east half of section 30, it is a symmetrical ridge about 45 feet high and 100 feet wide. It is breached at the gully, and a smooth plain extends to the southwest. That plain is underlain with 10 to 30 feet of silty sands and some clay and gravel. From the moraine down the gully to the north one sees numerous very large foreign erratics, but from the moraine up the gully to the west and southwest only the Baraboo quartzite blocks and small amounts of fine pea-sized foreign gravel are seen.

Similar but larger lakes were present in sections 16, 17 and 18 northeast of Devils Lake (Fig. 1). Peck and Steinke glacial lakes were named early (Salisbury and Atwood, 1900; Trowbridge, 1917). Glacial Ott Lake is the name given here for convenience to the easternmost and smallest basin in the Sauk Point Loop. At one time those basins probably were merged into one lake which would have drained into glacial Devils Lake via Hells Canyon. As the ice border retreated somewhat from the end moraine shown on Figure 1, the water level would have dropped and the lakes would have become separated from each other. Ott Lake in the southeastern part of section 16 would have been the first to be drained or filled with outwash. Peck and Steinke Lakes, farther west at lower levels, remained longer.

Just how long the lakes were able to survive is not known. However, in sections 9 and 16, northeast of Devils Lake is the low swampy area known today as Hanson Marsh. It was a lake that survived for many centuries (Bachhuber, 1966). Ice at its furthest extent, at the position shown in Figure 1, covered the area of the marsh but withdrew almost immediately thereafter to build an end moraine on the ridge to the west and another to the north, surrounding Hanson Marsh and forming a lake. Rhythmically-banded lacustrine sediments at least 25 feet thick were laid down in the lake along the ice margin. Bachhuber (1966) has counted representative samples of the supposed varves which represent at least 600 years of time. These are only part of that lacustrine sequence. Similar studies have not been attempted for Steinke, Peck, or Ott Lakes.

While the ice stood around the old lake at Hanson Marsh, spruce forests to the west of the area were contributing pollen to the lake sediments. The pollen sequence throughout the deposits shows clearly the post-glacial climatic changes as reflected in the local vegetation. In brief they record a transition from spruce to pine to mixed hardwoods and other deciduous trees (Bachhuber, 1966).

At its maximum, expanded Devils Lake may have reached an elevation of 1155 feet, enough to drain the lake to the northwest down Skillet Creek (Trowbridge, 1917). (Elevations cited by

Trowbridge differ from those cited here because of availability of more accurate maps today.) Thwaites (1960) does not accept any available evidence that the lake actually overflowed through Skillet Creek even though Trowbridge (1917) found erratics in Messenger Creek on the lake side within 16 feet of the Skillet Creek divide.

The Cary moraine at the north end of West Bluff has left its mark up to 1050 feet in elevation only. How much higher the Cary ice went is not known, although the writer has found large igneous and dolomite boulders up to 1160 feet on the northwest side of that nose (SW ¼, SE ¼, NE ¼, sec. 14, T 11 N, R 6 E). Farther south along Highway 123, cobbles of igneous erratics are found to elevations of 1210 feet. Thus, this writer would agree with Trowbridge (1917) that Devils Lake overflowed into Skillet Creek. Furthermore, the cutting of lower Skillet Creek valley in quartzite must have been accomplished by far more discharge than is available from the present drainage area. The monuments and jagged spurs now present in the gorge are considered to reflect frost processes like those in the bluffs around Devils Lake itself.

At its maximum advance, over 11 miles of the Cary ice front was contributing water to the lakes in the Devils Lake area (Trowbridge, 1917, p. 364). His argument is that ice was brought to the terminous at a rate of 6 inches a week or 26 feet a year. Assuming ice was melted along the entire front in a zone 100 feet wide by 26 feet deep, we get a measure of the minimum amount of water that could reach the lakes. Surely some melt water farther back from the front would also reach the area. Trowbridge concludes that the annual discharge to the lakes would be at least on the order of 1.5 billion cubic feet.

The Devils Lake basin itself has a capacity to the discharge level at Skillet Creek of about 7.5 billion cubic feet. Thus the main lake basin should have been filled to overflowing in only five years. The upper lakes would have held a relatively small amount before draining into Devils Lake. With the ice standing in the area more than 600 years surely Devils Lake overflowed for considerable time through Skillet Creek and later possibly past the north end of West Bluff, at the margin of the ice, even though no features or deposits there prove this unequivocably.

Trowbridge has supported these rough estimates of water volume by a check on the amount of material deposited from the glacial waters. Trowbridge calculated that six miles of the ice front drained into Steinke Lake, depositing over 2.5 billion cubic feet of debris. In Peck Basin its 0.5 miles of ice front contributed at least 142 million cubic feet of debris. The Devils Lake gap between the two morainal dams contains over 2 billion cubic feet of debris. Thus, it would seem clear that these lakes must have had more than enough water to drain through the headwaters of Skillet Creek, the lowest divide available if the Cary ice stood higher than 1155 feet against the north end of West Bluff.

Unfortunately it is not yet possible to date deposition of the large foreign boulders deep in the soil up to at least 1160 feet elevation on the northwest side of West Bluff. The dolomite erratics are very little etched; gabbro and other coarse textured boulders are not disaggregated so it is assumed they were left by ice immediately preceding the building of the prominent end moraine. A large fresh gravel kame (SE ¼, SE¼, sec. 25, T 12 N, R 5 E) is 3.5 miles west of the same front at Baraboo, and a deep kettle hole (SW ¼, NE ¼, sec. 15, T 10 N, R 6 E) is one mile beyond the front. They attest to an advance of the ice beyond the prominent end moraine. Thwaites (1958) and earlier writers, except Weidman (1904), do not accept these features as resulting from direct glacial action. However, about 40,000 cubic yards of foreign erratics from gravel to boulders have been removed from the kame which shows typical cross stratification and irregular sorting—far too much material to be ice rafted and deposited with such internal fabric. Till is present below the kettle which is as perfectly developed as any.

In the Steinke Lake sediments Salisbury and Atwood (1900, p. 120 and plate 28, p. 108) noticed laminated silts and clays in which marked deformation of certain horizons were present. Locally more than 60 feet of these deposits were excavated, but the exposures are now covered. Salisbury and Atwood (1900, p. 134) outline the history of that lake briefly. Because the basin is enclosed to the south, east, and west by quartzite, it was in a logical position to receive and hold water. The first lake formed against the ice to the north had no outlet until the water rose to the level of the lowest divide on the southwest side where the water overflowed to the west and northwest into Devils Lake via Hells Canyon. Sediments borne into the basin by the glacial drainage were deposited as deltas and outwash in the lake. The coarser particles were left near the ice; the finer ones were carried farther away. Continued melt water from the ice front brought more and more sediment into the lake until its delta front extended completely across the lake, filling it to the level of the outlet. Later drainage followed the retreating edge of the ice directly westward into Devils Lake.

Other drainage modifications in the area accompanied and followed the lakes. An example is that of Skillet Creek, the small tributary to the Baraboo River, which flows northwesterly from the southwest divide of Devils Lake. Before glaciation of the district, Skillet Creek probably flowed in a general northeasterly direction to the Baraboo River (Salisbury and Atwood, 1900, p. 138). The Cary ice blocked the stream forcing it to seek a new course. The only course open was to the north and west in front of the advancing ice. Drainage from the ice, depositing glacial-fluvial and then glacial-lacustrine materials, forced the stream farther westward until finally it reached its position across the Cambrian sandstone plain well to the north and west of its former route. In that position ancestral Skillet Creek began to downcut after deglaciation and drainage of glacial lake Baraboo that inundated up to 980 feet elevation the lowland where Baraboo is now located. It superimposed itself on the bedrock and cut a new gorge. Such superposition could have occurred only after the cessation of overflow of water into Skillet Creek from the glacial lake occupying the gorge of Devils Lake. To drain Lake Baraboo it was necessary to clear the ice from the east nose of the Baraboo Range proper, near Portage (Bretz, 1950). The position of the lower part of Skillet Creek well on the westward flank of the outwash apron of Cary age can be attributed to the initial topography left during the draining of Lake Baraboo.

Stagnant Ice Features

The retreat of the ice from Sauk Point at the crest of the Baraboo Range was by melting *in situ* for it left behind typical ice stagnation features with knob and swale topography. Many knobs are small kames of poorly sorted but water worked sand and gravel; the depressions are almost invariably kettles produced by the melting out of buried ice blocks in the debris. The stagnant buried ice area formed at the junction of an advancing lobe from the north and another from the south—a kettle interlobate moraine of very small size when compared to the Kettle Interlobate Moraine of eastern Wisconsin. Yet, its origin would have been similar. Section 15 at Sauk Point (Fig. 1) contains the better features of this ice stagnation interlobate area. Relief is generally only 10 to 30 feet between the knobs and adjacent kettles. It is readily viewed from the east-west highway extension of County Highway DL.

Behind the end moraine as mapped through the area of Figure 1, numerous ice stagnation features may be seen. These are particularly well-developed on the flanks of the Baraboo Range to the north toward the city of Baraboo and also to the south and east toward the Wisconsin River. Many knobs are kames; many swales are kettles. Such ice stagnation features on the steeper slopes of the Baraboo Range are generally nowhere as well developed or as large as those of the lowlands. It is in the lowlands that the larger ice blocks were buried more readily.

POTHOLES

Black (1964) has described potholes on the East Bluff of Devils Lake overlooking the late-Woodfordian (Cary) moraine which plugs the southeast gorge. The potholes are carved in bedding plane surfaces of the Baraboo Quartzite *in situ* and also in loose blocks of the quartzite that are scattered irregularly on the beveled upland surface. Polished chert-rich gravel of the Windrow Formation is associated with some potholes and has been found in them (Salisbury, 1895, p. 657).

On July 29, 1964, after the pothole paper was submitted for publication, Black used a power auger to drill 12 holes through the quartzite rubble scattered over the higher part of East Bluff. Most holes were less than five feet deep; the deeper holes penetrated only six to eight feet. All encountered a silty clay zone with 5 to 10 percent well-rounded and polished pebbles of the Windrow type scattered uniformly throughout. The zone is reported to be 16 feet thick in a dug well (Salisbury, 1895) near the junction of the trails at the apex of the bluff. The clay is mostly of the expandable type—swelling greatly with a sodium-rich water softening agent. Such clay is not common in Tertiary or Mesozoic deposits in the upper Mississippi River area which have kaolin—a non expanding clay.

Through the years most writers have attributed the potholes and associated gravels to streams of Paleozoic, Cretaceous, or Tertiary age that flowed across a continuous upland surface at and above the level of the rim. The writer thought no one seriously had considered them to be glacial prior to publication of his paper (Black, 1964), but subsequently he found that Powers (1960) raised the question without attempting to answer it. We know now that at least one of the potholes at the extreme east nose of the Baraboo Range, which contains Cambrian sandstone firmly adhering to its walls, must have been produced in late Precambrian or earliest Cambrian times. Not all of the other potholes of that locality can be ascribed necessarily to the same time of formation even though it would be most logical. By analogy it would be logical also to suspect that the potholes on the East Bluff of Devils Lake were produced at the same time, but this does not prove it.

Regardless of when the potholes were formed, it is clear that the loose blocks in which we find potholes have been moved subsequent to grinding of the potholes. Some blocks have been split, and one side or bottom of its pothole is now gone. Others are turned on their sides or are upside down. These are scattered along with other loose blocks of the Baraboo Quartzite over the chert-rich, gravelly clay (Windrow Formation) on the upland. The splitting off of the blocks from bedrock and movement of the loose blocks to their present location can most easily be explained on the basis of movement by glacial ice or possibly by melt waters associated with ice. The hundreds of blocks of Baraboo Quartzite on top of the Windrow Formation cannot be explained by simple down weathering in place, and no quartzite nearby is higher. Such blocks of the quartzite on top of the Windrow Formation must be considered true glacial erratics.

The large erratic to the north of the pothole area is so described by Black (1964). It weighs 85 tons and must have been moved upslope to its present resting place. This surely could only be accomplished by ice. Other smaller but impressive quartzite erratics may be seen on the South and West Bluffs of Devils Lake as well (Fig. 11). No mechanism of erosion of the smoothly beveled up-

FIGURE 11. "Erratic" of Baraboo Quartzite on the highest part of the South Bluff of Devils Lake.

land surface, known to the writer, can leave behind such large loose blocks to rise above the general level.

These various phenomena would imply that glaciation of the Devils Lake area had occurred some time prior to the late-Woodfordian (Cary) advance. This seems certain from a variety of evidence that cannot be detailed here. However, for example, dolomite and igneous rock erratics are found 100 feet above the Cary moraine at the north end of West Bluff. Moreover, a kame deposit 3.5 miles west of the front near Baraboo has more than 40,000 cubic yards of gravel, and a deep kettle with till lies one mile west of the front at the Badger Ordinance Works south of the Park. They attest to nearby extensions of glacier ice beyond the end moraine of the Cary as recorded on Figure 1. The freshness of dolomite and igneous erratics, the lack of erosion and filling of the kettle, the amazing freshness of the igneous outcrops near Denzer, the youthfulness of the loess on the upland, and other criteria would suggest that the time of such glaciation did not long precede that of the Cary. Unfortunately, this is a very perplexing problem for which we have relatively little information to go on, and it cannot be discussed further here.

Erratics

For convenience, erratics within the area of Devils Lake Park may be classified into two groups. One contains those rocks, such as igneous and highly metamorphosed materials, that could have originated only from a point far to the north. The other contains those rocks of local derivation which are in anomalous situations. This section is concerned largely with the second group—the large mass of debris brought in by the Cary ice and dumped inside the end moraine is clearly of glacial origin. At Devils Lake erratics have been washed out from the terminal area of the ice that blocked the north and southeast gaps. Erratics have been carried by drifting ice at least 90 feet above the present lake level (Salisbury and Atwood, 1900, pp. 133). Trowbridge (1917, p. 366) in one hour found 103 erratic boulders in the valley of the north fork of Messenger Creek and one diabase cobble on the west slope of the divide in the drainage of Skillet Creek. He found igneous rock erratics 164 feet (202 feet in his paper reflects use of now outdated topographic maps) above the present level of Devils Lake and only 28 feet below the divide. Other glacial cobbles occurred within 16 vertical feet of the divide. Thus the origin of erratics behind the end moraine and those carried out from the terminous by outwash waters and floating icebergs in the proglacial lakes are readily explained. These are recognized easily because of their obvious foreign source.

In the second group of rocks, however, we find various local materials which are distributed in the area in such a way that it is far more difficult to prove that they obtained their present locations on the basis of glacial ice directly. In this group are placed the large Baraboo Quartzite erratic blocks and fragments which occur on East Bluff on top of the Windrow Formation and also those which occur on the South and West Bluffs and on Sauk Hill on the Baraboo Quartzite itself. To this group is added also the Paleozoic cherts which lie outside the end moraine. These categories require additional comment.

It is difficult not to accept as glacial erratics the angular quartzite rubble on top of the Windrow Formation on East Bluff. If one accepts the 85-ton Baraboo Quartzite block near the block fields north of the pothole area on the East Bluff as a glacial erratic, then it would seem to the writer that we must also accept similar large angular blocks of the Baraboo Quartzite on the South (Figure 11) and West Bluffs and on Sauk Hill as well. They lie on rounded relatively smooth upland surfaces, protruding through the loess cap which is a few inches to two or three feet thick. These blocks are loose and rest directly on the quartzite. Hence, they have not attracted attention by previous workers in the area. However, no process of planation by sea or streams could leave such large angular fresh blocks behind to rise above the smoothly planed surfaces. At least it seems unusual to this writer to see such large angular blocks rising above the general level of a truncated surface that is supposed to be exhumed from beneath hundreds of feet of Paleozoic sandstones and dolomites. These are the highest surfaces in the area. The blocks can not have been let down from a higher cover or plucked out of the upland by any means other than glacial ice. To the writer it is far easier to explain such loose blocks as having been brought in some time after the exhumation of the upper surfaces. The logical time to do this is during the Pleistocene, by glacial action. Many blocks are angular with very sharp corners; relatively little pitting has taken place, and frost riving is minimal. A Wisconsinan age for them would seem most logical, yet an earlier Pleistocene age is possible.

Associated with the erratic blocks of Baraboo Quartzite on the South Bluff are distinct channels in the upland surface which are also peculiar. One due south of the lake crosses through the crest of the range and has steep overhanging banks 10 to 15 feet high (Fig. 12). Corners of the blocks are very sharp. A few blocks presumably derived by frost action lie at the foot of the bank, but hundreds of cubic yards of material have been removed from the largest channel. No accumulation of such debris is seen either to the north or to the south. Where has it gone? Are such features

FIGURE 12. Overhanging wall of Baraboo Quartzite on top of the South Bluff of Devils Lake, looking northward. Part of a channel possibly cut during the Pleistocene.

related to the Paleozoic or Mesozoic erosion cycles that have affected the area, or is this again something that may be attributable to a pre-Cary glacial event? Did glacial water flow across the upland which is higher than the divide at the head of Pine Hollow? Pine Hollow has some rare foreign rocks such as schist and rounded Windrow-type pebbles among the angular quartzite, sandstone, sandy dolomite, and chert. Glacial water may have aided in cutting it. However, we have really no basis for saying one way or the other except for the relative freshness of the edges and faces of the Baraboo Quartzite exposed in these peculiar features. We have inserited at least one late-preCambrian or early Cambrian pothole, but it is a very small feature obviously protected by the Cambrian sandstone. No sandstone was seen anywhere in association with the loose angular blocks of the Baraboo quartzite on the upland or with the sharp channels. Hopefully, more detailed subsurface study will provide additional clues to the perplexing origin of these features.

The chert erratics present another puzzling situation. Chert behind the end moraine of Cary age clearly can be explained as having been brought in by ice. It has been customary to explain chert, locally identifiable as Ordovician—Silurian in age to the west of the Cary terminous, as having been "let down" during the weathering and removal of the Paleozoic formations that once overlay the Baraboo Quartzite (Thwaites, 1958 and 1960). However, the abundance of chert of Silurian age is puzzling. One would expect that the younger formations which would be removed first in the Paleozoic-Mesozoic-Tertiary weathering cycles would be essentially absent from the upland in contrast with chert of the underlying older formations. Detailed statistical sampling has not been done, but yet we find considerable Silurian chert. This seems incongruous because there is no difference in size nor in weatherability of the Ordovician-Silurian chert. Is it possible that the chert has not been simply let down but has actually been brought in by ice of an earlier glaciation that did not have abundant igneous materials in the ice? Again we have no basis for discussion of such a problem, because the evidence is still too meager to constrain our thinking.

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EVIDENCE FOR FAULT ZONES IN THE BEDROCK OF MILWAUKEE COUNTY

Carl A. R. Distelhorst and A. G. Milnes

Because of the irregular cover of Pleistocene deposits, little is known about the overall geologic structure of the bedrock in Milwaukee County. Recently, however, a compilation has been made of the geologic information obtained from the innumerable boreholes located in the county (Distelhorst 1967) and on this basis a more detailed picture of the bedrock structure can be constructed.

Those boreholes which penetrated sufficiently deeply intersected a prominent and unmistakable contact, that between the Niagran Dolomite (Silurian) and the underlying Maquoketa Shale (Ordovician). This contact has been logged and recorded in many holes throughout the county and thus provides a convenient horizon for determining the bedrock structure. At each borehole, the height above sea level of this contact was calculated from the information compiled from the well log records of the Wisconsin Geological and Natural History Survey. These heights were placed in height groups each spanning 100 feet (see Fig. 1). The symbols representing the various height groups form definite broad bands across the county map, and enable rough stratum contours at 100 foot intervals to be constructed.

The most striking feature of the distribution of height group symbols on Fig. 1 is a line of discontinuity which runs southwestwards from the mouth of Milwaukee River. South of this line the stratum contours seem to have been displaced towards the east. Closer inspection reveals that in a number of the boreholes situated close to this line, the Silurian–Ordovician boundary shows an anomalous position, either much higher or much lower than that to be expected from neighboring wells (Fig. 1). This line probably represents a fault zone in which the strata have become much disturbed. The downthrown block is to the northeast, but on the present data the true direction of movement and hence the amount of movement this zone represents cannot be determined.

The same procedure has been carried out for the Devonian–Silurian boundary, another easily logged contact but one only found in the northeast corner of the county (Fig. 2). Again there is suggestion of displacement of stratum contours (though the evidence

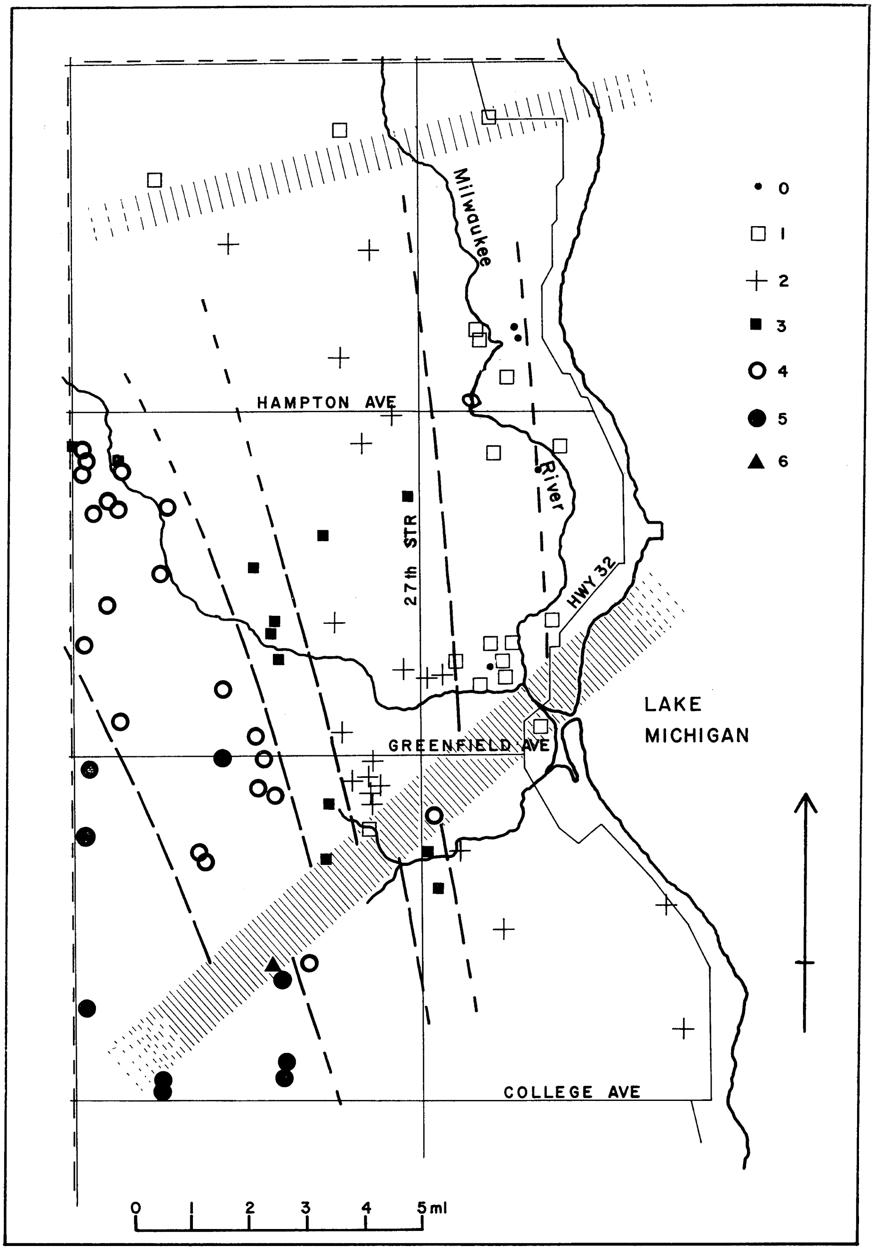

FIGURE 1. Structure contour map of the Silurian–Ordovician boundary, Milwaukee County, Wisconsin. Shaded areas—postulated fault zones; thick dashed lines—approximate structure contours. Height group symbols: the Silurian–Ordovician boundary lies between 0 and 50 feet (symbol 0), 50 and 150 feet (symbol 1), 150 and 250 feet (symbol 2), 250 and 350 feet (symbol 3), 350 and 450 feet (symbol 4), 450 and 550 feet (symbol 5), or above 550 feet (symbol 6), above mean sea level.

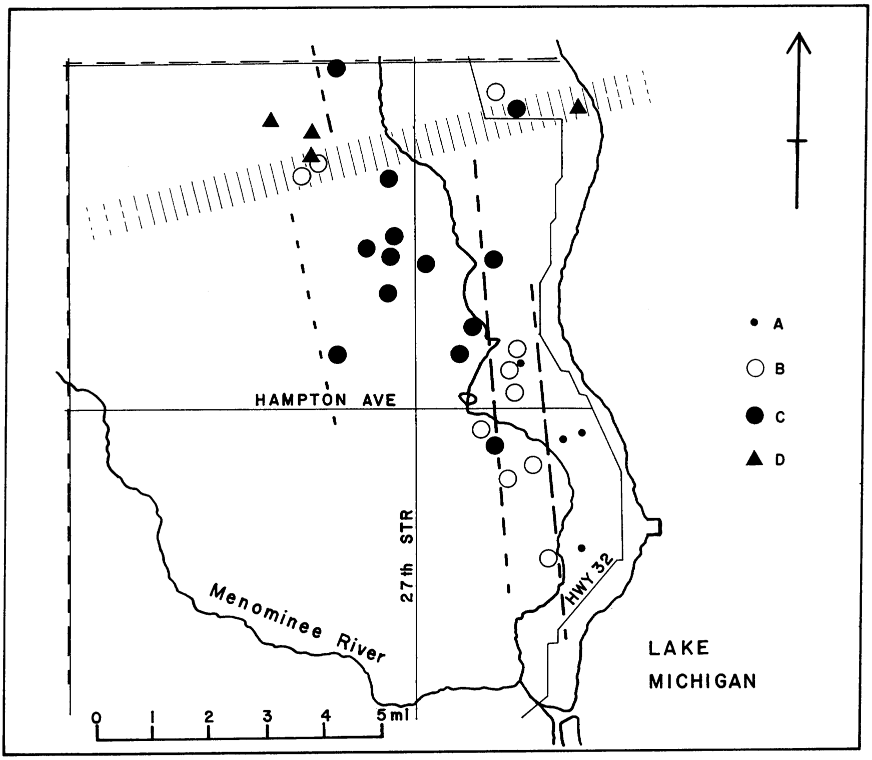

FIGURE 2. Structure contour map of the Devonian–Silurian boundary in northern Milwaukee County, Wisconsin. Ornament as in Fig. 1. Height group symbols: the Devonian–Silurian boundary lies between 300 and 400 feet (symbol A), 400 and 500 feet (symbol B), 500 and 600 feet (symbol C), or above 600 feet (symbol D), above mean sea level.

is much more tenuous) and a succession of anomalous readings, along a narrow zone running eastnortheast–westsouthwest. Anomalous heights are also obtained for the Silurian–Ordovician boundaries in other wells along the same line (two of the three most northerly wells shown on Fig. 1 are lower than the stratum contours to the south would indicate). Another fault zone is thus postulated in the extreme north of the county, in this case with the downthrown block to the south.

The northernmost of these two fault zones is probably a continuation of the north-east striking fault known to exist under the town of Waukesha to the west (Foley et al., 1953). The southern fault zone was previously thought of as a fold structure (Foley, op. cit.) but this was on the basis of structure contours drawn on the top of the St. Peter Sandstone, a much less well defined horizon than the one used here. There is, however, good indication of a slight monoclinal warping in both the Devonian–Silurian and Silurian–Ordovician contacts. In both Fig. 1 and Fig. 2, two of the stratum contours lie closer together than the others.

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THE DISTRIBUTION OF IRON IN LAKE SEDIMENTS

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Abstract

In Lake Mendota sediments, iron is present as the sulfides (hydrotroilite and/or greigite), in organic material, detrital material, magnetic spherules and as 'acid-soluble' iron which has been shown to be coprecipitated with calcite (the predominant mineral phase in the lake muds) by adsorption. A small fraction of the acid-soluble iron may also be tied up as the polyphosphates.

Introduction

The cycling of iron within and through the aquatic ecosystems has been extensively investigated because the amounts and kinds of ions or molecules containing iron in the ferrous or ferric states are directly relatable to the pH and Eh of the water in which they occur (Mortimer, 1941–42; Hutchinson, 1957; Gorham, 1958; Hem, 1959). None of these investigations however has reported on the influence of mineralogy on the partitioning of iron between the lake water and the solid phases in the bottom sediments with which the water is in contact. This important variable which would greatly influence the amount and rate of iron leaching from the lake muds has been neglected because of the complete lack of information on the nature of iron in lake sediments (Hutchinson, 1957). The present investigation is aimed at providing some information on the various forms of iron in the bottom muds of Lake Mendota.

Sampling and Field Observations

The grab samples used in the analyses were obtained with an Eckman dredge along a traverse from Picnic Point to Maple Bluff (Fig. 1). The core samples were obtained near University Bay (Fig. 1) with a three-inch diameter piston corer mounted on the Water Chemistry Research Vessel, Kekule. Water depths were determined with a fathometer. Detailed information is available on

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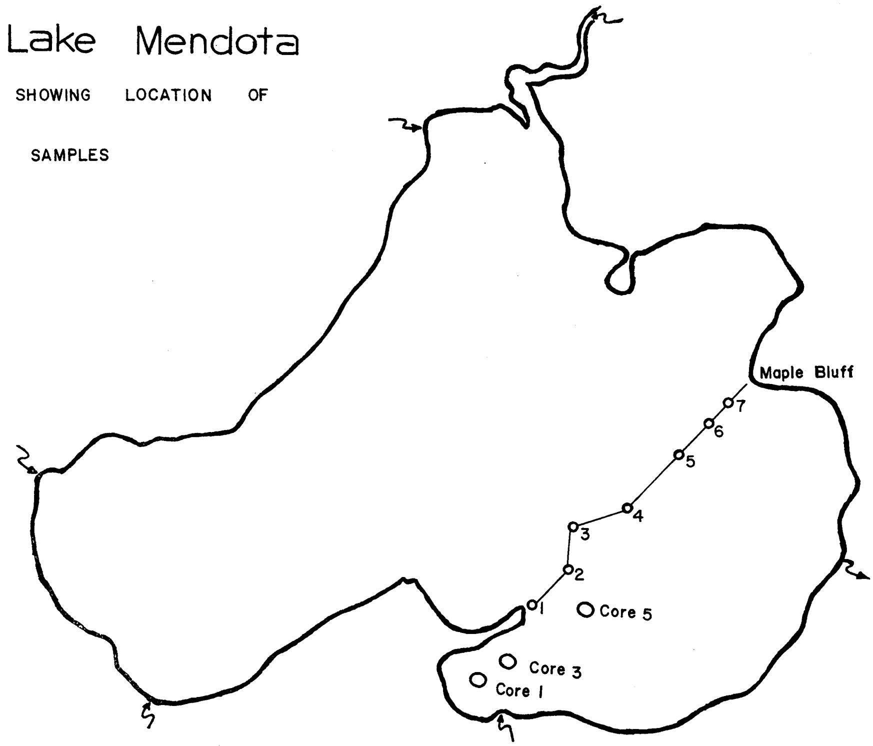

FIGURE 1.

the physical properties of Lake Mendota sediments (see for example, Twenhofel, 1933; Hanson, 1952; Murray, 1956); no attempt will be made to describe these properties in this report.

The often reported knife-sharp nature of the contact between the sludge and the marl was not observed in any of the cores used in this study. In all the core sections examined, the sludge passed gradationally into the lake waters at the top and at the bottom graded into marl over a zone ranging from five to ten centimeters marked by a gradual lightening of color. Apparently the false impression of a knife-sharp contact (as reported by Hanson, 1952, and Murray, 1956) was created by compression of the core section during sampling. Emery and Dietz (1941) reported that gravity corers gave shortenings of up to 60 percent in some marine sediments off the coast of California. Core shortening of comparable magnitude is quite possible in these sediments considering the high fluidity of the sludge (water content up to 85 percent). Murray (1956) describes the core:—"when the core and liner were removed from the steel tube, the water above the sediments in the liner remained clear despite the agitation of the water and sediments in the sampling process". This may be considered a measure of the degree of compression of his core samples. Furthermore, the thickness of the sludge measured directly along the core column or determined on the basis of sulfur content of the sediments, is generally much greater than that reported by Murray and may be regarded as another evidence that the cores studied by him were compressed. The core section obtained for this study almost completely filled the core barrel showing that the shortening of the column was very small.

Laboratory Investigations

All the samples were stored frozen until required for analysis. To minimize the air oxidation of the ferrous iron, the interval between the collection of the samples and the determination of the ferrous iron was kept at less than a week. The analysis for ferrous iron was made on wet samples; the total iron content was determined on oven-dried samples.

Ferrous Iron.[1] The analysis for acid-soluble (ferrous) iron consists of boiling the sediment sample with 1N. HCl, filtering off the iron in the solution and reducing the filtrate with a 10 percent solution of hydroxylammonium hydrochloride. The iron in the extract is then determined by the o-phenanthroline method using a Beckman Model B spectrophotometer with a wavelength setting of 519 mμ (a make up from a filtrate was used as the standard in the reference cell). The details of the procedure used in the analyses are given in *Standard Methods* (Am. Publ. Health Assoc. 1960).

Total Iron. To obtain the total iron, a weighed portion of the oven-dried sediment is digested with a mixture of HNO_3, $HClO_4$ and HF and the iron in the acid extract determined by the o-phenanthroline method. The experimental details involved in the analysis are given in Black (1965).

Sulfide Sulfur. Sulfide sulfur was analysed by the evolution method of Kolthoff and Sandell (1952). An excess of dilute HCl is added to a weighed amount of the sediment sample in a distillation

[1] Boiling in dilute acid will also dissolve a considerable quantity of ferric iron, if any happens to be present. It is however unlikely that ferric iron is present considering the fact that these samples were drawn in the late stages of stratification when the bottom sediments are known to be highly reducing. Ferric iron precipitated in bottom muds during the seasonal overturns has been shown (see Hutchinson, 1957; Mortimer, 1942/43) to be almost completely reduced to the ferrous state early, following the development of anoxic conditions in the hypolimnion. In addition, any ferric iron settling through the oxygenated epilimnion should in fact be reduced in the anaerobic hypolimnion before it can get to the bottom muds—ferrous and ferric ions in aquatic ecosystems are very sensitive to Eh-pH changes (J. D. Hem, 1959). It is simply unlikely that ferric iron should exist as a stable phase (except as pyrite, which however was not isolated in any of the samples) in the presence of relatively large concentrations of dissolved sulfide associated with these bottom muds.

flask. The acidified suspension is boiled gently for one hour on a hot plate and the liberated H_2S absorbed in a zinc acetate-sodium acetate mixture and subsequently determined volumetrically using a standard iodine solution as the titrant and starch solution as the end point indicator.

Total Sulfur. Analysis for total sulfur was by dry combustion to the sulfate followed by reduction and subsequent conversion of the sulfuric acid to H_2S. The precautions and experimental details for the determination of SO_4 as hydrogen sulfide (using a reducing mixture of hydriodic acid, hypophosphorus acid and formic acid) are given in Black (1965).

Results and Discussion

The analytic data for the dredge samples are given in Table 1; the data for the core samples are presented in Table 2. All depths are apparent depths, no corrections for core shortening have been made.

In all the samples examined, (see Tables 1 and 2), the iron occurs predominantly in the acid-soluble (ferrous) state. The difference between the total and acid-soluble iron at any given location can be accounted for as iron in organic matter, in detrital sediments and in the magnetic spherules (for a discussion of these spherules, see Nriagu, 1967). It was not possible to differentiate between these forms of iron owing to the difficulties involved in removing organic material from these sediments. Since these forms may be regarded as the "inactive" iron in the sediments (and because not much is known about their form anyway), no further discussion will be made about them.

Table 1. Sulfide-S, Total-S, Acid-soluble Fe and Total Fe Content of Dredge Samples of Lake Mendota Sludge*

Sample No.	Depth of Water (Ft.)	Sulfide Sulfur†	Total Sulfur†	Acid-soluble Iron†	Total Iron†
901/7	35	0.3	0.5	5.5	——
901/6	50	1.0	1.9	13.7	17.0
901/1	50	1.3	1.9	16.5	22.5
901/5	60	1.6	2.2	16.3	21.0
901/2	75	3.5	4.2	21.6	24.0
901/4	77	3.3	4.0	19.4	23.6
901/3	83	3.6	4.3	22.1	25.0

†Expressed as mg/gm dry weight.
*Samples were drawn on 9/1/66.

TABLE 2. SULFUR AND IRON CONTENTS OF CORE SAMPLES. DEPTHS OF WATER = 33 FT.

SAMPLE NUMBER	DEPTH BENEATH MUD SURFACE	*ACID-VOLATILE SULFUR	*TOTAL SULFUR	*ACID-SOLUBLE IRON	*TOTAL IRON
1	5–5cm	0.6	1.3	15.6	20.4
2	5–10	1.4	1.5	15.1	20.0
3	10–15	1.7	1.8	16.8	20.6
4	15–20	1.9	2.0	15.9	——
5	20–25	1.4	1.9	15.7	22.1
6	25–30	1.3	1.8	16.4	22.2
7	30–35	0.9	1.1	15.2	21.9
8	35–40	0.5	0.9	14.6	20.4
9	40–45	0.5	0.7	14.1	19.4
10	45–50	0.4	0.6	11.7	16.0
12	55–60	0.2	0.5	9.1	12.5
14	65–70	0.1	0.4	4.3	7.9
16	75–80	0.1	0.3	3.2	7.0
18	85–90	0.1	0.2	3.1	7.2

*Concentration expressed as mg/gm of the dry sediment.

The iron sulfide in these sediments is a black amorphous, acid-soluble substance believed to be hydrotroilte, $FeS.nH_2O$ (and/or greigite, Fe_3S_4) and is responsible for the color of the sludge. No pyrite or marcasite was isolated from these lake muds.

A feature shared by the sludge and marl is that the iron content is very much greater than should be required to hold all the sulfur present as FeS (for instance, the molar ratio of sulfide sulfur to acid soluble iron varies from 1:8 to 1:4); only a small part of the total iron in the sediments can be present as FeS even though a significant proportion of the sulfur in the sediment may be so contained. It is not clear however in what form this *excess iron** exists in the lake sediments. The question of mineralogy is important because it affects the aqueous chemistry of the solid (mineral) phase and would influence to a great extent the amount and rate of iron leaching from the sediments. The problem in dealing with the excess iron in the sediments is that the iron mineral phase(s) present cannot be detected by X-ray diffractometry or microscopic techniques.

Ferrous carbonate has been suggested as the solid form in which the excess iron exists in Lake Mendota sediments (Murray, 1956; Lee, 1962; Gardner and Lee, 1965). With the available chemical

* Excess iron is used here as an operational term referring to the acid soluble iron in these sediments not accounted for as the sulfides. It gives an indication of the 'reactive' iron in the sediments other than the sulfides.

TABLE 3. AVERAGE ANALYSIS OF WATER FROM LAKE MENDOTA

	(PPM)	MOLARITY
Alkalinity	142	0.0014*
Ca	30	0.00075
Mg	24	0.0001
Fe	0.1	0.000002
Mn	0.05	——
Chlorides	5.0	0.00014
Sulfates	17.0	0.00018
Ammonia Nitrogen	0.08	——
Organic Nitrogen	0.6	——
Silica (SiO_2)	1.0	——
pH	8.0	——

*Recalculated to HCO_3^-.

analyses of the lake water it is possible to calculate whether or not the waters of the lake are in equilibrium with respect to siderite. An average analysis of Lake Mendota water (courtesy of the Water Chemistry Laboratory, Univ. of Wisc.) is shown in Table 3.

Recalculation of these, assuming that at pH 8, the titration alkalinity equals the bicarbonate alkalinity and ignoring ammonia, organic nitrogen, Mn, and SiO_2, shows that the ionic strength is about 0.005; $m_{Fe^{++}} = 10^{-5.7}$; $m_{HCO_3^-} = 10^{-2.85}$.
The activity coefficient γ, for HCO_3^- and Fe^{2+} can be computed from the Debye–Huckel equation:

$$-\log \gamma_i = \frac{A \cdot z_i^2 \sqrt{I}}{1 + å_i \cdot B \cdot \sqrt{I}} \tag{1}$$

where A and B are constants relating to the solvent (in this case water); z is the ionic charge; I is the ionic strength of the solution; and $å_i$ represents the effective diameter of the ion in solution. Substituting $I = 0.005$ and the empirical values for the constants at 25°C (Garrels and Christ, 1965, p. 61–62) into the above equation, we obtain:

$$\gamma Fe^{2+} = 0.72 = 10^{-0.12}$$
$$\gamma HCO_3^- = 0.93 = 10^{-0.03}$$

Precipitation of siderite is generally believed to be controlled by the reaction:

$$FeCO_{3(s)} + H^+ = Fe^{2+} + HCO_3^- \tag{2}$$

$$\therefore K = \frac{a_{Fe^{2+}} \cdot a_{HCO_3^-}}{a_{FeCO_3} \cdot a_{H^+}} \tag{3}$$

where *a* represents the activity of the ion.

Assuming $a_{FeCO_3} = 1$, the equilibrium may be stated in terms of molarities m, and the activity coefficient γ:

$$m_{Fe^{2+}} \cdot m_{HCO_3^-} = \frac{K}{\gamma_{Fe^{2+}} \cdot \gamma HCO_3^-} \cdot a_{H^+} \qquad (4)$$

The equlibrium constant, K for this reaction calculated from free-energy data is 0.46 (Latimer, 1952).

$$\text{For } \gamma_{Fe^{2+}} = 10^{-0.12};\ \gamma HCO_3^- = 10^{-0.03}$$
$$a_{H^+} = 8.0;\ m_{HCO_3^-} = 10^{-5.7};\ \text{and } K = 10^{-0.34},\ \text{then}$$
$$\underline{m_{Fe^{2+}} = 10^{-5.4}}$$

The iron content of the lake (Table 3) is $10^{-5.7}$, therefore according to these calculations, the lake appears to be in equilibrium (just saturated with respect to $FeCO_3$. Thus within the limits of the assumptions used in these calculations, there is a likelihood of siderite being precipitated in the lake.

The preceding calculations represent the conditions during the overturn when a homogeneous chemical system is established in the lake and the pH is 8.0. During the periods of thermal stratification however, the pH of the hypolimnion near the mud-water interface commonly falls to 6.5–7.0 (Open File Report, Water Chemistry Dept). Substituting this pH range in equation 4, we find:

$$m_{Fe^{2+}} = 10^{-3.9} \text{ to } 10^{-4.4}$$

But the iron content of the lake water (Table 4) is $10^{-5.7}$ indicating that during the periods of bottom anoxia the interstitial water in contact with the sludge is undersaturated with respect to ferrous carbonate. The large difference in value between the observed and the calculated $m_{Fe^{2+}}$ suggests a high degree of instability and a strong possibility of solution of the ferrous carbonate.

If the excess iron exists as the ferrous carbonate, its stability must therefore be due to its inability to equilibrate with the dynamic variables of the interstitial water. Experiments on the solution kinetics of carbonates in dilute carbonic acid solutions indicated that the rates of the solution were dependent only on the rate of diffusion of the ions in the aqueous phase (Weyl, 1958). Possible factors (all of which are manifestations of surface phenomena) in the lake that may inhibit simultaneous solution of $FeCO_3$, thereby engendering non-equilibrium behavior, include adsorbed protective coating on the grains, isolation of the siderite grains as mechanical inclusions within the flocculent particles, and low temperature (which retards the rate of solid diffusion). There is however no evidence from these sediments to suggest that any of the processes is keeping either the calcite grains or the other chemical precipitates (e.g. the sulfides) out of reaction.

It is reasonable to suppose that if the excess iron is precipitated as the carbonate, the grains have the same size range as the calcite crystals. The grain size of the calcite crystals was determined by the method discussed in Henry, Lipson & Wooster (1951, p. 212–213). Diffraction photographs were taken of marl samples which were mounted on glass fiber with the maximum care to avoid crushing the calcite grains. Each sample gave well defined powder lines without spots showing that the crystals have a size range of 0.001 tot 0.0001 mm diameter. If therefore ferrous carbonate is present in these sediments, it would be as very fine particles with high specific surface area, a condition that would favor rapid decomposition in air. The decomposition of $FeCO_3$ in air is controlled by grain size and temperature (Seguin, 1966). Aeration of Lake Mendota sediments would thus be expected to cause a notable reduction in the excess iron, if present as the ferrous carbonate. Table 4 however shows that this is not the case. Furthermore, it has been shown by Gardner (1964) that after the initial rapid uptake of oxygen (probably due to the reaction of oxygen with the sulfides), the oxygenation of the iron compounds in the lake sediments becomes a linear function of time. This clearly should not be expected if the iron were precipitated as the easily oxidizable ferrous carbonate. These two observations thus cast considerable doubt on the suggestion that the excess iron has been precipitated as $FeCO_3$ (siderite).

TABLE 4. COMPARISON OF RATES OF OXIDATION OF IRON SULFIDES AND EXCESS IRON OF THE SLUDGE IN AIR*

SAMPLE NO.	SULFIDE-S		ACID-SOLUBLE IRON	
	Initial (ppm)	After Aeration	Initial (ppm)	After Aeration (ppm)
901/1	1,300	70	16,500	11,200
901/3	3,600	204	22,100	14,700
901/4	3,300	150	19,400	12,300
901/5	1,600	190	16,300	12,900

*To obtain the data, the sludge samples were aerated until the dark color had changed to grey-brown. The sulfide sulfur and acid-soluble iron were determined again. The aeration procedure consisted of exposing the periodically stirred, wet sludge to the laboratory air. Distilled water was added to keep the samples continuously moist.

If therefore the excess iron is not precipitating as $FeCO_3$, the alternative phenomena which may account for it include:

1. Formation of organic complexes and chelates
2. Formation of solid phases other than siderite
3. Coprecipitation of the iron with the calcite.

To estimate the amount of iron in the sludge associated with organic compounds and chelates, the sludge samples were leached with acetone, the extract carefully evaporated to dryness and the residue analysed for iron by the o-phenanthroline method. The results are given in Table 5 below.

TABLE 5. IRON CONTENT OF ACETONE EXTRACTS FROM SLUDGE SAMPLES

Sample No.	Depth of Water (Ft.)	Fe in Acetone Extract (ppm)	Initial Acid-Soluble Fe (ppm)
901/5	60	13	16,300
901/2	75	26	21,600
901/4	77	21	19,400
901/3	83	19	22,100

The data above show that acetone-soluble organic compounds and chelates not bound up as solid and particulate organic matter account for only a very small fraction of the iron in the sludge. Apparently, not much of the excess iron is associated with the yellow coloring matter observed when organic muds are treated with acetone as has been suggested by J. D. Hem (1959).

In addition to the carbonates, other iron minerals (possible in these sediments) that may exist metastably in aqueous environments are silicates and phosphates (see Weyl, 1966). Iron silicates may be ruled out because most of them are insoluble in dilute acids. The occurrence of phosphorus not associated with organic matter or clay minerals has been reported in Lake Mendota sediments (Wentz, 1967). It seems reasonable to suggest that a part of this phosphorus is combined as acid-soluble polyphosphates, the metastability of which may be due to biologic and/or chemical factors. The presence of ferric phosphate should not be affected by aeration which is in accordance with the data presented in Table 5. The mean phosphate content of the lake sediments is in the range 1 to 2 mg/gm on a dry weight basis (Sawyer et al., 1944; Kaneshige, 1952; Delfino, 1967, Pers. Comm.). Clearly this quantity is insufficient to account for all the excess iron in the samples examined.

The final possibility is that the greater part of the excess iron is coprecipitated with calcite by adsorption. Coprecipitation of iron with calcite would mean that the activity of the solid carbonate phase is not one as has been assumed in the calculation but less than one. From Equation 3 one finds that the effect of lowering a_{FeCO_3} is to increase the value of the calculated $m_{Fe}2+$. This effect would of course decrease the difference between the calculated and observed $m_{Fe}2+$ and hence should be particularly significant during periods of stratification when the pH falls to 6.5–7.0. The smaller this difference is, the less undersaturated the water is relative to $FeCO_3$ and the less likelihood of the solid $FeCO_3$ going into solution. It is thus possible to account, at least partially, for the stability of the excess iron during periods of bottom anoxia by coprecipitation which has decreased the activity of the solid carbonate phases in the aqueous system.

Such a coprecipitation would also reasonably explain the data of Table 6; the apparent stability being due to the very slow diffusion of iron through the calcite grains which thereby controls its rate of oxidation. Furthermore, the chemical reaction rates of a constituent in solid solution has been shown to approximate a zero'th order process (Crocket et al., 1966). This may be the explanation for the linear rate of oxygen uptake observed during the manometric oxygenation of these lake sediments (Gardner & Lee, 1965).

In conclusion, the available evidence suggests that the greater fraction of the excess iron in Lake Mendota sediments has been coprecipitated with calcite (the predominant single mineral in the sediments) rather than precipitated as the pure compound, $FeCO_3$, as has been suggested by Murray (1956), and Lee (1962). A small part of the excess iron may also be tied up as polyphosphates. Further experiments are necessary to evaluate the exact mechanism of coprecipitation, particularly the influence of organic complexing and biochemical processes.

The influence of the nature of solid phase (with which the lake water is in contact) on the cycling of iron in the lake is obvious. Iron structurally incorporated into calcite is of course not a readily exchangeable iron. Most of the iron released from the sediments during thermal stratification must therefore come mainly from sources of 'available' iron other than the excess iron, notably the sulfides, (the phosphates), and perhaps, in the early stages of stratification, the oxides also. Evidence that part of the iron leached from the sediments has resulted from the dissolution of iron sulfides comes from the observed coexistence of free H_2S and Fe^{2+} in the hypolimnion during the latter stages of bottom anoxia. Since iron sulfides can only dissociate under certain restricted conditions (low Eh, and pH less than 7.0; see Garrels and Christ, 1965) it follows that dislocation of iron in the lake by dismutation must be very small. Consequently, the lake sediments must be acting as a large sump for iron, a suggestion which has already been confirmed by Rohlich (1963) who reported an iron retention in the lake of over 80 percent.

ACKNOWLEDGEMENTS

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EFFECT OF FLOODING, DRAINAGE AND pH ON TRANSFORMATIONS OF Mn AND Fe IN 19 WISCONSIN SOILS[1]

E. H. Graven and O. J. Attoe[2]

The results of a previous study (2) indicated that limited periods of flooding or waterlogging can greatly increase the amount of exchangeable Mn in soils and cause acute Mn toxicity in alfalfa. Owing to its dependence on the redox potential of the soil, Mn availability is conditioned by the amount of easily decomposable organic matter present and by seasonal variations in temperature, moisture and microbial activity. Flooding of soils is generally followed by a rapid rise in water soluble and exchangeable Mn and a somewhat slower rise in these forms of Fe (1, 7, 10). Harter and McLean (3) found that a moisture content intermediate between field moisture capacity and complete saturation was sufficient to fill all except the largest pores of a clay loam soil and cause nearly as large an increase in exchangeable Mn as complete flooding. Although some disagreement exists concerning the relation between soil pH and the content of exchangeable Mn (5, 12, 14), liming acid soils is generally known to lower the amount of this constituent. Oxidation of Mn in soils may be due largely to microbial activity (9, 11, 13), but greater difficulty has been encountered in demonstrating microbial oxidation of Fe (4) because this process also proceeds in sterilized soils.

The present study was initiated to obtain information on the effects of flooding and drainage on the transformations of Mn and Fe in a number of important Wisconsin soil types representing a wide range in pH, texture and other properties.

Methods and Materials

Twenty-gram samples of the air-dry soils were flooded in weighed 100-ml glass bottles by the addition of 40 mls of distilled

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water. Exchangeable Mn and Fe were determined after 0, 5, 15, 35 and 75 days of flooding. For reference purposes, similarly treated samples were flooded in 800-ml beakers at the same time. After 75 days of flooding, the latter samples were thoroughly stirred, transferred to Buchner funnels and the excess water removed by suction. Suction was maintained for 45 minutes after the surface water had disappeared. Twenty-five grams of this moist soil was subsampled into weighed glass bottles. The moisture content was determined from separate samples. The bottles were stored open to the atmosphere at room temperature and the soils were maintained near field moisture capacity (FMC) by watering to the initial weight every third day. Exchangeable Mn and Fe were determined after 0, 5, 15, 35 and 75 days at FMC.

Exchangeable Mn and Fe were extracted with *N* $Mg(NO_3)_2$; easily reducible Mn was extracted with *N* NH_4OAc (pH 7.0) containing 0.2% hydroquinone; and total Mn was brought into solution by use of HF-$HClO_4$. Mn and Fe were determined colorimetrically (6) using $Na_3H_2IO_6$ oxidation and orthophenanthroline methods, respectively. Organic matter was determined by the Walkley–Black method (15). Cation exchange capacity was determined flame-photometrically following saturation with *N* $Ca(OAc)_2$ at pH 7.0 and displacement with *N* $Mg(OAc)_2$. Exchangeable cations were displaced with *N* NH_4OAc adjusted to pH 7.0 and determined flame-photometrically. The clay content was determined by the pipette method (8). Soil pH was determined on a thin soil paste.

Results and Discussion

The values for the chemical properties of the individual soils are given in Table 1, and the range and average values for these properties by pH groups are given in Table 2. The relatively high values for exchangeable Mn in many of the soils prior to flooding were no doubt due to the well-known effect of drying on increasing the content of this constituent. The linear correlation coefficients obtained for pairs of these properties, as indicated in Table 3, show a close relation among the three forms of Mn. A close relation was also found between the clay content and the properties of exchangeable Mn, cation exchange capacity and total cations. Similarly, there was a close relation between cation exchange capacity and the contents of organic matter and total cations.

The data presented in Fig. 1 shows that flooding for as little as 5 days caused a marked increase in the values for exchangeable Mn in all three soil pH-groups and in exchangeable Fe in the pH 5.3-group. The Mn values reached a maximum after 15 to 35 days and declined somewhat with further flooding. The reason for the

TABLE 1. CERTAIN CHEMICAL PROPERTIES OF THE 19 WISCONSIN SOILS

Soil No.	Soil Type	Soil pH	Exch. Mn	Easily Reducible Mn	Total Mn	Cation Exchange Capacity	Organic Matter	Clay	Total Cations
			ppm	ppm	ppm	meq/100g.	%	%	meq/100g.
1	Trempealeau silt loam........	4.8	49	199	527	16.3	1.4	24.2	11.1
2	Superior sandy loam..........	5.2	6	17	236	6.9	1.8	12.3	3.8
3	Freer silt loam...............	5.3	46	481	864	12.8	3.1	14.3	6.4
4	Tama silty clay loam.........	5.3	45	295	981	24.3	3.7	27.7	14.2
5	Plainfield sand...............	5.5	5	101	551	1.9	0.4	3.5	0.9
6	Wyocena loamy sand.........	5.5	26	175	405	2.6	0.9	3.9	2.0
7	Freer silt loam...............	5.6	82	653	1641	11.3	2.4	12.9	6.5
8	Lapeer loam..................	5.7	57	268	630	18.4	1.7	25.3	14.3
9	Sparta sand..................	5.7	23	276	662	3.1	1.1	3.4	1.9
10	Pence loam..................	5.8	11	112	507	12.6	3.2	7.5	7.0
11	Lapeer sandy loam...........	5.8	25	129	527	3.6	1.2	6.9	3.1
12	Dunbarton silt loam..........	5.9	54	447	978	16.2	2.2	24.9	14.2
13	Dane silty clay loam..........	6.0	62	620	1165	15.8	2.0	28.1	13.0
14	Griswold sandy loam..........	6.0	28	361	578	4.9	1.3	6.8	3.9
15	Dane silt loam...............	6.3	67	722	1587	16.7	2.0	17.8	15.0
16	Nippersink silt loam..........	6.3	48	522	993	12.3	1.6	19.2	10.5
17	Miami silt loam..............	6.9	28	407	863	18.3	2.7	21.2	15.1
18	Sebawa silt loam.............	6.9	31	461	988	21.5	2.6	23.9	17.4
19	Shiocton loamy sand..........	7.4	1	2	120	6.4	2.0	9.2	6.3

TABLE 2. RANGE AND AVERAGE VALUES FOR CERTAIN CHEMICAL PROPERTIES OF THREE pH GROUPS OF 19 WISCONSIN SOILS

SOIL PROPERTY	pH 4.8–5.5 (6 SOILS)		pH 5.6–6.0 (8 SOILS)		pH 6.3–7.4 (5 SOILS)	
	Range	Ave. Value	Range	Ave. Value	Range	Ave. Value
pH	4.8– 5.5	5.3	5.6– 6.0	5.8	6.3– 7.4	6.8
Exch, Mn, ppm	5–49	30	11–82	43	1–67	35
Easily reducible Mn, ppm	17–481	211	112–653	359	2–722	422
Total Mn, ppm	236–981	595	507–1641	836	120–1587	911
Cation exch. cap., meq/100 g	1.9–24.3	10.8	3.1–18.4	10.8	6.4–21.5	15.0
Organic matter, %	0.4–3.7	1.9	1.1–3.2	1.9	1.6–2.7	2.2
Clay, %	3.5–27.7	14.3	3.4–28.1	14.5	9.2–23.9	18.3
Total cations, meq/100 g	0.9–14.2	6.4	1.9–14.3	8.0	6.3–17.4	12.9

TABLE 3. LINEAR CORRELATION COEFFICIENTS* FOR THE RELATION BETWEEN VARIOUS CHEMICAL PROPERTIES OF THE 19 SOILS

	SOIL pH	CATION EXCH. CAP.	OR-GANIC MATTER	TOTAL CA-TIONS	TOTAL MN	EASILY REDUC. MN	EXCH. MN
Clay	.06	.88	.49	.91	.45	.48	.66
Soil pH		.03	.14	.33	.07	.16	.18
Cation exch. cap.			.68	.84	.44	.41	.55
Organic matter				.55	.35	.29	.24
Total cations					.52	.54	.53
Total Mn						.93	.84
Easily reduc. Mn							.84

Significant at respective levels if value is equal to or greater than following: 1% = ±.57, 5% = ±.46 and 10% = ±.39. All values shown are positive.

decline is not clear but it may be due to absorption of Mn by a larger population of anaerobic microorganisms present during the latter part of the flooding period. The highest values for exchangeable Mn were attained in the 5.8 and 6.8 pH-groups. In contrast, the values for exchangeable Fe continued to rise all through the 75 days of flooding, and the highest values were attained for soils in the pH 5.3-group and the lowest in the pH 6.8-group. Drainage of the pots and a return to field moisture capacity resulted in an abrupt drop in exchangeable Fe in all groups and in exchangeable Mn in the pH 6.8-group. The Mn values for the pH 5.3-group declined very slowly and those for the pH 5.8-group were inter-

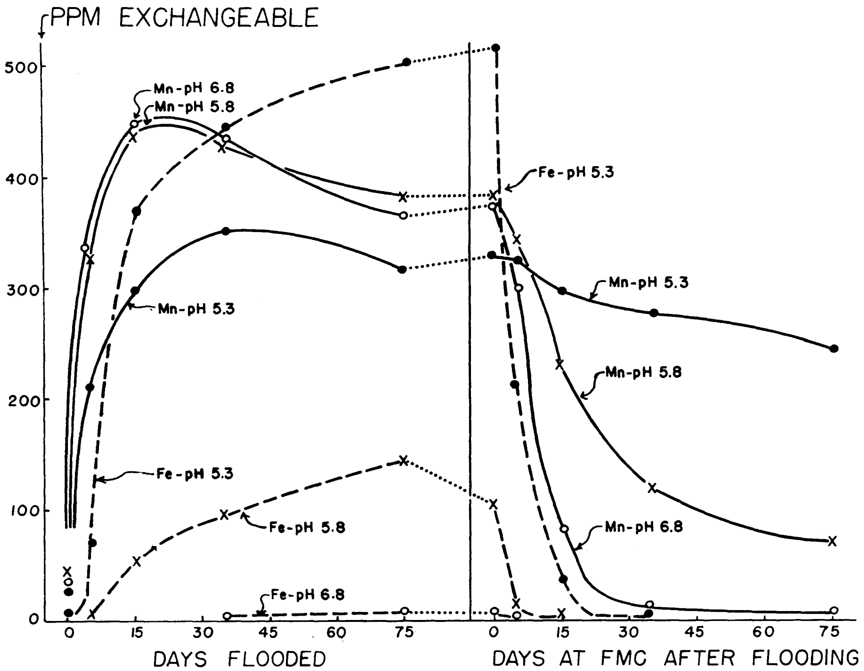

FIGURE 1. Effect of flooding, drainage and pH on the contents of exchangeable Mn and Fe for the three pH-groups of soils.

mediate. These results suggest that the most harmful effects on plant growth of relatively long periods of flooding or waterlogging could be for soils near the neutral point because of the very wide ratio of exchangeable Mn to Fe under these conditions. However, for rather short periods of saturation the most harmful effect could be for the more acid soils in which the exchangeable Mn remained at a very high level for extended periods following drainage. The results also suggest the need for caution in the amounts of water added to potted plants.

The data presented in Table 4 show that the exchangeable Mn values after 15 days of flooding were highly correlated with both total and easily reducible Mn. The decrease in this constituent during 35 days at FMC after 75 days of flooding was closely correlated with soil pH and % clay. The importance of the clay content in this relation appears to be due in part to the fairly close association between it and the forms of Mn present prior to flooding. The exchangeable Fe values after 35 days of flooding were highly correlated with soil pH (negatively) and % organic matter. Apparently, the presence of organic matter favored the reduction and

TABLE 4. COEFFICIENTS OF MULTIPLE CORRELATION AND STANDARD PARTIAL REGRESSION COEFFICIENTS FOR THE RELATION BETWEEN SELECTED SOIL PROPERTIES OF THE 19 SOILS IN RELATION TO FLOODING AND DRAINAGE

INDEPENDENT VARIABLES	STANDARD PARTIAL REGRESSION COEFFICIENTS FOR RESPECTIVE VARIABLES			COEFFICIENTS OF MULTIPLE CORRELATION
Exchangeable Mn after 15 days of flooding				
Easily reducible Mn; total Mn......	.44	.54	—	.96**
Easily reducible Mn; soil pH........	.97	—.14	—	.96**
Soil pH; % clay; % organic matter..	—.04	.37	.24	.52*
Decrease in exchangeable Mn during 35 days at FMC after 75 days of flooding				
Soil pH; % clay..................	.38	.53	—	.68**
Soil pH; % clay; % organic matter..	.40	.63	—.18	.69**
Exchangeable Fe after 35 days of flooding				
Soil pH; % organic matter.........	—.72	.57	—	.86**
Soil pH; % clay; % organic matter..	—.73	.13	.50	.87**
Exchangeable Fe after 5 days at FMC following 75 days of flooding				
Soil pH; % clay..................	—.55	.41	—	.67**
Soil pH; % clay; % organic matter..	—.54	.44	—.07	.67**

*Significant at 5% level.
**Significant at 1% level.

transformation of the Fe in the ferric oxides to the more soluble and exchangeable ferrous forms. The Fe values after 5 days of drainage were closely correlated with soil pH (negatively) and % clay.

The increases in water soluble and exchangeable Mn caused by flooding and decreases after drainage may be represented by the following equation:

$$MnO_2 + 4H^+ + 2e^- \underset{\text{(Oxidation)}}{\overset{\text{(Reduction)}}{\rightleftharpoons}} Mn^{++} + 2H_2O$$

Flooding and low soil pH values tend to shift the reaction to the right and drainage and relatively high pH values tend to shift it to the left. A similar equation may be used to represent the transformations of Fe under conditions of flooding and drainage. In this case Fe_2O_3 would be reduced to Fe^{++}. For soils near the neutral point, this reaction appears to proceed less readily than for MnO_2.

SUMMARY

Flooding gave large increases in exchangeable Mn in nearly all of the 19 soils studied. After drainage and a return to field moisture capacity, an abrupt decrease occurred in this constituent for

soils in the range of pH 6.0 to 7.4 and a much slower decrease in the more acid soils. In contrast, flooding resulted in a much slower increase in exchangeable Fe for the soils in this pH range and a more abrupt decrease in most of the soils after drainage. An important benefit derived from liming acid soils appears to be in causing a more rapid decline in excessive amounts of exchangeable Mn following drainage of saturated soils. The data reported help understand the response of plants to waterlogging and drainage of soils and emphasize the harmful effects that may result from overwatering of potted plants.

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THE FRAGIPAN IN SOILS OF NORTHEASTERN WISCONSIN[1]

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A brittle subsoil horizon called the fragipan occupies large areas in upland soils of northern Wisconsin, particularly in the northeast. This horizon restricts root growth (Figure 1) and movement of water, and is therefore of importance to an understanding of the ecology of forests and hydrology of drainage basins of northern counties. This is a report on recent investigations of the fragipan in Florence, Menominee, Oneida and Bayfield Counties, Wisconsin (Milfred, Olson and Hole, 1967; Olson, 1962; Hole, Olson et al., 1962; Ableiter and Hole, 1961; Hole and Schmude, 1959). This work was supported by the Wisconsin Geological and Natural History Survey.

DEFINITION

Among existing definitions of the fragipan (Soil Survey Staff, 1951; Carlisle, et al., 1957; Committee on Terminology, 1960; Soil Survey Staff, 1960), the following is one of the most complete. "A fragipan (modified from L. *fragilis,* brittle; and pan: meaning brittle pan) is a loamy subsurface horizon, often underlying a B horizon. It is very low in organic matter, has high bulk density relative to the overlying horizons, is seemingly cemented when dry, having hard or very hard consistence. When moist, a fragipan has moderate or weak brittleness (tendency for a ped or clod to rupture suddenly when pressure is applied rather than to undergo slow deformation). It is usually mottled, is slowly or very slowly permeable to water, and has few or many bleached fracture planes that form polygons" (Soil Survey Staff, 1960). Platy structure and vesicular porosity are also characteristic of many fragipan hori-

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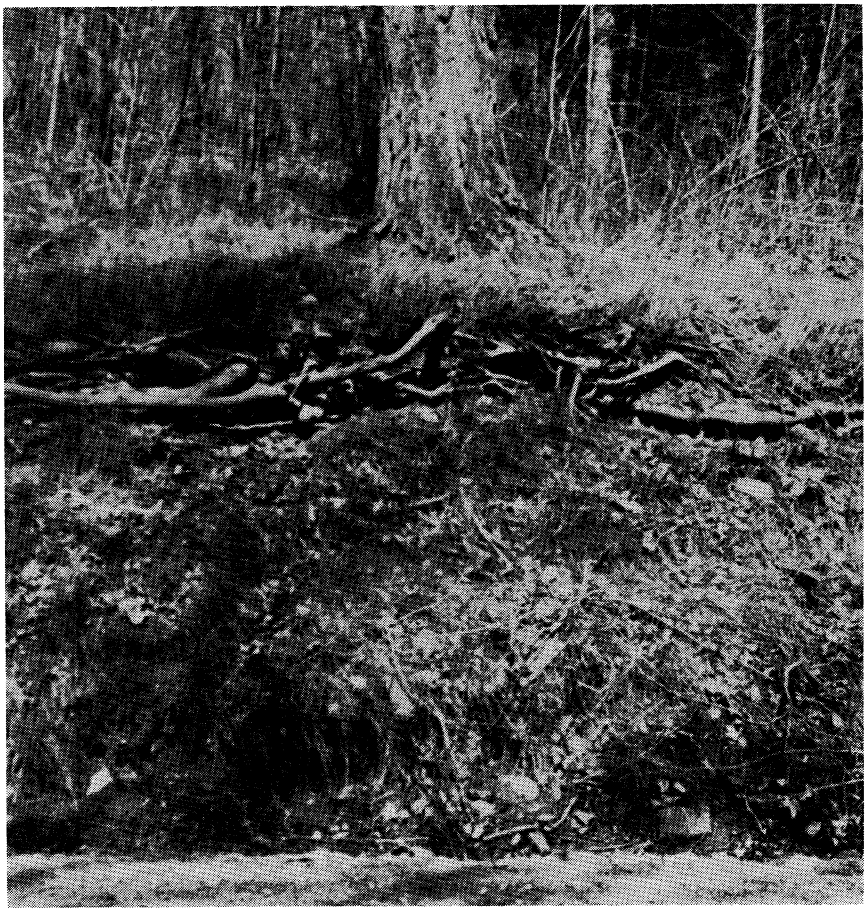

FIGURE 1. Photograph of the typical shallow rooting system of a tree growing in a soil with a strongly developed fragipan.

zons. A slab of fragipan will slake when immersed in water. The horizon designation is the letter x, added to the main horizon designation, as in A′x and B′x of the lower solum of a double (bisequal) soil profile (Figure 2).

PREVIOUS WORK

Whitson (1927) referred to a "hardpan" in the subsoil of Kennan soils of northern Wisconsin, but did not describe it. Nygard, et al., (1952) referred to "a gray partially gleyed, vesicular pan" lying below the Podzol solum in soils of the Iron River and Munising soil series in northern Wisconsin, Michigan and Minnesota. The Soil Survey Staff of the U. S. Department of Agriculture (1951)

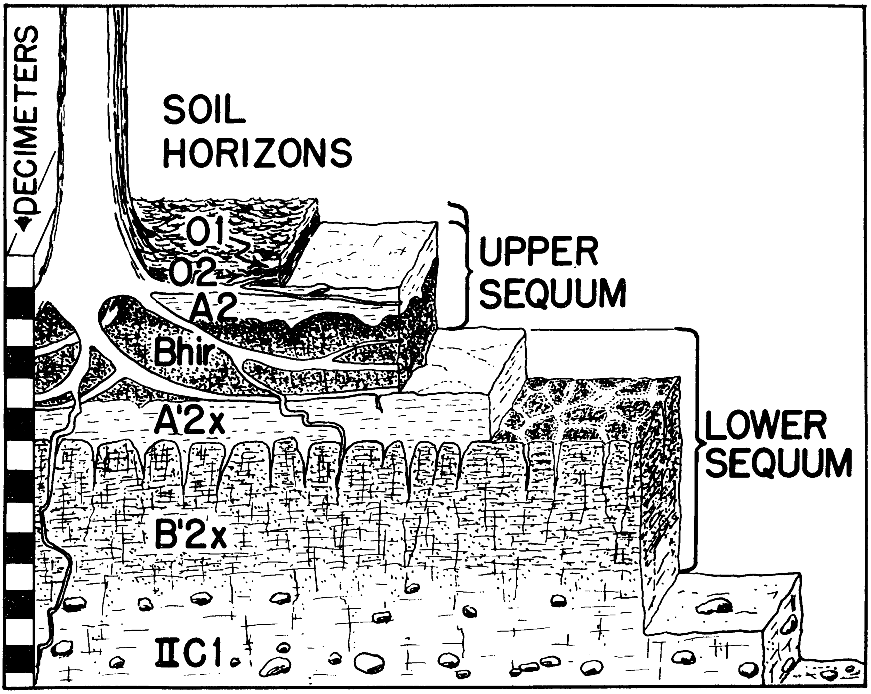

FIGURE 2. Cut-away block diagram of a bisequal soil, Goodman silt loam (Alfic Haplorthod), showing two fragipan horizons with extensions of the upper one down a polygonal system of cracks in the lower, somewhat finer textured one.

assigned the term fragipan to such nonindurated pans, as distinct from indurated pans (hardpans) and clay pans. During the past decade a number of workers (Carlisle, et al., 1957; Grossman, et al., 1959; Yassoglou and Whiteside, 1960; Jha and Cline, 1963; McCracken and Weed, 1963; Daniels, et al., 1966) have investigated the characteristics and genesis of the fragipan in detail. This horizon has developed under a variety of climates in a wide range of materials, including Wisconsin loess, glacial till and lacustrine deposits in the Lake States, residuum from sandstone, shale and limestone farther south, and unconsolidated coastal plain sediments in southeastern states. The fragipan does not occur in desert soils (Aridisols) and other soils in which calcium carbonate and other carbonates and salts either create a friable soil condition or cement the soil into a hardpan (duripan); or in which claypans have formed under the influence of the sodium ion. The fragipan does not occur in prairie soils (Mollisols) in which root growth and accumulation of organic matter have favored a more porous and friable soil condition than is required for the formation of the pan.

The fragipan occurs in forest soils grouped in the soil orders, Inceptisols, Spodosols, Alfisols and Ultisols (Soil Survey Staff, 1960). The investigations indicate that fragipan horizons have developed by compaction of a mixture of noncalcareous silts and sands with relatively little clay (Figure 3) and low content of organic matter. Weak cementation is thought to be by films of clay, silica, alumina, or iron oxide but this has not been definitely proved. The fragipan has formed at sites where biologic activity in the subsoil has been so slight that the fragipan has not been disturbed appreciably since its formation. The fragipan has developed in the lower part of many bisequal soils (Gardner and Whiteside, 1952), that is to say, below a Podzol (Spodosol, Soil Survey Staff, 1960) sequum of hori-

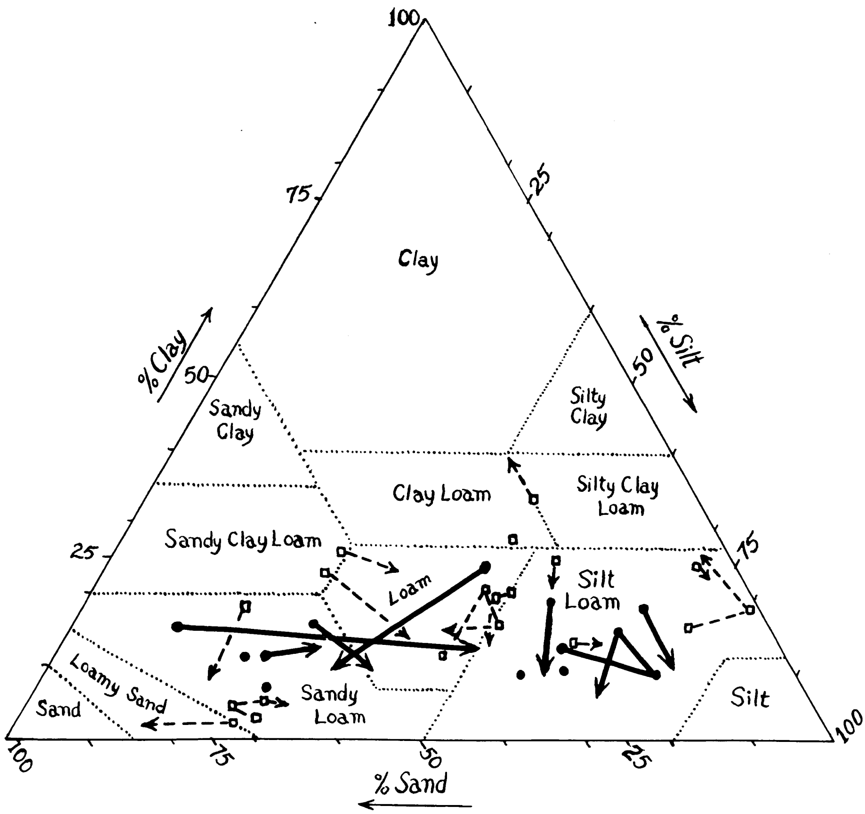

FIGURE 3. Textures of fragipan horizons plotted on a soil textural triangle. Solid lines represent data for soil samples from northeastern Wisconsin. Dotted lines represent data for fragipans from other parts of the country (Olson, 1962). Arrowheads indicate the fragipan sample taken at the greatest depth in each soil from which two or more subhorizons were sampled.

zons (Figure 2) and in a sequum consisting of an eluvial (A′2x) horizon and an illuvial (B′2x) horizon. Bisequal soils of Wisconsin, including Alfic Haplorthods like the Goodman silt loam (Figure 2), have been discussed elsewhere (Carroll, 1959; Ableiter and Hole, 1961; Hole, et al., 1962; Beaver, 1963, 1966; Ranney, 1966). The fragipan has been recognized in some soils on all continents except Antarctica.

Geographic Distribution in Wisconsin

The fragipan occurs extensively in Wisconsin north of a boundary (A–A′, Figure 4) which approximates the isotherm for the average annual air temperature of 41° F (5° C) or about 43° F, (6° C) in the soil at a depth of 50 cm. For the most part the boundary lies west of the carbonate-rich glacial drift of northeastern Wisconsin. The postulated A–A′ boundary of Figure 4 first appeared on a map published by Nygard, et al., (1952) to indicate the souhern limit of a zone of Podzol, Brown Forest and Brown Podzolic soils, now classified as Spodosols and Inceptisols (Soil Survey Staff, 1960). The boundary closely parallels and lies somewhat north of range limits for several species of plants, such as the orchid *Habenaria obtusata* (Curtis, 1959), within the northern mesic conifer–hardwood forest. Weaker fragipans occupy large areas in a 40-mile-wide zone to the south (A–A′ to D–D′, Figure 4; Carroll, 1959; Beaver, 1963). In both zones the fragipan commonly occurs in acid bisequal soils.

Procedures

In the course of soil survey operations in the four Wisconsin counties indicated in Figure 4, soil scientists working in the cooperative soil survey have described and analyzed soil profiles that included fragipan horizons. Observations were made of limitation of root growth by the fragipan (Figures 1 and 2) and, in early spring, of movement of water. Portions of this horizon that were experimentally exposed to weather for one to two years slaked differentially. Resistant gravel-size fragments were collected for analysis from the slaked mass. Bulk density of representative soil peds was determined by the method of coating dry peds with paraffin. Porosity was calculated from bulk density and an assumed specific gravity of mineral matter of 2.65. Estimates of root distribution were made by weighing oven-dried roots by horizons from columns of soil 6 inches (15 cm) in diameter. Particle size distribution analyses were made by the hydrometer method (Day, 1956). Meaningful calculations of pedogenetic gains and losses of soil plasma by the index mineral method were found to be impossible, because of

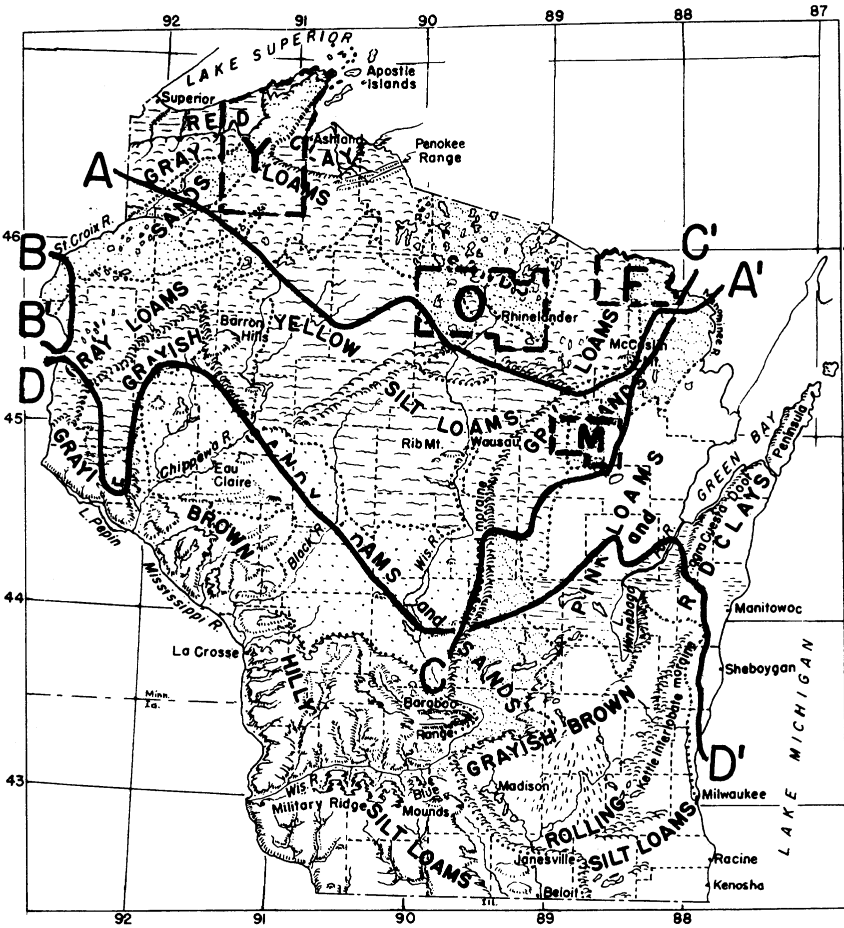

FIGURE 4. Index map of Wisconsin showing four generalized boundaries: (A–A′), the southern limit of most strongly developed fragipans in Wisconsin; (B–B′), the eastern limit of carbonate-rich glacial drift of the Grantsburg glacial lobe; (C–C′), the western limit of carbonate-rich glacial drift of the Green Bay glacial lobe (after Thwaites, 1943); (D–D′), the southern limit of the zone of bisequal soils (in part after Carroll, 1959 and Beaver, 1963). The four counties in which fragipans have been studied by one or both of the authors are labeled: F, Florence; M, Menominee; O, Oneida; Y, Bayfield.

the heterogeneity of the Pleistocene deposits from which the soils formed. Contents of reductant-soluble iron oxide and Na_2CO_3-extractable silica and alumina, cation exchange capacity, exchangeable cations, contents of total carbon and nitrogen, and X-ray diffraction studies of clay minerals were made by methods outlined by Jackson (1956, 1958). Soil reaction, and contents of available nitrogen, available phosphorus and available potassium were determined by the State Soil Testing Laboratory, and in the Cooperative Subsoil Fertility Project at the University of Wisconsin, Madison. Thin sections were prepared by the method of Buol and Fadness (1961) and studied with the petrographic microscope.

Results and Discussion

The fragipan is recognized in the field by its compactness in place and brittleness in hand specimen. The search in the laboratory for other properties that definitely differentiate this pan from other soil horizons in the same soil profiles has been rather unsuccessful, here (Table 1) as in other laboratories. The fragipan in northeastern Wisconsin is a nonuniformly compacted, texturally heterogeneous, slightly mottled, platy and vesicular horizon that formed in a cold acid subsoil layer with sparse root growth. Since its formation, the pan has been little disturbed by plant roots and animals. Mottles are few, faint to distinct, and medium, reddish brown to yellowish red in moist color (5YR 4/4–5/8). The textural range of the fragipan (Figure 3 and Table 1) is from sandy loam to silt loam, which is in the middle of the wider range from loamy sand to silty clay loam reported from other parts of the United States (Olson, 1962). Heterogeneity of particle size and a low content of clay apparently favor the compaction necessary to form a fragipan of bulk density between 1.42 and 1.97 (Table 1). Weather-resistant gravel-size (2 to 3 cm in diameter) fragments from the IIB′2x horizon of a Superior sandy loam contained 10% clay, 39% silt and 51% sand as compared with 24% clay, 45% silt and 31% sand in the bulk sample from the same horizon. The relatively low content of clay and its peculiar distribution in the fragipan allow for the essential bridges and menisci of clay at many points of contact between silt and sand grains. The amount of clay present is not sufficient to cause noticeable disruption of the pan by expansion and contraction during wet–dry cycles. Platy structure and vesicularity may be inherited from the condition of the horizon before it consolidated to the point that small plant roots could no longer invade the prisms, blocks and coarse plates. Platiness and vesicularity have been observed in the field and laboratory to be formed by freeze–thaw cycles (Olson, 1962). Some voids in the A′2x horizon may have resulted also from eluviation of clay from it during a pre-fragipan stage of development by percolating water and possibly also by advancing freezing fronts. Fragments of clay films deposited by running water on ped surfaces were observed in thin sections of fragipan horizons. These are presumably remnants, particularly in the upper fragipan, of formerly more

TABLE 1. RANGES OF SOME PROPERTIES OF SOIL HORIZONS FROM SEVERAL NORTHEASTERN WISCONSIN SILTY SOIL PROFILES[1] WITH FRAGIPANS.

Horizons and Range in Depth cm	Bulk Density	Pore Space	Root Distribution[3]	Particle Size Distribution								Avail. P	Avail. K
					Silt			Sand					
				Clay	Fine	Medium	Coarse	Very Fine	Fine	Medium	Coarse and Very Coarse		
		%	%	%	%	%	%	%	%	%	%	#/A	#/A
O2	—	—	92–139	—	—	—	—	—	—	—	—	—	—
A1 and A2 0–15	1.02–1.40	47–57	1–314	7–16	2–12	11–45	15–36	6–21	2–31	2–12	0–9	4–100	35–480
B2hir[2] 7–30	1.07–1.72	35–59	0.3–5	7–18	4–9	9–33	11–35	13–28	1–24	2–12	1–9	14– 48	65–140
A'x 25–45	1.42–1.97	26–44	0.3–3	7–13	2–11	6–33	8–39	2–24	1–26	1–12	1–16	4–168	45–180
B'x 30–100	1.54–1.86	30–40	0.1–4	5–24	2–21	5–31	8–39	7–31	1–55	1–22	1–23	1–160	75–215
C 65+	1.53–1.92	28–44	0.1–1	3–20	0–14	0–26	0–43	2–30	1–55	1–60	0–48	17–250	25–150

[1]Two Profiles each of Goodman, Stambaugh and Fence silt loams (Hole, Olson, Schmude and Milfred, 1962; Hole and Schmude, 1959), and one profile each of Norris silt loam (Milfred, Olson and Hole, 1967) and Brill silt loam, Iron River silt loam and Superior sandy loam (Olson, 1962).

[2]Bhir is the Podzol B that is dark with humus (h) and iron oxide (ir).

[3]gm of oven-dried roots per ft.^{2} X 1 in. thick, average per horizons.

Table 1 (continued).

Horizons	C	C.E.C.	Exchangeable Cations				Base Saturation	Na_2CO_3 Extractable SiO_2	Na_2CO_3 Extractable Al_2O_3	Reductant-Soluble Fe_2O_3	pH
			Ca	Mg	K	Na					
	%	me/100g			me/100g		%	%	%	%	
A.......	1.2–15.6	6–75	1.0–29.5	0.2–13.5	0.1–8.0	0.1–0.5	23–67	0.03–0.38	tr–0.03	0.2–1.6	4.4–6.5
Bhir....	1.0–5.3	7–18	0.8–2.6	Tr–0.4	0.1–0.2	0.1–0.2	8–50	0.1 –0.05	tr–0.04	1.0–2.0	4.3–6.2
A'x.....	0.3–1.5	4–10	0.8–3.4	0.1–1.3	0.1–0.3	0.1–0.2	19–49	0.02–0.06	0.02–0.04	0.9–1.7	4.9–5.7
B'x.....	0.1–1.1	4–12	0.7–4.3	0.4–3.2	0.1–0.3	0.1–0.2	35–67	0.02–0.07	0.01–0.03	1.3–2.7	4.5–6.5
C.......	Tr–0.3	2–15	0.7–6.0	0.1–T.6	0.1–0.2	0.1–0.2	30–67	0.04–0.08	tr–0.06	0.3–2.0	4.8–6.1

extensive clay films. Eluviation of some clay from the lower sequum, particularly in the A′2 horizon, and distribution of remaining clay as "bridges" between skeletal grains improved the texture and fabric with respect to pan formation, in many of the soils studied. No definite evidence was found of chemical cementation of the fragipan by silica, alumina or iron oxide. Laboratory experiments suggested that clay and possibly iron oxide are cementing materials. The wide dissemination of a cementing material through the horizon would seem to be a prerequisite to brittleness.

Proposed Genetic Sequence

It is possible that the first major horizonation to develop in these soils was the slight textural differentiation of the lower sequum into A′2 and B′2 horizons, the first of which included the zone now occupied by the upper sequum. This differentiation took place during a moist period and may have reached a climax when the lower sequum had settled and become compact enough to be somewhat impervious to eluviation and root penetration, except along polygonal shrinkage cracks. These may have formed by desiccation during the relatively warm–dry period of 6,000 to 4,000 years ago (Smith, 1965), and may have been enlarged by eluviation since then. The upper Podzol (Spodosol) sequum may represent a state of equilibrium with the northern hardwood–hemlock forest during the last two thousand years. Disturbance of the forest by lumbering during the past century has apparently weakened the Podzol sequum at many sites (Milfred et al., 1967).

It is proposed that the fragipan is most extensive in northeastern Wisconsin because (1) textural heterogeneity of initial drift materials was commonly favorable for development of compact horizons, (2) the maximum effective precipitation has been in the northeast, where the resulting notable percolation of water through the soil in the early stages of pedogenesis and particularly after periods of drouth hastened eluviation of fines and settling of the subsoil into a compact state, and (3) the subsoil was colder than in more southern landscapes and therefore had unfavorable temperatures for root growth and related faunal activity both before and after compaction of the fragipan.

Tree-Throw and Perching of Water Related to the Fragipan

The mottling in the fragipan suggests that an early stage of development of perched gley, known in Germany as pseudogley (Mückenhausen, 1956) has been reached. While digging trenches in these soils in early spring, the writers have observed seepage of water over the surface of the fragipan into the trenches. In studies of the under surfaces of root masses of wind-thrown trees, particularly of large maple trees *(Acer saccharum)*, we have noted extensions below the horizontal roots (Figures 1 and 2) of a polygonal arrangement of vertical sheets of small roots delineating cells about 10 cm deep and 10 cm across. This diameter matches the average diameter of the polygons observed in the upper part of the B′2x horizon (Figure 2).

The frequency of tree-throw on forest soils of northern Wisconsin, as evidenced by the presence of about 140 cradle-knolls per acre in some areas (Milfred, et al., 1967), is attributable to the restriction of root growth caused in part by the fragipan, and in considerable part by the cool temperatures prevailing in the subsoil.

The perching of water over the fragipan creates reducing conditions in saturated horizons, and can be expected to increase surface runoff in wet seasons, particularly in early spring. Seepage water moves laterally downslope over the pan, and has been observed to initiate slumping of subsoils in highway cuts. Some seepage water also has moved vertically down through prism joints and a few porous inclusions in the fragipan.

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A COMPARISON OF RED CLAY GLACIO-LACUSTRINE SEDIMENTS IN NORTHERN AND EASTERN WISCONSIN[1]

G. W. Petersen, G. B. Lee and G. Chesters

ABSTRACT

Selected red, clayey, glacio-lacustrine sediments from the southern shores of Lake Superior in northern Wisconsin and from the Fox and Wolf river drainage basins in eastern Wisconsin were compared because field observations suggested that a similarity exists between these sediments, and also between the soils formed from them.

Close similarities were found in the particle size distribution of the carbonate-free clay fractions, and in the types and amounts of mineral species in each clay fraction, supporting the theory that the finer fractions of the sediments in both areas were derived from a common source and were deposited in a similar manner. The source of the noncarbonate clay fraction is most likely the Lake Superior basin which is believed to have discharged fine-grained sediments into the Lake Michigan basin during the retreat of Cary ice. Differences between the sand, silt, carbonate, iron oxide and feldspar contents of the sediments from the two areas are likely due to the influence of local bedrock and earlier drift. The lower carbonate content of deposits in northern Wisconsin may account for the greater leaching depth and degree of podzolization observed in these soils.

INTRODUCTION

Present Investigation

Deposits of red, clayey, glacio-lacustrine sediments, interjacent with Valders till and other drift deposits, are found along the Fox and Wolf River Valleys of eastern Wisconsin and to a lesser extent

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along the western shores of Lake Michigan. Similar deposits are located along the shores of Lake Superior in Minnesota, Wisconsin and Michigan (Fig. 1).

The calcareous nature of these deposits and their similarity in color and texture suggests that their fine fractions were derived from a common source, namely, the Lake Superior Basin (Murray,

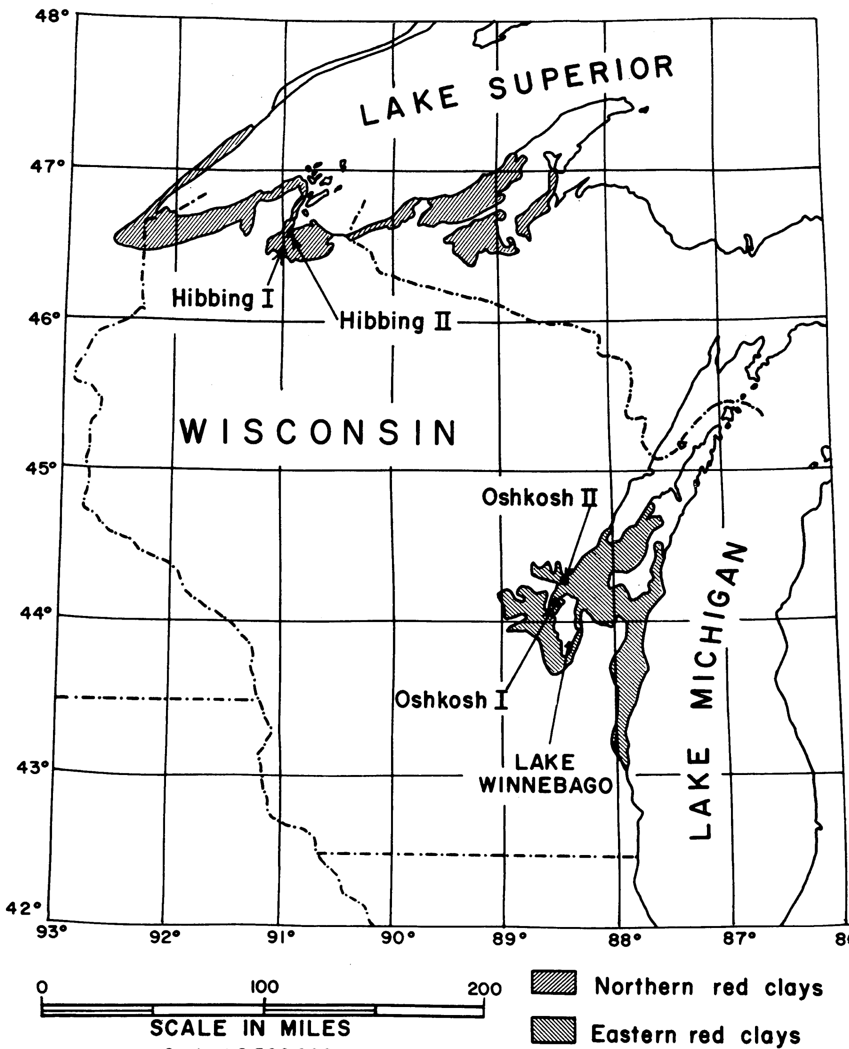

FIGURE 1. Sample sites and clayey drift areas. Glacial till and glacio-lacustrine deposits are not differentiated.

1953). However, detailed analyses of the mineralogy and the types and amounts of carbonates and free iron oxides in the silt and clay fractions have not been reported. Because of the pedological implications of these characteristics, and their influence on the genesis and classification of soils formed from these deposits, an investigation of fine-textured, glacio-lacustrine sediments from eastern and northern Wisconsin was undertaken.

Previous Investigation

The most recent glacial till deposits in eastern Wisconsin (designated "Valders" by Thwaites, 1943 and more recently "Valderan" by Frye and Willman, 1960) consist mainly of calcareous, reddish-brown clay to clay loam or loam till (Lee, *et al.*, 1962). Valders till differs from the Cary till in this area in having a reddish-brown rather than a yellowish-brown color; in part of the region the Valders till has a much higher clay content. The interval of deglaciation between Cary and Valders advances is marked by the Two Creeks Forest Bed, whose radiocarbon age is 11,850 ± 100 years before present (Broecker and Ferrand, 1963).

Alden (1918) described the red drift of eastern Wisconsin as a dense calcareous clay, the bulk of which was silt and clay of such fineness that it could have been transported long distances in suspension. The high concentration of silt and clay has led several investigators to suggest that the red sediments are lacustrine deposits (Chamberlin, 1873–77, p. 214–228), or glacial till deposits that were derived from lake clays (Alden, 1918; Thwaites, 1943; Murray, 1953). These red sediments may also have been partially derived from the earlier Cary deposits that were eroded and redeposited by the Valders ice sheet (Murray, 1953). However, the high silt and clay content and red coloration, attributed to the presence of hematite both as discrete particles and particle coatings (Murray, 1953), suggests that these red sediments were derived from the red sandstones and shales of the Lake Superior region (Alden, 1918). Murray (1953) suggested that as Cary ice retreated silts and clays from the Superior basin (Glacial Lake Keweenaw) were siphoned into the Lake Michigan basin (Early Lake Chicago) and the Green Bay lowlands. With the advance of Valders ice the silts and clays were eroded, mixed with other materials, transported to surrounding uplands and deposited as glacial till. As Valders ice retreated, melt waters in front of the ice formed large glacial lakes into which silts and clays were deposited (Thwaites, 1943; Murray, 1953). Thus the drift in eastern Wisconsin includes glacial till and glacio-lacustrine deposits, as well as glacio-fluvial and eolian sediments. Many of the red clay deposits in northern Wisconsin are also of glacio-lacustrine origin (Ableiter and Hole,

1961) and probably were deposited in glacial Lake Duluth following the ice retreat in that region (Leverett, 1929; Murray, 1953).

Experimental Procedures

Source of Samples

Reddish-brown, calcareous, glacio-lacustrine clays (Fig. 1) are the parent materials of certain "red clay" soils in northern and eastern Wisconsin and adjacent states. The topography of these soils is level or slightly undulating. In contrast to the red clay soils of the eastern part of the state, those of the north are leached to a greater depth and are more strongly podzolized. In both areas red clay lacustrine soils may be interjacent with soils formed in clayey glacial till, glacio-fluvial sediments, beach deposits or dunes.

The two pairs of sediment samples chosen for detailed investigations are described in Table 1. One pair (designated Oshkosh I and II) was selected to represent the glacio-lacustrine parent materials of the Oshkosh soils of eastern Wisconsin (Lee *et al.*, 1962). The other pair (designated Hibbing I and II) was selected on the basis of field observations and other preliminary investigations to represent parent materials of Hibbing, Ontonagon and related soils in northern Wisconsin. All samples were obtained below soil sola and appeared to be unaffected by pedalogic weathering.

Analytical Techniques

The samples were dispersed and their sand (2,000 to 50 μ), silt (50 to 2 μ) and clay ($< 2\mu$) contents determined as outlined by Day (1956).

Table 1. Location and Description of Sample Sites

Sample	Location	Depth, In.	Color*	Texture	Elevation, Ft.
Hibbing I	SE¼ SW¼, sec. 31, T. 47 N., R. 5 W., Bayfield County	32 to 44	2.5YR 4/4	silty clay	675
Hibbing II	NW¼ NW¼, sec. 11, T. 47 N., R. 5 W., Bayfield County	30 to 48	2.5YR 4/4	clay	900
Oshkosh I	NW¼ SW¼, sec. 33, T. 20 N., R. 17 E., Winnebago County	35 to 51	5YR 5/3	clay	750
Oshkosh II	SW¼ SW¼, sec. 18, T. 22 N., R. 17 E., Outagamie County	19 to 45	5YR 5/3	clay	790

*Munsell color system.

Following sample dispersion, the sand fraction was separated by filtration through a U. S. Standard 300 mesh sieve. Separation of the silts and clays was achieved by sedimentation (Janke, Ph.D. Thesis, Univ. of Wisconsin, 1962) ; in this method carbonates and iron oxides were not removed prior to fractionation. The clay fractions were further separated into coarse (2.0 to 0.2μ), medium (0.2 to 0.08μ) and fine (<0.08μ) particle size ranges (Kittrick and Hope, 1963), and leached of salts with water and acetone.

The carbonate percentage of each of the sand, silt and clay fractions was determined by treatment with excess acid and the quantity of acid required to neutralize the carbonates was determined by titration (USDA Handbook 60, 1954). Because this procedure does not differentiate between carbonates, carbonate contents were expressed as $CaCO_3$.

Iron oxides were extracted from the separated fractions by a citrate-dithionite technique (Aguilera and Jackson, 1953) and determined by the colorimetric orthophenanthroline procedure (Jackson, 1958, p. 389–390).

Clay suspensions, dried on glass slides to obtain parallel-orientation (Jackson, 1956, p. 183–188), were analyzed on a North American Philips X-ray diffractometer[2] equipped with copper target and nickel filter. After removal of iron oxides, clay fractions were magnesium saturated and solvated with 10 percent aqueous glycerol, to expand the d-spacing of montmorillonite to 18 Å. This was followed by potassium saturation to collapse montmorillonite to 14.2 Å and some of the vermiculite from 14.2 to 10 Å. The terms montmorillonite and vermiculite, as used here, refer to specific mineral species as differentiated by their lattice swelling characteristics. Following potassium saturation, the samples received successive heat treatments at 350 to 540°C. Heating the samples to 350°C collapsed any remaining vermiculite to 10 Å. Chlorite was identified by a 14.2 Å d-spacing that persisted through each of the heat treatments and was enhanced by the 540°C treatment. Mica was identified by a 10 and 5 Å d-spacing that persisted throughout the heat treatments. Interstratified clay minerals, which exhibit average d-spacings of 24 to 32 Å rather than a spectrum of sharply-defined peaks diagnostic of a mixture of discrete mineral species, collapsed to 10 to 14 Å on heating. Quartz was indicated by 4.1 and 3.35 Å d-spacings that persisted throughout the heat treatments.

Because silt fractions contain only small amounts of expansible layer silicates, no attempt was made to expand them prior to X-ray diffraction analysis, nor were heat treatments deemed necessary. The silt fractions (50 to 2μ) were ground to <5μ and slides were

[2] The authors express their gratitude to Dr. S. W. Bailey of the University of Wisconsin Geology Department for the use of X-ray diffraction facilities.

prepared by aqueous glycerol solvation. Feldspars were identified by their 3.24 and 3.18 Å diffraction peaks; carbonates were distinguished by the 3.03 Å d-spacing for calcite and 2.88 Å for dolomite.

INTERPRETATION

Investigations were initiated to test the hypothesis that the red, clayey sediments of northern and eastern Wisconsin are derived from a common source (Murray, 1953). These red sediments are probably transported silt and clay-sized fragments from red sandstone and shales of the Lake Superior region (Alden, 1918). The sediments should not be identical, however, because of the influences of local bedrock and older drift in supplying materials like carbonates and feldspars to the sediments.

Evidence that the samples collected at the Hibbing and Oshkosh sites (Fig. 1) are typical of glacio-lacustrine deposits follows: Field estimates of texture indicate that the parent materials of Hibbing and related soils such as Ontonagon and Pickford have a high content of clay and a relatively low sand content. Analysis of a C2 horizon of an Ontonagon soil from Ontonagon County, Michigan, (Soil Survey Laboratory Staff, 1952) showed this material to contain 66.5 percent clay, 21.3 percent silt and 12.2 percent sand. Analysis of the C2 horizon of a less well drained soil formed from similar deposits (Pickford), also in Ontonagon County, Michigan (Soil Survey Laboratory Staff, 1952), showed it to contain 66.8 percent clay, 28.8 percent silt, and 4.4 percent sand. Carbonate content of this soil was 13 percent. Field observations made in the Valders drift region of eastern Wisconsin indicate that the parent materials of Oshkosh soils typically consist of reddish-colored calcareous, clays or silty clays. Laboratory analysis of 28 samples (Lee, *et al.*, 1962) showed that 26 of them ranged in clay content from 40 to 82 percent and that half of them contained in excess of 60 percent clay. All samples contained less than 5 percent sand. Average carbonate content for 26 of the samples (Janke, Ph.D. Thesis, University of Wisconsin, 1962) was 27.5 percent; most samples ranged from 20 to 30 percent.

The particle size distribution of samples selected for detailed study are shown in Tables 2 and 3. When these samples are placed in the USDA Textural Classification (Soil Survey Staff p. 205–213), the Hibbing I sample is placed in the silty clay textural class because of its relatively high silt content; the other three samples are classified as clays. Each of the samples is characterized by a high clay and low sand content, although the Hibbing II sediment contains appreciably more sand than the other three sediments. The Oshkosh samples contain about one and a half times as much coarse clay (2 to 0.2μ) as the Hibbing, while the contents of medium

(0.2 to 0.08μ) and fine clay (<0.08μ) were very similar in all samples when determined as a percentage of the intact sediment (Table 3). The similarities in particle size distribution are even more striking when expressed as percentages of the total clay fraction; the Hibbing samples contain slightly less coarse clay, and slightly more fine clay than the Oshkosh samples. Thus the hypothesis that the northern and eastern red clay sediments of Wisconsin are derived from a common source, but are not identical because of the influence of local source materials is feasible and will be tested more rigorously in this discussion.

The carbonate content of all fractions except the fine clay (Table 4) show that the Oshkosh samples are generally more calcareous than the Hibbing. Expressed as a percentage of the particular fraction, the coarse clays and silts of the Oshkosh sediments contain in excess of 30 percent carbonate. The carbonate contents of the medium and fine clay fractions are much lower than those of the silts and coarse clays. A possible explanation of this phenomenon is the increased solubility of the finer-sized carbonates resulting from their greater surface area. Increased solubility of carbonates

TABLE 2. PARTICLE SIZE DISTRIBUTION OF SEDIMENT SAMPLES

SAMPLE	SAND (2000 TO 50 μ)	SILT (50 TO 2 μ)	CLAY (<2 μ)
	%	%	%
Hibbing I	3.2	41.8	55.0
Hibbing II	12.4	32.6	55.0
Oshkosh I	0.2	28.8	70.9
Oshkosh II	3.0	22.0	74.9

TABLE 3. PARTICLE SIZE DISTRIBUTION OF CLAY FRACTIONS OF SEDIMENT SAMPLES

SAMPLE	COARSE CLAY 2.0 TO 0.2 μ)		MEDIUM CLAY (0.2 TO 0.08 μ)		FINE CLAY (<0.08 μ)	
	A	B	A	B	A	B
	%	%	%	%	%	%
Hibbing I	32.4	58.9	14.0	25.5	8.6	15.6
Hibbing II	32.0	58.2	14.3	26.0	8.7	15.8
Oshkosh I	45.3	63.8	17.9	25.2	7.7	10.9
Oshkosh II	48.3	64.5	16.8	22.4	9.8	13.1

A Expressed as a percentage of the total sediment sample.
B Expressed as a percentage of the total clay fraction.

in cold glacial lake waters also causes a more rapid dissolution of the finer-sized carbonate particles.

The fact that the parent sediments of Hibbing soils contain less than half as much carbonate as the sediments from which Oshkosh soils are formed (Table 5) may have pedological significance. Field observations of these soils indicate that Hibbing soils are leached (of carbonates) to greater depths and exhibit evidences of podzolization, such as albic tonguing (stripping of oxide coatings from soil particles) to a greater degree than do Oshkosh soils.

The carbonate data were used to determine if the particle-size distribution of the sediments from the two areas are more nearly alike when determined on a carbonate-free basis. The data in Table 5 shows that the noncalcareous clay ($<2\mu$) contents of the sediments from the two areas are almost identical. Also the distribution of clays (Table 6) into the three particle-size ranges are very similar: 56 $\pm$ 1 percent coarse clay, 28 $\pm$ 2 percent medium clay and 15.5 $\pm$ 1.5 percent fine clay expressed on the basis of the total clay fraction. The elimination of carbonate from the particle-size distribution improves greatly the similarity in distribution of clay

TABLE 4. CONTENT OF CARBONATES (AS $CaCO_3$) IN SEDIMENT SAMPLES

SAMPLE	CARBONATE (AS $CaCO_3$) IN									
	Sand		Silt		Coarse Clay		Medium Clay		Fine Clay	
	A	B	A	B	A	B	A	B	A	B
	%	%	%	%	%	%	%	%	%	%
Hibbing I.....	0.5	15.4	8.0	19.2	4.3	13.3	0.5	3.5	0.1	1.7
Hibbing II....	2.4	19.1	6.2	18.9	3.2	10.1	0.6	4.0	<0.1	0.2
Oshkosh I.....	0.1	52.5	9.8	33.9	16.2	35.8	2.2	12.6	<0.1	0.8
Oshkosh II....	2.4	78.5	8.2	37.3	17.5	36.2	1.6	9.3	0.5	4.8

A $CaCO_3$ expressed as a percentage of the total sediment sample.
B $CaCO_3$ expressed as a percentage of the particular size fraction.

TABLE 5. CONTENTS OF NONCALCAREOUS SAND, SILT AND CLAY AND CARBONATE (AS $CaCO_3$) IN SEDIMENT SAMPLES

SAMPLE	SAND	SILT	CLAY	$CaCo_3$
	%	%	%	%
Hibbing I................	2.7	33.8	50.1	13.4
Hibbing II...............	10.0	26.4	51.1	12.5
Oshkosh I................	0.1	19.0	52.5	28.4
Oshkosh II...............	0.6	13.8	55.4	30.2

size particles for the two areas (compare Table 2 with 5 and 3 with 6).

The iron oxide percentages of the sediment separates are shown in Table 7. When iron oxides within individual size fractions are expressed as percentages of the total sediment sample, these percentages are partially a reflection of the relative sample weights of each fraction within that sample. Therefore, it is also desirable to examine the iron oxide percentages within a particular size fraction when making comparisons between samples. Expressed as a percentage of the total sediment, the iron oxide percentages found in the sand fraction are extremely low; however, the Oshkosh I sample is 9% iron oxide probably in the form of concretions. The iron oxide percentages of the silt, coarse clay and medium clay fractions of the Hibbing sediments are somewhat higher than those

TABLE 6. PARTICLE SIZE DISTRIBUTION OF CLAY FRACTIONS OF SEDIMENT SAMPLES EXPRESSED ON A CARBONATE*-FREE BASIS

Sample	Coarse Clay		Medium Clay		Fine Clay	
	A	B	A	B	A	B
	%	%	%	%	%	%
Hibbing I	28.1	56.1	13.5	26.9	8.5	16.9
Hibbing II	28.8	56.4	13.7	26.8	8.6	16.8
Oshkosh I	29.1	55.5	15.7	29.9	7.6	14.5
Oshkosh II	30.8	55.6	15.2	27.5	9.3	16.8

*All carbonate expressed as $CaCO_3$.
A Expressed as a percentage of the total sediment sample.
B Expressed as a percentage of the total clay fraction.

TABLE 7. CONTENT OF IRON (AS Fe_2O_3) IN SEDIMENT SAMPLES

Sample	Iron (as Fe_2O_3) in									
	Sand		Silt		Coarse Clay		Medium Clay		Fine Clay	
	A	B	A	B	A	B	A	B	A	B
	%	%	%	%	%	%	%	%	%	%
Hibbing I	0.02	0.78	0.63	1.51	0.60	2.14	0.40	2.96	0.03	0.39
Hibbing II	0.07	0.53	0.38	1.16	0.92	3.20	0.44	3.24	0.03	0.39
Oshkosh I	0.02	8.87	0.24	0.84	0.38	1.31	0.34	2.17	0.04	0.46
Oshkosh II	0.05	1.63	0.23	1.06	0.39	1.26	0.33	2.18	0.03	0.37

A Fe_2O_3 expressed as a percentage of the total sediment sample.
B Fe_2O_3 expressed as a percentage of the particular size fraction.

TABLE 8. CONTENT OF IRON (AS Fe_2O_3) IN CARBONATE*-FREE SEDIMENT SAMPLES

SAMPLE	IRON (AS Fe_2O_3) IN									
	Sand		Silt		Coarse Clay		Medium Clay		Fine Clay	
	A	B	A	B	A	B	A	B	A	B
	%	%	%	%	%	%	%	%	%	%
Hibbing I..	0.02	0.92	0.68	1.87	0.63	2.47	0.40	3.06	0.03	0.40
Hibbing II.	0.07	0.66	0.41	1.43	0.95	3.55	0.44	3.37	0.03	0.39
Oshkosh I..	0.02	18.67	0.27	1.27	0.45	2.04	0.35	2.48	0.04	0.46
Oshkosh II.	0.05	7.58	0.25	1.69	0.47	1.97	0.34	2.40	0.03	0.39

*All carbonates expressed as $CaCO_3$.
A Fe_2O_3 expressed as a percentage of the total sediment sample.
B Fe_2O_3 expressed as a percentage of the particular size fraction.

of the Oshkosh sediments; the fine clay fractions are very similar. When the iron oxide percentages are calculated on a carbonate free basis (Table 8), the iron concretions in the sand fractions of the Oshkosh sediments become more apparent and slightly more iron oxides are present in the coarse and medium clay fractions of the Hibbing samples, which may be attributed to their closer proximity to the iron source of these red sediments.

X-ray diffractograms (summarized in Table 9) indicated similar clay minerals in the Oshkosh and Hibbing sediment samples in each of the clay fractions. These similarities are particularly evident in the fine and medium clay fractions. The fine clay fractions of all the sediment samples consist predominately of montmorillonite with some interstratified material and small amounts of mica, whereas the medium clays consist of montmorillonite, with measurable amounts of mica, vermiculite, chlorite and some interstratified materials. Both the Hibbing and Oshkosh coarse clay fractions are comprised of mica, vermiculite, chlorite, montmorillonite, interstratified materials, quartz, feldspars, calcite and dolomite. Although some differences exist in diffraction peak intensities between the same size fractions of different samples, this is not necessarily indicative of differences in quantitative mineralogy since peak intensities are controlled by crystal orientation and degree of crystallinity as well as concentration.

Diffractograms of silt fractions showed them to consist largely of quartz, feldspars, calcite and dolomite, with some chlorite and mica. Hibbing silt fractions showed slightly more intense feldspar

TABLE 9. SEMI-QUANTITATIVE MINERAL COMPOSITIONS OF CLAY AND SILT FRACTIONS OF SEDIMENTS

Fraction	Sample	Mineral Species							
		Mt*	Vt	Mica	Chl	Int	Quartz	Flds	Carb
Fine Clays	Hibbing I	+++	—	tr	—	++	—	—	—
	Hibbing II	+++	—	tr	—	++	—	—	—
	Oshkosh I	+++	—	tr	—	++	—	—	—
	Oshkosh II	+++	—	tr	—	++	—	—	—
Medium Clays	Hibbing I	++	++	+	+	++	—	—	—
	Hibbing II	+++	+	+	+	++	—	—	—
	Oshkosh I	+++	+	+	+	++	—	—	—
	Oshkosh II	+++	+	+	+	++	—	—	—
Coarse Clays	Hibbing I	+	++	++	+	+	++	tr	+
	Hibbing II	+	++	++	tr	++	++	tr	+
	Oshkosh I	tr	+	++	+	+	+	tr	++
	Oshkosh II	+	+	++	+	+	+	tr	++
Total Silts	Hibbing I	—	—	+	tr	—	++++	+	+
	Hibbing II	—	—	+	+	—	++++	+	+
	Oshkosh I	—	—	+	+	—	+++	+	++
	Oshkosh II	—	—	tr	tr	—	+++	+	++

*Mt = Montmorillonite; Vt = Vermiculite; Chl = Chlorite; Int = Interstratified; Flds = Feldspars; Carb = Carbonates.
— = Undetected; tr = Trace; + = Low; ++ = Moderate; +++ = Abundant; ++++ = Dominant.

peaks and the Oshkosh samples more intense carbonate peaks, which is likely indicative of the effect of local drift and bedrock.

Because calcite is dissolved during the citrate-dithionite pretreatment of clay samples to remove free iron oxides (Petersen *et al.*, 1966), water smears of untreated clay fractions were analyzed by X-ray diffraction. Insufficient carbonates were present in the fine and medium clays to show characteristic diffraction peaks of either dolomite or calcite. However, water smears of the coarse clay fractions showed characteristic peaks of both minerals, being more intense in the Oshkosh samples. This corresponds to the intensities of carbonate peaks in the various silt fractions and supplies further evidence for the local addition of carbonates.

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LIGHT PENETRATION STUDIES IN THE MILWAUKEE HARBOR AREA OF LAKE MICHIGAN[1]

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INTRODUCTION

Biologists have long recognized the importance of light in natural waters and its relationship to biological productivity. A number of papers have been published bearing on light penetration, such as that of Birge and Juday (1929) which concerned submarine illumination in a number of Wisconsin lakes, the work of Sauberer (1939) on several Alpine lakes, and Strickland's (1958) review of solar radiation in the oceans. Of particular interest in this study was the work of Chandler (1942) on light penetration and its relation to turbidity in Lake Erie, as well as the studies by Beeton (1958, 1962) on light transmission in the Great Lakes.

Five stations were visited in this investigation which were located in Lake Michigan, near the Milwaukee harbor (Fig. 1). It is at this point that the Milwaukee River empties into Lake Michigan. Just before the river enters the lake, its waters are joined by the Kinnickinnic and Menomonee Rivers. All three flow through the highly industrialized section of southeastern Wisconsin. By the time their waters reach Lake Michigan, they have been subjected to a wide variety of influences from farms, cities and industries.

The purpose of this study was to discover the extent to which the highly turbid waters of the Milwaukee River influences light pentration in nearby Lake Michigan and to interpret the relationship of the Secchi disc determinations to photometer measurements.

EQUIPMENT AND METHODS

Light penetration measurements were made with a submarine photometer, number 268 WA, from the G. M. Manufacturing and Instrument Corporation. Light intensity was recorded in microamperes as registered on the microameter in the boat and the microameter readings were converted to footcandles. The photometer was calibrated by the Electrical Engineering Department of the Univ-

[1] Contribution No. 2, Center for Great Lakes Studies, University of Wisconsin—Milwaukee.

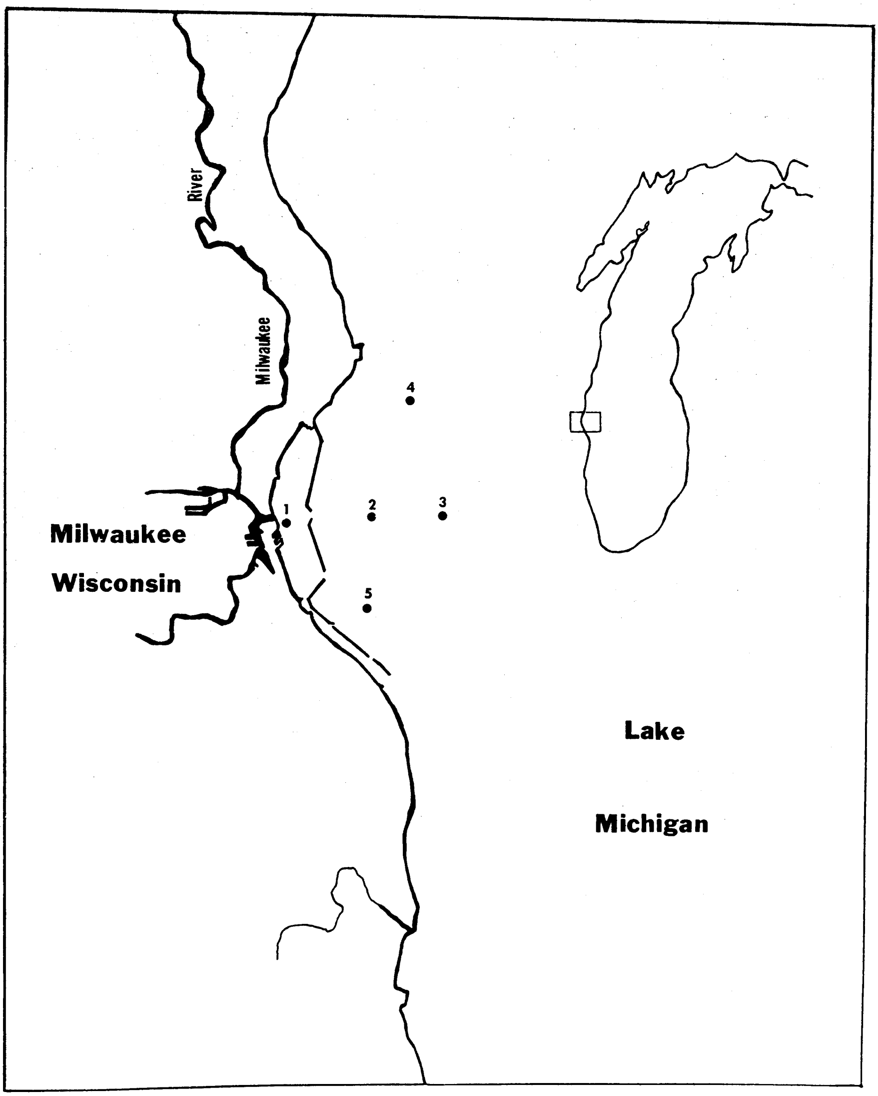

FIGURE 1. Lake Michigan at Milwaukee, Wisconsin showing the location of the principal stations.

ersity of Wisconsin using an incandescent tungsten filament lamp. Paired surface and subsurface light intensity measurements were made at one meter depth increments at each station and the data presented are of total visible light.

A standard Secchi disc, with a diameter of 20 centimeters divided into black and white quadrants was used to measure transparency. The greatest depth in feet at which the Secchi disc was visible was determined and then the photometer was lowered to that depth and light intensity measured.

Five stations were established near the mouth of the Milwaukee River. An attempt was made to visit them at weekly intervals between June and November, 1965.

Station 1 was located inside the seawall at the mouth of the Milwaukee River (Fig. 1), where the depth of the water was 6 meters.

Stations 2 and 3 were located one and one-half and three miles from shore, east of the mouth of the Milwaukee River. The maximum depth at station 2 was 15 meters; at station 3, 24 meters. Most of the comparative data was obtained at these three stations.

Station 4 was located north of the harbor entrance, about two miles from shore and in water 17 meters deep.

Station 5 was located south of the harbor entrance, two miles from shore and in water 11 meters deep. Light penetration measurements made at stations 4 and 5 showed no significant differences from those taken at stations 2 and 3.

Except for some special studies on diurnal changes in light intensity, the data presented in this study were taken on fairly clear, calm days between the hours of 0800 and 1600.

Weather conditions made it impossible to obtain measurements as often as desired and prevented all stations from being visited at weekly intervals. Certain segments of the data were omitted which were incomplete or of questionable value.

Effect of River Water on Light Penetration

The amount of incident light penetrating to various depths is greatly reduced in the harbor as compared to that in Lake Michigan, one and one-half miles from shore (Fig. 2). In the harbor, penetration of one percent of the incident light to a depth greater than one meter occurred only in summer. Light penetration in the fall was drastically reduced. This is believed to be due in part to the angle of incident light falling on the surface of the water and in part to the greater turbidity of the water caused by wave action and heavy rainfall.

Light penetration to the 5 meter depth in the harbor is negligible (Table 1), whereas about 10 percent of the total visible light penetrates to that depth at station 2 (one and one-half miles from shore) and nearly 15 percent at station 3 (three miles from shore).

The transmission of incident light to a depth of 5 meters compares favorably with measurements reported by Beeton (1962) for another area of open Lake Michigan. He wrote that the percent transmission of various wave-lengths of light to the five meter depth fell approximately between 3.5 percent for the red and 25. percent for the green. In the present study, the penetration of total surface illumination ranged from about 7 to 19 percent (Table 1). Light transmission was 10 to 14 percent greater at station 2 in Lake Michigan during July and August than in western Lake Erie at the five meter depth during a comparable period (Chandler, 1942).

The curves at station 2 (Fig. 2) tend to be somewhat irregular, particularly in the fall of the year. This indicates that the column of water is not optically homogeneous throughtout and may be caused by concentrations of plankton at certain depths or to turbidity differences resulting from water movements.

The optical properties of waters can be described by vertical extinction coefficients *(K)*.

$K = 2.30 \ (\log I, \mathrm{h} - \log I \ (\mathrm{h} + 1))$

I, h and I (h + 1) = light intensity at depths h meters and (h + 1) meters. The 2.30 compensates for the use of base — 10 logarithms.

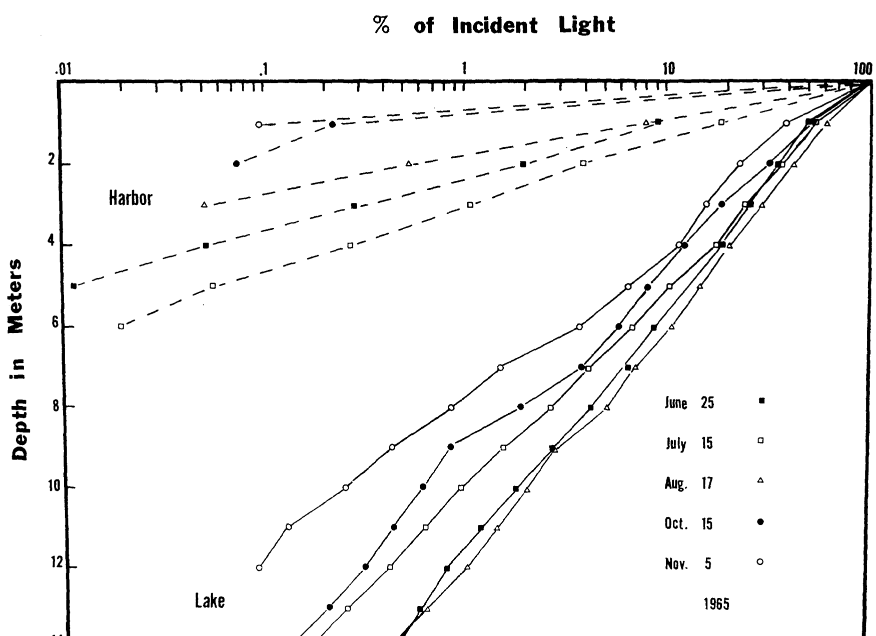

FIGURE 2. Relation between depth and total visible light expressed as a percentage of the light falling upon the surface of the water.

The coefficient indicates the rate of decrease of light as the depth increases. It is based on Lambert's Law and represents the percentage of original light held back at each depth.

The average vertical extinction coefficients for the curves in Figure 2 are given in Table 1. The extinction coefficients for the turbid waters of the Milwaukee harbor are particularly high, most of them surpassing those of western Lake Erie (Beeton, 1962), although not as high as Little Star Lake, Wisconsin (Whitney, 1938).

Light penetration in the waters of Lake Michigan at Milwaukee, Wisconsin (stations 2 and 3), as indicated from the vertical extinction coefficients, was less than those reported by Beeton (1962) for another area of Lake Michigan. These data (Table 1) suggest that the turbid waters from the Milwaukee River are influencing light transmission at one and one-half, and as far as three miles from shore.

TRANSPARENCY

Forty-nine Secchi disc measurements were compared with the photometer readings made at the same depths and are expressed as the percentage of surface light present at the depth of Secchi disc extinction. The 22 Secchi disc readings made in the harbor were consistently shallower than the 27 readings obtained from Lake Michigan proper (Fig. 3). However, the average percentage of surface light intensity at Secchi disc depth was 28.1 percent, in the harbor and 16.5 percent in Lake Michigan. Beeton (1958) reported 14.7 percent from Lake Huron, whereas Poole and Atkins (1929) reported 15.8 percent from the English Channel, and Clarke (1941) gave a value of 15.2 percent for the Atlantic Ocean.

This disparity between percentage of surface light intensity in the harbor and in Lake Michigan at Secchi disc extinction is undoubtably due to the highly turbid waters which are concentrated at the mouth of the Milwaukee River. Sauberer (1939) reported similar results from turbid waters. He obtained a greater percentage of surface light at the Secchi disc depth which he attributed to the suspended materials which caused diffusion and scattering of light. Chandler (1942) showed that in Lake Erie, Secchi disc measurements were inversely related to turbidity.

Several investigators (Riley, 1941; Halicki, 1958) have attempted to derive a value at which Secchi disc reading could be converted into the depth at which one percent of the surface light, as determined by photometer measurements, was present. This is termed the euphotic depth and Strickland (1958) reported that this should be about 2.5 times the Secchi disc depth. Riley (1941) used

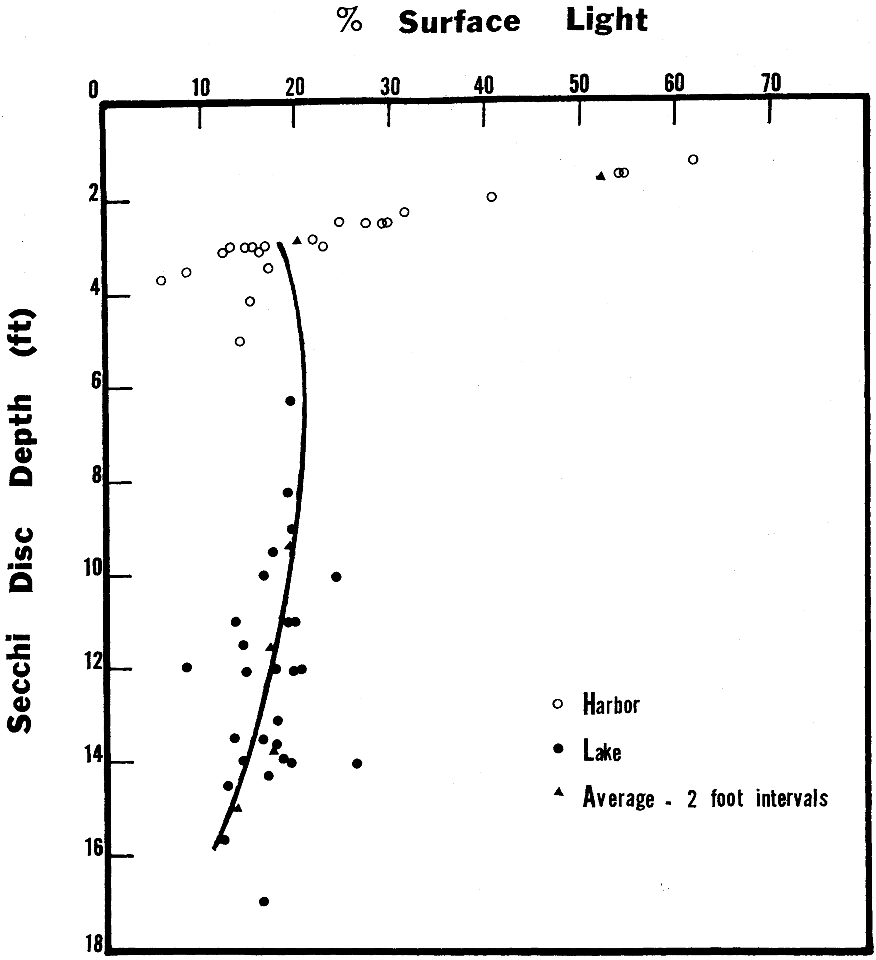

FIGURE 3. Relationships of Secchi disc readings to percentage transmission of surface light at that depth.

a conversion factor of 3 for the Atlantic Ocean and Halicki (1958) obtained 4.3 for western Lake Erie.

In this study, factors of 3.1 were obtained for Lake Michigan at stations 2 and 3 (Table 1). However, a value of 2.1 was obtained at station 1, in the harbor.

Several authors (Jones and Wills, 1956; Halicki, 1958; Vollenweider, 1960; Graham, 1966) have indicated that conversion factors and values derived from Secchi disc readings are applicable only within the specific body of water. These data suggest that the

TABLE 1. VERTICAL EXTINCTION COEFFICIENTS, PERCENTAGE OF INCIDENT LIGHT AT THE 5 METER DEPTH, SECCHI DISC READINGS, AND THE EUPHOTIC DEPTH FOR STATIONS 1, 2 AND 3 IN LAKE MICHIGAN AT MILWAUKEE, WISCONSIN

DATE	TIME	SKY	STATION 1				STATION 2				STATION 3			
			K	%	D	I	K	%	D	I	K	%	D	I
June 25, 1965	1030–1400	Clear	1.55	.051	.92	2.3	.37	9.92	3.40	11.5	.37	13.39	3.51	11.5
July 3, 1965	0920–1225	Clear	1.71	.008	.91	1.6	.38	8.67	3.10	11.5	.29	17.18	4.88	16.3
July 15, 1965	1230–1415	Clear	1.42	.055	1.07	3.0	.52	10.00	3.66	10.1	.47	10.60	3.66	9.8
July 27, 1965	0925–1430	Partly Cloudy	1.60	.007	.76	2.0	.44	8.76	3.66	10.3	.32	18.10	3.66	13.0
Aug. 11, 1965	0815–1040	Clear	1.97	.001	.46	1.0	.34	19.44	4.27	14.5	.25	16.67	5.18	17.5
Aug. 17, 1965	1000–1140	Partly Cloudy	2.13	.002	.76	1.5	.41	14.89	4.27	12.0	.56	10.97	3.05	8.5
Aug. 24, 1965	1010–1150	Clear	1.83	.002	.61	1.0	.39	9.15	3.66	12.4	.38	15.56	4.27	11.6
Oct. 15, 1965	0930–1500	Clear	3.60	.000	.24	0.3	.51	8.13	2.93	8.5	.33	13.16	—	11.0
Nov. 5, 1965	1300–1340	Clear	4.76	.000	.38	0.2	.57	7.01	2.90	7.8	—	—	—	—
Average......	....	....	2.29	.014	.68	1.4	.44	10.66	3.54	10.9	.37	14.45	4.03	12.4
I/D.........	....	....			2.10				3.09				3.07	

Symbols
K—vertical extinction coefficient.
%—percent of incident light reaching the 5 meter depth.
D—Secchi disc depth in meters.
I—euphotic depth, in meters, where one percent of the surface light is present.
I/D—conversion factor; the relationship between the Secchi disc reading and one percent of surface light.

harbor water and Lake Michigan water should be treated as distinct entities in so far as Secchi disc measurements are concerned.

SUMMARY

The higher percentage transmission of surface light intensity at Secchi disc depth (16.5 percent) as compared with previous reports for other bodies of water (Poole and Atkins, 1929; Clarke, 1941) and particularly with Lake Huron (Beeton, 1958) indicates that Milwaukee River water had some effect on light penetration in Lake Michigan, at least to a distance of one and one-half miles from shore.

Vertical extinction coefficients substantiate this conclusion. The percentage of surface light held back at each depth gradually increased, from .37, three miles from shore to .44, one and one-half miles from shore at Milwaukee, Wisconsin. The increase is even greater in the Milwaukee harbor where the average vertical extinction coefficient was 2.29. All three values are higher than that reported from another area of Lake Michigan (Beeton, 1962).

The percentage transmission of surface light intensity at Secchi disc depth is greater in turbid water.

Further studies are necessary in order to determine more precisely the integration of Milwaukee River water into the waters of Lake Michigan.

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THE MOVEMENT, RATE OF EXPLOITATION AND HOMING BEHAVIOR OF WALLEYES IN LAKE WINNEBAGO AND CONNECTING WATERS, WISCONSIN, AS DETERMINED BY TAGGING

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INTRODUCTION

The walleye, *Stizostedion vitreum vitreum* (Mitchill) in Lake Winnebago and connecting waters is the most sought-for sport fish especially during the spawning run in the rivers and during the ice fishing season on Lake Winnebago. Various studies concerning the walleye in these waters have been initiated to further contribute knowledge that will lead to improved management practices and provide for a sustained annual yield in the future. The tagging study is one phase of this comprehensive program.

The water areas involved in the study include Lake Winnebago and Big Lake Butte des Morts on the 107-mile-long Fox River and lakes Poygan and Winneconne on the 216-mile-long Wolf River. The Wolf River joins the Fox River in Big Lake Butte des Morts, 10 river miles above Lake Winnebago and then enters the lake as the Fox River at Oshkosh (Figure 1). The Fox River also flows out of Lake Winnebago at Neenah and Menasha and flows 39 river miles north to Green Bay, Lake Michigan. The runoff water from 6,000 square miles enters Lake Winnebago.

Lake Winnebago has an area of 137,708 acres with a maximum depth of 21 feet and average depth of 15.5 feet. The lake is roughly rectangular in shape: 28 miles long and 10.5 miles wide at its widest point. The smaller upriver lakes (Poygan, Winneconne and Big Lake Butte des Morts) have areas of 14,102; 4,507 and 8,857 acres, respectively. The depths of these smaller lakes are similar with maximum depths not exceeding 11 feet which are located in the river channels. All four lakes have many characteristics common to shallow eutrophic lakes.

Spawning walleyes from Lake Winnebago must migrate through one or more of the smaller upriver lakes to enter either the Wolf or Fox rivers to spawn. Walleyes from Lake Winnebago travel as far as 90 miles up the Wolf River and when water levels permit

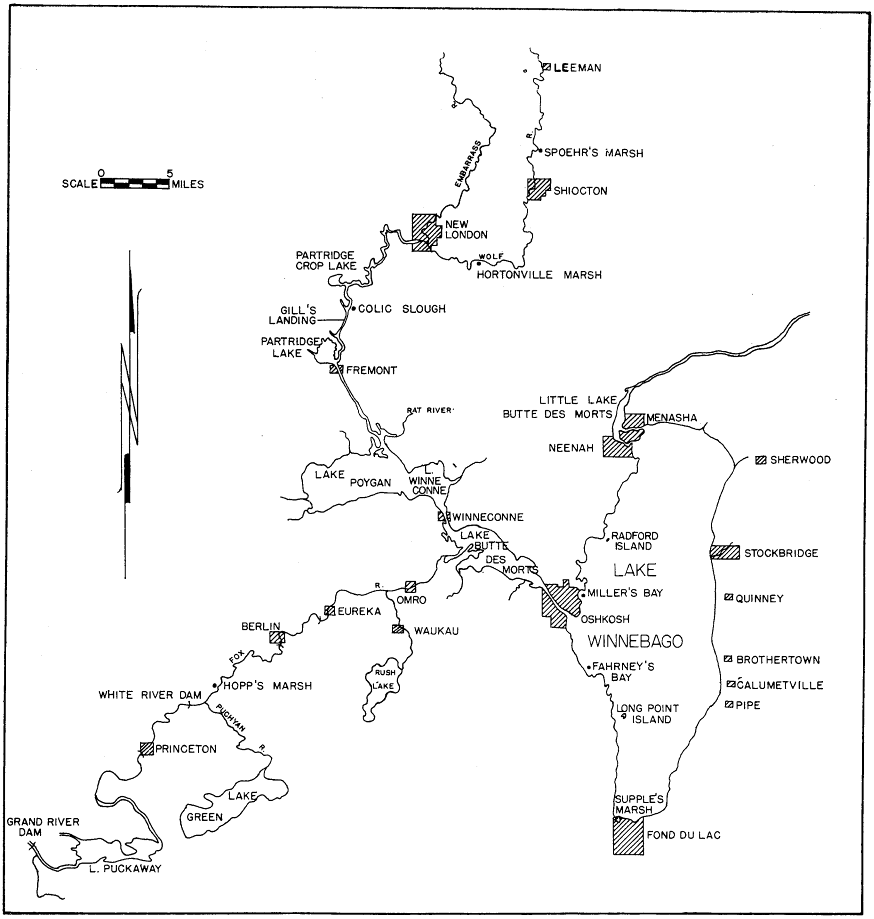

FIGURE 1. Lake Winnebago and connecting water areas involved in the tagging study.

passage over the Eureka dam some 40 miles up the Fox River to spawn in adjacent grass and sedge marshes.

OBJECTIVES

Objectives of the tagging program which was initiated in September, 1960, were to obtain information on angler exploitation, angler exploitation in relation to migration, extent of migration, times of migration, homing tendencies of spawning fish, effects of dams, effect of tagging on growth, suitability of various type tags and effect of entrapment gear on tag recoveries.

The original plan was to tag as many walleyes as possible during the fall, 1960, in Lake Winnebago and to tag 1,000 walleyes in Lake Poygan during the winter, 1960–61. The tagging program, however, was continued through the spring of 1964 and includes additional tagging areas.

METHODS

Capture Methods

On Lake Winnebago during the fall, 1960–62 ,walleyes were obtained from commercially fished Lake Erie type trap nets and 45-foot trawls. During this period, an A.C. shocker unit was also used during daylight hours to obtain walleyes in areas inaccessible to commercial fishermen. Trap nets were also set at the mouth of the Fox River off Oshkosh from January through April, 1964.

All walleyes tagged on marshes adjacent to the Wolf and Fox rivers were captured with an A.C. shocker unit during the spawning period, 1962–63.

On lakes Poygan and Winneconne, walleyes were captured in commercially fished hoop and trap nets set under the ice from January–March, 1961 and 1963.

Tagging Methods

The normal procedure for tagging fish was to remove them from source of entrapment, place in a holding tank, measure them (total length in inches to the nearest tenth), tag them and release them in the same approximate area of entrapment.

All of the fish except 994 fish tagged with plastic dart tags (Yamashita and Waldron, 1958) were marked on the upper jaw with either monel-metal or aluminum strap tags passing around the maxillary and premaxillary (Shetter, 1936). Eschmeyer and Crowe (1955) demonstrated no statistically significant difference in the rate of recovery among walleyes tagged in the upper and lower jaws with No. 3 strap tags.

The plastic dart tags were 0.0625 inch in diameter and 2.5 inches long. Five colors were used—orange, white, red, green and yellow. The tags were stamped with a serial number near the distal end of the shaft. The dart tags were inserted into the epaxial musculature immediately below the spiney dorsal fin where the 3/8-inch barb pierced through the interspinous bones so when the tag was tugged the barb contacted the interspinous bones.

Recapture Methods

Recaptures of tagged walleyes were reported voluntarily by anglers and commercial fishermen; no rewards were offered. Fishermen were alerted to the presence of tagged walleyes by the local press, radio, television and posters at boat liveries, resorts and public access points. To stimulate combined cooperation, all reports of recapture were acknowledged with a form letter giving locality, date and length of fish at tagging. In addition to the recaptures reported by fishermen, tagged walleyes were recaptured by project personnel during field operations which included electrofishing on the spawning marshes.

RESULTS

The number of walleyes tagged and the number recovered each succeeding year after tagging are shown in Table 1. Of 14,885 tagged in the five years, 3,237 or 21.8% have been reported caught by anglers during a six-year span, 1961–66. Recoveries the first year after each tagging period were consistently the highest.

April was the peak month for tag returns from anglers every year, 1961 through 1966, except in 1962, when May was the peak month. January and February were also high tag return months in 1961 and 1964 (Figure 2).

In addition to angler returns 372 tagged fish were recaptured by private and state commercial fishing crews in nets and trawls and by project personnel with electro gear. All of these fish were returned to the water after the length, tag number, date and locality of capture were recorded. Anglers eventually reported catching 90 (24.2%) of these 372 fish.

The size of the tagged walleyes ranged from 10.2 to 28.6 inches in total length with 49.2% falling in the 15- to 19-inch groups (Table 2). Smaller-sized walleyes were available, but the intent was to tag only walleyes over 10 inches which were assumed more vulnerable to the angler. For example, only 2.5% of the 10-inch group and 6.5% of the 11-inch group were recaptured while for lengths 12 through 26 inches the return ranged from 17.3 to 30.0% for each one-inch group.

In Lake Winnebago, 102 recaptured walleyes were measured by project personnel after they had carried monel jaw tags over one growing season. Their growth during this period is compared with the average annual increment of untagged fish in the population (Priegel, in press) in Table 3. Although the percentage of the normal increment attained by the tagged fish varied widely, the average of 53.7 for the group suggests a marked retardation of growth as a result of the presence of monel jaw tags. Several investigators (Rose, 1949; Smith, Krefting and Butler, 1962; Patterson, 1953; and Eschmeyer and Crowe, 1955) have shown that the presence of jaw tags tends to retard the growth rate of walleyes. Retardation of growth was also noted in the Lake Winnebago walleye.

TABLE 1. NUMBER AND PERCENTAGE (IN PARENTHESES) OF TAGGED WALLEYES REPORTED BY ANGLERS IN LAKE WINNEBAGO AND CONNECTING WATERS, 1960–66

Locality of Release	Date Tagged		Number Tagged	Year After Tagging†						Total
	Month*	Year		1	2	3	4	5	6	
Lake Winnebago	9, 10, 11,	1960	6,290	1,482 (23.6)	114 (1.8)	30 (0.5)	5 (0.1)	1(**)		1,632 (25.9)
	9, 10, 11,	1961	1,740	319 (18.3)	55 (3.2)	9 (0.5)	5 (0.3)	4 (0.2)		392 (22.5)
	9, 10, 11,	1962	4,401	500 (11.4)	106 (2.4)	53 (1.2)	65 (1.5)			724 (16.5)
	1, 2, 3, 4	1964	391	32 (8.2)	23 (5.9)	25 (6.4)				80 (20.4)
Lake Poygan	1, 2, 3	1961	454	84 (18.5)	8 (1.8)	4 (0.9)	1 (0.2)	1 (0.2)		98 (21.6)
	1, 2	1963	271	22 (8.1)	4 (1.5)	7 (2.6)	10 (3.7)			43 (15.9)
Lake Winneconne	1, 2, 3	1961	602	126 (20.9)	17 (2.8)	4 (0.7)	1 (0.2)		1 (0.2)	149 (24.8)
	1, 2	1963	179	14 (7.8)	1 (0.6)	1 (0.6)	9 (5.0)			25 (13.9)
Hopp's Marsh, Fox Rover	4	1962	203	33 (16.2)	11 (5.4)	2 (0.9)	2 (0.9)	1 (0.5)		49 (24.1)
	4	1963	81	9 (11.1)	2 (2.5)	2 (2.5)	1 (1.2)			14 (17.4)
Berlin Marsh, Fox River	4	1962	27	4 (14.8)	4 (14.8)			1 (3.7)		9 (33.3)
	4	1963	11	2 (18.2)	1 (9.1)	1 (9.1)				4 (36.4)
Hortonville Marsh, Wolf River	4	1963	53	4 (7.5)	2 (3.8)		1 (1.9)			7 (13.2)
Spoehr's Marsh, Wolf River	4	1963	182	8 (4.4)	1 (0.5)		2 (1.1)			11 (6.0)
Total	....	....	14,885	2.639 (17.7)	349 (2.3)	138 (0.9)	102 (0.7)	8 (0.1)	1 (**)	3,237 (21.8)

*Months are numbered consecutively from January (1) to November (11).

**Less than 0.05 percent.

†Fall tagging (9, 10, 11): First year extends from date of tagging through December 31 of the following year.

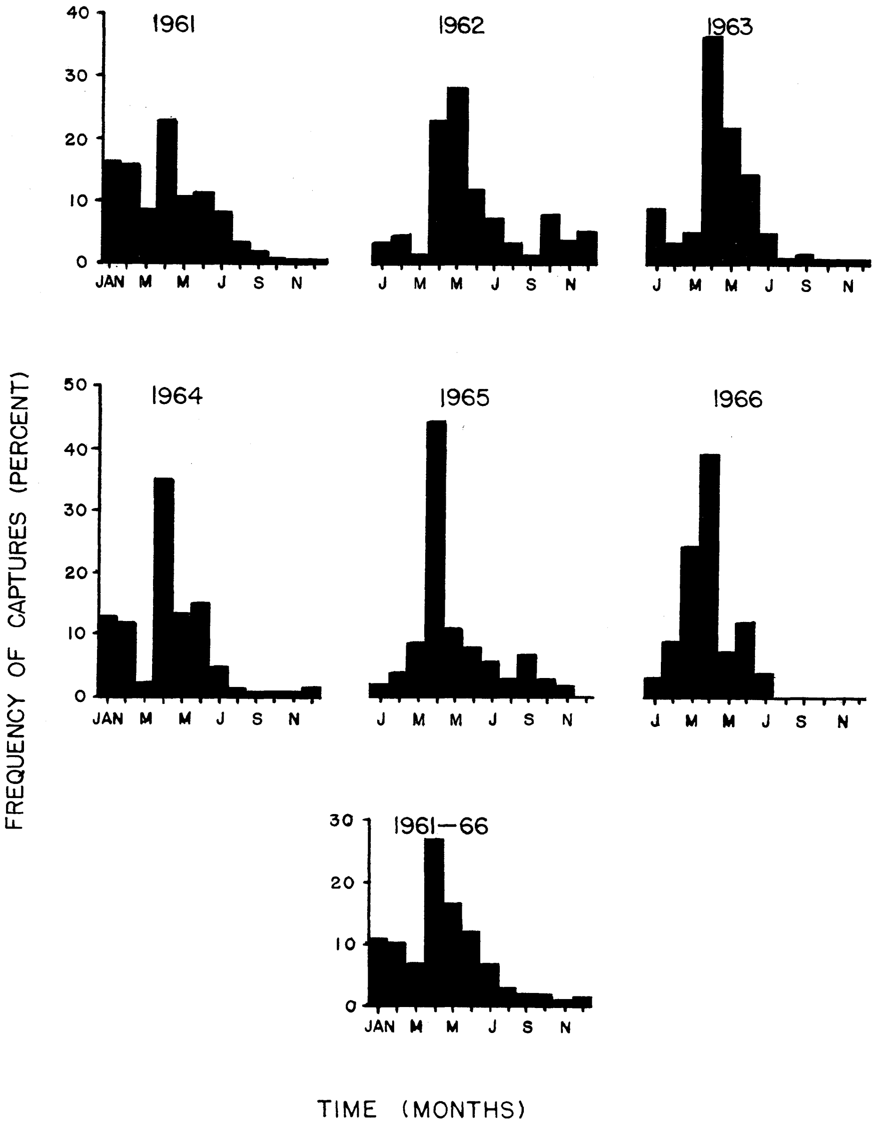

FIGURE 2. Walleye returns by months for the years 1961–66.

Anglers returned 418 (35.3%) of the 1,183 No. 4 Monel tags used which was superior to the return of No. 3 monel tags (19.4%)., aluminum strap tags (21.5%) and plastic dart tags (23.0%). The serial numbers on the monel tags were easily distinguished while on the aluminum strap tags serial numbers were difficult to distin-

TABLE 2. LENGTH FREQUENCY OF TAGGED AND ANGLER RECAPTURED WALLEYES IN LAKE WINNEBAGO AND CONNECTING WATERS

Length Groups in Inches (T.L.)	Tagged Fish		Recaptured Fish		Percentage Captured for Length Groups
	Number	Percent	Number	Percent	
10.0–10.9	239	1.6	6	0.2	2.5
11.0–11.9	1,117	7.5	73	2.3	6.5
12.0–12.9	1,180	7.9	204	6.3	17.3
13.0–13.9	1,200	8.1	265	8.2	22.1
14.0–14.9	1,222	8.2	279	8.6	22.9
15.0–15.9	1,469	9.9	357	11.0	24.3
16.0–16.9	1,663	11.2	390	12.0	23.4
17.0–17.9	1,378	9.3	266	8.2	19.3
18.0–18.9	1,406	9.4	345	10.7	24.5
19.0–19.9	1,395	9.4	372	11.5	26.2
20.0–20.9	1,154	7.7	325	10.0	28.1
21.0–21.9	705	4.7	184	5.7	26.1
22.0–22.9	421	8.9	105	3.2	24.9
23.0–23.9	204	1.4	42	1.3	20.6
24.0–24.9	84	0.6	15	0.5	17.9
25.0–25.9	33	0.2	6	0.2	18.2
26.0–26.9	10	0.1	3	0.1	30.0
27.0–27.9	4	*			
28.0–28.9	1	*			
Total	14,885		3,237		21.8

*Less than 0.05 percent.

guish because the digits were embossed and wore down within one year. Many of the aluminum strap tags were paper-thin when returned to us so it was conceivable that after one year considerable tag loss could occur.

There was no evidence of tag loss for plastic dart tags and all fish examined showed that the plastic dart tags were solidly embedded. Some infection around the tag was reported by the anglers but never observed by project personnel. Plastic dart tags are easy to apply, but the legend became difficult to distinguish after one summer season. The tags used had a serial number near the end of the shaft; however, it would have been more beneficial to have a serial number at the end of the shaft near the barb to enhance distinguishing the legend. The lighter colors (orange, white and yellow) are preferred (as against green and red) as it is easier to distinguish the legend.

Tagging during the fall of 1960 and 1962 on Lake Winnebago provided sufficient data to evaluate the use of trap nets, trawls and an A.C. shocker unit as means of capturing walleyes for tagging studies. Of the 10,691 walleyes tagged during this period, trawling

TABLE 3. GROWTH OF TAGGED WALLEYES RECOVERED AFTER ONE GROWING SEASON

Length Groups in Inches	Number of Fish	Average Total Length (Inches) at Time of		Average Increments (Inches)		Increment of Tagged Fish (Percentage of Increment of Untagged Fish)
		Release	Recovery	Tagged Fish	Untagged Fish	
12.0–12.9....	5	12.6	13.4	0.8	1.8	44.4
13.0–13.9....	1	13.3	14.4	1.1	1.8	61.1
14.0–14.9....	4	14.3	15.4	1.1	1.3	84.6
15.0–15.9....	6	15.6	16.1	0.5	1.2	41.6
16.0–16.9....	6	16.7	16.9	0.2	1.2	16.6
17.0–17.9....	14	17.6	17.9	0.3	1.0	30.0
18.0–18.9....	14	18.6	19.1	0.5	1.0	50.0
19.0–19.9....	20	19.5	20.2	0.7	0.8	87.5
20.0–20.9....	11	20.4	20.8	0.4	0.8	50.0
21.0–21.9....	9	21.5	21.7	0.2	0.6	33.3
22.0–22.9....	6	22.5	23.0	0.5	0.4	125.0
23.0–23.9....	6	23.5	23.8	0.3	0.4	75.0
Total or weighed average......	102					53.7

accounted for 1,555 (14.6%), trap netting for 4,087 (38.2%) and electrofishing for 5,049 (47.2%).

The angler return of walleyes tagged while electrofishing was 25.5% and it was 23.5% for walleyes captured in trap nets. Only 6.4% of the walleyes taken by trawling gear were returned by anglers. The pressure on a few walleyes exerted by 200–800 pounds of commercial species when the trawl is lifted, the expansion of the swim bladder and the handling of the fish during tagging operations most likely resulted in a substantial mortality of trawl-caught walleyes used for tagging.

Hopp's Marsh and marshes near the city of Berlin on the Fox River and Spoehr's Marsh, Hortonville Marsh and Colic Slough on the Wolf River were electrofished to recover tagged walleyes during the spring, 1961–66. Fifty-six tagged walleyes were recovered on these spawning marshes, 16 on Fox River marshes, and 40 on Wolf River marshes. Of the 16 recovered on Fox River marshes, nine had originally been tagged on Hopp's Marsh while the other seven were tagged on Lake Winnebago. Four of the 40 recaptured on Wolf River marshes were originally tagged on Spoehr's Marsh, while 8, 5 and 23 were tagged on lakes Poygan, Winneconne and Winnebago, respectively. Angler returns indicate that same patterns with fish originally tagged in Lake Winnebago being recaptured in both the Wolf and Fox rivers (Table 4); however, angler

TABLE 4. THE NUMBER AND PERCENT (IN PARENTHESES) OF ANGLER RETURNS BY RECAPTURE LOCATION

LOCATION TAGGED	YEAR	LOCATION RECAPTURED BY ANGLERS						
		L. Winnebago	L. Poygan	L. Winneconne	Big L. Butte des Morts	Fox River	Wolf River	Below Outlet of Lake Winnebago
L. Winnebago	1960	1,190 (72.9)	24 (1.5)	74 (4.5)	20 (1.2)	70 (4.3)	226 (13.9)	28 (1.7)
	1961	302 (77.1)	1 (0.3)	13 (3.3)	5 (1.3)	17 (4.3)	39 (9.9)	15 (3.8)
	1962	528 (72.9)	7 (0.9)	29 (4.0)	8 (1.1)	50 (6.9)	92 (12.8)	10 (1.4)
	1964	41 (51.2)		3 (3.8)	1 (1.3)	21 (26.2)	14 (17.5)	
	Total:	2,061 (73.9)	32 (1.1)	119 (4.2)	34 (1.2)	158 (5.6)	371 (13.1)	53 (1.9)
L. Poygan	1961	11 (11.2)	11 (11.2)	9 (9.2)	1 (1.0)		66 (67.4)	
	1963	2 (4.7)	9 (20.9)	6 (13.9)	2 (4.7)	1 (2.3)	23 (53.5)	
	Total:	13 (9.2)	20 (14.9)	15 (10.7)	3 (2.1)	1 (0.7)	89 (62.4)	
L. Winneconne	1961	36 (24.3)	9 (6.1)	20 (13.5)	2 (1.4)		81 (54.0)	1 (0.7)
	1963		1 (4.0)	4 (16.0)	5 (20.0)	2 (8.0)	13 (52.0)	
	Total:	36 (20.7)	10 (5.8)	24 (13.8)	7 (4.0)	2 (1.1)	94 (54.0)	1 (0.6)
Fox R. Marshes	1962	16 (27.6)			7 (12.1)	34 (58.6)		1 (1.7)
	1963	5 (27.8)	1 (5.6)		2 (11.1)	10 (55.5)		
	Total:	21 (27.6)	1 (1.3)		9 (11.8)	44 (58.0)		1 (1.3)
Wolf R. Marshes	1963	1 (5.9)	1 (5.9)	2 (11.8)	1 (5.9)		13 (70.5)	

returns from the Wolf River were 13.1% as compared to 5.6% from the Fox River. Only three (0.9%) of the 315 angler returns from fish originally tagged in lakes Poygan and Winneconne, were recaptured in the Fox River, as compared to 182 (59.1%) from the Wolf River.

Of the 12,822 walleyes tagged and released in Lake Winnebago, anglers reported capturing 2,828 of which 2,061 (73.9%) were reported taken in Lake Winnebago (Table 4.) The remaining 767 recaptured walleyes were taken in Lake Poygan (1.1%), Lake Winneconne (4.2%), Big Lake Butte des Morts (1.2%), the Wolf River (13.1%) and Fox River (5.6%) and below the outlet dams at Neenah and Menasha (1.9%). Walleyes were recaptured throughout the year in these water areas connecting into Lake Winnebago.

Anglers reported capturing 141 walleyes of 725 originally tagged and released in Lake Poygan, of which 89 (62.4%) were taken in the Wolf River during the spawning migration. Only 20 (14.9%) were recaptured in Lake Poygan.

Of the 781 walleyes tagged and released in Lake Winneconne, anglers reported capturing 174 of which 94 (54.0%) were reported taken in the Wolf River during the spawning migration. The number recaptured in Lake Winneconne was 24 (13.8%) with 36 (20.7%) being recaptured in Lake Winnebago.

On the Fox River marshes, 322 walleyes were tagged. Anglers reported recapture of 76, with 44 (58.0%) being caught in the Fox River and 21 (27.6%) being caught in Lake Winnebago. Nine (11.8%) were recaptured in Big Lake Butte des Morts and one each in Lake Poygan and below the Neenah–Menasha dams.

On the Wolf River marshes, 235 walleyes were tagged, with anglers reporting recapture of 18 of which 13 (70.5%) were taken on the Wolf River. Two were recaptured in Lake Winneconne and one each in lakes Winnebago, Poygan and Big Lake Butte des Morts.

Migration of walleyes out of Lake Winnebago into the upriver lakes and rivers during the late fall and winter was expected but the extent was unknown. During tagging operations in January and February, 1961 on lakes Poygan and Winneconne, 12 walleyes, previously tagged in Lake Winnebago during the fall, 1960, were taken while in January and February, 1963, nine walleyes previously tagged in Lake Winnebago during the fall, 1962, were taken in commercially fished nets. Angler returns of walleyes tagged in Lake Winnebago during the fall of 1960, 1961 and 1962 and taken through the ice in the upriver lakes during the following winter were 19.9, 3.3 and 4.7% respectively of the total annual returns from the upriver lakes. Angler returns also indicate that of the walleyes tagged in lakes Poygan and Winneconne, only 14.9% and 13.8%, respectively, are caught in these lakes. Angler returns of Lake Poygan tagged walleyes were from the Wolf River (62.5%) and Lake Winnebago (9.2%) and for Lake Winneconne 54.0% were from the Wolf River and 20.7% from Lake Winnebago. Net and angler returns would indicate a sufficient migration of walleyes out of Lake Winnebago during the late fall and winter into the upriver lakes.

Following the first year after tagging, 28 walleyes that were tagged and released in Lake Winnebago were caught by anglers below the outlet dams of Neenah and Menasha. Water levels were unusually high during the spring of 1961, and may account for this migration over the dams the first year after tagging. For the entire six-year period 57 tagged walleyes were reported taken by anglers below the outlet dams.

The average distance traveled for 2,559 walleyes that were originally tagged in Lake Winnebago and for which exact locations of recaptures were known was 18.8 miles. The maximum distance traveled was 97 miles from Oshkosh, Lake Winnebago to Leeman, Wolf River. Of 2,559 recaptures, 340 (13.3%) were taken within the same area as tagged, 226 (8.8%) were within two miles of the tagging site, 298 (11.6%) were within 2 to 5 miles, 607 (23.7%) 5 to 10 miles, 550 (21.5%) from 10 to 25 miles and 538 (21.0%) from 25 to 97 miles. The average distance traveled for 115 walleyes from Lake Poygan, 143 from Lake Winneconne, 70 from Fox River marshes and 17 from Wolf River marshes, was 28.9, 28.2, 22.1 and 33.2 miles, respectively.

Eschmeyer (1942) recovered four walleyes tagged in the Norris Reservoir at an average distance of 4.8 miles. Most of these tagged in Houghton Lake, Michigan, by Carbine and Applegate (1946) were recovered at an average distance of 3 miles, but three had gone 130 miles downstream. Doan (1942) recovered 22 specimens in western Lake Erie, most of them about 20 miles away but one had gone 200 miles to the east end of the lake. The average distance of travel at Lac la Rouge, Saskatchewan (Rawson, 1957) was 3.5 miles for 281 recaptures with one specimen going upstream 65 miles. The general pattern of rather limited movement in walleye populations with a few long-distance wanderers does not apply to the Lake Winnebago walleye population because of the distance traveled during spawning migrations.

During the course of the study, nine fish originally tagged in Lake Winnebago were recaptured in Lake Puckaway, a distance of 68 river miles from Lake Winnebago. These fish had to pass over four low-head dams in the Fox River: Eureka, Berlin, White River and Princeton. One walleye tagged during April, 1963, in Hopp's

Marsh, Fox River was also recaptured in Lake Puckaway during June, 1963.

Discussion and Significance

The return of 3,237 or 21.8% of the 14,885 tagged walleyes by anglers over a six-year period definitely demonstrates the effectiveness of angler exploitation in this large and extensive water area especially when one considers the voluntary return. There were no closed seasons nor minimum size limits in effect for walleyes during the study period. Herman (1947) reported a recovery of 9.3% of 3,694 walleyes tagged from 1944–46 in the Wolf River, Wisconsin, after three years; however, at that time, the season was closed from February 1 until after the peak of spawning in April and a 13-inch minimum size limit was in effect during this period. Patterson (1953) after one year reported a recovery of 20.5% for 984 walleyes tagged in Escanaba Lake, Wisconsin, where there was a 100% creel census, no closed seasons, no minimum size limit and no bag limits during this period. Hubley and Jergens (1959) recovered 5.7% of the 1,784 walleyes tagged in the spring of 1958 within seven months after tagging in a 40-mile stretch of the Upper Mississippi River. Eschmeyer and Crowe (1955) reported that from the grand total of 11,354 walleyes that had been jaw-tagged in Michigan during the period 1939–52, 12.2% were recovered. In Blackduck River, Minnesota, sport and commercial fishermen returned 25.1% of 4,697 walleyes tagged in 1949 after three years (Smith, Krefting, and Butler, 1952).

Angler returns were consistently higher the first year after tagging for each tagging period and location (Table 1). Lack of returns two or more years later is probably due to tag loss and fish mortality because of high first-year returns in different years.

The length frequency of walleyes when tagged and at the time of angler recapture is based on the size at tagging, as the error in using lengths provided by the anglers when the fish was captured is too great or in many cases the length was not provided by the angler. Walleyes over 12 inches were more vulnerable to the anglers (Figure 3). The fact that 44% of the angler returns occurred in April and May during the spawning migration accounts in part for the greater vulnerability of larger size walleyes. The average size of male walleyes at maturity is 12.7 inches for females it is 17.3 inches (Priegel, in press).

Frequently the question regarding the taking of female walleyes during the spawning migration before they had a chance to spawn comes up for discussion. Tag returns from anglers which provided date of capture during the spawning period on the Wolf River in 1961, 1962 and 1963, were tabulated from ice-out to May 1 to de-

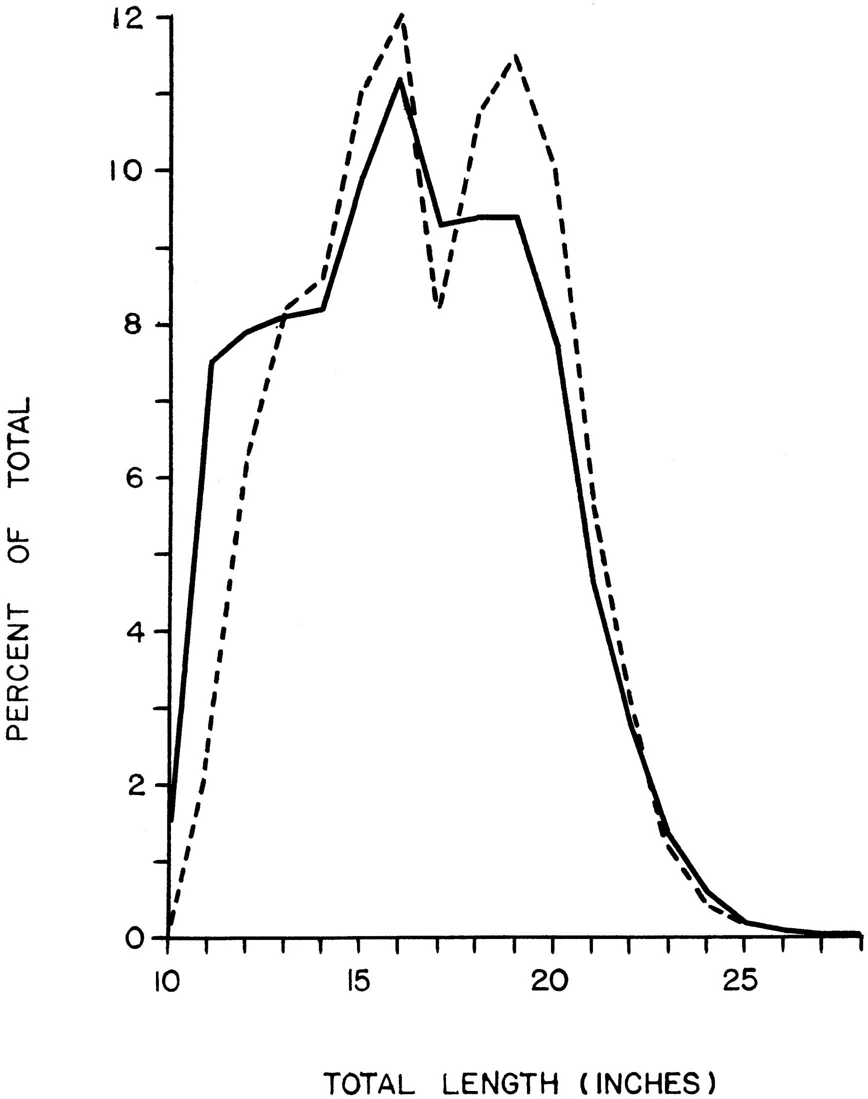

FIGURE 3. Length frequency of tagged (solid line) and angler recapture (broken line) walleyes in Lake Winnebago and connecting waters.

termine when the majority of female walleyes were caught—before or after spawning. All fish over 19 inches are considered females as determined from age and growth studies (Priegel, in press). The percent of tagged female walleyes taken after the peak spawning period was 68.5, 84.2 and 80.7 for the years 1961, 1962 and 1963, respectively (Table 5). Based on these tag returns it is reasonable to conclude that proportionately more untagged females are taken also after the peak spawning period. The same situation was noted for male walleyes as the percent of tagged male walleyes taken after the peak spawning period was 62.6, 89.2 and 87.1 for the years 1961, 1962 and 1963 respectively.

Angler exploitation of tagged walleyes was consistently higher during the spawning migration period than during the non-migratory season. April and May in 1961 through 1965 were the months during the spawning migration while in 1966, March and April were used because of the early spring breakup (Table 6). Angler returns of tagged walleyes during the spawning migration ranged from 33.3% of the total in 1961, to 63.9% of the total in 1966.

January and February were also high tag return months in 1961 and 1964, due to intensive winter angling pressure on Lake Winnebago, and the availability of walleyes tagged during the fall. The periods of highest tag returns coincide with the best fishing months and periods of heaviest fishing pressure.

There is currently no closed season on walleyes in Lake Winnebago and connecting waters; however, in the future, if a closed season would be essential to preserve the walleye fishery, a closed season during April and May would be most beneficial. April and May were consistently the high tag return months during the study period, 1961–66.

The tendency of the walleye to return to specific spawning areas in lakes and streams has been noted by several investigators: Stoudt, 1939; Stoudt and Eddy, 1939; Eschmeyer, 1950; Smith, Krefting and Butler, 1952; Eschmeyer and Crowe, 1955; Rawson, 1957; Olson and Scidmore, 1962; and Crowe, Karvelis and Joeris, 1963. All observed that stream-spawning walleyes tagged on specific spawning grounds tended to return to them. The tendency for spawning walleyes to return to the spawning area where they had been marked in previous years, or at least utilize the same major river was also noted in the Lake Winnebago area. On Hopp's Marsh, Fox River, 9 of 13 recaptures taken while electro-fishing during the spawning period were originally tagged and released on Hopp's Marsh. On Spoehr's Marsh, Wolf River, 4 of 27 recaptures taken while electrofishing during the spawning period were originally tagged and released on Spoehr's Marsh. None of the 322 walleyes tagged during the spawning period in 1962 and 1963 on Fox River marshes were ever recaptured by anglers or project personnel in the Wolf River or adjacent marshes although 24% were returned by anglers from Lake Winnebago and the Fox River. A single fish was returned from Lake Poygan. None of the 235 walleyes tagged

TABLE 5. TAGGED WALLEYES TAKEN DURING THE SPAWNING SEASON IN THE WOLF RIVER 1961–63. FISH OVER 19 INCHES ARE CONSIDERED FEMALES. PEAK SPAWNING IS IN PARENTHESIS

LENGTH GROUPS IN INCHES (T.L.)	1961 (APRIL 8)		1962 (APRIL 12)		1963 (APRIL 3)	
	Before	After	Before	After	Before	After
13.0–13.9					4	23
14.0–14.9	7	17	1	3		8
15.0–15.9	15	15		7	2	8
16.0–16.9	13	18	2	13	3	24
17.0–17.9	6	11		4	2	7
18.0–18.9	5	16	1	6	1	11
19.0–19.9	7	16		10		4
20.0–20.9	14	24		5	4	4
21.0–21.9	4	17	3	7	2	6
22.0–22.9	5	7	1	3		7
23.0–23.9			1	3		2
24.0–24.9		1	1	2		1
25.0–25.9				1		1
26.0–26.9				1		
Total	76 (34.9)	142 (65.1)	10 (13.3)	65 (86.7)	18 (14.5)	106 (85.5)
Female	30 (31.5)	65 (68.5)	6 (15.8)	32 (84.2)	6 (19.3)	25 (80.7)
Male	46 (37.4)	77 (62.6)	4 (10.8)	33 (89.2)	12 (12.9)	81 (87.1)

TABLE 6. THE NUMBER AND PERCENTAGE (IN PARENTHESES) OF ANGLER RETURNED TAGS BY MONTHS, 1961–66

YEAR	1961	1962	1963	1964	1965	1966	TOTAL
January	232 (16.4)	20 (3.3)	55 (8.9)	22 (12.9)	2 (2.0)	4 (3.3)	335 (11.0)
February	228 (16.1)	27 (4.4)	22 (3.6)	21 (12.3)	5 (5.0)	11 (9.0)	314 (10.4)
March	121 (8.6)	8 (1.3)	30 (4.9)	4 (2.3)	9 (8.9)	30 (24.6)	202 (6.7)
April	320 (22.7)	139 (22.7)	224 (36.4)	60 (35.1)	45 (44.6)	48 (39.3)	836 (27.6)
May	150 (10.6)	169 (27.7)	135 (21.9)	23 (13.5)	11 (10.9)	9 (7.4)	497 (16.4)
June	158 (11.2)	72 (11.8)	90 (14.6)	26 (15.2)	8 (7.9)	15 (12.3)	369 (12.2)
July	114 (8.1)	43 (7.0)	29 (4.7)	8 (4.7)	6 (5.9)	5 (4.1)	205 (6.8)
August	51 (3.6)	19 (3.1)	7 (1.1)	2 (1.2)	3 (3.0)		82 (2.7)
September	24 (1.7)	10 (1.6)	10 (1.6)	1 (0.6)	7 (6.9)		52 (1.7)
October	9 (0.6)	49 (8.0)	5 (0.8)	1 (0.6)	3 (3.0)		67 (2.2)
November	1 (0.1)	23 (3.8)	4 (0.6)	1 (0.6)	2 (2.0)		31 (1.0)
December	4 (0.3)	32 (5.2)	5 (0.8)	2 (1.2)			43 (1.4)

on Wolf River marshes were ever recaptured in the Fox River or adjacent marshes although 8% were returned from the Wolf River and downstream lakes.

The loss of 57 walleyes (1.8% of all tag returns) for the entire six-year period over the outlet dams at Neenah and Menasha must be considered negligible when considering the large, extensive water area involved in this study.

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THE TAXONOMY AND ECOLOGY OF LEECHES (HIRUDINEA) OF LAKE MENDOTA, WISCONSIN

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INTRODUCTION

Wisconsin, with over 8000 lakes, mainly located in the northern half of the state, ranks second only to Minnesota in number of lakes in the United States. Although many studies have been concerned with the taxonomy and ecology of their biota, there are certain groups of animals in these lakes on which little research has been done. Among these are the leeches, which from the systematic point of view have been studied for only a few lakes (Muttkowski, 1918; Baker, 1924; Pearse, 1924; Bere, 1931). Questions related to their spatial and temporal distribution, population densities, and life histories have remained almost completely unanswered. Such is the case with the leeches found in Lake Mendota.

Lake Mendota is situated in the central portion of southern Wisconsin and is the largest of a chain of four lakes in the Yahara Basin, all of which were formed by modification of the river valley by glacial activity. Among the morphometric characteristics of Lake Mendota cited by Birge and Juday (1914) are: maximum length, 9.5 km; maximum breadth, 7.5 km; maximum depth, 25.6 m; mean depth, 12.1 m; circumference, 23.4 km; and total surface area, 39.4 sq. km.

The first to mention the leeches of Lake Mendota was Muttkowski (1918) who noted the following species in his study of the fauna of the lake:

Erpobdella punctata
Nephelopsis obscura
Glossiphonia sp.

Another early study which included observations on the leeches of Lake Mendota was done by Pearse (1924). He mentioned *Piscicola punctate* as a parasite of carp, bluegill and large-mouth black bass and *Placobdella parasitica* of the bluegill.

METHODS

From September, 1964 through August, 1965, I had the opportunity to study the taxonomy and ecology of the leeches in Lake Mendota.

A quantitative analysis of Lake Mendota leeches to determine their vertical and horizontal distributions and seasonal variations in population density was accomplished by collecting material with the aid of an Ekman dredge (15 x 15 cm) and a sheet metal frame (50 x 50 cm). A transect from Bascom Woods to Governor's Island was sampled every month (usually between the 20th and 22nd day) from September, 1964 through August, 1965. In May, 1965 ten other transects were sampled also (Figure 1). Samples were taken from the bottom of the following isobaths of each transect: 0, 1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 24 meters. Wet and dry weights measurements were made on a single-pan analytical balance.

RESULTS

The following 16 species of leeches were identified during the study:

Glossiphonia complanata
Glossiphonia heteroclita
Batracobdella phalera
Batracobdella picta
Helobdella stagnalis
Helobdella punctata—Lineata
Helobdella lineata
Helobdella elongata
Placobdella ornata
Placobdella parasitica
Placobdella montifera
Placobdella sp.
Dina parva
Erpobdella punctata
Nephelopsis obscura
Haemopis marmorata

My list of species of Lake Mendota leeches includes all those mentioned by previous authors except for *Piscicola punctata,* which I did not find. Thus, the fauna of leeches in Lake Mendota could be represented by seventeen species which belong to four families; namely *Piscicolidae* (1 genus and 1 species), *Glossiphonidae* (4 genera and 12 species), *Erpobdellidae* (3 genera and 3 species), and *Hirudinidae* (1 genus and 1 species).

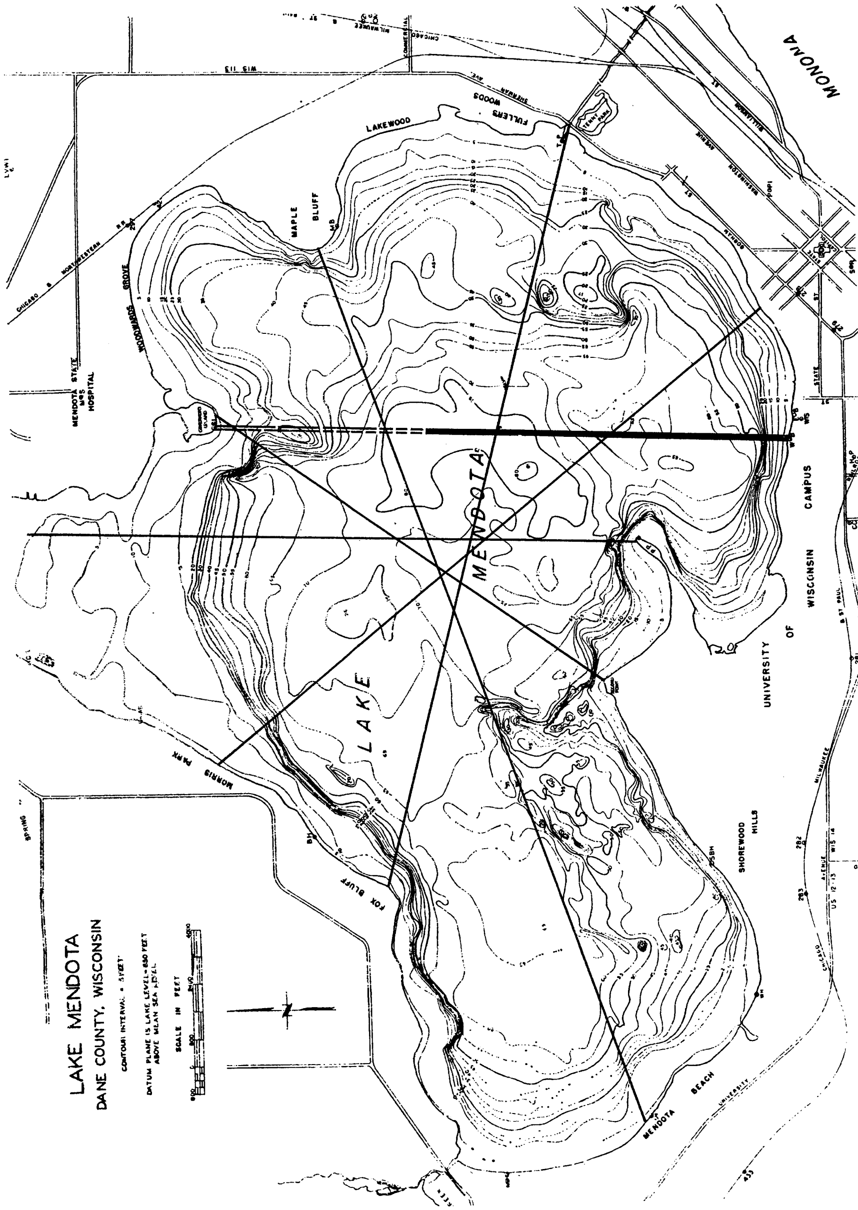

FIGURE 1. Lake Mendota. Position of transects.

FAMILY GLOSSIPHONIDAE

1. *Glossiphonia complanata* (Linnaeus) 1758

This species is known over the whole of North America (Verrill, 1874; Moore, 1901, 1906, 1924, 1952; Nachtrieb, Hemingway and Moore, 1912; Ryerson, 1915; Baker, 1924; Miller, 1929, 1937; Bere, 1931; Rawson, 1953; Meyer and Moore, 1954). It is also found over the whole of Europe, in Asia (India—Japan—Bering Islands), and Africa (for example in the Congo). *G. complanata* occurs in many habitats but appears to show a preference for lakes and running water and especially stone bottoms, while it is rarely found in vegetation. It occurs in oligotrophic lakes, but more frequently in eutrophic lakes. This study is the first to report this species in Lake Mendota.

In Lake Mendota *G. complanata* may be found at almost all times on the northern and southern shores of the lake, where the bottom (0–1 meter depth) is covered with boulders, stones and pebbles, with a mixture of gravel and sand. In these areas it has a population density of 44.4–266.4 individuals per square meter. As may be seen from Table I, *G. complanata* may be encountered in some other habitats in Lake Mendota, such as sand, sand and mud, mud with detritus, or mud and detritus with vegetation. In such habitats, it occurs with a smaller population density.

The vertical distribution of *G. complanata* in this lake is slight and during the year 1964–65 it was not found at depths of over one meter (Figure 2). Such is the case also in the markedly eutrophic Dojran Lake, Macedonia, Yugoslavia (Sapkarev, 1964), eutrophic Fures, Denmark (Bennike, 1943), but not in the markedly oligotrophic Ohrid Lake or the Prespa Lake, Macedonia, Yugoslavia (Sapkarev, 1963). In the latter two lakes, *G. complanata* is a eurybathic form found at all depths of the lake.

The average, seasonal changes of the population density and biomass of *G. complanata,* calculated for the whole littoral zone of Lake Mendota, are given in Figure 3. From this figure it may be seen that the population tends to have the lowest density in the winter and spring months (11.1 individuals per square meter) and the highest density in the summer and fall months (maximum in August—99.9 individuals per square meter). The maximum population density was associated with the appearance of young individuals after a reproductive period from the end of May to the beginning of July. Concurrently, the biomass, in wet and dry weight, attains its relative maximum in fall (0.93 gr. wet weight or 0.20 gr. dry weight per square meter) two or three months after the appearance of the new generation.

TABLE I. THE POPULATION DENSITY (INDIVIDUALS PER SQUARE METER) OF LEECHES IN DIFFERENT HABITATS OF LAKE MENDOTA

Habitats / Species	Stone	Gravel	Sand	Sand and Mud	Mud with Detritus	Mud and Detritus with Vegetation	Sand and Mud with Shells	Deep Lake Mud
Glossiphonia complanata	44.4– 266.4	44.4– 177.6	11–1– 44.4	11.1– 44.4	11.1– 44.4	11.1– 88.8	—	—
Glossiphonia heteroclita	11.1– 44.4	– 44.4	—	11.1– 44.4	11.1– 44.4	11.1– 88.8	—	—
Batracobdella phalera	– 44.4	– 44.4	– 44.4	– 88.8	– 44.4	11.1– 88.8	—	—
Batracobdella picta	—	—	—	—	—	– 44.4	—	—
Helobdella stagnalis	44.4–3108.0	44.4–2220.0	44.4–266.4	44.4–488.4	44.4–444.0	44.4–2175.6	11.1–133.2	11.1–88.8
Helobdella punctata—lineata	—	—	—	—	—	– 44.4	—	—
Helobdella lineata	– 44.4	– 44.4	—	– 44.4	– 44.4	– 44.4	—	—
Helobdella elongata	11.1– 222.0	11.1– 177.8	11.1–133.2	11.1– 88.8	11.1– 88.8	11.1– 133.2	– 44.4	—
Placobdella ornata	– 44.4	– 44.4	—	– 44.4	– 44.4	– 44.4	—	—
Placobdella parasitica	—	– 44.4	—	—	– 44.4	– 44.4	—	—
Placobdella montifera	—	—	—	—	—	– 44.4	—	—
Placobdella sp.	– 44.4	– 44.4	– 44.4	—	—	—	—	—
Dina parva	44.4– 266.4	44.4– 177.6	44.4– 88.8	—	—	11.1– 44.4	—	—
Erpobdella punctata	44.4–1332.0	44.4–1330.0	11.1–133.2	– 44.4	– 44.4	11.1– 133.2	—	—
Nephelopsis obscura	44.4–1110.0	44.4–1110.0	11.1–177.6	– 44.4	– 44.4	11.1– 133.2	—	—
Haemopis marmorata	44.4– 177.6	44.4– 88.8	—	11.1– 44.4	11.1– 88.8	11.1– 266.4	—	—

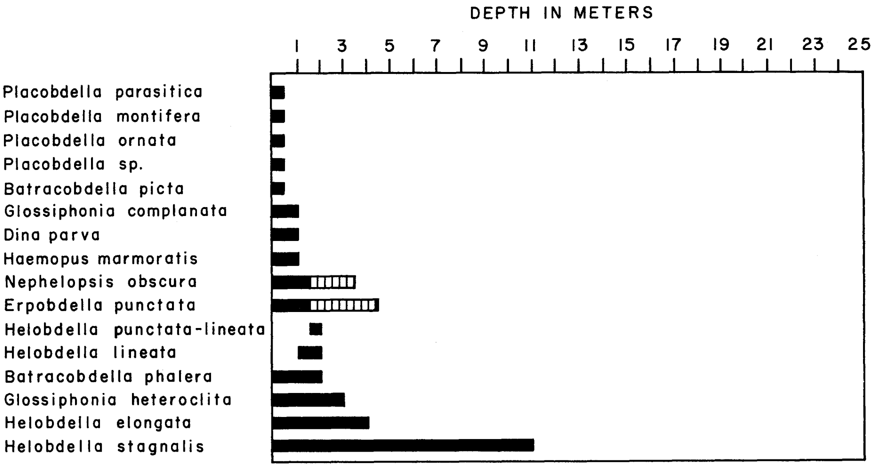

FIGURE 2. Bathymetrical distribution of the leeches in Lake Mendota.

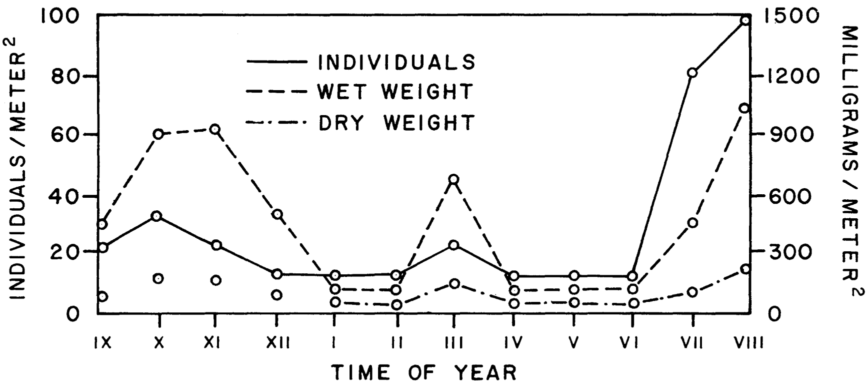

FIGURE 3. Average seasonal changes of the population density and biomass of *Glossiphonia complanata* in the littoral zone of Lake Mendota during 1964–65.

Two specimens of *G. complanata* with eggs were found in the period between the end of May and the beginning of June. Another specimen with eggs was found at the beginning of July and still another specimen with young ones in July. Young individuals were encountered during all of July and August. A similar reproductive period for *G. complanata* was described by Bennike (1943) and Sapkarev (1946).

I had an occasion to observe *G. complanata* preying upon *Physa gyrina* and *Planorbis parvus* and on the oligochaeta *Limnodrilus*. Muttkowski (1918), on several occasions, found small leeches of the genus *Glossiphonia* (I think that these are individuals of *G.*

complanata) attached to the underside of the beetle larva, *Paephenus lecontei.*

2. *Glossiphonia heteroclita* (Linnaeus) 1758

This species, like the previous one is quite common in North America. In addition to other habitats, it has also been found in lakes such as Nipigon (Moore, 1924), Georgian Bay (Ryerson, 1915), Allequash, Man and Trout lakes (Bere, 1931). It has been reported in many European lakes also (Pawlowski, 1936; Bennike, 1943; Sapkarev, 1963, 1964; Ökland, 1964).

G. heteroclita is also identified for the first time in Lake Mendota. It occurs most frequently in a habitat of mud with detritus and overgrown with vegetation (11.1–88.8 individuals per square meter), but is found also in sand with mud, as well as on stones (11.1–44.4 individuals per square meter). Its vertical distribution does not extend below a depth of three meters (Figure 4). It is found frequently at a depth of two meters, and less often in shallower parts of the littoral zone.

In the course of this study the maximal density of population occurred in August, as described previously for *G. complanata.*

I found only one specimen of this leech, on July 10, 1965, with eggs attached. During August, 1965, I found several specimens with both eggs and young attached to the ventral surface. Bennike (1943) has found *G. heteroclita* with eggs and with young from June to October in Denmark. Thus the period of reproduction extends slightly over four months. In central Europe the period of reproduction appears to last from April to September.

3. *Batracobdella phalera* (Graf) 1899

Batracobdella phalera is known only throughout the United States (Graf, 1899; Baker, 1924; Miller, 1929; Bere, 1931) and Canada (Moore, 1906; Ryerson, 1915). In Wisconsin it can be found in many of the northeastern lakes (Bere, 1931), in the Lake Winnebago region (Baker, 1924), and I have now found it in Lake Mendota. Its distribution in the lake is limited in depth from 0 to 2 meters. With the greatest density of population being 88.8 individuals per square meter, it is rather rare in this lake. I found it most frequently in the Second Point and Bascom Woods areas. It occurs in various habitats, but has the greatest density of population in areas having a bottom of mud with detritus and covered with vegetation.

4. *Batracobdella picta* (Verrill) 1872

Like the previous species of this genus, *B. picta* is known in both the United States and Canada (Verrill, 1872; Moore, 1906, 1952;

Miller, 1929; Bere, 1931). In northeastern Wisconsin it has been found in many lakes. I have found only one specimen of this leech in Lake Mendota, between University Bay and Picnic Point at about a depth of 0.20 meters. Pearse (1924) mentions it as a parasite on the sucker and perch in Lake Michigan.

5. *Helobdella stagnalis* (Linnaeus) 1758

This species is very common and cosmopolitan, being found in both North and South America, over all of Europe, and in Asia and North Africa.

One of the reasons for the wide distribution of this leech lies in its ability to exist in numerous habitats. Bennike (1943) in his paper, "Contributions to the Ecology and Biology of the Danish Freshwater Leeches", writes: "There is only one type of freshwater, in which it has not been found, i.e., the sphagnum bogs; it has even been found in an extremely dystrophic lake, but in one locality only (Store okosso)." Thus in Lake Mendota, as in many other lakes, it may be found in various habitats as can be seen from Table I. This means *H. stagnalis* is an eurytopic form, but also an eurybathic form, because its vertical distribution is rather great—from the shore line to a depth of 12–15 meters. Esrom Lake (Berg, 1938), Fures Lake (Bennike, 1943) and Prespa Lake (Sapkarev, 1963) offer similar cases. It is unique in being the only leech whose range extends throughout all zones in Lake Mendota.

From Figure 5 it is possible to see that *H. stagnalis* has the greatest population density in the littoral zone (an average density of 421.8 individuals per square meter at the 0 meter depth), a much smaller population density in the sublittoral zone (an average of 14.8 individuals per square meter) and the smallest density in the profondal zone (an average of 3.7 individuals per square meter at a depth of 12 meters). This is also the case in Esrom Lake (Berg, 1938), Fures Lake (Bennike, 1943), Dojran Lake (Sapkarev, 1964) and Borrewant Lake (Ökland, 1964).

The vertical distribution of *H. stagnalis* in the lake as related to the seasonal change in the density of population may be seen in Figure 6. From this, one can see that the population density is greatest in the littoral zone, especially during the summer and early fall.

The average seasonal change in number and biomass for the littoral zone only is presented in Figure 7. The maximum population density and biomass of *H. stagnalis* is found in July and August (e.g., 1527.4 individuals, 0.83 gr. wet weight or 0.15 gr. dry weight per square meter in month of July). The minimum occurs in the winter months (e.g., in February, 22.2 individuals, 0.06 gr. wet weight or 0.01 gr. dry weight per square meter). The

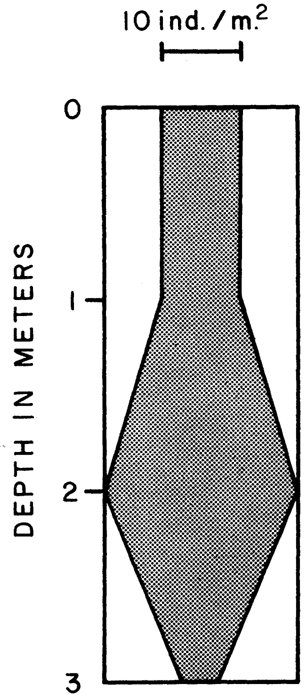

FIGURE 4. Average vertical distribution in the density of population of *Glossiphonia complanata* in Lake Mendota.

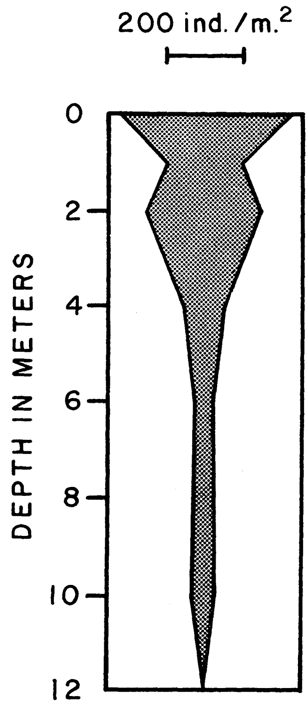

FIGURE 5. Average vertical distribution in the density of population of *Helobdella stagnalis* in Lake Mendota.

occurrence of the maximal population density in the summer, especially in the month of July, may be explained by the recruitment of a new generation. The earliest date that I observed a specimen with eggs attached to the ventral surface was May 10. In my collections during the period from May 20 to May 30, I found about 80 percent of the individuals with eggs, 10 percent with young, and about 10 percent with neither eggs nor young. Individuals captured during the period from June 1 to June 9 were found in the following state: about 60 percent with young, 30 percent with eggs, and approximately 10 percent with neither young nor eggs. During the whole month of July (especially beginning with July 5) I found free, young individuals of *H. stagnalis,* while the number of the old ones was reduced to a minimum. In August samples, all captured individuals were of the new generation. This fact may indicate that a great number of the old individuals die off after the reproduction period.

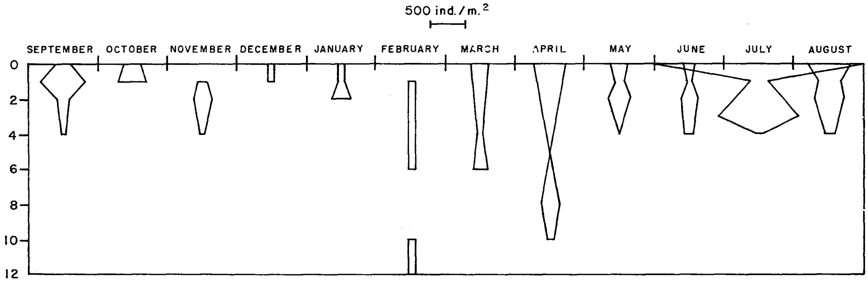

FIGURE 6. Vertical distribution and seasonal change in the density of population of *Helobdella stagnalis* during 1964–65 in Lake Mendota.

Individuals of *H. stagnalis* with eggs on their ventral surface which I captured on May 10, were kept in an aquarium having a water temperature between 16 and 19°C. Observations showed that between May 19 and May 22 some had young on their ventral surface and by the end of May and the beginning of June all were with young.

Thus, on the basis of the above, the reproductive period of *H. stagnalis* in Lake Mendota appears to cover less than two months (May and June). In eutrophic Dojran Lake I have found individuals of *H. stagnalis* with young during the months of August and September (Sapkarev, 1964). Bennike (1943) has found that the reproductive period of *H. stagnalis* in freshwater habitats of Denmark extends over more than four months (from May to September). An even longer season, from April to September, has been reported from North America (Castle, 1900) Central Europe (Herter, 1937) and Iceland (Bruun, 1938). Even in the northwestern part of Iran, the reproductive period has been found to last from February to June (Bennike, 1940). On the other hand, in the Alps the reproductive period is much shorter from late July to early August (Zshokke, 1900).

To determine the horizontal distribution of this leech in the lake, I took quantitative samples from ten different transects during May. The results are shown in Figure 8. Except for Morris Park and Governor's Island, it was found in all transects. A somewhat larger population density was found in the vicinities of Bascom Woods, Mendota Beach, Fox Bluff, and Maple Bluff. The greatest vertical distribution occurred at Second Point and Yahara Canal.

I was able to observe that *H. stagnalis* uses Chironomid larvae, tubificids and *Hyalella azteca* for food. This leech has been reported to feed on Chironomid larvae and other small freshwater invertebrates by Pawlowski (1936), Bennike (1943), Mann (1955, 1957) and Hilsenhoff (1963).

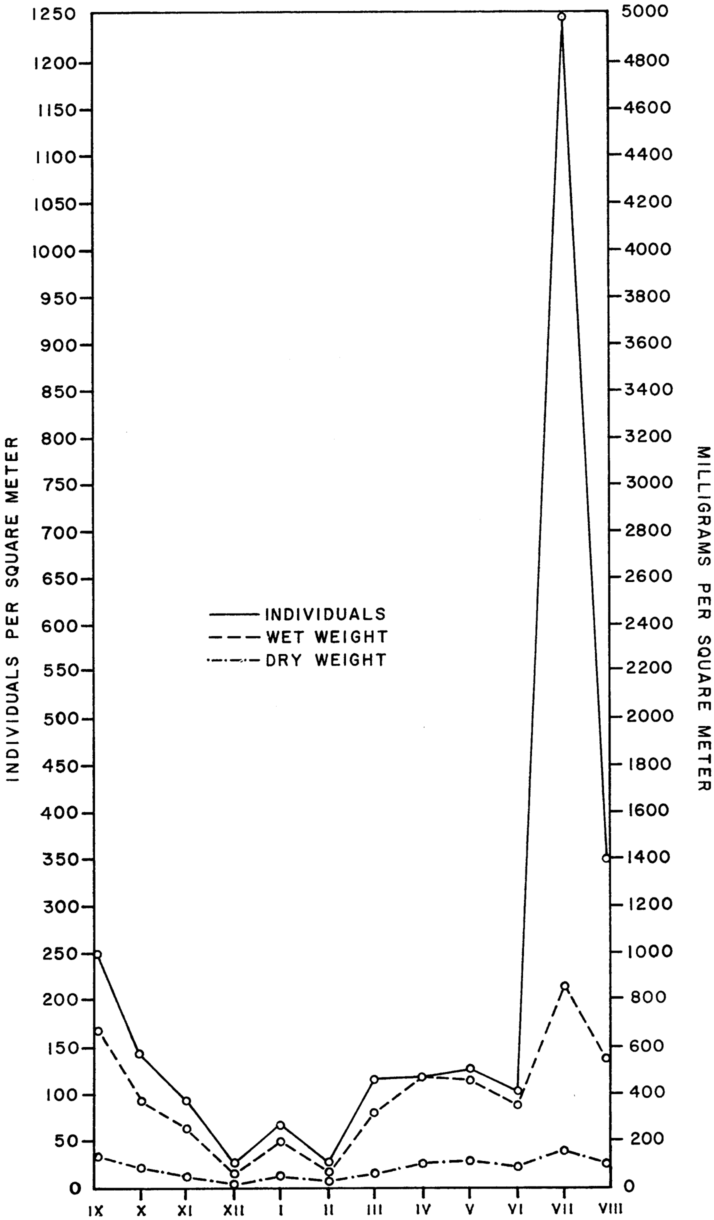

FIGURE 7. Average seasonal changes of the population density and biomass of *Helobdella stagnalis* in the littoral zone of Lake Mendota during 1964–65.

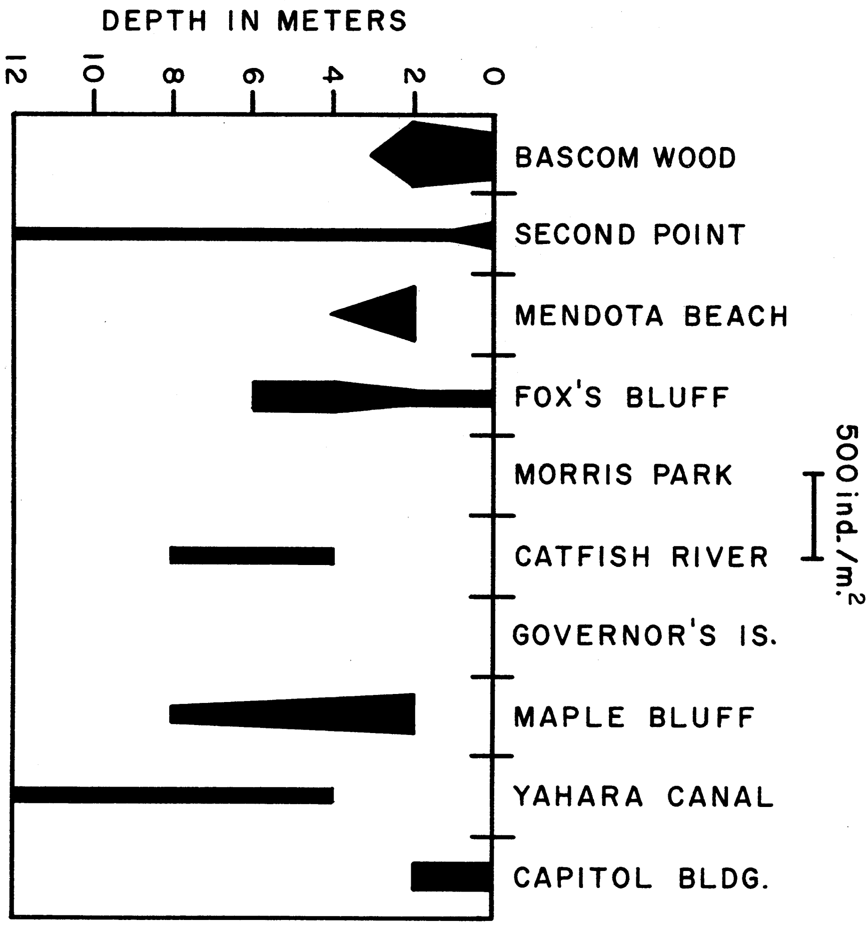

FIGURE 8. Horizontal distribution of the density of population of *Helobdella stagnalis* in Lake Mendota on the month of May, 1965.

6. *Helobdella punctata—lineata* (Moore) 1939

This species was described for the first time by J. P. Moore (1939) on the basis of material from Puerto Rico. My collection of leeches from Lake Mendota included only a single individual of this species. It was caught at a depth of two meters, where the lake bottom was composed of mud and sand with detritus and covered with vegetation. Because I found just one individual, I was able to recognize it only by its external morphological characteristics. It would be useful if more individuals could be found and studied in greater detail in order to establish whether it is in fact *H. punctata—lineata*.

7. *Helobdella lineata* (Verrill) 1874

This North American leech is encountered in Lake Mendota very infrequently. I was able to collect several specimens at a depth of one to two meters (Figure 2), where the bottom was composed of stones and gravel, mud and sand, mud with detritus, or mud and detritus with a cover of vegetation (Table 1). One specimen with eggs and two specimens with young were found on August 12.

Baker (1924) writes of it in another Wisconsin lake, Lake Winnebago, referring to it as *Helobdella fusca* variety *lineata.*

8. *Helobdella elongata* (Castle) 1900

Helobdella elongata is found in Canada and the United States (Castle, 1900; Moore, 1906, 1912, 1924; Ryerson, 1915; Miller, 1929; Rawson, 1930; Bere, 1931). It is mentioned here for the first time as occurring in Lake Mendota. It was found with greater frequency than the previous two species of this genus. I found it together with *H. Stagnalis,* especially in the Bascom Woods and Picnic Point transects. Excluding *H. stagnalis,* this leech has the greatest vertical distribution of all leeches in Lake Mendota (Figure 2). Its range in depth extends from the shore line to four meters, which would mean that it like all others except *H. stagnalis,* occurs only in the littoral zone.

The maximal population density is found along the shore line on the stoney bottom (177.6 individuals per square meter) with a biomass of 2.13 gr. wet weight or 0.36 gr. dry weight per square meter. The population density decreases with increasing depth. It settles in all kinds of habitats except in the deep lake muds (See Table 1).

Hilsenhoff (1964) is of the opinion that *H. elongata* feeds on tendipeded larvae or small mollusks.

9. *Placobdella ornata* (Verrill) 1872

For the genus *Helobdella* as well as for the genus *Placobdella,* I have found four species, all of them very rare. This species is found throughout the rivers, bogs, ponds, and lakes of North America (Verrill, 1872; Moore, 1901, 1906, 1912; Andrews, 1915; Ryerson, 1915; Miller, 1929; Rawson, 1930; Bere, 1931) and Japan (Oka, 1917). In my collection of leeches from Lake Mendota, I have collected a few specimens along the shore line in University Bay and Catfish Bay.

10. *Placobdella parasitica* (Say) 1824

Placobdella parasitica has been found in North America mainly in bogs, but also in lakes, occurring as a parasite of various animals. It was observed in Lake Mendota by Pearse (1924) as a parasite on bluegills, and elsewhere in the vicinity of Madison (Wingra springs Region) by Cahn (1915). I found just one specimen from the marshy part of University Bay of Lake Mendota.

11. *Placobdella montifera* (Moore) 1912

Placobdella montifera is distributed throughout the United States and Canada. It is found in many lakes in these countries; for example in Lake Nipigon (Moore,1924), Georgian Bay of Lake Huron (Ryerson, 1915), in many of the lakes (oligotrophic and eutrophic) of northeastern Wisconsin (Bere, 1931). Pearse (1924) mentions it as parasite on smallmouth black bass in Lake Geneva and on carp and hackleback sturgeon in Lake Pepin. I collected just one specimen in Lake Mendota in the area between Catfish Bay and Governor's Island.

12. *Placobdella sp.*

I observed two young specimens of a leech near the Yahara Canal along the shore line on the stones. Both of them belong to the same species of the genus *Placobdella,* but I was not able to determine the species to which they belonged.

FAMILY ERPOBDELLIDAE

1. *Dina parva* (Moore) 1912

The family *Erpobdellidae* is represented in Lake Mendota by three species belonging to three different genera. *Dina parva* is distributed throughout the United States and Canada (Moore, 1912, 1924), including many Wisconsin lakes (Baker, 1924; Bere, 1931). In Lake Mendota I encountered it most frequenttly in the area from Picnic Point to Mendota Beach together with *Erpobdella punctata* and *Nephelopsis obscura.* The latter two are more abundant than the former. I found it primarily on a rocky bottom and less frequently on a bottom of vegetation or sand (Table 1). It has a very limited vertical range, which extends in depth from 0 to 1 meters (Figure 2). The same distribution, density of population, and habitat for *Dina lineata* was observed in the macedonian lakes, Prespa and Dojran (Sapkarev, 1963, 1964).

2. *Erpobdella punctata* (Leidy) 1870

Erpobdella punctata is widely distributed in North America and occurs in various habitats including lakes (Moore, 1901, 1924; Ryerson, 1915; Muttkowski, 1918; Baker, 1924; Bere, 1931; Rawson, 1953 and others). This species was found in Lake Mendota by Muttkowski (1918).

In my research, it was the most abundant species among the *Erpobdellidae* and almost always was found together with *Nephelopsis obscura.*

As is stressed by Muttkowski (1918), optimal conditions for this species are on the shore margin where coarse gravel and stones are intermixed. This appears to account for the great abundance of the species on the northern and southern shores of Lake Mendota. From Table 1, one can see that the density of population is greatest on a stony bottom. Here the population density can attain a magnitude of 1332.0 individuals per square meter. In July and August, the period when the young generation appears, the density can be considerably greater in certain areas.

As shown in Figure 2, *E. punctata* was found at a depth of about 0–1.50 meters. The largest number of individuals occurs at a depth of 0–0.50 meters with an average of 85.1 individuals per square meter at a depth of 0.20 meters.

In winter and early spring *E. punctata* occurs in small numbers. In some months during this period, no individuals were found. From July to October and especially from July to August, a marked maximum occurred (Figure 9). This maximum density of population is associated with the appearance of a new generation.

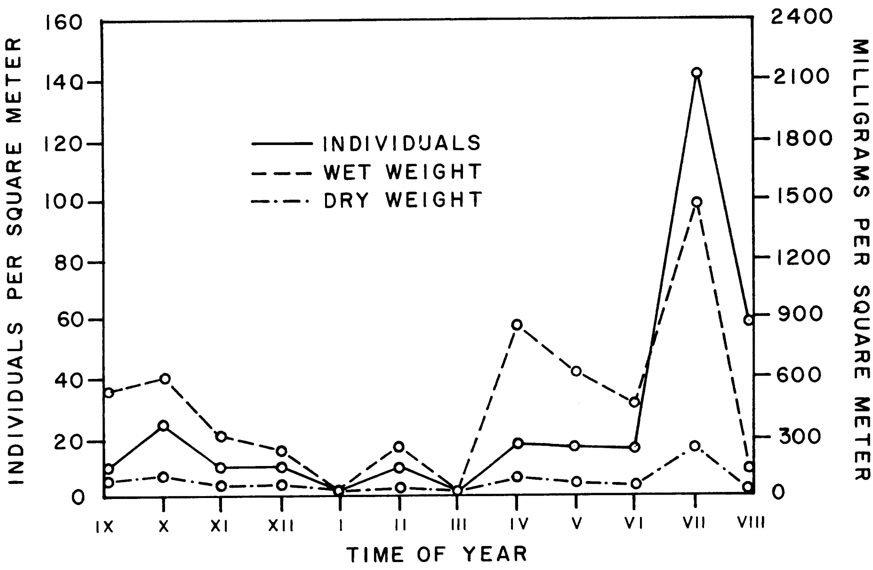

FIGURE 9. Average seasonal changes of the population density and biomass of *Erpobdella punctata* in the littoral zone of Lake Mendota during 1964–65.

Egg-cocoons have been found from May to August. After that time only empty cocoons have been found. The length of these cocoons varies from about two to eight millimeters. The number of eggs per cocoon is variable, but the largest number of cocoons were found with two to six eggs. When the young first appear in the cocoon, their length is about three millimeters, and when they leave the cocoon they are about five millimeters in length. The young in the same cocoon were frequently of very different sizes. Most of the young leave the cocoons in July. The egg-cocoons are common on the stones of rock and gravel shores to a depth of 0–1 meter. The number of egg-cocoons varies in the different habitats and localities. I was able to calculate their number per square meter as 888.0–2220.0. However, in some places the number can be either much larger or much smaller. The common European species, namely *E. octoculata*, has the same period of reproduction (Pawlowski, 1936; Berg, 1938; Bennike, 1943; Sapkarev, 1964).

I have observed that *Erpobdella punctata* uses *Oligochaeta* and larvae of *Chironomidae* for food. Muttkowski (1918) has found may-fly larvae *(Hexagenia, Caenis)* and *Trichoptera* larvae in *Erpobdella punctata.*

3. *Nephelopsis obscura* (Verrill) 1872

Like *Erpobdella punctata,* this species of the *Erpobdellidae* is widely distributed in North America and is found in different habitats, especially in the stony shore line of lakes (Verrill, 1872; Ryerson, 1915; Moore, 1924). *N. obscura* has been reported in many Wisconsin lakes (Muttkowski, 1819; Baker, 1924; and Bere, 1931). It was noted for the first time in Lake Mendota by Muttkowski (1918).

As is shown in Figure 2, the species was found at depths of 0–1.50 meters. The greatest density was found at about 0.20 meters with an average of 66.6 individuals and a biomass of 1.29 gr. wet weight or 0.21 gr. dry weight per square meter.

The species was found on almost all dredging days throughout the year. It is numerous in the summer samples (July and August), where an average number of individuals for the littoral zone was 97.7 per square meter. The corresponding biomass was 0.95 gr. wet weight or 0.14 gr. dry weight per square meter (Figure 10). The maximal density of population in July and August was due to the appearance of a new generation in that period. It seems that this species has a reproductive period similar to *Erpobdella punctata.*

Family Hirudinidae

1. *Haemopis marmorata* (Say) 1824

This single species of the family *Hirudinidae* in Lake Mendota

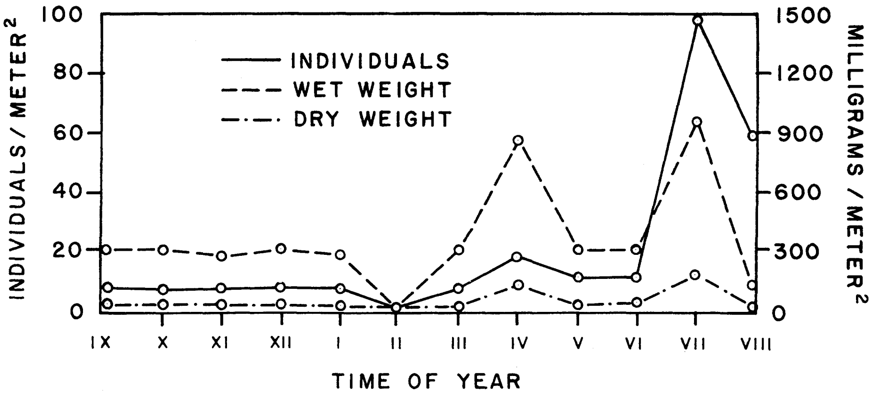

FIGURE 10. Average seasonal changes of the population density and biomass of *Nephelopsis obscura* in the littoral zone of Lake Mendota during 1964–65.

has been found in the Picnic Point and Pheasant Branch areas. It is frequently discovered under stones in the shore line or imbedded in the wet soil. Near Picnic Point it is found to a depth of 1 meter (Figure 2).

It has been encountered in some lakes of northeastern Wisconsin (Bere, 1931) as well as in other parts of the United States (Moore, 1901; Cahn, 1915) and Canada (Ryerson, 1915; Moore, 1924; Rawson, 1953).

DISCUSSION

A biocenotic analysis of the leeches in Lake Mendota shows that all species inhabit the littoral zone (Table 2). For each family, the number of species decreases with an increase in depth. Only one species of *Glossiphonidae*, namely *Helobdella stagnalis*, was present in the sublittoral and the upper region of the profundal zone.

It is readily seen from Table 3 that the fauna of *Hirudinea* of Lake Mendota is composed mainly of two families of leeches, namely *Glossophonidae* and *Erpobdellidae*. Of the total number of individuals, 85.7% are in the family *Glossophonidae*, whereas 17.6% belong to *Erpobdellidae*. Therefore, *Glossiphonidae* is the dominant family from the standpoint of numbers of species and individuals. During the year (1964–65), *Helobdella stagnalis (Glossiphonidae)* was dominant in numbers of individuals (75.6%), while *Glossiphonia complanata (Glossophonidae)* ranked second (7.7%). Very few individuals of *Helobdella elongata, Batracobdella phalera* and other species of *Glossiphonidae* were encountered; less than 0.9% for each.

TABLE II. THE NUMBER OF SPECIES OF LEECHES ENCOUNTERED AT DIFFERENT ISOBATHES OF DIFFERENT ZONES IN LAKE MENDOTA

ZONES	LITTORAL						SUBLITTORAL					PROFUNDAL			
Depth in meters	0	1	2	3	4	5	6	7	8	9	10	11	12	....	25
Family															
Glossiphonidae..........	12	7	6	3	2	1	1	1	1	1	1	1	1	—	—
Erpobdellidae..........	3	3	2	2	1	—	—	—	—	—	—	—	—	—	—
Hirudinidae..........	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Total..........	16	11	8	5	3	1	1	1	1	1	1	1	1	—	—

TABLE III. RELATIVE DOMINANCE OF THE SPECIES OF LEECHES IN LAKE MENDOTA BASED ON THE TOTAL NUMBER OF INDIVIDUALS ENCOUNTERED DURING 1964–65

SPECIES	PERCENT
Family *Glossiphonidae*	*85.68*
1. *Glossiphonia complanata*	7.66
2. *Glossiphonia heteroclita*	0.94
3. *Batracobdella phalera*	0.36
4. *Batracobdella picta*	0.01
5. *Helobdella stagnalis*	75.58
6. *Helobdella puctata—lineata*	0.01
7. *Helobdella lineata*	0.10
8. *Helobdella elongata*	0.88
9. *Placobdella ornata*	0.10
10. *Placobdella parasitica*	0.01
11. *Placobdella montifera*	0.01
12. *Placobdella* sp.	0.02
Family *Erpobdellidae*	*13.77*
1. *Dina parva*	1.01
2. *Erpobdella pinctata*	7.05
3. *Nephelopsis obscura*	5.71
Family *Hirudinidae*	*0.55*
1. *Haemopsis marmorata*	0.55

The average total number and biomass of all *Glossophonidae* at various depths in the lake is presented in Figure 11. As may be seen from this figure, the maximum density of population and biomass occurs in the littoral zone at a depth of 0 to 3 meters (the average of a one year period at the 0 meter depth is 558.7 individuals, corresponding to a biomass 2.13 gr. wet weight or 0.43 gr. dry weight per square meter).

Figure 12 shows average seasonal changes in population density and biomass of *Glossiphonidae* in the littoral zone during 1964–65. The minimal density of population and biomass occurs in the winter months (December–February). The maximum number of individuals occurs in the summer months (July–August) and is associated mainly with the appearance of new generations of *Helobdella stagnalis* and *Glossiphonia complanata.*

The average vertical distribution in numbers and biomass of *Erpobdellidae* in Lake Mendota is presented in Figure 13. *Erpobdellidae* has little vertical distribution, occurring only to a depth of 1.50 meters. Maximum density occurs along the shore line (0–0.50 meters).

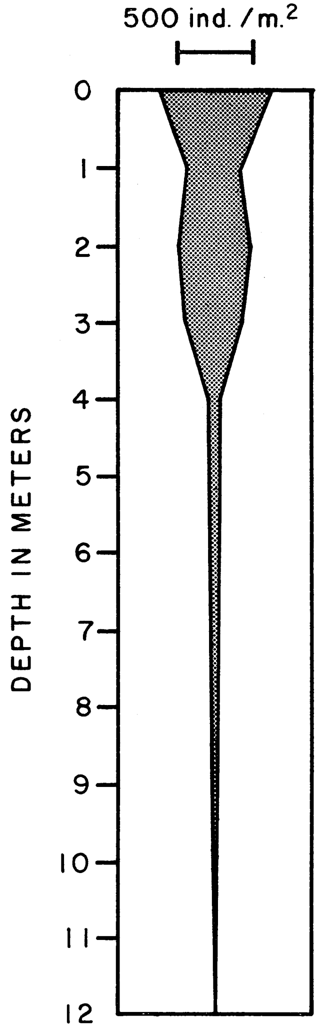

FIGURE 11. Average vertical distribution in the density of population of *Glossiphonidae* in Lake Mendota.

The most abundant species of *Erpobdellidae* are *Erpobdella punctata* with 7.0% and *Nephelopsis obscura* with 5.7% of the total number of individuals of leeches in Lake Mendota. This means that the former comes as the third and the latter as the fourth in num-

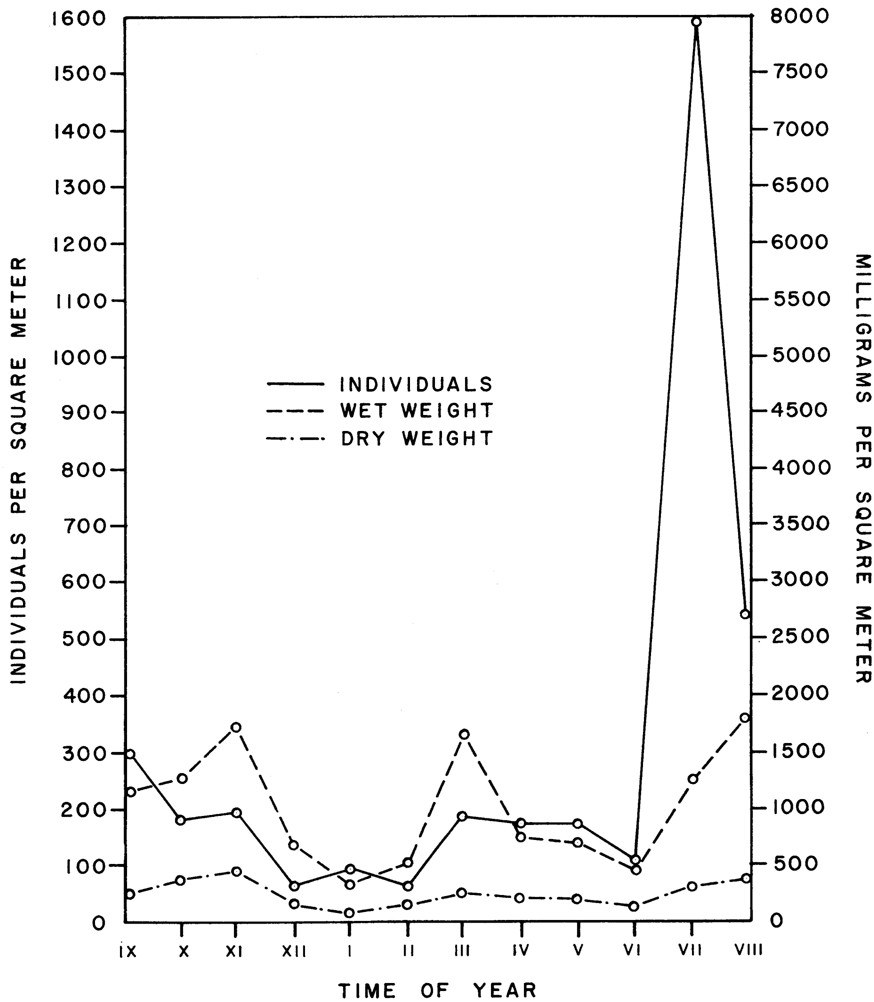

FIGURE 12. Average seasonal changes of the population density and biomass of *Glossiphonidae* in the littoral zone of Lake Mendota during 1964–65.

ber of individuals of leeches in the lake. The third species of *Erpobdellidae, Dina parva,* has a relative density of just about one percent.

The average seasonal changes in population density and biomass (wet and dry weight) of the *Erpobdellidae* during the study are represented in Figure 14.

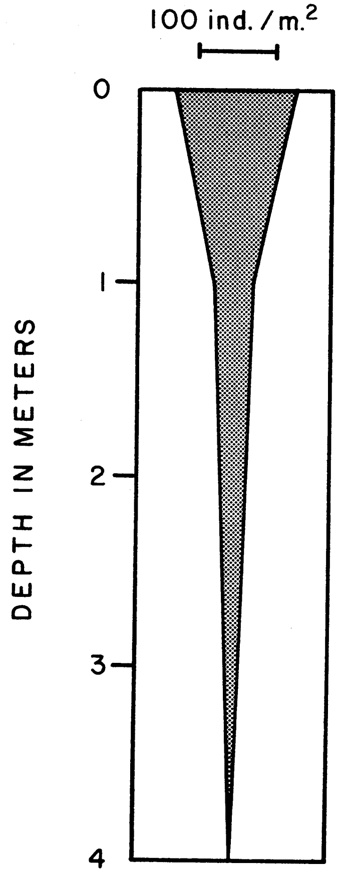

FIGURE 13. Average vertical distribution in the density of population of *Erpobdellidae* in Lake Mendota.

The minimal population density and biomass of *Erpobdellidae* occurs in the winter months (January–March) and is probably associated with the severity of the environment at that season of the year. The maximal density of population occurs in the summer months (July–August) and corresponds with the appearance of a new generation of *Erpobdella punctata* and *Nephelopsis obscura*.

Finally, Figure 15 shows the average, vertical distribution of all leeches in Lake Mendota. It may be seen that: 1) the greatest density of population and biomass (710.4 individuals, 5.16 gr. wet weight, or 0.92 gr. dry weight per square meter at a depth of 0

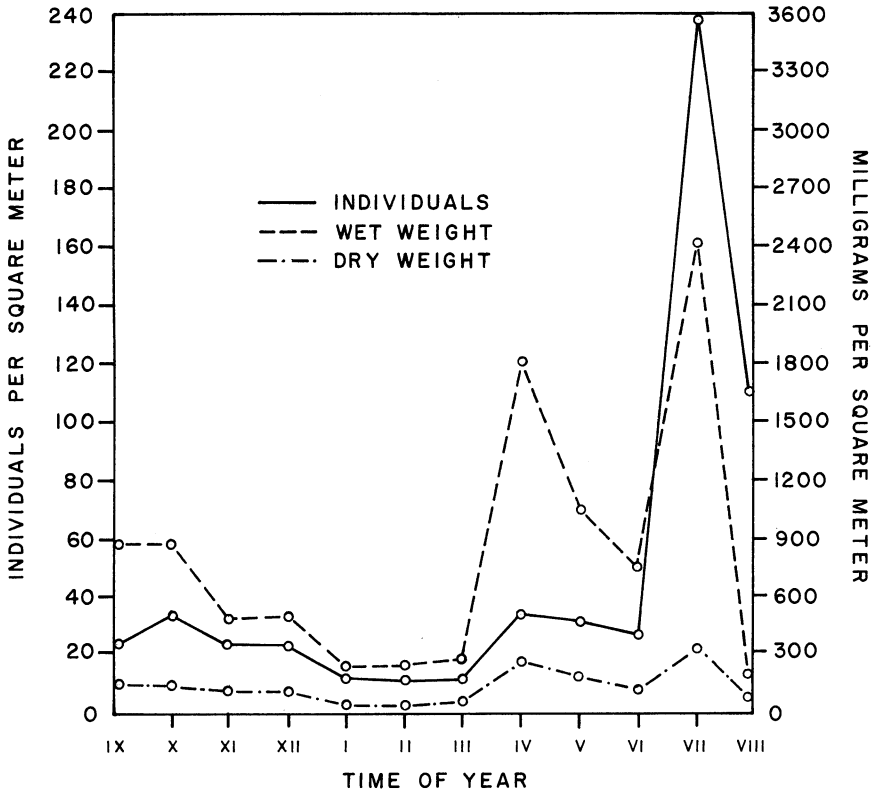

FIGURE 14. Average seasonal changes of the population density and biomass of *Erpobdellidae* in the littoral zone of Lake Mendota during 1964–65.

meter) is found in the littoral zone; 2) an insignificant number of individuals (14.8 individuals, 0.05 gr. wet weight, or 0.01 gr. dry weight per square meter) occurs in the sublittoral zone; 3) in only a few cases during the study period were several individuals (of *Helobdella stagnalis*) found along the rim of the profundal zone (3.7 individuals, 0.0014 gr. wet weight or 0.0003 gr. dry weight per square meter) at a depth of 12 meters.

Table 4 shows the average population density and biomass of the leeches per square meter in the three zones of Lake Mendota, as well as the average figures calculated for all zones.

Figure 16 shows the vertical distribution of the population density of the leeches during the study period. It is possible to see that the greatest vertical distribution occurs at the end of winter and the beginning of spring, but that the greatest density of population occurs in the summer (July–August).

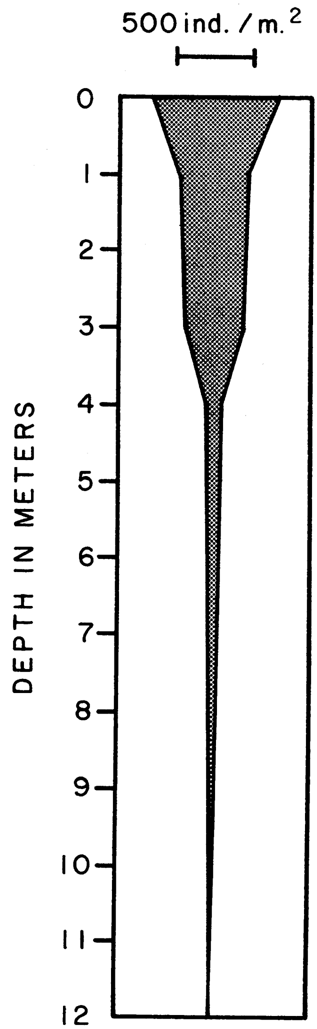

FIGURE 15. Average vertical distribution in the density of population of *Hirudinea* in Lake Mendota.

As in the case of *Glossiphonidae* and *Erpobdellidae,* it is natural that the maximum density of population and biomass of all *Hirudinea* fauna should occur in the summer months (July–August). At this time the young generation of several species appears, particularly of the most abundant leeches, such as *Helob-*

TABLE IV. THE AVERAGE POPULATION DENSITY AND BIOMASS OF LEECHES (HIRUDINEA) IN DIFFERENT ZONES OF LAKE MENDOTA

ZONES / Per Square Meter	LITTORAL	SUBLITTORAL	PROFUNDAL	AVERAGE FOR ALL ZONES
Individuals	355.2	13.6	0.7	90.3
Wet weight in gr	1.8657	0.0443	0.0003	0.4648
Dry weight in gr	0.3455	0.0092	0.00006	0.0888

della stagnalis, Erpobdella punctata, Nephelopsis obscura and *Glossiphonia complanata.* It is also natural that the minimum density of population and biomass should occur in the winter months (December–February), probably as the result of very severe conditions during that period of the year. The average seasonal changes in population density and biomass of all leeches in the littoral zone of Lake Mendota during 1964–65 are represented in Figure 18.

The horizontal distribution in the density of the leeches in Lake Mendota in May 1965 is represented in Figure 17. From this one can see that the leeches having a larger density of population occur in the Maple Bluff, Fox's Bluff, Bascom Woods, and Second Point areas. However, the greatest vertical distribution is found in the Second Point, Yahara Canal, Maple Bluff and Fox's Bluff regions.

ACKNOWLEDGMENTS

I would like to take this opportunity to thank the University of Wisconsin for supporting my research and sponsoring the Ameri-Skopje. I wish to extend my particular appreciation to Professor

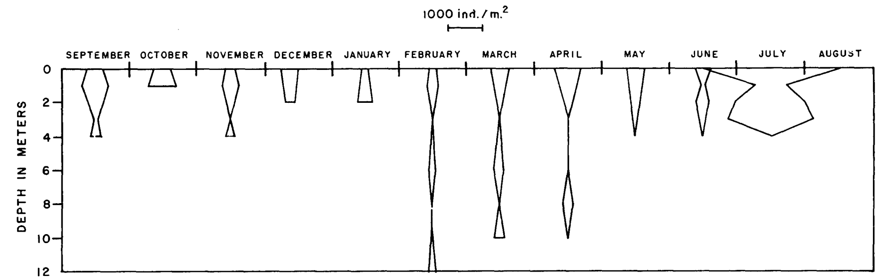

FIGURE 16. Vertical distribution in the density of population of the leeches during 1964–65 in Lake Mendota.

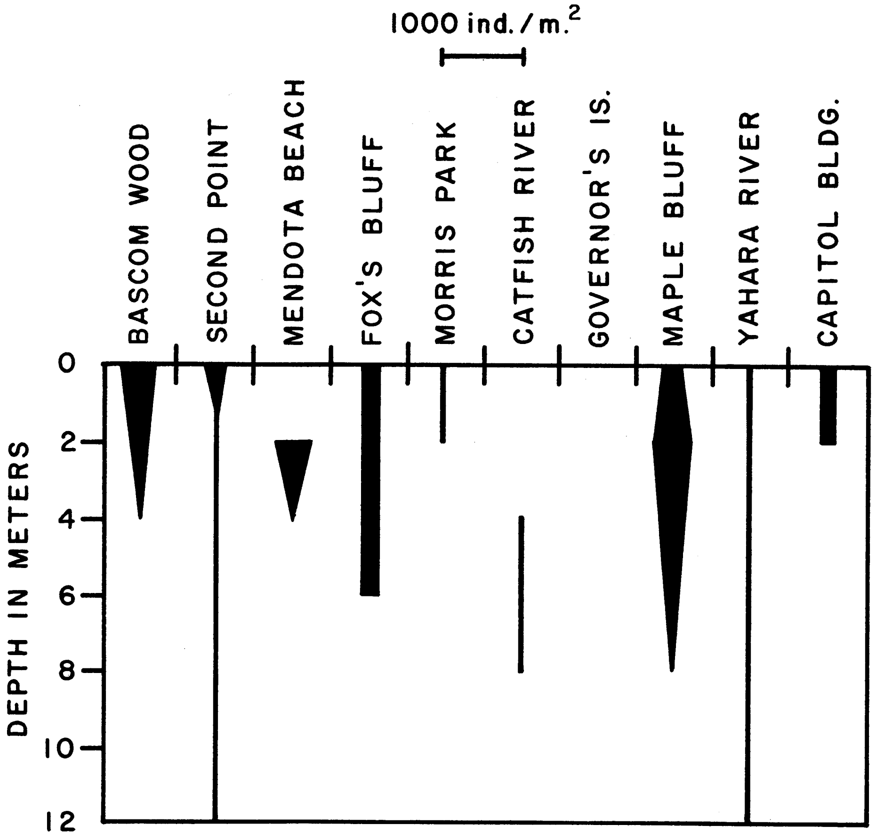

FIGURE 17. Horizontal distribution in the density of population of the leeches in Lake Mendota on the month of May, 1965.

can–Yugoslav Exchange for staff members of the University of Arthur D. Hasler, Director of the Laboratory of Limnology, for the many suggestions which he made concerning my work; to Dr. Marvin C. Meyer, Professor of Zoology, University of Maine, for verifying my identifications of Lake Mendota leeches; to Mr. Gary L. Hergenrader, graduate student in the Laboratory of Limnology, with whose help I was able to take the bottom samples during the winter period; and to Mr. Paul E. Sager, graduate student at the Laboratory of Limnology, for his help in reviewing the manuscript. Finally, I should also like to thank all others, especially the members of the staff of the Laboratory of Limnology, Department of Zoology of the University of Wisconsin, for the many ways in which they have contributed to this project.

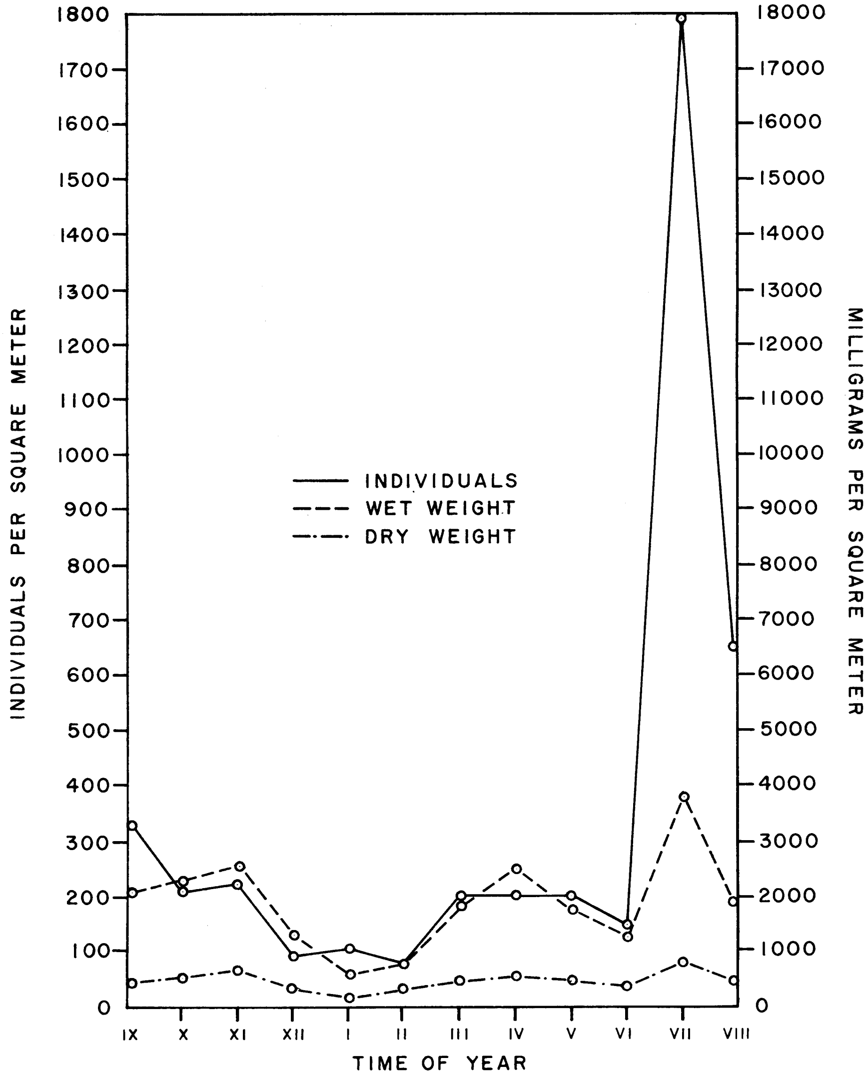

FIGURE 18. Average seasonal change of the population density of biomass of *Hirudinea* in the littoral zone of Lake Mendota during 1964–65.

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RABIES AND RABIES CONTROL IN WISCONSIN

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A prerequisite to any consideration of rabies control in Wisconsin is a review of the status of the disease, a resume of some of the factors that have contributed to the situation, and a summary of the specific control approaches utilized.

Status of Rabies

The prevalence and relative distribution of rabies in wild and domestic animals in Wisconsin (Table 1) is not unlike that reported in the United States (Scholtens and Tierkel, 1963). Despite annual fluctuations in the total number of rabies cases in the state, the disease in domestic animals has not varied significantly since 1952. The major change has occurred in wild animal rabies, especially the skunk *(Mephitis mephitis)*.

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Table 1. A Summary of Animal Rabies in Wisconsin. (1952–1966)

Year	Total	Number of Laboratory Cases					
		Domestic	Wild	Skunk	Fox	Bat	Raccoon
1952	56	27	29	27	1	0	1
1953	49	21	28	25	2	0	1
1954	90	47	43	36	6	0	1
1955	39	17	22	19	3	0	0
1956	41	23	18	13	2	0	2
1957	74	23	51	37	5	6	2
1958	227	33	194	184	7	3	0
1959*	92	23	69	64	4	1	0
1960	24	15	9	5	1	0	1
1961	30	21	9	5	1	2	0
1962	42	24	18	12	1	5	0
1963	62	33	28	17	7	5	1
1964	95	62	33	12	11	6	3
1965	64	39	25	21	2	1	1
1966	68	41	27	22	4	1	0

*Since 1959, wild animals were tested only if there was human exposure.

In 1958, there were 184 laboratory confirmed cases of rabies in skunks, more than 10 times the number recorded two years earlier. Due to the volume of wild animals submitted for rabies examination and the fact that at least 85 per cent of all submitted skunks were rabid, the State Laboratory of Hygiene, beginning in 1959, examined wild animals only if there was human exposure. All of the rabies laboratory examinations in Wisconsin are conducted by the State Laboratory of Hygiene. Wild animal rabies figures subsequent to 1959 are therefore not directly comparable with those of prior years. Since the establishment of this new laboratory policy, the number of confirmed skunk rabies cases, all involving human exposure, has persisted and even risen moderately indicating the existance and a possible increase of rabies in this species.

Despite a sizable population, the fox *(Vulpes fulva* and *Urocyon cinereoargenteus)* has not been an important rabies target in Wisconsin (Table 1). Rabies in insectivorous bats was initially detected in Wisconsin in 1957, and since then has been detected annually in low numbers (Table 1). Despite a large and increasing raccoon *(Procyon lotor)* population, rabies persists in this species at a low level (Table 1).

Until 1960 the principle domestic animal target of rabies was the dog. Since then, the cow and the dog have fluctuated as the leading domestic animal victim. Sporadic rabies cases have also occurred in cats, swine and horses.

Wildlife Populations

Since the reservoir of rabies in Wisconsin exists among wild populations, a review of some population trends of involved species is appropriate. To census any wild population on a state-wide basis is difficult, however related data can sometimes be utilized to project

Table 2. Some Wildlife Harvest Figures in Wisconsin. (1920–1965)

Year	Species (thousands)		
	Skunk*	Fox**	Raccoon*
1920	56.3	—	4.6
1930	56.7	3.4	6.4
1940	50.7	11.0	13.6
1950	11.6	28.5	34.3
1960	0.8	57.0	50.0
1965	0.4	52.8	63.2

*Harvest figures from WCD trapping and hunting records.
**Harvest figures from WCD bounty records.

trends of these wild populations. For example, bounty payment figures provide a kill figure which can be utilized to project population trends. A summary of fox bounty records (Table 2) suggests a fluctuating population which has tended to increase since 1930. Despite this apparent increase of fox numbers there has been no conspicuous alteration in rabies prevalence (Table 1). During this 35 year span, fox pelt prices have ranged from $12 to 40¢ with the highest prices paid at either end of the period (Wisconsin Conservation Department, 1965[a]).

The raccoon is not a bountied animal in Wisconsin, but it is utilized as fur, meat and sport. Harvest figures for the raccoon (Table 2) have increased from 4,600 in 1920 to 63,200 in 1965. Raccoon fur prices have varied during this period ($4.35 in 1920; 65¢ in 1948; $2.50 in 1965) and undoubtedly influence the harvest. Low fur prices result in less trapping effort and a larger raccoon population. Since 1945 the raccoon has become an important sports animal and harvest figures now include a larger proportion of animals taken by hunting than by trapping. Increasing harvest figures and reports of crop depredation, vandalism, etc. indicate an extensive and growing raccoon population. This apparent rise in raccoon numbers has not been accompanied by a parallel increase in rabies.

The skunk, Wisconsin's major rabies target, was once an important fur animal. In fact it was the second most important fur bearer in the state in 1918 when 74,300 skunks brought Wisconsin trappers almost one-third of a million dollars (Scott, 1940). Because of its fur value the skunk was protected by prescribed trapping seasons until 1930 when the Conservation Commission was asked by the Department of Agriculture to withdraw protection of the skunk because it was a reservoir of rabies. As late as 1945, more than 58,000 skunks were harvested. Fur prices have declined steadily since the mid-1940's and today a prime skunk pelt is worth less than a dollar.

Trapping in general and for skunks in particular has declined drastically since 1945, and in recent years the number of skunks harvested is less than a thousand. Table 3 depicts this decline in trapping interest despite a marked increase in other outdoor activities. The drop in fur value accompanied by the decline in trapping has resulted in a decreased harvest of skunks and an apparent increase in their numbers.

Land Use Changes

There are 36 million acres in Wisconsin of which 34% in crop land and 40% is forests. Several important land-use changes in Wisconsin have undoubtedly contributed to changes in wildlife numbers. Similar to the national trend of farming and land use, the number of farms, farmers, and acres in farms has declined in recent years (Table 4). In addition to the reduction of acres in farms (from 23.5 to 21.2 million) more than 770,000 acres have been retired in various Conservation Reserve programs (Buse and Brown, 1965).

The purchase and development of land for wildlife purposes is a major program in Wisconsin. The Game Division of the Wisconsin Conservation Department in 1927 initiated a land acquisition program. Since that time they have 208 individual projects underway or completed in which they own 273,000 acres and lease another 291,000 acres for public hunting. In addition there are 4.5 million acres of national, state or county forest land, and private forest croplands available for public recreation. In 1961 the Wisconsin Outdoor Recreation Act established a one cent per pack tax on cigarettes. These funds (approximately 5 million dollars annually) are earmarked for land acquisition to protect and promote natural resources in the state.

Another growing industry in Wisconsin is wildlife farming. There are 27 beaver farms (6,600 acres), 156 deer farms (100,582

TABLE 3. WISCONSIN CONSERVATION DEPARTMENT LICENSE SALES. (1920–1965)

Year	Type of License (thousands)				
	Trapping	Hunting	Deer	Fishing	Sportsman*
1920	20.0	NR**	50.2	NR	NR
1930	18.9	NR	77.3	NR	NR
1940	15.3	295.7	102.3	233.1	2.8
1950	10.4	455.8	289.4	716.7	20.0
1960	4.4	278.3	269.8	612.9	65.3
1965	2.1	378.8	382.6	490.9	218.5

*A sportsman license allows hunting, fishing and trapping.
**Not required.

TABLE 4. FARM TRENDS IN WISCONSIN. (1935–1965)

	1935	1945	1955	1965
Total Number Farms (Thousands)	200	178	155	124
Total Farm Acreage (Millions)	23.5	23.7	23.2	21.2
Total Land in Farms (%)	66	66	64	60

acres), 1,012 game bird farms (7,085 acres), 350 muskrat farms (45,717 acres) and 128 shooting preserves (43,775 acres). In addition the federal government has more than 150,000 acres in wildlife refuges.

Reforestation provides another example of land alterations which can result in wildlife habitat improvement. In 1959 state nurseries alone distributed 43 million trees for reforestation (Wisconsin Conservation Department 1965[b]). Another 1.9 million game food shrubs were sold to private land owners by state nurseries.

Various combinations of the aforementioned changes could have an important impact on wildlife populations. Accompanying this increase in the number of potential rabies vectors, is the increased opportunity for human contact with wildlife. Wisconsin is in step with the nation concerning increased outdoor recreation. It has 71 state recreation areas with camp sites, 39 federal areas, 169 county or city areas and 270 private camping establishments (Wisconsin Conservation Department, 1965[c]). In state parks alone during 1964 there were six million visitors and over 700,000 camper days spent. The steady increase in hunting and fishing license sales (Table 3) further attests to this outdoor trend.

Rabies Control Program

Despite these increased opportunities for human contact with rabies, the disease has not been a major human health problem in Wisconsin. There has been one human rabies death, the result of a bat bite, in the state during the last decade.

Although wild animal bite records are not maintained in Wisconsin, the majority of wild animal rabies suspects submitted for diagnosis involve human exposure; therefore, the threat of human rabies is ever present and real. To combat this potential rabies problem, various agencies and organizations acting independently and on occasion together have produced a variety of rabies control programs. Basically the approach has been one of education involving the public, physicians, veterinarians and wildlife professionals as well as pet vaccination programs and the control of local wildlife populations.

The Wisconsin Department of Agriculture through its Animal Health Division promotes an educational program on rabies for Department employees and veterinarians. A monthly computation of animal rabies cases by county is issued to all concerned individuals. Its monthly newsletter "Animal Health" is supplied free to state veterinarians and reports the status of rabies in wild and domestic animals, the location of recent cases, current rules and regulations concerning the disease, and other significant rabies information. On several occasions a geographic section of the state has been quarantined due to the threat of rabies.

Local Veterinary Associations with the aid of University of Wisconsin extension personnel have established county vaccination clinics. Almost half of the 72 counties in Wisconsin have sponsored local rabies vaccination clinics which have varied in size, procedure and success. Most of these programs were initiated in 1958 when rabies was very prevalent in the state. Some programs were discontinued after several years, others exist today, and new clinics are being added annually—especially in recreation areas.

The State Health Department conducts an educational program similar to the Department of Agriculture, but directed toward local health agencies and physicians. Data on the status of rabies, appropriate therapeutic procedures, and recommended laboratory protocol are stressed. Their newsletter as well as conventional news media are utilized. The State Laboratory of Hygiene of the State Health Department conducts all of the diagnostic rabies work in Wisconsin, a free service available to physicians and veterinarians.

Since the major rabies problem involved wildlife, the Wisconsin Conservation Department is concerned and sponsors an active program of information and education. Department personnel are informed on the status of the disease in wild and domestic animals via periodic administrative directives stressing signs of disease, procedure for handling rabies suspects, and the appropriate protocol following human exposure.

Campers are an important high risk group; therefore, an educational program on rabies in wildlife involving the press, television, and radio is periodically directed at this group as well as other outdoor sportsmen. Rabies warnings are posted at appropriate state camp grounds and dogs are restrained in all parks. The vaccination of hunting dogs is promoted.

If rabies problems exist in local skunk, fox or raccoon populations adjacent to a camp site, control by shooting and trapping is initiated. In addition an extension predator trapping program has been initiated to teach farmers or other interested sportsmen to trap wild animals.

The combination of the aforementioned programs, education of the public and involved professionals, has proven effective in containing this important disease problem in Wisconsin. The continuation of this educational approach with rabies surveillance, vaccination, and control of local wild populations is anticipated and essential.

Summary

Rabies has been present in Wisconsin for many years in both wild and domestic animal populations. Despite annual fluctuations

since 1952, no significant change in the prevalence of rabies in domestic animals has occurred. Wildlife rabies, specifically in the skunk, has varied considerably during this period. Some of the environmental alterations that have contributed to the wildlife rabies picture are new agricultural patterns, reforestation and increased recreation activities.

Various agencies including the State Departments of Agriculture, Health, and Conservation pursue an informational and educational rabies program aimed at the public, physicians, veterinarians and wildlife professionals. This in combination with vaccination clinics and control of local wildlife populations contains the rabies problem in Wisconsin.

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NOTES ON WISCONSIN PARASITIC FUNGI. XXXIII

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This series of notes is, unless stated otherwise, based on collections made during the season of 1966.

General Observations

A high incidence of powdery mildews in Wisconsin is noted by Dr. Koji Hirata who has recently (1966) published a book entitled "Host Range and Geographical Distribution of the Powdery Mildews". Through 1962, according to his tabulation, 380 different powdery mildew–host combinations had been reported for this state—more than for any other state in the Union. This despite the fact that Wisconsin is not exceptionally rich in total number of higher plant species. Hirata ascribes this profusion, no doubt correctly, to the intensive collecting efforts of the late J. J. Davis and the writer, carried on almost continuously for the past eighty-odd years.

MYCOSPHAERELLA sp. on stems of *Eleocharis acicularis* (L.) R. & S. collected June 26 at Madison appears to have developed parasitically. The clear grayish-black perithecia are closely gregarious, deeply sunken, subglobose, about 115–140 μ diam.; asci hyaline, narrowly clavate, 60–65 x 9–11 μ; ascospores hyaline, subfalcate, approx. 16–17 x 5 μ. The host plants were on rapidly drying soil, but were in the main still green and healthy.

MYCOSPHAERELLA SARRACENIAE (Schw.) House on the brown upper portions of otherwise still green "pitchers" of *Sarracenia purpurea* L., collected June 11 at Hope Lake Bog near Lake Mills, Jefferson Co., may possibly, it would seem, have initiated its development parasitically.

MYCOSPHAERELLA sp. is amphigenous on suborbicular to irregularly elongate brownish-cinerous, mostly marginal areas on leaves of *Heliopsis helianthoides* (L.) Sweet, collected in Iowa Co., near Mazomanie, August 5. The perithecia are scattered to gregarious, black, thick-walled, subglobose, about 175–225 μ diam.; asci hyaline, short-pedicellate, subcylindric or slightly obclavate, 37–42 x 5–7.5 μ; ascospores hyaline, fusoid, 10–11 x 2.5–2.7 μ. Possibly parasitic.

SPHAERULINA sp., probably parasitic in its early development, has been noted at different times in several localities on still attached and also on fallen leaves of *Quercus ellipsoidalis* Hill. The scattered, epiphyllous perithecia do not mature in the fall but can be brought to maturity in the following spring by holding in a moist chamber for several days, as was done with a collection made October 13, 1965 at Tower Hill State Park, Iowa Co. The black, globose, thick-walled perithecia are approx. 135–150 μ diam.; asci hyaline, curved and clavate, 40–45 x 8–9 μ; ascospores hyaline, straight, narrowly cylindric, 3-septate, about 15 x 3 μ. The dimensions of asci and spores do not correspond with any of the several species of *Sphaerulina* described as occurring on oak leaves.

PRINGSHEIMIA (?) sp., possibly parasitic, occurs on dead white areas on leaves of jet-bead, *Rhodotypos tetrapetala Makine* (cult.), collected at Madison, July 27. This is a coarser form than *Pringshemia sepincola* (Fr.) Hoehn. which develops on rose twigs. In the specimen on *Rhodotypos* the fruiting structures (perithecia?) are epiphyllous, black, globose, erumpent, gregarious, widely ostiolate, about 135–150 μ diam.; asci hyaline, 8-spored, broadly clavate, the wall appearing quite thick, overall about 60 x 35 μ; ascospores hyaline, broadly fusoid, 4-septate with usually one or two cross septa, about 26–28 x 10–11 μ.

PHYLLOSTICTAE, appearing parasitic, but undetermined as to species, continue to be found. Descriptive notes on some of these follow mention of the names of the host plants on which they occurred:

1) On *Sorghastrum nutans* (L.) Nash, near Leland, Sauk Co., June 14. The spots are 1.5–3 mm. long, narrowly ellipsoid with tan centers and purplish borders, the pycnidia scattered, black, subglobose, small, about 85–115 μ diam., the conidia hyaline, subcylindric to subfusoid, biguttulate, approx. 12–16 x 3.5–5 μ. No septa were seen, but it seems possible this may be a poorly developed *Ascochyta* or *Stagonospora*. 2) On *Aquilegia canadensis* L., near Leland, Sauk Co., July 8. The lesions are subcircular, sordid brown, sinuous, with pale brown inner portion and relatively wide blackish-purple margins, the pycnidia epiphyllous, gregarious or scattered, black, subglobose, widely ostiolate, about 100 μ diam., the conidia hyaline, biguttulate, subcylindric, broadly ellipsoid, or more rarely broadly subfusoid, 7.5–11 x (2.5)3.5–4 μ. 3) On *Pyrus ionensis* (Wood) Bailey, at Madison, August 30. The lesions are orbicular, reddish-brown, subzonate, about 1–2 cm. diam., the pycnidia epiphyllous, scattered, flattened, quite superficial, light brown, thin-walled, rather widely ostiolate, about 75–100 μ diam., the conidia hyaline, short-cylindric or ellipsoid, shall, approx. 4–5 x 1.7–2 μ.

It seems possible that the spots are due at least in part to *Fusicladium dendriticum* action. 4) On *Geum canadense* Jacq., near Leland, Sauk Co., July 8.The lesions are subcircular, sordid brown, immarginate, slightly sunken, small, about 1.5–3.5 mm. diam., the pycnidia epiphyllous, loosely gregarious, black, subglobose, thick-walled, rather widely ostiolate, about 125–175 μ diam., the conidia hyaline, fusoid, subfusoid, or narrowly ellipsoid, frequently biguttulate, (5–)6.5–9.5 x 2.3–2.6 μ. Suggestive of *Phomopsis,* but no scolecospores were observed. 5) On *Prunus virginiana* L., at Madison, June 30. The lesions are orbicular, bright reddish-brown, subzonate, circumscissle and dehiscent, about .3–1 cm. diam., the pycnidia epiphyllous, pallid brown, flattened and imperfect below, tiny, about 40–60 μ diam., the conidia subhyaline with a faintly sooty tinge, variable in shape, oblong, ovoid, broadly ellipsoid or broadly subfusoid, 4.5–8 x 2.7–4.2 μ. 6) On *Gaultheria procumbens* L., near Leland, Sauk Co., June 22. The lesions are white, rounded, up to 5 mm. diam., the pycnidia epiphyllous, scattered, shining black, rather deeply immersed, globose, about 100–150 μ diam., the conidia pallid brownish in mass, but individually appearing hyaline, straight, rod-shaped, approx. 5.5–8.5 x 1.32–2 μ. The conidia of *Phyllosticta gaultheriae* Ell. & Ev. are described as running 5–7 x 4–5 μ. 7) On *Solidago riddellii* Frank, at Madison, September 16. The lesions are dark-bordered with gray central portion, narrow elongate, ranged along the leaf midrib, the pycnidia subcuticular, epiphyllous, gregarious, black, thick-walled, somewhat flattened, about 150 μ diam., the conidia hyaline, ellipsoid or sufusoid, approx. 10–13 x 5–7 μ. Except for the subcuticular habits this is much like *Leptothyrium similisporum* (Ell. & Davis) Davis which occurs on several species of *Solidago* in Wisconsin. 8) On *Solidago patula* Muhl., near Leland, Sauk Co., August 12. The lesions are grayish, immarginate, orbicular, 1 cm or more in diam., the pycnidia scattered, pallid brownish, thin-walled, subglobose, about 200 μ diam., the conidia hyaline, slender-cylindric, contents granular, approx. 7.5–10 x 1.2–1.7 μ, non-septate. Approaches *Septoria* in conidial dimensions. 9) On *Erigeron annus* (L.) Pers., near Leland, Sauk Co., July 8. The spots are tan with narrow, darker brown margin, orbicular or semi-orbs impinging on the leaf margin, .6–1.2 cm. diam., the pycnidia epiphyllous, gregarious, pallid brownish, thin-walled, subglobose, about 90–150 μ diam., the conidia hyaline, broadly ellipsoid, ovoid, occasionally subfusoid, approx. 5–7.5 x 2.5–3.5 μ, very numerous. 10) On *Silphium perfoliatum* L., near Leland, Sauk Co., July 20. The spots are few and scattered, usually only one or two per leaf, rounded, with cinereous centers and darker borders, about 2–6 mm. diam., the pycnidia appearing amphigenous, gregarious, pallid brownish, thin-walled and translucent, subglobose, approx. 100–150 μ diam., the conidia hyaline, subcylindric or subfusoid, approx. 4.5–7 x 2.3–2.7 μ.

PHOMOPSIS sp., which appears to have originated parasitically, infects the stems and capsules of *Aquilegia canadensis* L. collected near Leland, Sauk Co., August 3. The pycnidia are black, thick-walled, subglobose, about 125–150 μ diam. Both types of conidia are present in abundance, the scolecospores flexuous, thread-like, hyaline, (15–)17–21 x .7–1 μ the others fusoid, hyaline, approx. 7.5 x (1.8–)2.2–2.7(–3) μ.

PHOMOPSIS (?) spp. have been studied on several hosts. 1) On *Veronica arvensis* L., at Tower Hill State Park, Iowa Co., June 1. Superficially this collection closely resembles examples of *Septoria veronicae* Desm., but the latter all have scolecospores about 1 μ thick and mostly quite long and flexuous. The specimen in question, however, has two classes of spores: a) robust, obtuse, mostly slightly curved, hyaline, continuous, about 22–25 x 2.5–3 μ, and b) less numerous ordinary scolecospores, approx. 25–40 x 1–1.30 μ. 2) On *Aster sagittifolius* Wedem. near Leland, Sauk Co., August 3. The spots are large, up to 3 cm. diam., suborbicular, light reddish-brown with cinereous zonate banding, the pycnidia epiphyllous, zonately arranged, black, thick-walled, subglobose, approx. 150–200 μ diam., the conidia hyaline, slender-fusoid, straight to slightly curved, (8–)9–12(–15) x (2.3–)2.5–2.7(–3) μ. No scolecospores observed. 3) On *Tragopogon pratensis* L., near Edgerton, Rock Co., September 18, 1965. On the flower peduncles. The pycnidia are gregarious, sometimes even confluent, black, subapplanate, widely ostiolate, approx. 150–250 μ diam., the conidia hyaline, fusoid or subfusoid, (7.5–)8.5–10(–12) x (2–)2.5–3 μ. No scolecospores observed.

ASCOCHYTAE which occur on the leaves of higher plants are generally strong and obvious parasites, characterized by conspicuous, often extensive, but nevertheless sharply defined lesions, with the pycnidia being rather large and flesh-colored or light brownish, and often in a zonate arrangement. Most investigators of these fungi, the writer included, have assumed strong host specificity, and in many cases this is almost certainly so. However, in a series of collections made during the past several years, particularly in 1966, in the vicinity of Leland, Sauk Co., host specificity seems open to question. On June 21, 1966 three *Ascochytas* were collected on *Asarum canadense* L., *Mitella diphylla* L. and *Sanguinaria canadensis* L. in a very limited area of not more than 150 feet square. Those on *Mitella* and *Sanguinaria* appear to be identical with previous collections made in the same general vicinity and reported on in my Notes 30 and 31. The following day, June 22, at a point less than two miles distant, the *Ascochyta* on *Sanguinaria* was found again and close by there occurred a similar form on *Symplocarpus foetidus* (L.) Nutt. The following tabulation of pycnidial and conidial measurements would seem to suggest forms closely related, if not identical. The measurements of conidia are based on those which are septate and presumably mature:

Asarum—Pycnidia 125–200 μ diam.; Conidia 7.5–10(–12) x (2.5–)2.8–3.5 μ

Mitella—Pycnidia 90–150 μ diam.; Conidia 6.5–8(–10) x 2.5–3.3 μ

Sanguinaria—Pycnidia 150–180 μ diam.; Conidia (7–)7.5–10(–12) x 2.5–3.8 μ

Symplocarpus—Pycnidia 100–200 μ diam.; Conidia 7.5–11 x 3–3.5 μ

The only report I have found of *Ascochyta* on any of these genera is that of *A. versicolor* Bubak, said to occur on *Asarum caudatum* Lindl. in Idaho, but this species has conidia 10–25 x 4–6.5 μ, out of the range of the Wisconsin specimens. Whether one or more species is involved in the Wisconsin material is a question unfortunately not likely to be resolved in the foreseeable future, but the need for caution in the description of these fungi is plain.

ASCOCHYTA spp., undetermined but obviously parasitic, including two mentioned in the preceding note, show the following characteristics: 1) On *Symplocarpus foetidus* (L.) Nutt., near Leland, Sauk Co., June 22. One large lesion is narrowly oval and elongate, about 3 cm. x .8 cm., with narrow blackish-brown border and sordid greenish internal portion, the flesh-colored pycnidia amphigenous, thin-walled, subglobose, approx. 100–200 μ diam., the conidia hyaline, subcylindric or subfusoid, occasionally curved, often slightly constricted at septum, about 7.5–11 x 3–3.5 μ. A very few conidia are somewhat longer and 2-septate. 2) On *Asarum canadense* L., near Leland, Sauk Co., June 21. The lesions are circular or broadly oval, .5–1 cm. diam., with greenish or grayish centers, the pycnidia gregarious, flesh-colored, thin-walled, subglobose, approx. 125–200 μ diam., the conidia hyaline, cylindric or subcylindric, 7.5–10(12) x (2.5–)2.8–3.5 μ. Only about 20% of the conidia are septate, the continuous ones being smaller and presumably immature. 3) On *Anemone canadensis* L., near Leland, Sauk Co., July 8. The lesions are orbicular and grayish-brown, with darker borders, up to 1 cm. diam., the pycnidia epiphyllous, gregarious to crowded, pallid brownish, subglobose, about 125–150 μ diam., the conidia hyaline, cylindric, almost uniformly septate, approx. 7.5–9 x 2.5–3 μ. 4) On *Decondon verticillatus* (L.) Ell., near Trout Lake, Vilas Co., July 1, 1914. Collected by J. J. Davis who placed the specimen in the herbarium as "*Ascochyta decodontis* ined.", but did not report on it in his Notes. The pycnidia are pallid yellowish-brown, thin-walled, rather widely ostiolate, mostly about 100 μ diam. In a note enclosed with the specimen Davis states the conidia are "cylindrical to subfusiform and acute at one end, straight or slightly curved, 15–22 x 3 μ". In a mount examined by the writer the conidia were mostly shorter and the majority without a septum. *Phyllosticta neseae* Peck on this host is said to have conidia approx. 7–10 x 2.5 μ, not too different from the Wisconsin specimen. 5) On *Hieracium aurantiacum* L. at Madison, June 24. The lesions are oval to orbicular, dull brownish with narrow darker margin, zonate or subzonate, about .5–1.7 cm. diam., the pycnidia epiphyllous, scattered to gregarious, pallid brownish, subglobose, approx. 150–250 μ diam., the conidia hyaline, uniformly septate, cylindric or subcylindric, straight or slightly curved, (6.5–)7.5–11 x (2.6–)2.8–3.7 μ.

HENDERSONIA CRASTOPHILA Sacc. occurs in seriate arrangement on elongate, narrow, white lesions on the adaxial surfaces of leaves of *Panicum virgatum* L. collected at Madison September 11, 1964. The *Hendersonia* appears to be in association with *Puccinia panici* which occurs on the reverse side of the leaves. Presumably the rust infection preceded the development of the *Hendersonia*, so the latter is probably only weakly parasitic. On the other hand, *H. crastophila* is present on leaves of *Sporobolus asper* (Michx.) Kunth., collected the same day at a location in Iowa Co. near Blue Mounds, in a probable parasitic relationship, as there is no other fungus present.

"SEPTORIA" SIGMOIDEA Ell. & Ev., occasionally found on *Panicum virgatum* L. in Wisconsin, is plainly not a *Septoria* in the usual conception of that genues. It has been suggested that it may be identical with *Hendersonia crastophila Sacc.*, but the conidia with their strong curvature, pronounced taper at both ends, and length of about 60–75 μ do not seem to fit in this species. It is more likely the fungus should be referred to *Phaeoseptoria* Speg. It is to be regretted that *S. sigmoidea* seems to have escaped the attention of the late Roderick Sprague, the outstanding authority on *Phaeoseptoria*.

SEPTORIA, undetermined as to species, occurs on several hosts, with descriptive notes as follows: 1) On *Eriophorum virginicum* L. at Hope Lake Bog near Lake Mills, Jefferson Co., June 11. The pycnidia, which occur on the dead tips of otherwise living leaves, are shining black, globose, about 150 μ diam., the conidia hyaline, mostly somewhat lax and slightly curved, with granular contents but appearing continuous, approx. 30–50 x 1.7–2.5 μ. *Septoria* *eriophori* Oud. has pycnidia only about 75 μ diam., while *S. eriophoricola* Hollos has pycnidia 110–150 μ diam., with filiform conidia 30–40 x 1 μ. 2) On *Decodon verticillatus* (L.) Ell., near Trout Lake, Vilas Co., July 1, 1914. Coll. J. J. Davis. The pycnidia are globose, brownish, thin-walled, about 125–175 μ diam., the conidia hyaline, indistinctly several-septate, laxly curved, wider and obtuse at one end, tapering at the other, approx. 2–3.5(–4) x 35–45 μ. Not *Septoria lythrina* Peck which has filiform conidia. There appear to be no previous reports of *Septoria* on *Decodon.* 3) On *Eupatorium sessilifolium* L. collected October 13, 1965 at Tower Hill State Park, Iowa Co., and overwintered out-of-doors at Madison until mid-May 1966. The specimen as collected had well-marked, rather small, orbicular or angled, fuscous spots, on which epiphyllous pycnidium-like structures with poorly defined contents were scattered. The spring of 1966 was in the main cold and dry, but when examined the pycnidia were found to be filled with well-developed conidia. The pycnidia are black, rather thick-walled, ostiolate, subglobose, approx. 125–150 μ diam., the conidia hyaline, straight or slightly curved, continuous or obscurely septate, (10–)12–17(–22) x 1.4–1.7 μ. Perhaps a cold-weather development of *Septoria eupatorii* Rob. & Desm. which normally has conidia about 25–35 x 1.5 μ. 4) On *Ambrosia psilostachya* DC., near Mazomanie, Dane Co., July 20, 1935. Coll. J. J. Davis. This seems close to, perhaps identical, with *Septoria ambrosicola* Speg. The Wisconsin specimen has small, orbicular, light brownish spots, with pycnidia approx. 50–100 μ diam., the conidia hyaline, mostly strongly curved, tapering toward the apices, continuous or obscurely multiseptate, about 40–85 x 1–2 μ. *S. ambrosicola* is described as having the spots amphigenous, orbicular, determinate, 1–3 mm. diam., whitish, pycnidia 90–100 μ diam., the conidia hyaline, attentuate at both ends, subarcuate or merely flexuous, continuous, 50–100 x 1.5–2 μ.

LEPTOTHYRIUM SIMILISPORUM (Ell. & Davis) Davis normally occurs as a definite parasite on the leaves of *Solidago rigida* L. and other goldenrods. However, in a specimen on *S. rigida,* collected at Madison, September 1, the fungus is confined to, but still profusely present on, the outer margins of applanate, rounded, yellowish galls produced by a midge (cecidomyiid) on the leaves. The writer has, over the years, seen hundreds of such gall-infested leaves, but never before have any of the galls been seen to bear a fruiting fungus.

MELASMIA ULMICOLA B. & C. has long been reported as occurring on elms in Wisconsin and has been represented by a number of specimens from Wisconsin and elsewhere in the Wisconsin Herbarium. Recent collections of the conidial stage of *Gnomonia ulmea* (Schw.) Thum., *Cylindrosporella ulmea* (Miles) v. Arx, have led to a re-examination of the *"Melasmia ulmicola"* specimens and it appears highly likely that most, if not all, are really more or less well-defined *C. ulmea*. The conidia of *Melasmia ulmicola* are said to be minute and oblong-botuliform, but the overall description is inadequate and the identity of the fungus remains somewhat uncertain.

MONOCERAS KRIEGERIANUM (Bres.) Guba is the type species of *Monochaetia* and *Pestalotia"*, p. 290 (1961). This fungus causes a conspicuous leaf of fireweed, *Epilobium angustifolium* L. It has been variously referred to *Pestalotia, Monochaetia* and *Hyaloceras*. Guba's description of *Monoceras* and its type species is based in part on a specimen collected by J. J. Davis near Luck, Polk Co., Wis., August 25, 1916.

PESTALOTIA (?) sp. is epiphyllous on small, sharply defined, rounded, reddish-brown spots on *Hypericum kalmianum* L. collected at Madison, July 29. The conidia are variously ciliate, from almost straight to moderately curved, clear grayish, 3-septate, about 15–18 x 5 μ. Except for the tiny (1–2 mm.) spots, the leaves are green and vigorous appearing, so parasitism seems a possibility.

The MONILIA stage of *Monilinia fructicola* (Wint.) Honey ordinarily develops on the flowers and fruits of species of *Prunus*, but what appears to be this stage is hypophyllous or large, orbicular, purplish-brown lesions, up to 3 cm. diam., on shoot leaves of *Prunus americana* Marsh. Collected at Madison, June 30.

BOTRYTIS spp. have been noted on several additional hosts. These are but more of a considerable number of so far undetermined, parasitic-seeming members of this genus observed over many years on a variety of plants: 1) On *Rumex acetosella* L., near Verona, Dane Co., September 9. The fungus appears definitely parasitic on pallid streaks of varying width which originate near the apices of otherwise still green leaves. 2) On *Ranunculus abortivus* L., near Albany, Green Co., May 26. *Botrytis* has occasionally been found on the rounded basal leaves of this host, as has been reported in these notes. However, in a specimen collected May 26 near Albany, Green Co., the bract-like leaves encircling the bases of the flowering pedicels were involved and the infection had spread to the pedicels causing a conspicuous drooping of otherwise still healthy appearing flowering parts of many plants. 3) On *Geranium maculatum* L., near Leland, Sauk Co., July 1, 1965. On rounded, sharply defined, brown lesions, about .7–1 cm. diam. 4) On *Helianthus strumosus* L., New Glarus Woods Roadside Park, Green Co., June 16. All the plants in a large clone had the leaves blighted just below the growing point. It did not appear frost damage could have been responsible.

ACREMONIUM sp. has overgrown sori of *Puccinia heucherae* (Schw.) Diet. on *Heuchera richardsonii* R. Br. collected July 1 at Faville Prairie near Lake Mills, Jefferson Co. In my Notes 29 (Trans. Wis. Acad. Sci. Arts Lett. 52: 239. 1963) there is mention of a very similar, if not identical, fungus overrunning *Kuehneola uredinis* and *Pucciniastrum agrimoniae*.

CLADOSPORIUM (?) sp. is epiphyllous on small, 1.5–3 mm. diam., rounded, very sharply defined reddish-brown spots on *Acer pennsylvanicum* L. (cult.) collected at Madison August 11, 1965. The cylindric, grayish-olivaceous conidia are rather strongly echinulate, about 11–15 x 5.5–6.5 μ, mostly uniseptate, but some with two septa, borne on loosely fasciculate, often tortuously geniculate, brownish-olivaceous, several-septate conidiophores, approx. 60–85 x 4–5 μ. Perhaps parasitic, since there is no other obvious causal agent and since, aside from the small spots, the leaves are in thriving condition.

CERCOSPORA CAMPTOSORI J. J. Davis on *Camptosorus rhizophyllus* (L.) Link was collected June 17 at Wyalusing State Park, Grant Co., where Davis first found it in 1914—a few years later he collected an additional specimen at Werley, also in northwestern Grant Co. An examination of numerous Wisconsin and extra-Wisconsin specimens of this fern in the Wisconsin Herbarium shows no specimens bearing this fungus. Since the walking fern attracts much attention and is frequently collected, and since according to Chupp *C. camptosori* is known only from Grant Co., Wis., it would seem to indicate that this fungus does indeed have a restricted range. In view of the notable sporadicity of many parasites, it is interesting that *C. camptosori* should have persisted for more than 50 years within these narrow boundaries.

CERCOSPORA (?) sp. occurs in profusion on rounded, reddish-brown lesions on leaves of *Steironema lanceolatum* (Walt.) Gray collected at Madison, September 1. The grayish-olivaceous conidiophores are simple, with only a suggestion of geniculation, in more or less dense fascicles, when they may be up to 80 μ in length, or they arise from definite, subglobose stromata, in which cause the measurable phore length is considerably less. Only a very few mature *Cercospora-type* conidia have been observed. These are obclavate or narrowly obclavate, subhyaline, 1–3 septate, about 25–35 x 2.5–3.5 μ, with a conspicuous basal scar. Also present are considerable numbers of hyaline, narrowly cylindric or fusoid conidia, mostly continuous, a few uniseptate, occasionally in short chains. No conidia were seen attached in a large number of mounts examined.

CERCOSPORA sp. is epiphyllous on cultivated *Syringa* ("Blue Hyacinth"—not in the *S. vulgaris* group) collected in the University of Wisconsin Arboretum at Madison, October 4. The spots are rounded, mottled brownish-cinereous, up to about 1 cm. diam., the conidiophores sinuous, subgeniculate, clear brownish-olivaceous, several-septate, about 45–75 x 4–5 μ and fascicled on small stromata, the few conidia seen pallid olivaceous, rather broadly obclavate, truncate at base, tip obtuse, about 60 x 5 μ, 3-septate. The only species with conidia of this type mentioned by Chupp as occurring on *Syringa* is *Cercospora amurensis* Zilling, but it does not otherwise resemble the Wisconsin specimen.

CERCOSPORA (?) sp. is hypophyllous on small, rounded, immarginate, pallid yellowish areas on *Kuhnia eupatorioides* L. collected near Leland, Sauk Co., August 3. The conidiophores are scattered, approx. 20–40 x 3.5–5 μ, 1–2 septate, from slightly sinuous to subgeniculate, sometimes denticulate, clear light grayish-brown, the conidia subhyaline, subfusoid to subcylindric, approx. 12–18 x 2.5–3 μ, continuous or uniseptate. Scarcely typical *Cercospora* conidia, but the specimen is perhaps somewhat immature and it seems likely that longer conidia might be produced in time. Chupp does not report any *Cercospora* on *Kuhnia.*

Solidago uliginosa Nutt., collected in northern Forest Co., October 2, 1965, has the upper stem and smaller leaves profusely covered with a *Sarcinella*-like fungus which, while largely superficial, appears to have invaded the trichomes and is thus perhaps weakly parasitic.

K. T. Harper, in the years 1960–63, made an intensive ecological study of the climax maple-basswood forest of Wisconsin. As an adjunct of this study he checked 114 more or less characteristic higher plant species of the maple-basswood community in connection with the fungus parasites reported over the years as occurring on them in Wisconsin. He found that 104 of these higher plant species were known to be attacked by one or more fungal parasites, that a total of 339 species of parasitic fungi were concerned, and that there was an average of more than 4 parasites for each of the 114 higher plants considered.

ADDITIONAL HOSTS

The following hosts have not been previously recorded as bearing the fungi mentioned in Wisconsin.

ALBUGO TRAGOPOGONIS (DC.) S. F. Gray on *Ambrosia trifida* L. Iowa Co., Ridgeway, June 24, 1921. Coll. J. J. Davis & A. B. Seymour. Davis failed to report *A. tragopogonis* on this host and the single specimen was overlooked until recently.

PERONOSPORA FICARIAE Tul. on *Ranunculus acris* L. Manitowoc Co., Point Beach State Forest, June 20, 1960. Coll. J. A. Reed.

PERONOSPORA PARASITICA (Pers.) Fr. on *Arabis canadensis* L. Sauk Co., near Leland, August 12.

PERONOSPORA ARTHURI Farl. on *Oenothera strigosa* (Rydb.) Mack. & Bush. Pierce Co., Spring Valley, July 20, 1925. Coll. J. J. Davis.

BASIDIOPHORA ENTOSPORA Roze & Cornu on *Solidago gigantea* Ait. Dane Co., Madison, October 12, 1920. Coll. J. J. Davis. Davis did not report this, but a scraping shows the sporangiophores so characteristic of this species.

ERYSIPHE CICHORACEARUM DC. on stems of *Monarda punctata* L. Sauk Co., near Leland, September 12. Powdery mildew conidia are regularly present on the leaves of this host, but this is the first Wisconsin collection of cleistothecia. Also on *Artemisia biennis* Willd. Dane Co., Madison, October 2.

SPHAEROTHECA HUMULI (DC.) Burr. var. *fuliginea* (Schl.) Salm. on *Erigeron strigosus* Muhl., Sauk Co., near Leland, August 17.

PHYLLACTINIA CORYLEA (Pers.) Karst. on *Cornus obliqua* Raf. Dane Co., Madison, September 30. Coll. D. P. Mahoney.

Powdery mildews indet. (conidia only) have been noted 1) On *Trifolium arvense* L. Barron Co., near Prairie Farm, September 19, 1965, and 2) On *Salvia haematodes* L. (cult.). Dane Co., Madison, September 24.

PECKIELLA LATERITIA (Fr.) Maire on *Lactarius indigo* (Schw.) Fr. Milwaukee Co., Milwaukee, October 1903. Coll. C. Thot.

MYCOSPHAERELLA SPLENIATA (C. & P.) House on overwintered leaves of *Quercus alba* L. Sauk Co., near Leland, May 13. The microconidial stage, *Phyllosticta livida* Ell. & Ev., without doubt developed parasitically in the previous season.

COLEOSPORIUM ASTERUM (Diet.) Syd. II on *Solidago caesia* L. Milwaukee Co., Cudahy, October 24, 1965. Coll. C. T. Lind.

PUCCINIA ANDROPOGONIS Schw. I on *Pentstemon pallidus* Small. Oneida Co., near Tripoli, June 19, 1965. Coll. & host det. F. S. Crosswhite.

PELLICULARIA FILAMENTOSA (Pat.) Rogers on *Prenanthes racemosa* Michx. Dane Co., Madison, July 19.

PHYLLOSTICTA EMINENS H. C. Greene on *Salix discolor* Muhl. Dane Co., Madison, September 5. The fungus is in rather small amount and does not produce the conspicuous lesions so characteristic of the type specimen, but microscopic correspondence is close.

PHYLLOSTICTA VIRGINIANA (Ell. & Halst.) Seaver on *Prunus pumila* L. Bayfield Co., Barnes, September 12, 1956. The specimen was included in a large collection of *Tranzschelia* on this host and overlooked until recently.

PHYLLOSTICTA DECIDUA Ell. & Kell. on *Agastache scrophulariaefolia* (Willd.) Ktze. Iowa Co., Gov. Dodge State Park, July 15.

PHYLLOSTICTA CACALIAE H. C. Greene on *Prenanthes alba* L. Sauk Co., near Leland, September 8.

NEOTTIOSPORA UMBELLIFERARUM H. C. Greene on *Cicuta maculata* L. Dane Co., Madison, July 6. Both pycnidia and conidia are somewhat smaller on the average than in the type on *Oxypolis* (see Trans. Wis. Acad. Sci. Arts Lett. 47:113. 1958), but the dimensional differences would seem to be within the acceptable range.

ASCOCHYTA EQUISETI (Desm.) Grove on *Equisetum laevigatum* A. Br. Iowa Co., near Arena, August 5.

ASCOCHYTA GRAMINICOLA Sacc. on *Setaria viridis* (L.) Beauv. Burnett Co., Roosevelt Twp., October 2, 1965. Coll. G. Patz.

ASCOCHYTA NEPETAE J. J. Davis on *Glecoma (Nepeta) hederacea* (L.) Trev. Dane Co., Madison, August 30. Referred here with some doubt. Accompanying the typical uniseptate conidia are much more numerous rod-shaped microconidia about 3–5.5 x 1–1.7 μ, and some pycnidia contain microconidia only.

ASCOCHYTA COMPOSITARUM J. J. Davis on *Aster cordifolius* L. Sauk Co., near Leland, August 3. Also on *Helianthus tuberosus* L., Sauk Co., near Leland, August 17.

DARLUCA FILUM (Biv.) Cast. on *Cronartium quercuum* (Berk.) Miyabe on *Quercus ellipsoidalis* Hill. Burnett Co., Webster, August 31, 1916. Coll. J. J. Davis.

STAGONOSPORA ALBESCENS J. J. Davis on *Carex trichocarpa* Muhl. Sauk Co., near Leland, September 8.

SEPTORIA PENTSTEMONICOLA Ell. & Ev. on *Pentstemon pallidus* Small. Marathon Co., near Knowlton, June 19, 1965. Coll. & host det. F. S. Crosswhite.

SEPTORIA RUDBECKIAE Ell. & Halst. on *Rudbeckia serotina* Nutt. Marathon Co., near Rothschild, August 4, 1965. Coll. M. Torin. On a phanerogamic specimen in the University of Wisconsin Herbarium.

PHAEOSEPTORIA FESTUCAE R. Sprague var. MUHLENBERGIAE Sprague on *Muhlenbergia tenuiflora* (Willd.) BSP. Sauk Co., near Leland, September 12. On narrow, rather elongate, cinereous, brown-bordered lesions. Sprague considered the species of *Phaeoseptoria* to be essentially saprophytes, but the present specimen suggests parasitic development.

PIROSTOMA CIRCINANS Fr. on *Andropogon scoparius* Michx. Green Co., near Albany, September 23.

HAINESIA LYTHRI (Desm.) Hoehn. on *Geum triflorum* Pursh f. *pallidum* Fassett. Dane Co., Madison, August 10. Although this white-flowered form is not generally recognized as distinct it is very constant, certain plants having been observed annually by the writer over a 23 year period, and is evidently much less susceptible to fungus attack, with the present instance being the first noted in the entire period, in contrast to the species proper which is frequently infected. Also on *Carya cordiformis* (Wang.) K. Koch. Sauk Co., near Leland, September 7. The *Sclerotiopsis* stage of the fungus has been earlier noted on this host in Wisconsin.

SCLEROTIOPSIS CONCAVA (Desm.) Shear & Dodge on *Vitis riparia* Michx. Dane Co., Madison, September 14, 1965. The *Hainesia* stage has already been noted on this host in Wisconsin.

COLLETOTRICHUM GRAMINICOLA (Ces.) Wils. on *Cenchrus pauciflorus* Benth. Dane Co., near Middleton, September 24, 1965. Coll. G. Patz.

PHLEOSPORA ANEMONES Ell. & Kell. on *Anemone riparia* Fern. Trempeleau Co., near Dodge, October 2, 1965. Coll. J. Graham.

MONILIA stage of MONILINIA FRUCTICOLA (Wint.) Honey on flowers of *Prunus cerasus* L. Door Co., Sturgeon Bay, June 7. Coll. & det. D. A. Biris.

CLADOSPORIUM ASTERICOLA J. J. Davis on *Aster macrophyllus* L. Sauk Co., near Leland, August 17.

CERCOSPORA NIGRICANS Cooke on *Cassia fasciculata* Michx. Dane Co., Madison, September 16.

CERCOSPORA PERFOLIATA Ell. & Ev. on *Eupatorum sessilifolium* L. Sauk Co., near Leland, July 30. The spots here are more sharply defined than is usual with this species, but microscopically it corresponds well.

TUBERCULINA PERSICINA (Ditm.) Sacc. on *Puccinia podophylli* Schw. I on *Podophyllum peltatum* L. Green Co., near Albany, May 26.

ADDITIONAL SPECIES

The fungi mentioned, with several exceptions, have not been previously reported as occurring in Wisconsin. Some name revisions of earlier reported entities are listed here as it is felt they are more likely to come to the attention of the reader under this heading.

DIMERIELLA ERYSIPHOIDES (Ell. & Ev.) Farr (*Venturia erysiphoides* Ell. & Ev.) appears to be the correct name of the fungus on *Andropogon scoparius* Michx., reported by me as *Venturia sporoboli* Greene.

STROMATINIA GLADIOLI (Drayton) Whetzel on *Gladiolus hortulanus* Bailey. Columbia Co., Cambria, September 16. Coll. & det. R. Pinney.

COLEROA SPOROBOLI (Greene) Barr. replaces *Venturia sporoboli* H. C. Greene according to M. E. Barr who has made a revisionary study of the Venturiaceae. She states (personal communication) "The fungus in its subcuticular development, superficial appearance, and other characters, agrees with modern concepts of *Coleroa* rather than *Venturia.*" This fungus occurs on *Sporobolus cryptandrus* (T.) Gray, *S. heterolepis* Gray and *Oryzopsis asperifolia* Michx. in Wisconsin.

COLEROA RUBICOLA (Ell. & Ev.) Müller is the name applied by M. E. Barr to *Coccochora rubi* J. J. Davis which occurs on *Rubus canadensis* L. and *R. hispidus* L. in Wisconsin. In a personal communication she states that the latter is but a stromatic form of *Coleroa rubicola.*

SEYNESIELLA JUNIPERI (Desm.) Am. is, according to M. E. Barr, the name properly applied to the fungus previously reported as *Asterina cupressina* Cooke which occurs on *Juniperus communis* L. var. *depressa* Pursh in Wisconsin.

PUCCINIA BRACHYPODII-PHOENICOIDIS Guyot & Malencon var. DAVISII Cummins & Greene on *Oryzopsis asperifolia* Michx. Various stations, mostly in northern Wisconsin. The rust on this particular host was reported in former Wisconsin lists as *Puccinia pygmaea* Erikss., but Cummins & Greene (Mycologia 58:719. 1966), in a paper entitled "A review of the grass rust fungi that have uredial paraphyses and aecia on *Berberis–Mahonia*", have erected this segregate and selected as the type a specimen collected by J. J. Davis at Agenda, Ashland Co., October 13, 1911.

GYMNOSPORANGIUM ASISTICUM Miyabe ex Yamada III on *Juniperus virginiana* L. Columbia Co., Gibraltar Rock County Park near Okee, May 13. Coll. & det. J. L. Cunningham. Confirmed by F. D. Kern. Probably a new host worldwide, according to Dr. Cunningham.

PHYLLOSTICTA MALI Prill & Delacr. on *Pyrus malus* L. Dane Co., near Pine Bluff, August 4, 1960. The Wisconsin specimen corresponds closely with No. 1676 "Herbarium Mycologicum Romanicum", distributed as this species. The conidia are oval, about 6 x 3 μ, and of a greenish tint. In the Saccardian description conidial dimensions are given as 6.5–8 x 4–4.5 μ, but in other particulars the specimens correspond fairly well with the description.

PHYLLOSTICTA PRIMULICOLA Desm. on *Primula obconica* Hance (cult.). Dane Co., Madison, July 7. The small, black pycnidia are about 100–125 μ diam., the hyaline conidia ellipsoid to subfusoid, approx. 3.5–5 x 1.5–2.5 μ. Grove in "British Stem and Leaf Fungi" p. 34, states concerning this species "Very common, but the pycnidia are nearly always empty". This seems to be the case with the Madison specimen as well, since only one of the pycnidia examined had conidia, but in that one they were numerous and well-developed.

Coniothyrum wisconsinensis sp. nov.

Maculis distinctis, plerumque tantum uno vel duo in frondibus, obscuro-cinereis vel brunneis vel rufo-brunneis, marginibus angustis fuscis, subcirculis, ca. 2–4 mm. diam.; pycnidiis epiphyllis, gregariis, nigris, muris crassis, ostiolatis, subglobosis, ca. (75–)100–125(–150) μ diam.; conidiis levibus, claris, cano-olivaceis, late ellipticis vel subcylindraceis vel subglobosis interdum, (3.5–)4–5.5(–6.5) x 2.5–3.5 μ.

Spots sharply defined, usually only one or two per leaf, dull cinereous to brown or reddish-brown with narrow darker border, rounded, about 2–4 mm. diam.; pycnidia epiphyllous, gregarious, black, rather thick-walled, ostiolate, approx. (75–)100–125(–150) μ diam.; conidia smooth, clear grayish-olivaceous, broadly elliptic or subcylindric, or occasionally subglobose, (3.5–)4–5.5(–6.5) x 2.5–3.5 μ.

On living leaves of *Ulmus americana* L. University of Wisconsin Arboretum, Madison, Dane County, Wisconsin, U. S. A., July 19,

1966. Two other specimens were collected in the Arboretum on the same date within a quarter of a mile of the type. There are further collections from Dane, Iowa and Sauk counties.

Coniothyrium ulmi Tharp (Mycologia 9:116. 1917) had whitish, angular spots .5–3 mm. diam., with the conidia brown and ovate, 4–6 x 2–2.5 μ. It occurred on cultivated *Ulmus campestris* L.

SEPTORIA MINUTA Schroet. on *Luzula multiflora* (Ehrh.) Le-Jeune. Sauk Co., near Leland, May 28. The small black pycnidia, 50–75 μ diam., are subseriate to crowded on conspicuous, dark reddish-brown spots. The conidia are hyaline, appear continuous, and are mostly slightly curved, (15–) 18–23 (–28) x 1.7–2.3 μ.

Septoria clementsii sp. nov.

Maculis obscuro-viridulis, angulatis, magnitudinibus variis, saepe confluentibus, in foliis languidis; pycnidiis hypophyllis, gregariis, numerosis, nigris, muris crassis modice, subglobosis vel subapplanatis, ca. (75–) 85–125 (–150) μ diam.; conidiis hyalinis, continuis vel multiseptatis obscuris, sinuosis vel curvis varie, saepe attenuatis in apicibus unicis, ca. (45–) 55–75 (–90) x (1–) 1.5–2 (2.5) μ.

Spots dull greenish, angled, variable in size and often confluent on otherwise faded leaves; pycnidia hypophyllous, gregarious, numerous, black, moderately thick-walled, subglobose or somewhat flattened, approx. (75–) 85–125 (–150) μ diam.; conidia hyaline, continuous or appearing faintly multiseptate, sinuous to variously curved, often tapered strongly at one end, approx. (45–) 55–75 (–90) x (1–) 1.5–2 (–2.5) μ.

On languishing current season's leaves of *Aralia nudicaulis* L. Gov. Dodge State Park, Iowa County, Wisconsin, U. S. A., September 21, 1966.

Septoria clementsii was first collected in Wisconsin in 1962 and was discussed at some length in my Notes 30 (Trans. Wis. Acad. Sci. Arts Lett. 53:183. 1964). As pointed out there, it is considered to be the same as *Septoria macrostoma* Clements (No. 55 in Clements' "Cryptogamae Formationum Coloradensium", issued in 1906) and apparently represented only by the type specimen in the U. S. National Fungus Collections. As stated "According to Dr. C. R. Benjamin . . . publication was effected through distribution of the exsiccati, but it appears that in the case of *Septoria macrostoma* the Latin indication of host appearing on the label is insufficient to be considered an adequate description and therefore the name is not valid." The accompanying description is offered to remedy this and at the same time indicate Clements' connection with the species. The reason for his choice of the specific epithet "*macrostoma*" is not clear for there is no well-defined ostiole in this species. When the pycnidia are viewed by transmitted light the greater depth of wall looked through at the periphery does give the effect of a dark ring surrounding a lighter area, so perhaps the name was applied because of this.

DOTHISTROMA PINI Hulbary on *Pinus nigra* Arn. var. *austriaca* Aschers. & Graebn. Jackson Co., near Hixton, June 6. Coll. & det. A. J. Pray. It appears that the previous report of the similar *Lecanosticta acicola* (Thum.) Syd. on this host is erroneous and properly referable to *Dothistroma. Lecanosticta* does, however, occur in Wisconsin on Scotch pine, *Pinus sylvestris* L.

Cylindrosporella caricina sp. nov.

Maculis conspicuis, castaneis, centris pallidioribus saepe, orbicularibus vel ovatis, saepe confluentibus, ca. 1–2.5 cm. diam.; acervulis epiphyllis, subcuticularibus, planis, inconspicuis, sparsis vel gregariis, ca. 100–175 μ diam.; conidiophoris hyalinis, exilibus, saepe curvis, confertis, ca. 12–18 x 1–1.5 μ; conidiis hyalinis, rectis, angusto-cylindraceis, ca. 7–9 x 1 μ.

Spots conspicuous, chestnut-brown, often with lighter-colored centers, orbicular to ovate, often confluent, about 1–2.5 cm. diam.; acervuli epiphyllous, subcuticular, flattened, inconspicuous, scattered to gregarious, about 100–175 μ diam.; conidiophores hyaline, slender, often curved, closely ranked and compacted approx. 12–18 x 1–1.5 μ; conidia hyaline, straight, narrow-cylindric, approx. 7–9 x 1 μ.

On living leaves of *Carex lacustris* Willd. Tower Hill State Park, Iowa County, Wisconsin, U. S. A., August 24, 1966.

This fungus was collected in small amount at the same station in 1957 and was mentioned in my Notes 24 (Trans. Wis. Acad. Sci. Arts Lett. 47: 108. 1958). In 1966 the organism occurred in great profusion over an area of an acre or more. As noted in 1958, the large air spaces of the host leaves are well filled with a coarse, ramifying mycelium which is assumed to have been produced by the just described fungus.

Gloeosporidiella cercidis sp. nov.

Maculis magnis, conspicuis, suborbicularibus vel elongatis varie, plerumque ca. 3–5 cm. diam., centris rufo-brunneis splendidis, marginibus nigris, obscuris; acervulis hypophyllis, gregariis, immersis, ca. 75–150 μ diam.; conidiophoris inconspicuis, fere obsoletis; conidiis in cirrhis, hyalinis, formis variabilibus, subcylindraceis, ovoideis, allantoideis late, vel subfusoideis, etiam in magnitudinibus varie, ca. 6–12 x 2.5–5 μ.

Lesions large, conspicuous, suborbicular to variously elongate, mostly about 3–5 cm. diam., with bright reddish-brown central portions and rather poorly defined blackish margins; acervuli hypophyllous, clustered in groups, deeply imbedded in the mesophyll, approx. 75–150 μ diam.; conidiophores inconspicuous, almost obsolete; conidia extruded in short cirrhi, hyaline, variable in shape, subcylindric, ovoid, broadly allantoid, or subfusoid, and also variable in size, approx. 6–12 x 2.5–5 μ.

On living leaves of *Cercis canadensis* L. University of Wisconsin Campus, Madison, Dane County, Wisconsin, U. S. A., August 16, 1966.

The lesions dry out quickly and the central portions often shred and break away. The fungus appears highly parasitic and I have found no report of any similar organism on *Cercis*. On some leaves the acervuli are strongly developed on portions of the principal veins.

RAMULARIA ANGELICAE Hoehn. on *Angelica atropurpurea* L. Sauk Co., near Leland, September 30.

CERCOSPORA MURINA Ell. & Kell. on *Viola pennsylvanica* Michx. Sauk Co., near Leland, September 7. In my Notes 24 I mentioned the occurrence of what was probably this species on *Viola canadensis* L. from Sawyer Co., but the specimen was rather poor and no formal record was made at that time.

BENIOWSKIA SPHAEROIDEA (Kalchbr. & Cke.) Mason is the name applied by S. J. Hughes (Can. Jour. Bot. 36: 742. 1958) to the fungus, parasitizing *Panicum virgatum* L., misnamed *Botrytis uredinicola* by Peck, and discussed at length in my Notes 28 (Trans. Wis. Acad Sci. Arts Lett. 51: 77. 1962).

PRELIMINARY REPORTS ON THE FLORA OF WISCONSIN NO. 59. PLANTAGINACEAE—PLANTAIN FAMILY[1]

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The Plantaginaceae is best known for its weedy members, although these constitute a very small percent of the total number of species. Two of the three genera in the family are native in Wisconsin. *Littorella,* a specialized aquatic, is a rare member of the northern flora. The genus *Plantago* is represented by five native and four introduced species, one or more of which can readily be found almost anywhere in the state. *Plantago cordata* Lam. is a rare plant of small streams in the southern half of the state and should be actively looked for by anyone who ventures into the field.

Fortunately, for those who are unfamiliar with the family, the Wisconsin species are fairly distinct once one learns which characters are important. The perennial confusion of *P. major* L. and *P. rugelii* Dcne., especially of sterile or depauperate specimens, can only be resolved by close examination of the material. It would be pretentious to assume the keys in this report will "work" for every specimen that may be collected in the state, but I hope they will prove useful in the identification of most specimens. To facilitate correct determinations, I have illustrated the habit and important morphological features of each species. These drawings are idealized representations drawn from many different specimens and are to be thought of as representing only the "average" condition. All species are plastic and highly subject to environmental variation. The range of variation, as shown by the specimens at hand, is given in the description of each species. I have tried to restrict these discussions to include only those data which I believe accurate either through personal observations or experiments. In a few cases, I have relied on other authors for supplementary information. Chromosome counts, except where indicated, have been made by me. All localities are represented by specimens which I have seen. Reports in the literature, where no vouchers were available

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to me, have been omitted. Except for *P. cordata,* localities known only by county are not given.

I wish to express my sincere gratitude to the directors and curators of the following herbaria who so generously made their specimens available to me: Illinois Natural History Survey, Iowa State University–Ames, Michigan State University, Milwaukee Public Museum, Ohio State University, University of Illinois–Urbana, University of Michigan, University of Minnesota, University of Wisconsin, University of Wisconsin–Milwaukee, Wisconsin State University–Oshkosh and Wisconsin State University–Whitewater. My special thanks are given to Dr. Warren H. Wagner, Jr., for his continuing advice and encouragement in this and other projects and for critically reading the manuscript; Dr. Hugh H. Iltis without whose assistance this paper would have been impossible; Dr. Edward G. Voss for assisting in the identification of the *Littorella* specimens and for reading the manuscript; Dr. Neil Harriman who made several collecting trips in the poorly collected Lake Winnebago area; and Dr. Ronald L. Stuckey with whom I frequently discussed the material in this paper.

KEY TO FERTILE SPECIMENS OF THE PLANTAGINACEAE OF WISCONSIN

1. Flowers unisexual; pistillate flowers in a group in the axil of a single bract, each flower having 1–4 sepals; staminate flowers solitary, terminal, sepals four; fruit an achene; leaves terete or subterete, linear; stolons present __*Littorella americana* (1)
1. Flowers bisexual (except in gynomonoecious species) each flower subtended by a bract; all flowers having four sepals (two connate in *P. lanceolata*); fruit a circumscissile capsule; leaves flattened, linear to cordate; stolons absent __________*Plantago*
    2. Leaves cordate to broadly elliptic, definite blade and petiolar portions present; sepals and bracts glabrous.
        3. Major roots fleshy, 0.5–1.3 cm thick; peduncle 3–5 mm wide, central cavity ¾ or more of total diameter; seeds 2 per capsule; major veins of leaf not parallel to margin, appearing to arise from a "midrib", leaves leathery ____ __________________________________*Plantago cordata* (2)
        3. Major roots filamentous, 0.1–0.3 cm thick; peduncle 1–2 mm wide, central cavity less than ⅓ of total diameter; seeds 4–12 per capsule; major veins of leaf parallel to margin, leaves thin.
            4. Capsules oblong, dehiscence near base; seeds 4–9 per capsule; bracts and sepals lanceolate-attenuate; leaves broadly elliptic, margins bearing 3–7 small teeth, glabrous ______________________________*P. rugelii* (3)

4. Capsules rhombic-ovate, dehiscence medial; seeds 8–12 per capsule; bracts and sepals ovate-obtuse; leaves cordate-ovate, mangius entire, glabrate or hirsutulous -- *P. major* (4)

2. Leaves linear to spatulate, definite blade and petiolar portions absent or inconspicuous; sepals and/or bracts usually pubescent.

5. Stem freely branching, internodes 0.5–2 cm long; leaves opposite; seeds 2.8–4 mm long; spikes often appearing capitate ---------------------------------- *P. indica* (5)

5. Stem rarely branching, internodes absent or inconspicuous; leaves rosulate; seeds less than 3 mm long; spikes elongate.

6. Leaves linear, pilose, major veins 3; flowers conspicuously zygomorphic; stamens and style usually shorter than posterior corolla lobe; lobes variously pigmented at corolla throat; seeds lightly sculptured, medially constricted.

7. Bract 1.2–4 times as long as sepals; flowers spiraled on peduncle; tips of petals rounded; seeds 2.2–3 mm long ------------------------------- *P. aristata* (6)

7. Bract usually shorter than or just equaling sepals; flowers 4-ranked on peduncle; tips of petals acute; seeds 1.6–2 mm long ------------- *P. patagonica* (7)

6. Leaves spatulate or lanceolate, hirsute or glabrous, major veins 3,5,7; flowers actinomorphic or only slightly zygomorphic; stamens and style usually exceeding posterior corolla lobe (unless flowers are cleistogamous); lobes translucent or pigmented only at tip; seeds rarely sculptured, not constricted.

8. Leaves lanceolate; 2 sepals adjacent to bract connate; pigmented areas of bracts and sepals a narrow stripe; seeds 2 per capsule, hirsutulous ----------- ---------------------------------- *P. lanceolata* (8)

8. Leaves spatulate; all 4 sepals free; pigmented areas of bracts and sepals ⅔ of total area; seeds 3 (2–4) per capsule, glabrous.

9. Major veins 5,7; leaves 2.5–4 cm wide; bracts and sepals glabrous; flowers contiguous along spike; stamens well developed; root system extensive ---------------------------------- *P. media* (9)

9. Major veins 3; leaves 0.6–1.5 cm wide; bracts and sepals hirsute; flowers separated by internodes

FIGURE 1. Habit drawings of some Wisconsin species in the Plantaginaceae: A) *Plantago media;* B) *P. aristata;* C) *P. patagonica;* D) *P. indica;* E) *P. lanceolata;* F) *P. virginica;* G) *Littorella americana.*

along spike; stamens frequently aborted; root system sparce and poorly developed ____________ ______________________________*P. virginica* (10)

KEY TO STERILE SPECIMENS OF THE PLANTAGINACEAE OF WISCONSIN

1. Leaves terete or slightly flattened on adaxial side, linear *ca.* 1 mm wide, fleshy, glabrous, major vein 1, inconspicuous; stolons present; plant aquatic ________*Littorella americana* (1)
1. Leaves flattened, linear to cordate, 0.5–19 cm wide, thin to leathery, never fleshy, glabrous to pilose, major veins 3–9; stolons not present; plant usually terrestrial ________*Plantago*
   2. Leaves opposite, cauline; internodes 0.5–2 cm long; stem freely branching ___________________________*P. indica* (5)
   2. Leaves alternate, rosulate; internodes usually absent or less than 0.5 cm long; stem a corm or caudex, rarely branching.
      3. Leaves cordate, ovate or broadly elliptic with definite blade and petiole; blades 2–19 cm wide; major roots fibrous, or branched and fleshy.
         4. Major roots fleshy, 0.5–1.3 cm. thick; leaves leathery, spatulate to cordate-ovate; major veins appearing to arise from a "midrib" *i.e.* pinnate, not parallel to margin ________________________________*P. cordata* (2)
         4. Major roots filamentous, 0.1–0.3 cm thick; leaves thin to chartaceous, cordate to broadly elliptic; major veins parallel to leaf margin.
            5. Leaves broadly elliptic, never cordate; major veins 5,7, margin bearing 3–7 small teeth, base of petiole usually purple; plant glabrous or glabrate ________ __________________________________*P. rugelii* (3)
            5. Leaves ovate-cordate, major veins 3,5,(7), margin entire, undulate, base of petiole usually green; plant hirsutulous or glabrate ______________*P. major* (4)
      3. Leaves linear, lanceolate spatulate without definite blade and petiole; blades 0.5–4 cm wide; major roots in a tap system or (in old *P. lanceolata*) fibrous and arising from a stout caudex.
         6. Leaves spatulate, hirsute, margins entire or bearing 3–7 pectinate teeth.
            7. Major veins 5,7; leaf 2.5–4 cm wide, often revolute, appressed to ground; plant perennial, often forming caudex to 1.5 cm thick ______________*P. media* (9)
            7. Major veins 3; leaf 0.6–1.5 cm wide, erect or spreading; plant a short-lived annual with poorly developed root system, never a caudex__*P. virginica* (10)

6. Leaves linear or lanceolate, pilose or glabrous, margins entire or bearing 5–7 small teeth.
   8. Leaves lanceolate, glabrous, 0.5–4 cm wide, dark green, margins bearing 5–7 small teeth, major veins 5 (3,7); plant perennial often forming caudex 4–6 cm long, internodes absent; secondary branches frequent on large specimens ________*P. lanceolata* (8)
   8. Leaves linear, pilose, 0.2–0.6 cm wide, light green or silvery, margins entire, major veins 3; plant an-annual, occasionally forming short aerial stem with or without internodes; branches absent.
      9. Plants light green, thinly pilose; leaves of juvenile plants erect or slightly spreading; internodes short (2–5 mm) when present; secondary root system well developed ___________*P. aristata* (6)
      9. Plants silvery-green, thickly pilose; leaves of juvenile plants broadly spreading or appressed to ground; internodes absent; secondary root system poorly developed ________*P. patagonica* (7)

KEY TO FLOWERS AND FRUITS OF THE PLANTAGINACEAE OF WISCONSIN

1. Flowers unisexual, spike interrupted, *i.e.* bearing cluster of pistillate flowers at base and one terminal staminate flower separated 0.8–2 cm along floral axis; fruit an achene ____________ __________________________________*Littorella americana* (1)
1. Flowers bisexual, gynomonoecious or apomictic, flowers evenly distributed along spike; fruit a circumscissile capsule__*Plantago*
   2. Seeds 4–16 per capsule, testa more or less deeply sculptured; anthers conspicuously horned; bract and sepals glabrous; stigmatic hairs scattered, never in two rows, absent at corolla level.
      3. Bract and sepals attenuate; capsule oblong, 6.5–8 mm long, dehiscence near base; lower valve below sepals after dehiscence; 4–9 seeds per capsule; seeds 1.8–2.3 mm long; floral outline with conspicuous narrowing near base _____ ____________________________________*P. rugelii* (3)
      3. Bract and sepals obtuse-acute; capsule rhombic-ovate, 4–5 mm long, dehiscence medial; lower valve above sepals after dehiscence; 8–16 seeds per capsule; seeds 0.6–1 mm long; floral outline ovate ______________________*P. major* (4)
   2. Seeds 1–4 per capsule, rarely 5, testa smooth or very lightly sculptured; anthers cordate or horned *(P. indica)*; bract and sepals glabrous-pilose; stigmatic hairs scattered or in two parallel rows, usually present at corolla level.

4. Stamen and style length 0.5 mm or less; sepals and bracts pilose; petals with dark pigmentation at corolla throat; capsules with constriction above line of dehiscence; seeds slightly sculptured; face of seeds white with one or more dark bands.
   5. Bract 1.2–4 times as long as sepals; 4–8 pigmented areas on each petal near corolla throat; seeds 2.2–3 mm long, face with 2 concentric bands ______*P. aristata* (6)
   5. Brace shorter than or equaling sepals; 1 pigmented spot on each petal near corolla throat; seeds 1.6–2 mm long, face with one dark band ______*P. patagonica* (7)
4. Stamen and style length 1 mm or more or aborted; sepals and bracts glabrous or hirsute; petals without dark pigmentation at corolla throat or only near tip; capsules not constricted; seeds smooth; face of seeds usually lacking dark bands.
   6. Two sepals next to bract connate; pigmented areas on bracts and sepals a narrow stripe less than ⅓ total width; petals, bract and the fused sepals brown at tip; capsule dehiscence basal; seeds hirsutulous ____*P. lanceolata* (8)
   6. All sepals free; pigmented areas on bract and sepals at least ⅓ of total width; petals, bract and sepals green or translucent throughout; capsule dehiscence medial; seeds glabrous.
      7. Bract and sepals glabrous; corolla tube extending beyond calyx; planar area of seed inconspicuous or only partially developed.
         8. Style exceeding stamens; bract smooth, ovate, tip rounded; seeds 2 per capsule, 2.8–3 mm long; planar area visible only at one end; flowers odorless ____________________________*P. cordata* (2)
         8. Style *ca.* ½ as long as stamens; bract keeled, lanceolate, tip acute; seeds 3 (2–4) per capsule, 1.8–2.1 mm long, planar area not well defined; flowers fragrant _________________*P. media* (9)
      7. Bract and sepals hirsute; corolla tube equalling or shorter than calyx; planar area of seed ⅓–½ of face.
         9. Stigmatic hairs evenly distributed; petals with distinct midrib; bract keeled, chartaceous margin extending to tip; seeds 2.8–4 mm long, 2 per capsule __________________________*P. indica* (5)
         9. Stigmatic hairs in two rows (or absent in apomictic flowers); petals membranaceous

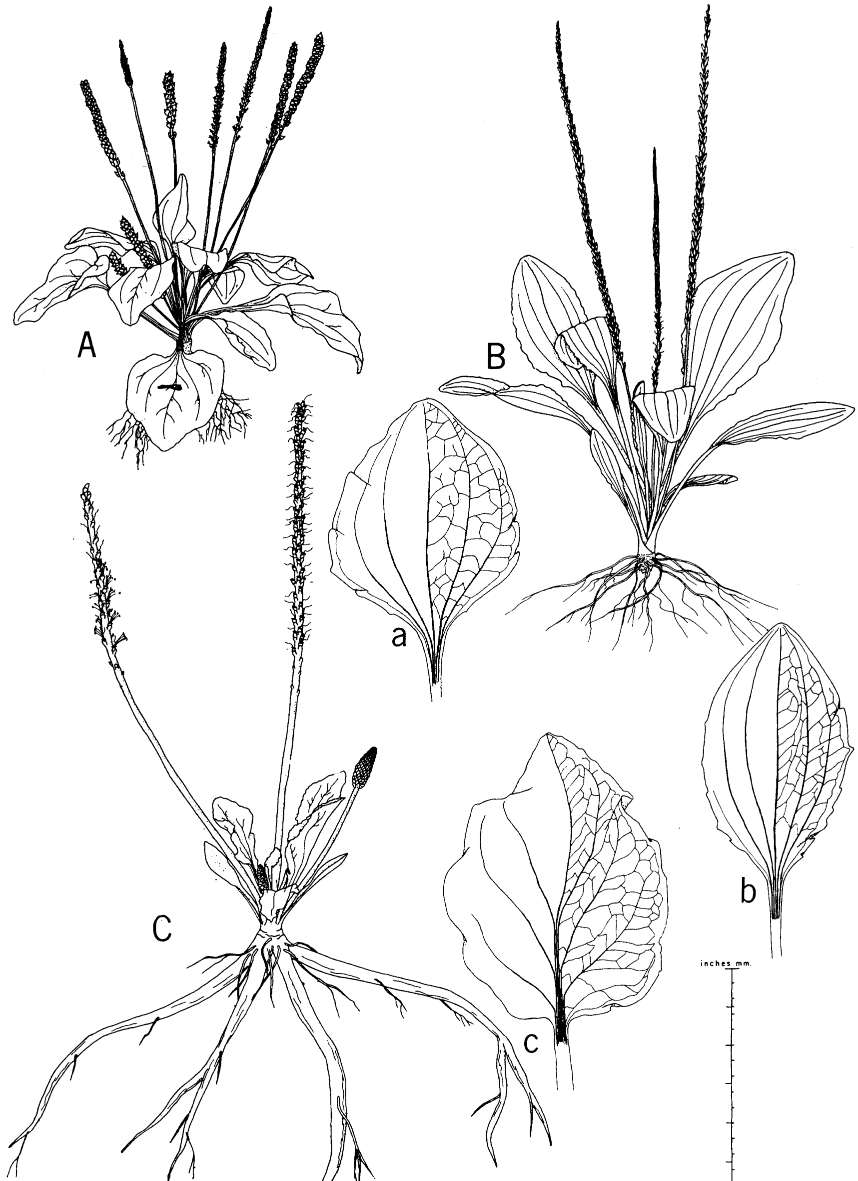


FIGURE 2. Habit drawings of some Wisconsin Plantagos: A) *Plantago major;* B) *P. rugelii;* C) *P. Cordata;* a,b,c) Leaves of respective species.

throughout, *i.e.* without a midrib; bract rounded, chartaceous margin not reaching tip; seeds 1.6–1.9 mm long, 3 per capsule ----*P. virginica* (10)

LITTORELLA BERGIUS

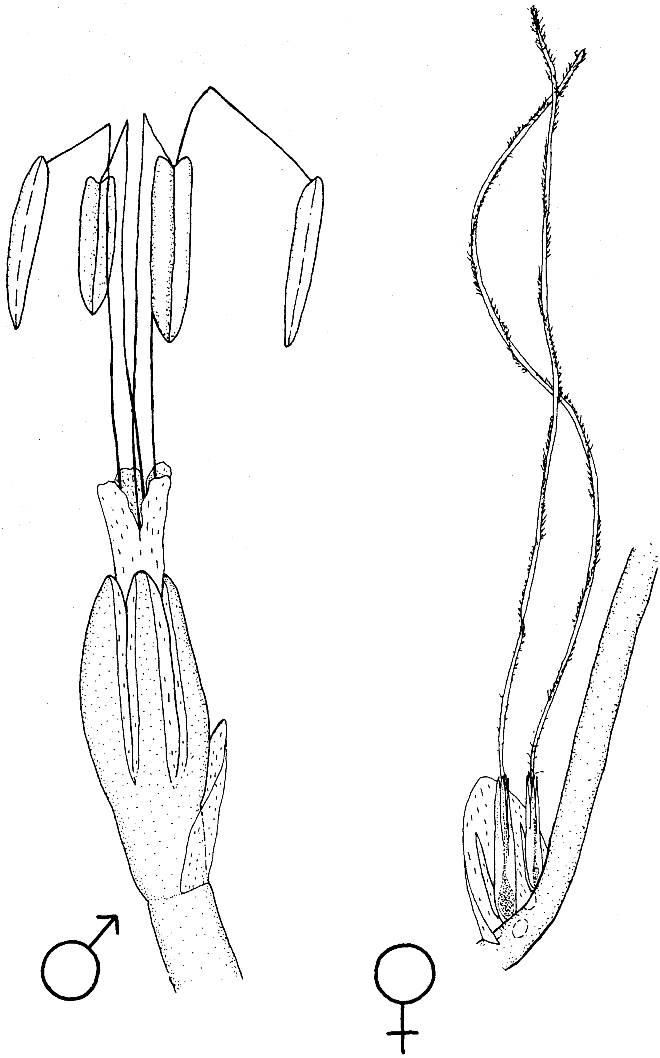
1. LITTORELLA AMERICANA Fern. *Rhodora* 20:62 1918. Map 2, Figs. 1G and 3.

L. uniflora (L.) Aschers. *sensu* Gleason (1962); and Gleason and Cronquist (1963).

L. uniflora v. *americana* (Fern.) Gl.

Plant a perennial herb. ROOTS: Fibrous *ca.* 1 mm thick. STEM: compact, may form a short caudex, frequently producing stolons 0.5–4 cm long. LEAVES: Rosulate, linear, terete or slightly flattened on adaxial side, truncate, with only one major vein, this only rarely visible on lower ⅓ of leaf; submerged leaves 1.3–3.7 cm long, erect; emersed leaves 2–8 cm long, arching. INFLORESCENCE: Total length 0.5–3 cm, flowers unisexual. STAMINATE FLOWERS: Terminal, only one per inflorescence; bract rounded, transparent; sepals 4, fleshy, often tinted light pink-brown, pigmented area ⅓ of total area, glabrous, 2.8–3.5 mm long, slightly keeled; corolla 4-lobed, erect at anthesis, transparent, projecting 1–1.7 mm beyond calyx; filaments 9–12 mm long; anthers *ca.* 2.5 mm long, tip rounded, base cordate, versatile, purple and/or yellow. PISTILLATE FLOWERS: In groups of 2–5 at base of inflorescence, hidden except for stigmas by leaves, entire cluster subtended by a single large, obtuse, transparent bract; sepals 1–4, linear, acuminate, transparent; corolla 3–4 toothed, teeth erect, attenuate; style filamentous 0.8–2.5 cm long; stigmatic hairs in one spiralling row. FRUIT: Achene, oblong, *ca.* 2 mm long; apparently rarely sets fruit. PHENOLOGY: Flowering June–August.

Fernald (1918) refers to *Littorella americana* as "One of the rarest plants of the North American flora . . ." It is surely uncommon but may often be overlooked or confused with other aquatics as it rarely blooms (For keys to vegetative specimens and morphologically similar aquatic plants, see Voss 1967.) Fassett (1934) referred to it as ". . . a characteristic and abundant plant in many lakes of northern Wisconsin." Voss (1965) discusses the species and gives a description of material from the Upper Peninsula of Michigan. Unfortunately, I have not seen the plant in the field but I do have a large collection of living plants collected at Cusino Lake (Michigan) by Ronald L. Stuckey. The data on this species, as given below, are based upon these collections.



Littorella americana

FIGURE 3. Flowers of *Littorella americana.*

Littorella is known from lakes in Maine, Michigan (Voss 1965), Minnesota (Lakela 1958), Newfoundland, New York (Muenscher 1934), Nova Scotia, Ontario, Vermont and Wisconsin (Map 2).

The name, *Littorella,* referring to the shore, is very appropriate as it is only in the littoral zone that it is found in bloom. Voss (pers. com.) reports that the Cusino Lake locality, where flowering specimens were collected in 1964, was under 2–3 feet of water in 1965 and 1966. The plants were still there, but without flowers. Experiments at the University of Michigan Botanical Gardens have shown that the plants require cool temperatures when emersed and cool or cold water when submersed. In cultivation, flowering can only be induced in emersed plants and under long-day conditions. The cultivated specimens were considerably larger than any collected in the field. Although I had many plants blooming simultaneously (all from the same clone), they did not set fruit. This indicates, perhaps, a genetically controlled self-incompatibility. This may also explain the rarity of fruit-set in the field. Reproduction is mainly vegetative by means of stolons. New plants are readily obtained by dividing old individuals or by cuttings from stolons.

PLANTAGO L.
SECT. PALEOPSYLLIUM Pilger

2. PLANTAGO CORDATA Lam. Illustr. Genr. I:338. 1791.
Heart-leaved Plantain Map 1, Figs. 2C, 4, 6A and 7A.
P. kentuckensis Michx.
P. canadensis Hort.

Plant a perennial herb. ROOTS: Primary massive and fleshy, 0.5–1.3 cm thick, branching several times; secondary roots fibrous. LEAVES: Spatulate in winter rosette, 1–3 cm wide; cordate-ovate but never truly cordate in late spring and summer rosette, 8–19 cm wide, 12–23 (50) cm long, lamina with a leathery texture, petiole base often purple; major veins (3) 5,7 (9), not parallel to margin but appearing to arise from a "midrib" ½ to ⅓ the distance up from the base of the expanded blade; leaf margin entire or undulate. INFLORESCENCE: Total length including peduncle 12–40 cm, glabrous, central cavity ⅔ total diameter of peduncle, 2–4 flowers per cm. FLOWERS: (Fig. 6A) Obovate in outline; sepals 2–2.3 mm long; bract 5/6 the length of sepals, obovate, tip truncate, pigmented area bordered on sides by very narrow hyaline margin, glabrous; petals elongate-deltoid, slightly revolute, translucent, spreading at anthesis; style length 1.5–2 times the stamen length, stigmatic hairs present at corolla level; anthers cordate at base, yellow. CAPSULE: (Fig. 7A) Ovate, 9–11 mm long, dehiscent below the middle, lower valve of capsule equalling sepals after dehiscence. SEEDS: 2 per capsule, tan—brown, testa smooth, mucilaginous coat heavy, 3–3.8 mm long, planar area conspicuous on one end of seed, obscured on other end, hilum and micropyle separated. (N = 12) PHENOLOGY: Flowering mid-April to early June (rarely in late fall). Fruit matures 1–3 weeks after anthesis.

Plantago cordata is a rare and fascinating plant. It has been collected so infrequently in the past 50 years that whenever a new locality is discovered or an old one rediscovered, it is either published (Svenson 1935, Chute 1942, Harper 1944, 1945) or cherished as a well-kept secret. So few botanists have seen it alive that I have heard respected workers question whether it still exists and whether it is even a distinct species.

The plant is quite similar, morphologically, throughout its range but varies slightly in size. The species is endemic to eastern United States and Ontario, excepting the coastal plain and northern forests, but most known localities are in the Great Lakes Region. I have seen *P. cordata* alive only in Adams Co., Ohio. Data on the biology of the species, as given below, are from plants of this locality. To my knowledge, there are only three or four other known extant localities. It was frequently collected in southeastern Wisconsin in the 1880's and 1890's but the last known collection is from Milwaukee Co. dated 1938. Wadmond's collection from Somers, Kenosha Co. (MINN, WIS) includes photographs taken in the

FIGURE 4. *Plantago cordata* and habitat in Kenosha Co., Wisconsin (Wadmond, June 30, 1899, near Sommers: MINN).

field (Fig. 4). The distribution in Wisconsin (Map 1) is, as throughout its range, correlated with limestone areas. From my observations, it appears that the plants can not tolerate bright sunlight even if they are in very wet areas. This lack of tolerance may be a factor in their decline, as the opening of the forests together with the draining of low areas destroyed their habitats.

Blooming starts in late April and early May when the plant is still in the winter-rosette condition (Fig. 2C) : Later inflorescences and infructescences are subtended by summer leaves (Fig. 2c). The induction of flowering is apparently brought about under short-day conditions and young inflorescences are often produced in the fall for the following spring. These young spikes are well protected by the imbricate petiole bases. Meiosis may occur in the fall but usually does not occur until spring. The important factor in inducing flowering is evidently a cold period. Under constant conditions, the plants will eventually develop a winter-rosette but will then remain quiescent until subjected to a cold treatment. Individuals will occasionally bloom again in the fall after a cold snap. There is no dormancy in the seeds at maturity. They must germinate rapidly as they only live about a month in storage at 40°F. They will not germinate under water. A detailed discussion of the biology of *P. cordata* will be given at a later date.

SECT. PLANTAGO

3. PLANTAGO RUGELII Dcne. in DC Prodr. XIII:695. 1852.
Rugel's Plantain Map 10, Figs. 2B, 6B, 7B and 8.

Plant an annual or perennial herb. ROOTS: Fibrous from a short stem. LEAVES: Rhombic-ovate or elliptic, glabrous, 2–10 cm wide; blades 6–20 cm long; major veins 5 (7, 9), parallel to margin, joining at base of blade; margin entire but bearing 5–9 small pectinate teeth. INFLORESCENCE: Total length including peduncle 12–50 cm, glabrous, 1–8 per plant, *ca.* 10 flowers per cm. FLOWERS: (Fig. 6B) Outline oblanceolate; sepals 2.2.–2.5 mm long; bract ½ the length of sepals, linear-lanceolate, tip attenuate, pigmented area ¼–⅓ total width, glabrous; petals subulate—deltoid, chartaceous, reflexed at anthesis; style length equal to stamen length, stigmatic hairs not present at corolla level; anthers conspicuously horned, purple or yellow. CAPSULE: (Fig. 7B) Oblong, 6.5–8 mm long, dehiscent at middle; lower valve of capsule below tips of sepals after dehiscence. SEEDS: (4)–7–(9) per capsule, dark brown, testa slightly sculptured, 1.8–2.3 mm long, planar area only vaguely defined but occupying *ca.* ⅓ of axial surface, hilum and micropyle separated. (N = 12). PHENOLOGY:

Flowering early June to November with peak in July (Fig. 8). Fruit maturing 2–3 weeks after anthesis.

Plantago rugelii, as its "look-alike," *P. major,* is an extremely variable and plastic species. We are fortunate that students of this species were not as anxious to name every morphological deviant as has been the case with *P. major.* Only two varieties have been named; *alterniflora* and *aspera* both by Farwell. I have seen types of these and hold them to be ecological variants; *alterniflora* is a depauperate dry-exposed form, *aspera* is a juvenile form.

Native in eastern North America and west to Texas and North Dakota, *P. rugelii* has been introduced in most other states but is common only in its native area. It is not so frequent in the northern parts of its range (in Wisconsin north of the Tension Zone (Map 10), *cf.* discussion under *P. major*) as farther south. This may represent a general northward migration of the species associated with a warming climate and surely, at least for the weedy forms, with the disturbances of man. Hansen (1961) reports it as established in certain areas of northern Europe. The more robust forms are associated with rich bottom-lands frequently in shady areas. Shull (1914) showed that the seeds will germinate after being submerged in water for up to 54 months. The robust form, when growing along streams, could be confused with *P. cordata* (see above) as both can produce very large leaves often having purple petiole bases (a character allegedly, but not, diagnostic of *P. rugelii*). Hamilton & Buckholtz (1956) concluded from their experiments that *P. rugelii* grew better in association with *Agropyron repens* than in areas where the grass was removed. In light of the putative relationship of the Plantaginaceae and the Scrophulariaceae, this might suggest a haustorial relationship which they did not investigate. I repeated the experiment but obtained rather poor growth in the plantain. No haustorial connections were found. The problems of identification and confusion with *P. major* involve mainly the more or less depauperate—weedy and/or juvenile forms of both species. The species undergo parallel changes when subjected to unfavorable conditions, especially those of dry, open hot areas such as roadbeds, paths, cracks in masonry, mud-flats, talus slopes and gravel pits. Here the leaves are small (2–3 cm wide) and often thickened; the inflorescences short (5–10 cm) and sparse; and frequently the capsules aborted or contorted It is almost impossible to distinguish sterile material of this type although some clues may be obtained from the leaf margins. From general field observations, it appears to me that of the two species, *P. major* is the more common weed in Wisconsin, whereas in Michigan, *P. rugelii* is the more common.

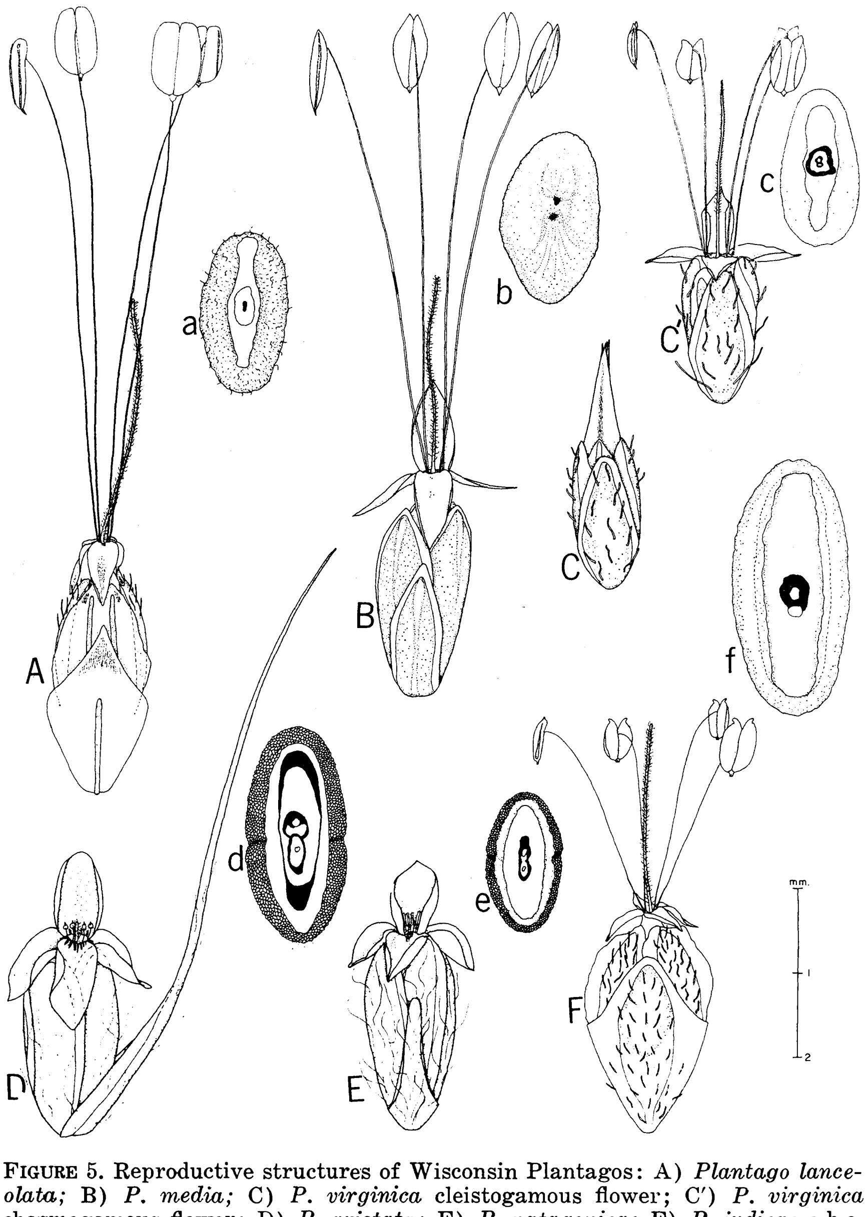


FIGURE 5. Reproductive structures of Wisconsin Plantagos: A) *Plantago lanceolata;* B) *P. media;* C) *P. virginica* cleistogamous flower; C′) *P. virginica* chasmogamous flower; D) *P. aristata;* E) *P. patagonica;* F) *P. indica;* a,b,c, d,e,f) Seeds of respective species.

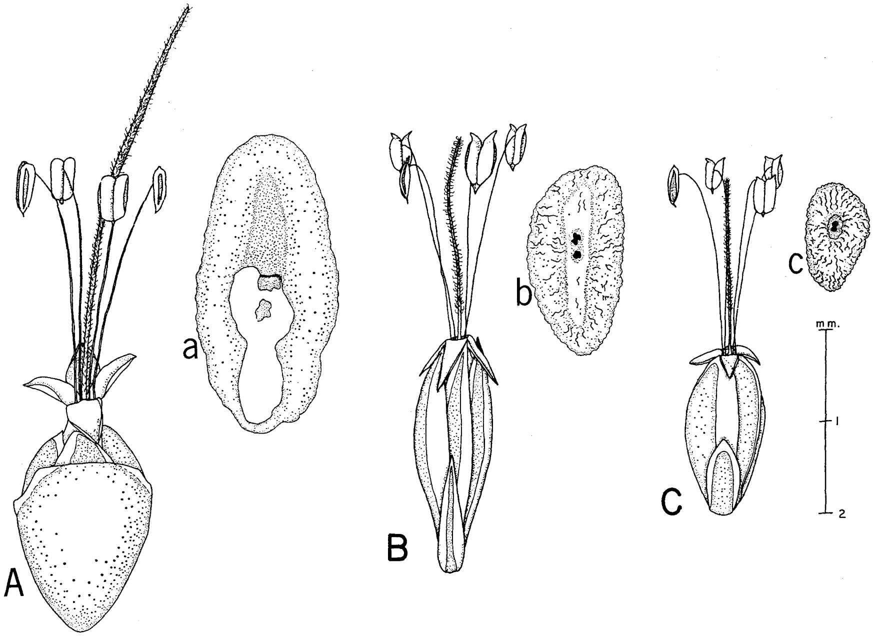


FIGURE 6. Reproductive structures of Wisconsin Plantagos: A) *Plantago cordata;* B) *P. rugelii;* C) *P. major;* a,b,c) Seeds of respective species.

Details on the reproductive biology of *P. rugelii* are not known. Strausbaugh (1950) reports on the occurrence of branched spikes in the species. It is a long-day plant but may remain blooming into early November (*Fig.* 8). The seeds are dormant when first shed but germinate after a cold treatment or several months in storage (Steinbauer & Grigsby 1957).

4. PLANTAGO MAJOR. L. Sp. Pl. ed. 1:113. 1753.
Broad-leaved Plantain, White-man's Foot
Map 9, Figs. 2A, 6C, 7F and 8.

Plant an annual or perennial herb. ROOTS: Fibrous from a compact stem. LEAVES: Ovate to cordate, glabrate or hirsutulous, 2–13 cm wide; blade 4–15 cm long; major veins 3, 5, (7), parallel to margin, joining at base of blade; margin entire or slightly undulate. INFLORESCENCE: Total length including peduncle 6–25 cm, glabrate; 1–30 spikes per plant; *ca.* 16 flowers per cm. FLOWERS: (*Fig.* 6C) Outline ovate; sepals 1.5–2.0 mm long; bract 1/3 the length of sepals, lanceolate, tip obtuse, pigmented area 2/3 of total width, glabrous; corolla lobes deltoid, chartaceous, reflexed at anthesis; style length equal to stamen length or slightly shorter; stigmatic hairs absent at corolla level; anthers conspicuously horned, frequently purple. CAPSULE: Rhombic-ovate, 4–5 mm long, dehiscent near the middle; lower valve of capsule usually exceeding tips of sepals. SEEDS: 12 (8–16) per capsule, black-brown, testa deeply sculptured, 0.6–1 mm long, planar area inconspicuous, hilum and micropyle adjacent. (N = 6). PHENOLOGY: Flowering mid-June to November (Fig. 8). Fruit maturing 2–3 weeks after anthesis.

Plantago major is well known for its variability and plasticity. Two subspecies, over a dozen varieties and innumerable forms have been credited to eastern North America. Fernald (1950) mentions several forms of Pilger's subspecies *eumajor* while Gleason (1952) classifies the plants as members of subspecies *pleiosperma* Pilger. These subspecies, based on number of seeds and general capsule shape, are questionable, as Dowling (1935) showed in intergradation of seed number in a population of *P. major* in Great Britain. Likewise, my own observations of greenhouse cultures have revealed variation in seed numbers from 4 to as high as 20 per capsule in *P. major* from Costa Rica, Hawaii, Michigan, Ontario and Wisconsin. Young plants, especially those forced to bloom when they have produced only a few elliptic leaves, will usually have a lower number of seeds per capsule. Capsule shape will also vary with age but not as greatly. The var. *scopulorum* Fries & Broberg has been collected on beaches in Wisconsin but such plants, in the greenhouse, will quickly revert back to "typical" form. The results of various transplant experiments are given by Marsden–Jones & Turrill (1930, 1933, 1935, 1937, 1938). The species is badly in need of revision and in view of the dubious nature of the intraspecific taxa, I choose, here, to treat the species as *P. major sensu lat.*

Plantago major is found throughout the world in areas disturbed by man, but is not abundant in the far north. With the exception of oceanic islands, it is difficult to state where the species is native and where it has been introduced by man. Whether or not it is native to North America is still a matter of speculation. The plant was supposedly called "White-man's Foot" by the Indians of eastern North America. If this is true, it would indicate an unfamiliarity with the plant by the Indians before European colonization. An interesting problem would be to determine whether there exist physiological-genetic differences between the Eurasian and American populations. Likewise a chronological distribution map (like that of *Rorippa sylvestris,* see Stuckey (1966) might help resolve the question. It was first collected in Wisconsin in 1887 in Wauwatosa.

Plantago major occupies a wide range of habitats from railroad yards and sandy hills to moist, rich soils of old fields and lawns but is rarely found in hard-packed soils. Curtis (1959) in his

Species List (p. 641) includes *P. major* as a member of the "Southern wet mixed forest" yet lists it in Table XXXI–1, "Prevalent species of weed communities of southern moist nitrogen-rich soils," as reaching its highest presence value (87%) there. He also lists (p. 641) *P. rugelii* as being a member of the "Dry mesic prairie." From herbarium data, the literature and my own observations, I can not help but think these two species are switched in the Species List. *Plantago major* does very poorly in shaded areas and rarely occurs in areas that are wet during the growing season. The opposite is true for *P. rugelii* (see above). The latter is apparently more abundant south of the "Tension Zone" (75 localities *vs.* 23 for *P. major*) while *P. major* is more abundant north of it (51 localities *vs.* 29 for *P. rugelii*). Hartley (1966) gives it as "infrequent" in the "Driftless Area" where *P. rugelii* is "common." This unequal distribution of the two species could, of course, simply be a matter of chance but, on the other hand, if *P. major* were truly introduced, it would not be particularly incongruous for *P. major's* weedy forms to have a slight advantage in the north, where *P. rugelii* is not native and both are competing in the weed communities. In the south, on the contrary, where *P. rugelii* is in its native area, the presence of autochthonous bottomland populations in addition to the weedy forms makes it more numerous.

Plantago major starts blooming 3–4 weeks later than *P. lanceolata* (Fig. 8) and continues later into the fall. Various abnormal forms of the spike, some of which are genetically controlled, have been described (Hammarlund 1921) including apical rosettes, leafy bracts, fasciation and branching. There is no evidence of gynomonoecism or other reduction of the normally hermaphroditic flowers. Sagar & Harper (1964) give seed-to-seed period as 6 weeks under cultivation. The seeds are dormant at the time of maturity but will germinate after several months or a chilling (Steinbauer & Grigsby 1957). The seeds may remain viable for periods of *ca.* 50–60 years (Chippendale & Milton 1934) and have given 10% germination after 40 years (Crocker 1938). Unlike *P. lanceolata,* seeds of *P. major* never germinate in the fall but do so sporadically the following season (Marsden–Jones & Turrill 1938).

SECT. PSYLLIUM (Juess.) Harms *in* Engler & Prantl

5. PLANTAGO INDICA L. Syst. Nat. ed. 10. II:896. 1759.
Psyllium, Indian Plantain Map 6, Figs. 1D, 5F, 6I and 8.
Psyllium indicum Du Mount de Cours
Psyllium annuum Thuill.
Psyllium ramosum Gilib.
Plantago ramosa (Gilib.) Ascherson

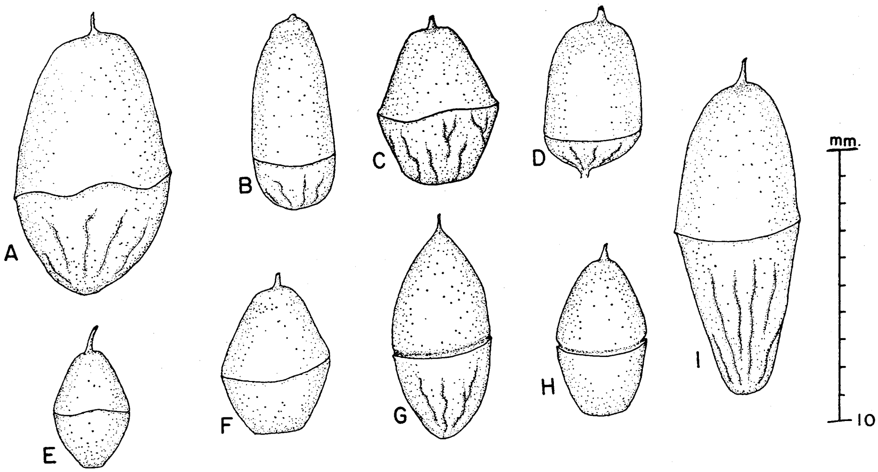


FIGURE 7. Capsules of Wisconsin Plantagos: A) *Plantago cordata;* B) *P. rugelii;* C) *P. media;* D) *P. lanceolata;* E) *P. virginica;* F) *P. major;* G) *P. aristata;* H) *P. patagonica;* I) *P. indica.*

Psyllium arenarium Mirbel
Plantago arenaria Poir.
Plantago psyllium sensu Gleason & Cronquist (1963), *non* L.

Plant an herbaceous or slightly woody annual. ROOTS: Major tap root with usually poorly developed fibrous side roots: STEM: Total length 10–50 cm, freely branching; internodes 1–4 cm long. LEAVES: Linear, hirsute, 1–7 cm long, 0.2–0.5 cm wide, opposite; major veins (1), 3, parallel the entire length of leaf; margin entire, ciliate. INFLORESCENCE: Total length including peduncle 2–6 cm, hirsute, 1–30 or more per plant; spike often appearing capitate, 10 flowers per cm. FLOWERS: (Fig. 5F) Outline obovate; sepals 2–3 mm long; bract 5/6 the length of sepals, ovate, lower bracts may be aristate, 2–2.5 times as long as sepals, bracts increasingly shorter from base of inflorescence to tip, tip of bract rounded, pigmented area 1/3 of total width and bearing conspicuously rounded keel hispid; corolla lobes elongate-deltoid, crenulate, central vein present, reflexed at anthesis; style length equal to stamen length, stigmatic hairs present at corolla level; anthers conspicuously horned, yellow. CAPSULE: Rounded-ellipsoid, 10–13 mm long, dehiscent at the middle. SEEDS: 2–(3) per capsule red-brown, testa smooth, 2.8–4 mm long; planar area occupying ½ of face, sunken, causing sides to appear revolute in x-section; micropyle and hilum separated. (2N = 12 Rahn, 1957). PHENOLOGY: Flowering July–September.

Plantago indica is readily identified by its caulescent habit. The only species we may confuse with it is *P. psyllium* L., a close relative, which is rarely introduced in eastern North America. I have seen no specimens nor heard any reports of the latter occuring in Wisconsin. It differs from *P. indica* in having leaves narrower, hirsutulous or glabrate, more linear bracts, and a generally "spindly" habit.

Plantago indica is native in Europe being most common in the countries bordering the Mediterranean Sea. It is probably frequently reintroduced in North America, as the seeds are still a popular remedy for constipation (Claus 1961). Additional uses of *Plantago* in medicine can be found in Shyreu (1935). In Wisconsin, the plants are found on sandy open areas frequently along beaches (Map 6). Goessel collected specimens at North Point in Sheboygan from 1919 to 1932. The plants die in the fall and over-winter as seeds. In the greenhouse, I have been able to keep individual plants alive for only 10 months. There is apparently no primary dormancy as the seeds germinate readily. Flowering is initiated only under long days. The species will probably become more frequent in the future.

SECT. LEUCOPSYLLIUN Dcne.

6. PLANTAGO ARISTATA Michx. Fl. Boraeli-Amer. I:95. 1803.
Bracted Plantain, Buckhorn Map 4, Figs. 1B, 5D, 7G and 8.
Plantago patagonica Jacq. v. *aristata* (Michx.) A. Gray
P. gnaphalioides Pursh. v. *aristata* (Michx.) Hook.
P. purshii Roem. *et* Schult. v. *aristata* (Michx.) Jones
P. nuttallii Rapin
P. aristata nuttallii (Rapin) Morris
P. squarrosa Nutt.
P. squamosa Nutt. ex Dcne.
P. frankii Steud.
P. filiformis Dcne.

Plant an annual herb. ROOTS: Major root tap; secondary roots usually abundant. STEM: In order specimens, especially those growing in moist areas, stem up to 1.5–6 cm long with internodes 2–5 mm long. LEAVES: Rosulate, usually erect, linear, 3–17 cm long, 3–6 mm wide, hirsute to pilose; major veins 3, parallel the entire length of leaf; margin entire, ciliate. INFLORESCENCE: Total length including peduncle 3–27 cm; peduncle hirsute, 1–10 per plant, 2–4 flowers per cm. FLOWERS: (Fig. 5D) Outline elliptic; vertically 4-ranked on peduncel but spirally arranged; sepals 2–2.5 mm long; bract reflexed, tip aristate, pigmented area 1/3 of total area but discernable only at base of bract, hyaline margin present only on lower 2–3 mm of bract, bract 1.2–5 times as long as sepals, thinly pilose; corolla zygomorphic, limb cordate, involute, tip of posterior limb rounded, 4–8 darkly pigmented patches on each limb near throat of corolla tube; style length equal to stamen length or slightly longer; stigmatic hairs present at corolla level; anthers ovate in outline, not versatile, spinose, included in upper corolla lobe, light yellow. CAPSULE: Acutely elliptic, narrow constriction circumscribing upper valve immediately above line of dehiscence; dehiscent below the middle; old corolla always remains on capsule at maturity. SEEDS: 2 per capsule, reddish-tan, testa finely sculptured, 2.2–3 mm long, with a shallow medial constriction crossing back; planar area occupying almost the entire face, face with two concentric dark elliptic bands; micropyle and hilum separate. (2N = 20 Rahn, 1957). PHENOLOGY: Flowering mainly in June but sometimes extending into October (Fig. 8). Fruit set 2–3 weeks after anthesis.

Plantago aristata is extremely variable in size but is usually readily identified by the presence of the aristate bract. Goodwin's study showed a general correlation between ecologically marginal habitat and small size. Although the mature plants ranged from single-spiked individuals *ca* 3 cm high to seven-spiked specimens up to 20 cm high, the various morphological units—bracts, capsules etc.—remained proportional (Goodwin, 1949). In the vegetative rosette stage, it is almost impossible to distinguish from *P. patagonica* with which it often forms mixed populations. *Plantago spinulosa* Dcne. is a morphological intermediate between the two species and may represent hybrids. Individuals of *P. aristata* may have relatively short pilose bracts while some individuals of *P. patagonica* (*e.g.* Thomson *Sept. 4, 1937* Millston, Wis. WIS) have reflexed spinose bracts. This probably represents a small amount of introgression. The parental species are phenologically separated (see below; Fig. 8) but do overlap. Alva Day (personal communication) grew plants from seeds of *P. purshii (P. patagonica?)* having long bracts but, in cultivation, the bract length reverted to the normal, short condition. She explains the long bract as perhaps a result of high moisture content of the soil.

Plantago aristata is native to the Great Plains of North America but, with the disturbances of man has spread throughout the United States (including Hawaii) and adjacent Canada. In Wisconsin, it is generally restricted to the prairies (Map 4) where it occupies the open, well-drained sites. Curtis (1959) lists it as in indicator of dry prairies. It is sometimes found as a weed along railroad beds and sandy beaches.

Day-length requirements are not specifically known but my observations on greenhouse materials indicate that a short day is required to initiate flowering. Once flowering has started, day-length is no longer important as the plants will continue to produce inflorescences under long days until the apex is eventually used up in the production of a terminal spike. If the plants are subjected to sudden changes in day-length, an apical rosette of vegetative leaves often develops on the spike. This may later produce lateral inflorescences. The plants will continue blooming for several months during which a stem 3–5 cm long may develop. *Plantago aristata* begins blooming 1–3 weeks later than *P. patagonica* (Fig. 8) at which time most stigmas of the latter are no longer receptive. Although I can not detect a fragrance in the flowers of either species, the relatively large and showy corolla and small, frequently included stamens, do suggest entomophily. I have seen small flies and bees visit the flowers but do not know whether they are significant pollen vectors. The plants are self-compatible. The seeds have little or no primary dormancy (Steinbauer & Grigsby, 1957). Even so, they rarely germinate the same year they are produced as the capsules do not dehisce readily and remain intact on an erect spike until late fall when the plant dies and finally falls over.

7. PLANTAGO PATAGONICA Jacq. Icon. P. Rar. II, Coll. Supl. 35. 1796.
Map 3, Figs. 1C, 5E, 7H and 8.

Plantago patagonica v. *gnaphalioides* (Nutt.) A. Gray

P. purshii sensu Fernald (1950) *non* Roem. *et* Schult.

Plant an annual herb. ROOTS: Major root tap; secondary roots poorly developed. LEAVES: Rosulate, erect or slightly spreading, linear, 3–12 cm long, 2–6 mm wide, often woolly-pilose; major veins 3, only one visible on adaxial surface, parallel the entire length of leaf; margin entire, ciliate. INFLORESCENCE: Total length including peduncle 4–20 cm; peduncles pilose, 1–15 per plant (usually only 4–6 per plant in Wisconsin); 2–6 flowers per cm. FLOWERS: (Fig. 5E) Outline elliptic; conspicuously vertically 4-ranked; sepals 1.0–2.4 mm long, pilose; bract usually equal to or shorter than sepals but sometimes projecting slightly beyond the calyx, always appressed to calyx, lanceolate, tip rounded, pigmented area bordered by very narrow chartaceous margin; corolla zygomorphic, limbs cordate at base, involute, posterior limb erect, tip acute, one pigmented patch on each limb near throat of corolla; style length equal to stamen length or slightly longer; stigmatic hairs present at corolla level; anthers elliptic in outline, not versatile, included in upper corolla limb, light yellow. CAPSULE: Rounded—elliptic, narrow constriction circumscribing upper valve immediately above line of dehiscence; dehiscent below the middle; old corolla always remains on capsule at maturity. SEEDS: 2 per capsule, reddish-tan,

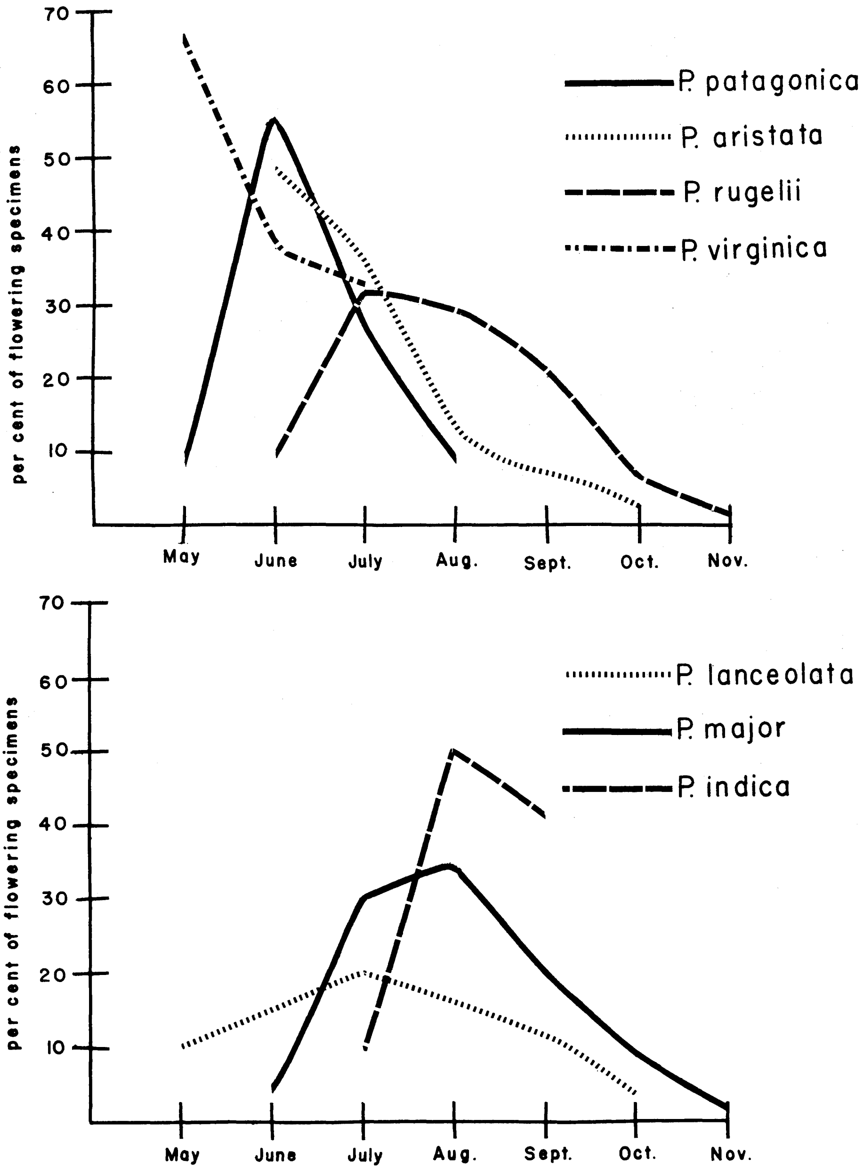


FIGURE 8. Phenology of selected Wisconsin *Plantago* species.

testa finely sculptured, 1.6–2 mm long shall ow medial constriction crossing back; planar area occupying almost entire face, face with one dark elliptic band; micropyle and hilum separate. (2N = 20

Rahn, 1957) PHENOLOGY: Flowering early May and June occasionally into September (Fig. 8).

Plantago patagonica, like *P. aristata* (see above), is quite variable in general size. The problems of classification and taxonomy arising between *P. patagonica* and *P. purshii* are readily apparent in the literature. I agree with Gleason and Cronquist (1963, p. 644) that our plants of *P. patagonica* are ". . . apparently identical with those from S. Amer. . . ." The interesting and perplexing problem is the explanation of this amphitropical distribution. Although the entire section of the genus is in need of a complete revision, I believe *P. purshii* of our western states is a very different entity (and probably a good species) from the *P. patagonica* of the central plains. I have never seen the western plant from any localities east of the Mississippi River. For additional comments (not in complete harmony with my views) see Poe (1928) and Morris (1900).

Restricted to the well drained soils of the Great Plains, *P. patagonica* occurs in the dry prairies of southern and western Wisconsin (Map 3). Unlike *P. aristata,* it does not form large weedy populations in areas disturbed by man. It is only rarely found along dry beaches and railroad beds. It also differs from *P. aristata* in that it can not tolerate very moist or wet soils. Under these conditions, it rapidly turns yellow and dies.

Plantago patagonica is a well marked short-day plant: I have kept it in the vegetative stage for a period of four months under 14 hour days but could readily induce blooming in the same plants under 8-hour days. The floral morphology and reproductive behavior are similar to *P. aristata* (see above). The plants begin blooming the second or third week of May (1–3 weeks before *P. aristata*). Individual plants may continue blooming for about a month. The seeds are dormant when first shed but will germinate after 3–4 months storage or alternating cold-warm treatments.

SECT. ARNOGLOSSUM Dcne.

8. PLANTAGO LANCEOLATA L. Sp. Pl. ed. 1:113. 1753.
Ribgrass, Ripplegrass, English Plantain, Buckhorn, Narrow-leaved Plantain. Map 7, Figs. 1E, 5A, 7D and 8.

Arnoglossum lanceolatum S. F. Gray

Plantago lanceaefolia Salisb.

P. flexuosa Guad. *ex* Rapin

P. capensis Bojer

P. longistipes Royale *ex* Barnéoud

Plant an annual or perennial herb. ROOTS: Juvenile, tap; old specimens, fibrous from short stem or caudex. STEM: Caudex 4–6 cm long in old specimens, frequently branching in robust individuals. LEAVES: Lanceolate 6–32 cm long, 0.5–4 cm wide, glabrate or hirsutulous; major veins 5 (3, 7), parallel the entire length of the leaf; margin usually denticulate with 5–11 small teeth. INFLORESCENCE: Total length including peduncle 10–40 cm, hirsutulous, peduncle ribbed, 1–10 per plant; floral group globose or elongate, 12–15 flowers per cm. FLOWERS: (Fig. 5A) Outline elongate-rhombic with construction between bract and sepals; sepals arising from a short pedicle *i.e.* not directly in the axil of bract, sepals 2–2.5 mm long, the two sepals next to bract fused into one doubly tipped, doubly ribbed unit; bract 4/5 the length of sepals, acuminate, ovate, the pigmented area reduced to a narrow rib, glabrous; petals elongate-cordate, slightly pigmented near tip, reflexed at anthesis; style length ½ of stamen length; stigmatic hairs present at corolla level; anthers cordate at base, yellow; the plants may be gynomonecious or gynodioecious. CAPSULE: Elongate, dehiscent at the base. SEEDS: (1) 2 per capsule, dark brown, testa lightly sculptured, often hirsutulous, 1.6–1.9 mm long; planar area 1/3 of face, slightly sunken; micropyle and hilum adjacent. (2N = 12 Rahn, 1957). PHENOLOGY: Flowering mid-May through October. Fruit maturing 3–4 weeks after anthesis.

Plantago lanceolata, like the other weedy plantains, is an exceedingly variable species throughout its range. Pilger (1937) divided it into two varieties and seven subvarieties. Other authors (*e.g.* Druce, 1928) recognize up to 12 varieties. Of these, only two, *sphaerostachya* Mert. & Koch (having a globose inflorescence and often pilose leaves) and *angustifolia Poir.* (having short, narrow leaves) have been cited as occurring in our area (Gleason 1952). Griffiths (1922) showed that the pubescence of *sphaerostachya* is dependent on environmental conditions: The dry-open habitat producing the small pubescent plant while a more mesic or wet habitat yielded the typical form. He also produced the sphaerostachya habit by placing the typical form in the dry-open habitat. Leaf shape and length are determined by the height of surrounding vegetation (Jenkin, 1925). My field observations and greenhouse cultures show that pubescence, leaf size (and to some extent shape) and general inflorescence size are apparently strongly influenced by the environment. I am therefore recognizing for Wisconsin only the typical, although polymorphic, variety.

A native of Eurasia but widely established throughout the world except in subartic and low-lying tropical areas, *Plantago lanceolata* is probably the best known member of the genus. The species has had a long association with man: Pollen deposits have often been used as an indicator of prehistoric man's migrations (Iversen, 1941, Godwin, 1944, 1956). There is no record of when it was first introduced into North America but because it is so abundant in Europe and especially in the British Isles (Sagar & Harper, 1964) it was probably brought to the early settlements.

Plantago lanceolata was first collected in Wisconsin in Marquette Co. in 1861 and represents the first *Plantago* known to be collected in the state. The distribution in Wisconsin (Map 7) is misleading in that the plant is much more abundant than the number of localities would indicate: One could probably find it in all counties. The problem here is probably like that of other weedy species which, unfortunately, are not collected because they are so ubiquitous. It is a common weed of door-yards, roadsides, paths and open fields. The plants will live under a broad range of ecological conditions but seem to prefer hard-packed soils (Harper *et al.,* 1965), alkaline conditions (Zeiner, 1946) and minimal competition for sunlight (Sagar & Harper, 1964).

Plantago lanceolata is a long-day plant (Snyder, 1948, Bünning & Kodon, 1954) blooming in our area from late May to early October with a peak around the second week in July (Fig. 8). The flowers may be pistillate, staminate or hermaphroditic and show a complete morphological spectrum of sexuality (Stout, 1919, Blaringhem, 1923, Hope–Simpson, 1939, Baker, 1963). The pollen is an important cause of hayfever in early summer (Wodehouse, 1945). Although normally wind-pollinated, *P. lanceolata* has been reported to be frequented by insects (Clifford, 1962). The seeds may germinate in the late summer or fall of the year they are produced but rarely produce flowers until the following spring. Buried seeds may remain viable for up to 40 years (Beal, 1905, Darlington, 1922, Kjaer, 1948) which may help to explain the rapid appearance of large populations in recently disturbed areas. If favorable conditions prevail, the seeds will germinate readily (Steinbauer & Grigsby, 1957).

SECT. LAMPROSANTHA Dcne.

9. PLANTAGO MEDIA L. Sp. Pl. ed. 1:113. 1753.
Hoary Plantain, Dwarf Plantain Map 5, Figs. 1A, 5B, 7C and 8.
Plantago concinna Salisb.
P. incana Stokes
P. bertolonii Godr.
Arnoglossum incanum S.F. Gray.

Plant an annual or perennial herb. ROOTS: Major root tap with abundant secondary fibrous rootlets. STEM: Compact, but in older specimens a caudex 1–2 cm long, rarely branching. LEAVES: Spatulate-obovate, 4-10 cm long, 2.4–4 cm wide, appressed, hirsute; major veins 5, 7 (9), parallel the entire length of the leaf; margin entire, slightly revolute. INFLORESCENCE: Total length including peduncle 12–35 cm; peduncles smooth, 1–5 per plant, 12–17 flowers per cm. FLOWERS: (Fig. 5B) Outline obovate, fragrant; sepals 2.0–2.4 mm long, all sepals distinct and separate; bract ⅔ as long as sepals, broadly lanceolate, tip acute, pigmented area ¾ of total width, glabrous; corolla limbs lanceolate, chartaceous, slightly revolute, posterior lobe erect, all others reflexed; style length ½ of stamen length; stigmatic haris present at corolla level; anthers broadly fusiform in outline, white or pink. CAPSULE: Rhombic, dehiscent at the middle. SEEDS: 3 (2–4) per capsule, dark brown, testa smooth, 1.8–2.1 mm long; planar area poorly defined, represented by slight depression; micropyle and hilum separate. (2N = 12, 24 Rahn, 1957). PHENOLOGY: Flowering mid-June to September.

Plantago media, a widely distributed weed from northern Europe to central Russia, is rare in our range. Pilger (1937) lists five varieties and four forms for the Old World material but does not cite any North American specimens. In Wisconsin, the species is known from only two localities (Map 5) and is represented by the typical variety. The plant is apparently re-introduced frequently as there is no record of its becoming well established anywhere in North America. It is not even listed in Steyermark (1940), Small (1933) or Rydberg (1932). Fernald (1950) refers to it as "occasional" as do Gleason (1952) and Gleason & Cronquist (1963). Hartley (1966) in his *Flora of the "Driftless Area"* calls it "rare" and "A weed on a golf course at La Crosse."—where he collected it once in 1956.

The species may be confused with *P. lanceolata* superficially but the higher seed number and the absence of fused sepals readily distinguish it. Rademacker (1940) gives the habitat as confined to base-rich areas of old, relatively undisturbed areas where cultivation is at a minimum. Steele (1955) notes it as "an exacting calcicole," *i.e.* requiring both high pH and calcium level. The plant is apparently very drought resistant (Sagar & Harper, 1964).

Plantago media is a long-day plant. The seeds are dormant at the time of capsule dehiscence but germinate after a cold treatment (Sagar & Harper, 1964).

SECT. NOVORBIS Dcne.

10. PLANTAGO VIRGINICA L. Sp. Pl. ed. 1:113. 1753.
Pale-seed Plantain, Sand Plantain, Dwarf Plantain.
Map 8, Figs. 1F, 5C&C′, 7E and 8.

Plantago caroliniana Walt.
P. ludoviciana Raf.

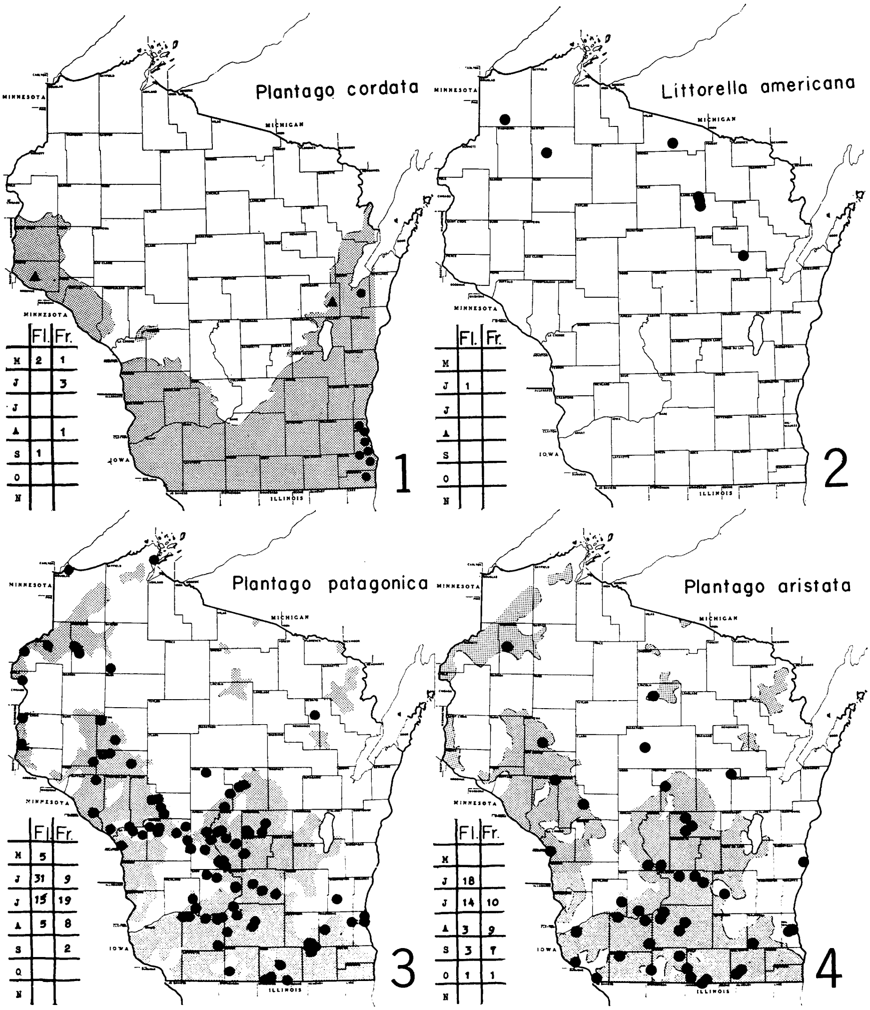
P. accendens Raf.
P. connivens Moench.
P. purpurascens Nutt. *ex* Rapin
P. missouriensis Steud.

Plant a short-lived annual herb. ROOTS: Weakly developed tap system attached to a short compact stem. LEAVES: Spatulate, 2–8 cm long, 0.6–1.5 cm wide, hirsute or, growing under moist conditions, hirsutulous; major veins 3, parallel entire length of leaf; margin enitre or pectinate with 3–5 small teeth. INFLORESCENCE: Total length including peduncle 3–15 cm, hirsute, 1–5 per plant, 2–4 flowers per cm. FLOWERS: (Fig. 5C & C′) Outline obovate; sepals 1.4–2.7 mm long; bract as long as or slightly shorter than sepals, bract ovate, tip rounded, pigmented area ¾ of total width, hispid; cleistogamous and chasmogamous flowers sometimes produced on one inflorescence, plants usually apomictic and bearing only cleistogamous flowers; cleistogamous flowers having aborted anthers and styles, corolla lobes always erect, bract and sepals more pointed than those of chasmogamous flowers; chasmogamous flowers having well developed anthers and styles, style shorter than stamens, stigmatic hairs in two rows down narrow edges of flattened style; style glabrous at corolla level; anthers inconspicuously horned, yellow. CAPSULE: (Fig. 7E) Rhombic-ovate, dehiscent at the middle; old corolla always present on mature fruit. SEEDS: 3 per capsule, light brown, testa smooth, 1.6–1.9 mm long; planar area occuping ⅓ of face; micropyle and hilum adjacent. (N=10 Chandler, 1954). PHENOLOGY: Flowering early May to July.

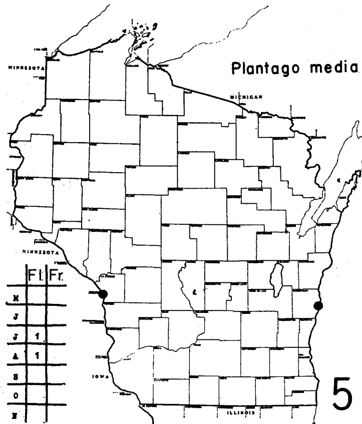
Plantago virginica is a short-lived (2 months maximum) spring ephemeral of pioneer habitats. Fernald's variety *viridescens,* based on shorter bracts and sepals than the typical variety and on bright green, more or less glabrous leaves, can easily be produced in the lab by growing the typical variety under moist conditions. The presence or absence of denticulations on the leaf margin is apparently under genetic control. The size of individuals varies from 3 to 20 cm in height (and proportional diameter of the rosette) and is highly correlated with population density and available moisture; the smaller specimens being from dense populations in drier areas.

Occurring natively from the East Coast west to Kansas and Arizona, *P. virginica* is becoming established as a weed in our western states. The species is probably more abundant in Wisconsin than the number of localities (Map 8) indicates. Because of its short growing season and usually very small size, it is easily overlooked. It "blooms" mainly in early or middle May (Fig. 8) when the dry prairies, sand hills, rocky slopes, old gravel pits, borrow-pits and similar well-drained areas are still moist from spring thaws.

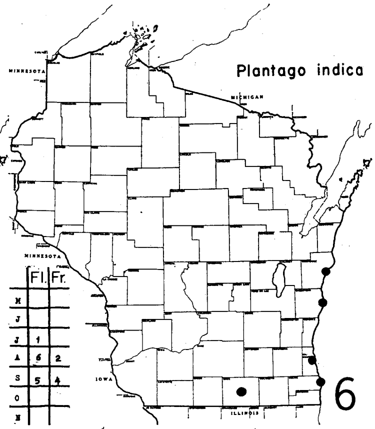
Plantago virginica is a day-neutral plant according to my experiments. I have induced flowering under both short and long day conditions. It is apparently a facultative apomict: Cleistogamous flowers with abortive stamens and very short styles are the typical form but often occur mixed with morphologically sexual, chasmogamous flowers; either on the same inflorescence or separate inflorescence on the same plant. The mechanism controlling this phe-



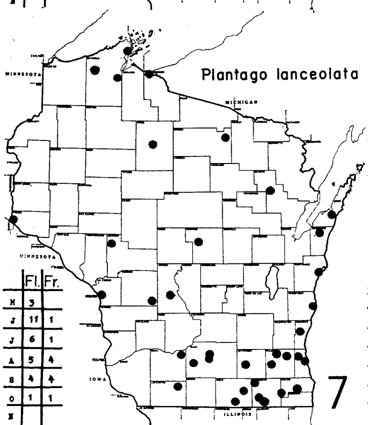
MAPS 1–4. Triangles represent county record only. Map 1) Shaded area underlaid with limestone; Maps 3 & 4) Shaded area savannas and prairie (Curtis, 1959).


Plantago media
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M
J
J 1
A 1
S
O
N

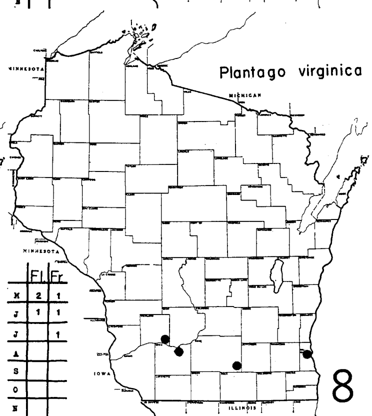
5


Plantago indica
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M
J
J 1
A 6 2
S 5 4
O
N

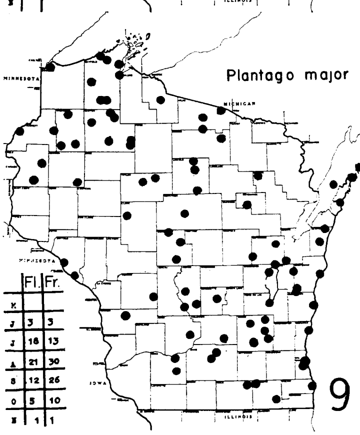
6


Plantago lanceolata
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M 3
J 11 1
J 6 1
A 5 4
S 4 4
O 1 1
N

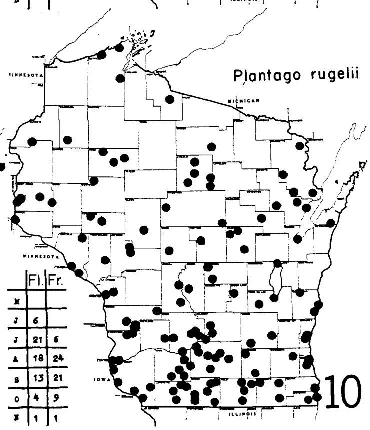
7


Plantago virginica
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M 2 1
J 1 1
J 1
A
S
O
N

8


Plantago major
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M
J 3 3
J 18 13
A 21 30
S 12 26
O 5 10
N 1 1

9


Plantago rugelii
MINNESOTA
MICHIGAN
IOWA
ILLINOIS
Fl. Fr.
M
J 6
J 21 6
A 18 24
S 13 21
O 4 9
N 1 1

10

nomenon is not known and individuals growing under identical conditions may display the entire morphological spectrum. Whether or not the seeds produced by the morphologically sexal flowers are produced sexually or apomictically has yet to be determined. The seeds are dormant when mature, but will germinate after a cold treatment or several months in storage. I have observed a second generation late the same year in a population west of Ann Arbor, Michigan, but this is apparently not typical.

Anderson (1959) gives *P. virginica* as an important source of the Ring-spot of pepper.

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