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WALTER F. PETERSON

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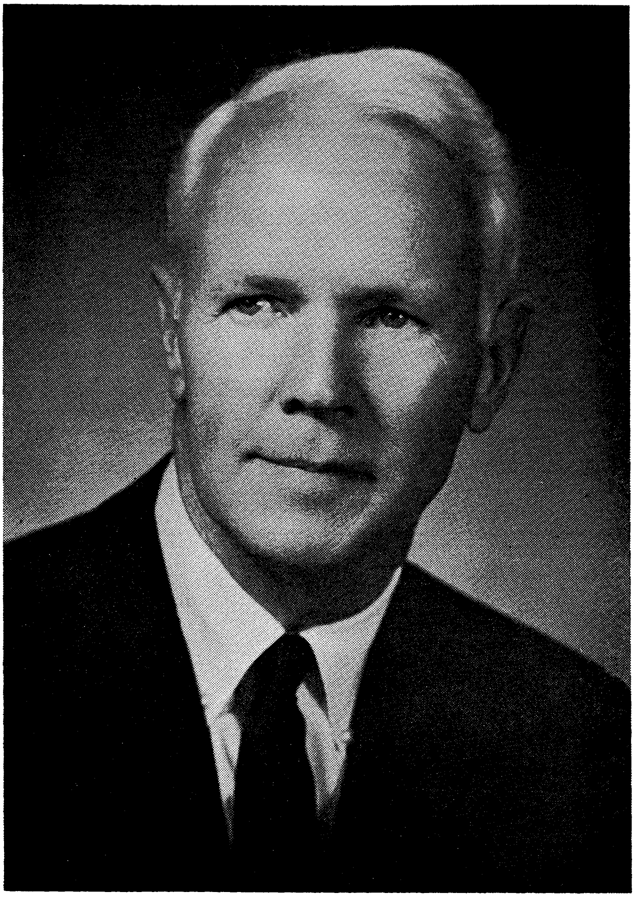

WILLIAM B. SARLES

49th President of the

WISCONSIN ACADEMY OF SCIENCES, ARTS AND LETTERS

OPPORTUNITIES FOR THE FUTURE OF THE WISCONSIN ACADEMY OF SCIENCES, ARTS AND LETTERS

William B. Sarles, President 1969–70
May 7, 1970

The "Theme" of the Academy's Centennial year is: "Preserving the Past—Planning the Future." Our meetings in Madison and Milwaukee, and our publications during this, our 101st year, will emphasize and amplify the theme, and will illustrate service to the present.

My excursion into the past will be brief, but hopefully significant because it is designed to serve as at least part of the foundation for that to be said about opportunities for the future.

Members and guests of the Academy will receive a reprinted copy of Bulletin No. 1, dated April, 1870, of the Wisconsin Academy of Sciences, Arts and Letters. This valuable publication tells how the Academy was organized, and by whom; presents its Constitution, By-Laws, and its March 16, 1870 Charter from the Wisconsin Legislature; and finally, states its Plan of Operations.

The Plan of Operations starts as follows: "Having thus a legal existence, and being provided by the State with secure and convenient apartments in the Capitol for its office, library and collections, the Academy is ready to commence the work for which it was established." This description of early housing and facilities makes us envious but at the same time serves as a reminder that we should strive more diligently and effectively to recapture that which was provided 100 years ago.

After describing work to be done and studies to be made in the sciences, arts and letters, the Plan, written by the Academy's President, J. W. Hoyt, presents a highly significant point: "The measure of accomplishment, in other words the efficiency and degree of usefulness of the Academy, will, of course, be determined by the competency and zeal of its members, the wisdom, energy, and devotion of its officers, and the cordiality and liberality with which their plans and efforts for the public good are seconded and sustained by the people and the State."

President Hoyt was right; the members and officers of the Academy have served it well. But at some time during the century we failed to accomplish our objectives with sufficient success to justify strong, continuing financial support from "the people and the

State." Perhaps we can regain the needed recognition and support from the State; we may if we can prove our worthiness.

President Hoyt continues in his "Plan of Operations" to make recommendations that have come to be of special significance today. "No institution of this or any other kind can be efficiently maintained without the means to employ and fairly compensate one or more competent and efficient officers, so that their whole time and energies may be consecrated to its work. . . . For the liberal support of these there must be a permanent fund. . . . Wisconsin may not yet hope to vie with some of the older States in the number and munificence of . . . private benefactions . . . but she may justly boast of men, not a few, who, by favor of the rare opportunities she has given them, have acquired so large a measure of wealth that the donation of an amount sufficient to place this Academy at once upon a sure foundation . . . would advance the public interest by a signal act of noble generosity." This was a hopeful plea that has turned out to be a prophetic statement. Our gathering this evening is an inadequate but sincere attempt to recognize the generosity of Professor Harry Steenbock who, "by a signal act of noble generosity" bequeathed a large share of the residue of his estate to the Wisconsin Academy of Sciences, Arts and Letters. We are grateful to Professor Steenbock to a degree that makes impossible an adequate expression of our gratitude. At the same time, we wish to honor him because he was a great and accomplished gentleman who contributed so much to the advancement of scientific knowledge as a research worker and teacher, and who appreciated and supported the arts and letters. Professor Steenbock loved Wisconsin and made it his life. All of Wisconsin—its people and its institutions—benefited by his life.

The Academy now has opportunities for the future that were envisaged 100 years ago by its President and his fellow charter members.

It is not my desire to present a detailed, step-by-step plan for the future of the Academy, but rather to emphasize some of the principal opportunities that we, as a truly interdisciplinary organization, can develop. Another way to do this is to speak of opportunities as challenges to the Academy, and this is what I propose to do.

The first opportunity, or challenge, involves communication of facts, concepts, and ideas.

There is an ever increasing number of scientists, technologists, scholars, and artists at work in the world. Their discoveries and proposals must be published or by some other means made known to all who have the intelligence to understand. Specialization of the discoverers and the innovators in any field of endeavor adds to the complexity of communication and the difficulty of comprehension.

Use of different languages and alphabets contributes to the magnitude of the problems of communication faced by even highly trained, competent scientists and scholars. Consider, for example, the difficulties encountered by an accomplished microbial geneticist who must try to translate intelligently a significant article published in Japanese by one of the growing number of microbiologists working in his special field in Japan! Microbial geneticists whose native language is English have enough trouble trying to understand the writings of their English-speaking colleagues who delight in the introduction of new terminology. Communication becomes even more difficult when ideas, interpretations, explanations, concepts, or descriptions must be elucidated and understood.

The question might be asked: Why is communication a challenge to the Academy? The Academy is concerned with support and development of sciences, arts and letters. The Academy, by means of its meetings and publications, is involved in the dissemination of information; in communication of knowledge to those competent to understand. The Academy is committed to stimulation of learning and to the awakening of interests. The Academy is concerned with bridging the gaps that exist between specialists and those who need to know significant facts, concepts, interpretations, and ideas.

What can the Academy do toward improvement of its efforts to achieve its objectives? The diversity of interests and of competence represented by its membership is valuable. It makes it possible for members and guests to gather in meetings and to publish volumes devoted to interdisciplinary communication of facts, concepts, and ideas. The specialists have their own journals and their own meetings that can be devoted entirely to their specialties. The Academy, because of its diversity, provides an opportunity for development of awareness of the accomplishments of others and the possibilities for improvement of communication.

In his book, "Scene of Change," published by Charles Scribner's Sons in 1970, Dr. Warren Weaver speaks of diversity and of unity of knowledge and concepts when he says: ". . . science should have no quarrel with the humane arts or with contemplative fields of thought, nor they with science. They are all, each using its characteristic methods, seeking to perceive order and unity in diversity. They are all based on faith, they are all creations of imaginative minds; they are all alive, growing, changing; they all are limited by what our linguistic apparatus and our cultural concepts permit. . . ." Dr. Weaver goes on to quote the late physicist, J. Robert Oppenheimer: "The artist and scientist both live always at the edge of mystery, surrounded by it. Both struggle to make partial order in total chaos. They can, in their work and in their lives, help themselves, help one another, and help all men."

There is still something missing from that which I've said and quoted about the opportunity—or the challenge—of communication and of diversity, and the missing part concerns communication with young men and young women. This is a special problem and a very special opportunity for the Academy. Dr. Weaver said that the sciences and arts are limited by what our linguistic apparatus and our cultural concepts permit. In his book, he describes the problems of trying to communicate facts, concepts, and ideas to the Hopi Indians, who do not share our grammar, our ideas, or our ways of dealing with experience. He points out that the Hopi Indians, even if they could understand English, could not comprehend our desires to study the sciences, arts and letters because "they have a metaphysics of their own, and deal with experience and reality in ways that are quite unlike ours, but which nevertheless work entirely satisfactorily for them."

No doubt I've gone a bit far in relating the challenges of communication with the young to those encountered in attempts to communicate with Hopi Indians. Our children and our young men and women have been exposed to English, mathematics, sciences, the humanities, and the arts. They have had the opportunity to grasp the basics of the facts, concepts, and ideas that we consider to be important. The principal opportunity—and the challenge—is to arouse their interests and enthusiasms for learning. Isn't there some way in which we can reach them more effectively, and help them to generate the curiosity, the thirst for knowledge, the practices of thinking, and the skills of doing that can be theirs?

Our Junior Academy of Science, now celebrating its 25th year of accomplishment and service should, I believe, be expanded to become the Junior Academy of Sciences, Arts and Letters. The time to appreciate diversity and unity of thought and endeavor might be earlier in a young person's life than we've thought. A broadened Junior Academy could, hopefully, provide the same opportunities now made available by the Academy only to adults.

Another opportunity for the Academy's development exists, I believe, in working with the young men and women who are undergraduate students in colleges and universities. We have at present a Junior Academy for high school students; we make no provisions for undergraduates who are beginning the serious business of finding themselves and deciding what they really want to do. These students, perhaps even more than those in high school, need the stimulants and the services that the Academy can provide.

My proposals of opportunities—and challenges—for the future of the Academy may be too general; too much concerned with strategy rather than tactics. But I have attempted to generate some thinking along lines that may lead to the improvement and development of the Academy; to make it achieve more effectively the objectives set forth in its Charter in March of 1870. Professor Steenbock's bequest has given us a chance to make progress. The Academy *can* become a more significant, dynamic force in the life of the State.

Frederick Jackson Turner: Non-Western Historian*

Ray Allen Billington

Ladies and Gentlemen: I am indeed honored to participate in such a momentous occasion as this. For a fruitful century the Wisconsin Academy of Sciences, Arts and Letters has stimulated the intellectual currents that elevated the state and its universities to an enviable spot in the hierarchy of the nation's harbingers of civilization. It has done so by refusing to succumb to the forces of specialization that increasingly departmentalize all knowledge today. As I have read over the fat volumes of Transactions of a generation ago, I have been struck by two things: the incomprehensible fortitude of those who endured hour after hour of learned discourse, and their good fortune in doing so. As they listened, half dozing perhaps, to papers on subjects far from their principal interest, they may well have been startled into rapt attention by a hypothesis, or a technique, or an idea that applied to their own research interest and that illuminated a hitherto dark corner. The Academy is to be commended to keeping alive the spirit of interdisciplinary investigation in a day when the knowledge explosion threatens to compartmentalize all learning.

It is for this reason that I want to talk with you tonight about Frederick Jackson Turner, a long-time member of the Academy, who more than any other historian of his day sought to popularize its ideals and utilize the approaches that it advocated. This, admittedly, is not the image of Turner in the popular mind. He is remembered, in Wisconsin, as the state's most distinguished contribution to the historical profession who trained a legion of students at Madison between 1889 and 1910 when he reluctantly left for Harvard because he believed that his resignation would awaken the regents to the dangers of their attacks on pure research. He is remembered nationally as the intellectual father of two theories. One, advanced in 1893 in his famed paper on "The Significance of the Frontier in American History," held that certain distinctive features of the American character could be traced to the three-centuries-long process that settled the continent; as opportunity in the form of free land and untapped natural resources altered behavioral patterns, men became more optimistic, inventive, mate-

* Doctor Billington delivered this address at the banquet of the fall gathering of the Academy held in Milwaukee, October 3, 1970.

rialistic, nationalistic, and democratic than their fellows with no frontier experience.[1] The other, the sectional hypothesis, occupied Turner for most of his life. As the frontier moved westward, he held, pioneers encountered and overran vast physiographic regions where differing natural conditions created differing modes of life. These 'sections' corresponded to European nations, and the history of the United States could be understood only by comprehending the manner in which national policy was decided by sectional conflict, interplay, and compromise.[2] Turner devoted most of his life to a vain attempt to prove that hypothesis.

Turner's stress on these two theories, linked with the immense popularity of the frontier thesis during the early years of the century, have created a popular impression of Turner as a propagandist who preached that one giant causal force shaped the nation's past. Critics rose by the score during the depression-oriented 1930s and 1940s to brand him as a monocausationist who ignored more vital causal forces by his stress on the frontier, who glorified nationalism at a time when internationalism was necessary to prevent world chaos, who blinded the people to the problems bred of industrialization and urbanization by his stress on the rural past.[3]

My purpose tonight is to challenge that distorted image and reveal Frederick Jackson Turner in his true light: as a historian whose views were so modern, whose techniques were so in advance of his times, whose conception of history was so broad, that he would feel as much at home in a meeting of the American Historical Association of today as he did in 1910. Above all I hope to demonstrate that he was a pioneer in the interdisciplinary approach to research, and that those who today explore those borderland areas in the social sciences could learn from his example.

Before plunging into that discussion, let me answer one necessary question: if Turner's views were so modern, why has his reputation

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[1] This general essay was first presented to the American Historical Association on July 12, 1893, at a meeting held in Chicago in connection with the World's Columbian Exposition. It was repeated before the State Historical Society of Wisconsin on December 14, 1893. Its first printing was in the *Proceedings of the Forty-First Annual Meeting of the State Historical Society of Wisconsin* (Madison, 1894), 79–112; it was reprinted later that year in American Historical Association, *Annual Report for the Year 1893* (Washington, 1894), 199–227. The essay has appeared dozens of times since then, in whole or in part, in every form from historical anthologies to expensively designed special books. It is perhaps most readily available in Frederick Jackson Turner, *The Frontier in American History* (New York, 1920), 1–38.

[2] Turner published a number of essays embodying his theories on sectionalism. Most important among these are those entitled "Sections and Nation," *Yale Review*, XII (October, 1922), 1–21, and "The Significance of the Section in American History," *Wisconsin Magazine of History*, VIII (March, 1925), 255–280. Both were reprinted in Turner, *The Significance of Sections in American History* (New York, 1932).

[3] For a summary of the views of Turner's critics see Ray A. Billington, *The American Frontier* (Washington, 1965. 2nd edn.), and *America's Frontier Heritage* (New York, 1966).

been so tarnished since his death in 1932? The answer, I suspect, can be found in the popularity of his frontier thesis. Repeatedly through his lifetime he was called upon to speak or write about the frontier; this was the subject expected of Turner when he was demanded for a commencement address, enlisted for the annual Phi Beta Kappa banquet, or seduced into writing a lucrative article for the *Atlantic Monthly.* Yet he had, after the turn of the century, abandoned research on the frontier to begin his sectional studies or to venture briefly into the field of diplomatic history. The lectures or essays composed under those circumstances simply expanded ideas that he had already voiced, substituting extravagant rhetoric for proof. When unshackled by factual information, as he was on such occasions, he was inclined to succumb to oversimplification and overstatement, substituting the bludgeon for the rapier, and writing with the unrestrained prose of the poet rather than the exactly defined words of the historian. These are the essays, collected in two published volumes, that aroused the ire of his critics and gave them evidence of his traitorism to the standards of his profession.[4]

Let me give you an example of the way in which he dug his own grave by these practices. Turner was to teach on the west coast during the summer of 1914, and had agreed to give the commencement address at the University of Washington on "The West and American Ideals"—a topic broad enough to cover anything he might possibly want to say when he began composing his remarks. Unhappily, he had little time for that composition. He intended to prepare a polished oration before leaving Cambridge, but Turner was a natural procrastinator, and the round of oral graduate examinations, the ocean of end-of-term blue books, the need of a hurried trip to Washington for a committee meeting, and the chaos involved in moving their residence from one house to another allowed the spring to pass with nothing done.[5] He left Boston on June 4, intending to make some progress during the week allotted to Madison, but that was ill-advised, for his daughter Dorothy was marrying John Main that week, and between wedding plans and old friends no work was done. Turner arrived in Seattle on June 15 or 16 with his commencement address still to be prepared—an

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[4] Turner's two published volumes of essays, referred to in the footnotes above, were his *Frontier in American History* (1920), and *The Significance of Sections in American History* (1932), the latter published after his death.

[5] Turner to Edmond S. Meany, May 26, 1914, in Roy Lokken, ed., "Frederick Jackson Turner's Letters to Edmond S. Meany," *Pacific Northwest Quarterly,* XLIV (January, 1953), 35; Turner to Mrs. William Hooper, May 26, 1914, Frederick Jackson Turner Papers, Henry E. Huntington Library and Art Gallery, TU-H, Box 2. Hereafter referred to as: "HEH."

address scheduled for delivery on June 17.[6] To compound his problems the packet of notes that he had hastily assembled had disappeared, so that he must depend on his memory even for the quotations.[7]

The result was predictible—an address that marvelously paraded most of the clichés of frontier history. The pioneer "knew not where he was going but he was on his way, cheerful, optimistic, busy and buoyant." He was "an opportunist rather than a dealer in general ideas," but possessed "a courageous determination to break new paths, indifference to the dogma that because an institution or a condition exists, it must remain." American democracy, Turner told his audience, "was born of no theorist's dream; it was not carried in the *Sarah Constant* to Virginia nor in the *Mayflower* to Plymouth. It came out of the American forest, and it gained new strength each time it touched a new frontier."[8] In one hastily prepared essay Turner had provided fuel that was to keep his critics happy for two decades.

In his own behalf, it must be said that he was less than proud of the fantasies that he invented on that occasion. "I am still moving by reflex action after my poor commencement address," he wrote a friend two days later,[9] and added that he felt as a man might who relaxes in the electric chair after the first shock.[10] His one solace was that the crying babies in the audience of 2,500 drowned out most of his words. "Always," he advised a friend, "take along a supply of babies when you preach."[11] These bantering words hid a genuine humiliation. At first he refused to allow the lecture to be published—"it was written to be spoken," he explained[12]—but when the editor of the *Washington Historical Quarterly* persisted, he succumbed. Only when he saw it in print did he recognize the many errors of fact and theory of which he was guilty. Preserved among his papers is a printed copy filled with corrections, adorned with frequent marginal notes, and bear-

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[6] Turner, "Memorandum," in Harvard Commission on Western History Correspondence, Harvard University Archives, Widener Library, Harvard University, Box 5, Folder: Turner, F. J. Hereafter referred to as "HC on WH Corr." The story of the Commission, which was financed by Mrs. Hooper to purchase books and manuscripts in western history for the Harvard University Libraries, is told in the introduction to Ray A. Billington, ed., *"Dear Lady": The Letters of Frederick Jackson Turner and Alice Forbes Perkins Hooper* (San Marino, Calif., 1970).

[7] Turner to Max Farrand, October 26, 1914. HEH TU Box 22.

[8] Turner, "The West and American Ideals," in *The Frontier in American History,* 290–310.

[9] Turner to Roger Pierce, June 19, 1914. HC on WH Corr., Box 9, Folder: In Re A. B. Hulbert.

[10] Turner to Charles Homer Haskins, June 18, 1914. Charles Homer Haskins Papers, Firestone Library, Princeton University.

[11] *Ibid.* A warm, sunny day attracted a larger crowd than Turner had anticipated—or wanted. *Seattle Sun,* June 17, 1914.

[12] Turner to Edmond S. Meany, July 22, 1914, in Lokken, ed., "Frederick Jackson Turner's Letters to Edmond S. Meany," *loc. cit.,* 35–36.

ing beside the more extravagant statements the underlined words: "Too strong."[13]

I do not want to suggest that all of Turner's later papers on the frontier were as inadequately prepared as this; I do maintain that the true Turner can be found not in warmed-over versions of a theory that no longer concerned him but in the research papers and letters to fellow historians where he expressed his real views on the nature and meaning of historical research. If we focus on this evidence we reveal a scholar who stood head and shoulders above his own generation in concepts, purpose, and methodology. Above all, Turner emerges as a pioneer in the interdisciplinary approach for which the Academy stands, and which is proving so valuable among the social sciences today.

This viewpoint was a product of his training, his intellectual environment, and his whole concept of history. His training under Professor William Francis Allen at the University of Wisconsin pointed him in the right direction. Allen, a mediaevalist, was interested to an unusual degree in the impact of social conflicts, economic forces, and cultural factors in shaping the civilization of the Middle Ages; he taught his young disciple that society was an evolving organism responding to a variety of pressures that must be investigated for complete understanding.[14] As Turner turned his own attention to studies of the American frontier he recognized the wisdom of his master. Alterations in the traits of intruding ethnic groups under the impact of frontier opportunity could be appraised only after the physical environment was properly understood. This meant mastering geography and geology; in 1898, when a young professor at Madison, Turner enrolled in a course on the physiography of the United States given by his friend and neighbor, Charles H. Van Hise.[15] This proved immensely valuable in his studies; what was more logical than to assume that the study of economics, or government, or sociology, would be equally revealing.

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[13] Turner listed some of his errors in writing to his good friend Max Farrand (including the statement that George Washington was born in South Carolina), then added: "There are other reasons why it lacks the perfection which is the dream of the wise and the good." Turner to Farrand, October 26, 1914. HEH TU Box 22. A printed copy of the address, with Turner's marginal comments, is in HEH TU File Drawer 15B, Folder: Commencement Address. University of Washington.

[14] The only adequate biography of Professor Allen is Owen P. Stearns, "William Francis Allen: Wisconsin's First Historian," Unpublished Masters Thesis, University of Wisconsin, 1955. Mr. Stearns has kindly allowed me to use the well-researched dissertation. Turner frequently commented on his debt to Allen. For a typical example see Turner to Merle Curti, August 8, 1928. HEH TU Box 29.

[15] The University of Wisconsin undergraduate newspaper, The *Daily Cardinal*, October 4, 1898, described the lecture course that attracted Turner. The careful lecture notes that he took during the course, all dated October and November, 1898, are scattered through his papers at the Huntington Library. They may be found in HEH TU File Drawer 12C, Folder: Van Hise Course; File Drawer 14D, Folder: Lecture. Physical Geography; and File Drawer 15A, Folder: Notes on Van Hise's Lectures.

This early training inclined Turner toward the interdisciplinary approach to history, but I like to believe that his resolutions were strengthened by the intellectual environment of Wisconsin provided by the Academy of Sciences, Arts, and Letters. He was elected a member in 1887, when still a graduate student, probably under the sponsorship of Professor Allen who was president that year.[16] From that day until his death in 1932 he served actively, presenting two of his important research papers for the first time at meetings in 1895 and 1896, commenting frequently at other sessions, persuading his students to present their findings in a series of papers at the annual gatherings, and acting as vice-president for the letters section in 1896.[17] We will never know the ideas planted in his mind or the flashes of inspiration that occurred as he listened to endless papers on the whole range of scholarly inquiry. Did Humphrey J. Desmond, a political scientist, turn Turner's interests to sectionalism when in 1888 he reported on "The Sectional Feature of American Politics?"[18] Did T. C. Chamberlin and Charles H. Van Hise stir the young historian's curiosity as they gave their numerous reports on geology, and turn him toward the geographic investigation that underlay his frontier and sectional concepts?[19] Did he suddenly awaken when listening in 1892 to E. A. Birge explain "Weissman's [sic] Theory of Heredity," to the knowledge that nearly all biologists believed in the inheritance of acquired characteristics, and thus see how traits stemming from the frontier environment could be passed on to future generations?[20] Those are unanswerable questions, but there seems no question that Turner's immersion in the interdisciplinary atmosphere of the Wisconsin Academy helped broaden his interests to the everlasting benefit of historical scholarship.

Finally, and probably most important, Turner was nudged toward an interdisciplinary approach by his own concept of the nature of

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[16] *Transactions of the Wisconsin Academy of Sciences, Arts and Letters, VII, 1883–1887* (Madison, 1889), 267.

[17] Turner read his paper on "State Making in the West" before the Academy in 1885, and another on "The Projected French Expedition of George Rogers Clark Against Louisiana in 1793" in 1896. *Ibid., XI, 1896–1897* (Madison, 1898), 549. The first of his student's papers before the society was delivered in 1891 when Turner himself read an essay by Kate A. Everest on "Early Lutheran Immigration to Wisconsin," *Ibid., VIII, 1888–1891* (Madison, 1892), 415. Others were presented at irregular intervals during the remainder of Turner's stay at Wisconsin. Notice of his activities on committees and as vice-president are in *Ibid., VIII, 1888–1891* (Madison, 1892), 413, and *XI, 1896–1897* (Madison, 1898), 256. The *Daily Cardinal,* January 6, 1897, also noted his elevation to the vice-presidency of the letters section.

[18] *Ibid., VIII, 1888–1891* (Madison 1892), 1–10. A printed copy of this essay, heavily underlined and annotated by Turner, is in HEH TU File Drawer 14B, Folder: Sectional Feature in American Politics.

[19] Charles H. Van Hise's evening address in 1893 on "The Evolution of the North American Continent" would certainly attract Turner's interest. T. C. Chamberlin was a constant reader of geological papers before the Academy at this time. *Ibid., X, 1894–1895* (Madison, 1895), 582.

[20] *Ibid., IX, 1893* (Madison, 1893), viii.

history. He was, above all else, no monocausationist, as his critics have branded him. More than most men of his generation—or today —he recognized the complexity of human behavior and the variety of forces motivating every action. "In truth," he told an audience early in his career, "there is no single key to American history. In history, as in science, we are learning that a complex result is the outcome of the interplay of many forces. Simple explanations fail to meet the case."[21] This remained Turner's credo; through his lifetime his quest was not for *the* force underlying an event, but for *all* forces. Early in his academic career he read the germinal essay by T. C. Chamberlin on "The Method of the Multiple Working Hypothesis," first published in 1897, and from that day on applied to historical studies the techniques Chamberlin used in geology.[22] Turner's method was to postulate every possible explanation for any happening, then test each successively with all available evidence. Only in this way, he believed, could the historian escape what he called "the warping influence of partiality for a simple theory."[23]

Before showing you how Turner applied that belief, let me digress to ask one obvious question. Should a historian wedded to the concept of the multiple hypothesis and aware that the complexity of human behavior precluded simple explanation, have devoted his life to proving the influence of the frontier and section on past behavior? Did he consider them more important than other forces: the class struggle, slavery, constitutional interpretation, or many more? Of course he did not. "I do not," he explained to Carl Becker in 1925, "think of myself as primarily either a western historian, or a human geographer. I have stressed those two factors, because it seemed to me that they had been neglected, but fundamentally I have been interested in the inter-relations of economics, politics, sociology, culture in general, with the geographic factors, in

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[21] Turner, "The Development of American Society," *The [Illinois] Alumni Quarterly,* II (July, 1908), 120–121. He used almost these words in a Phi Beta Kappa lecture at the University of Nebraska in 1907. The manuscript of this lecture is in HEH, TU Box 55. Edward E. Dale, "Memories of Frederick Jackson Turner," *Mississippi Valley Historical Review,* XXX (December, 1943), 355–356 remembered that he employed virtually the same phrase when lecturing to a class some years later.

[22] Thomas C. Chamberlin, "The Method of Multiple Working Hypotheses," *Journal of Geology,* V (November–December, 1897), 837–848. Chamberlin first read the paper at a meeting of the Society of Western Naturalists in 1889, and Turner may well have learned of it at that time. Many years later he wrote one of his students: "I, as you perhaps recall, valued Chamberlin's paper on the Multiple Hypothesis, which I have aimed to apply to history as he did to geology." Turner to Merle Curti, August 8, 1928. HEH TU Box 39. Wilbur R. Jacobs, "Turner's Methodology: Multiple Working Hypotheses or Ruling Theory?," *Journal of American History,* LIV (March, 1968), 853–863, argues that Turner never correctly applied the methodology advocated by Chamberlin, but that he treated his frontier and sectional hypotheses as ruling theories that were true instead of postulates to be tested.

[23] Turner used this phrase in his presidential address before the American Historical Association in 1910. Turner, "Social Forces in American History," in *The Frontier in American History,* 333.

explaining the United States of to-day."[24] This was common sense. Each man must specialize, and the mere fact of specialization does not mean that he assigns greater influence to his field of special interest than any other.

Turner, then, was committed to the use of the multiple hypothesis, and to the belief that no single key unlocked the secret of the past. Equally important was his realization that history was more than the "past politics" current in the 1890s; it was more too than the colorful narratives spun from the pens of the Francis Parkmans and the William H. Prescotts of that day. History, to Turner, was "a study of the social forces which caused and modified the political events, institutions, and ideas of the period."[25] Enough time had been wasted by nineteenth century scholars tracing the surface manifestations of political behavior. The time had come to probe below the surface, and analyze the underlying forces—economic, social, and cultural—that found ultimate expression in politics. "Behind institutions," he wrote in his famous 1893 essay, "behind constitutional forms, and modifications, lie the vital forces that call these organs into life and shape them to meet changing conditions."[26] This was his declaration of independence. His investigations would be focused on "the changes in the economic and social life of the people," as he put it, "that . . . ultimately create and modify organs of public action." No mere narrative, no superficial survey of political behavior would do.[27] His area of study was society as a whole, not its leaders. "The important point," he told the well-known sociologist Albion W. Small in 1904, "is to get more sociology into history and more history into sociology."[28]

This view of history doomed Turner to a lifetime of perpetual learning—and shamefully little writing. He had marked out for himself an impossible assignment; to understand human behavior in all its manifestations he must become a master of many disciplines, and a slave to none. He must use the tools of the economist, the sociologist, the demographer, the geographer, and the political scientist. At the same time he must remain true to his own dis-

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[24] Turner to Carl Becker, October 3, 1925. Carl Becker Papers, Cornell University Library. Hereafter referred to as: "Becker Papers. Cornell."

[25] Turner, Review of J. W. Burgess, *The Middle Period, 1817–1858* (New York, 1897), in the *Educational Review*, XIV (November, 1897), 390–391.

[26] Turner, "The Significance of the Frontier in American History," in *The Frontier in American History*, 2.

[27] In 1921 Turner wrote a publisher who had tried vainly for a generation to persuade him to write a textbook: "It is in narrative history that I am least experienced or (I fear) competent . . . My strength, or weakness, lies in interpretation, correlation, elucidation of large tendencies to bring out new points of view . . . I am not a good saga-man." Turner to Lincoln MacVeagh of Henry Holt & Company, April 5, 1921. Henry Holt & Company Archives, Firestone Library, Princeton University.

[28] Turner to Albion W. Small, November 4, 1904. College of Letters and Science, Department of History, Turner Correspondence, 1901–1905, Box 5, Folder: S, University of Wisconsin Archives, University of Wisconsin Library. Hereafter referred to as: "L & S, Dept. of Hist. Turner Corr., 1901–5. Wis. Archives."

cipline and avoid the traps of other social scientists who were all too ready to lay down rules of human conduct. "The human soul," he wrote in 1904, "is too complex, human society too full of vital energy and incessant change, to enable us to pluck out the heart of its mystery—to reduce it to the lines of an exact science or to state human development in terms of an equation."[29] Historians had made that mistake in the past, and their chronicles were strewn with the wrecks of "known and acknowledged truths."[30] Now they must utilize their breadth of experience, and with it temper their findings as they used the tools of other social scientists. To fail to do so would be to abandon the field to others less well equipped to ferret out the truth. "History," he wrote in 1914, "had a right to deal with large mass statistics, tendencies, etc., as well as the *event* and the individual psychology. I dislike to yield good territory to sociologists, political scientists, etc., on which the historian may raise good crops."[31]

More than any other historian of his generation, Turner succeeded in preserving that territory for his fellow craftsmen. At times he was a lone voice crying in the wilderness, but always he was an evangelist preaching a vital message with the fervor of conviction. As early as 1901 he urged on the students in the Division of Economics, Political Science and History the belief that "the various branches of our work are related," and cautioned them against letting the branches of social science drift apart unduly.[32] He drove home the message even more strongly when addressing a historical gathering at the St. Louis World's Fair three years later, their most serious problem was "how to apportion the field of American history itself among the social sciences." This meant calling into cooperation sciences and methods hitherto little used. "Data drawn from the studies of literature and art, politics, economics, sociology, psychology, biology, and physiography all must be used," he told his listeners. "The method of the statistician as well as that of the critic of evidence is absolutely essential. There has been too little cooperation of these sciences, and the result is that great fields have been neglected."[33] Once more in 1910 Turner made this plea the central theme of his presidential address before the American Historical Association. Just as geologists were using chemistry, mathe-

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[29] Turner, "The Historical Library in the University," in Brown University, *John Carter Brown Library. The Dedication of the Library Building, May the Seventeenth, A.D. MDCCCCIIII. With the Addresses by William Vail Kellen, LL.D., and Frederick Jackson Turner, Ph.D.* (Providence, R.I., 1905), 52–53.

[30] Turner, "Social Forces in American History," in *The Frontier in American History,* 333.

[31] Turner to George Lincoln Burr, September 5, 1914. George Lincoln Burr Papers, Cornell University Library.

[32] Notice sent to the members of the School of Economics, Political Science and History, October 5, 1901, by Turner and Richard T. Ely. A copy is in L & S, Dept. of Hist., Turner Corr, 1901–5. Wis. Archives.

[33] Turner, "Problems in American History," in *The Frontier in American History,* 20.

matics, botany and zoology to understand the dynamics of the inorganic earth, he warned, so must historians master the essential tools of the social sciences to unravel the skeins of the past.[34] This was a unique plea; Turner was the first president of this influential body to urge interdisciplinary techniques.

Moreover, Turner practiced what he preached, and used a variety of disciplines so successfully that his students and friends sometimes wondered if he had deserted his own cause. One of his Harvard undergraduates mirrored this confusion when he was heard to say that what Turner was doing in the classroom was all right, "but it wasn't history."[35] When a colleague accused him of being more of a sociologist than historian, Turner answered: "It is the subject that I am interested in, and I don't particularly care what name I bear."[36] Nor did he, so long as his unquenchable thirst for knowledge could be satisfied. The quest for the truth about the past mattered to him; the tools used in unearthing that truth did not. "I sometimes wonder," he told Carl Becker late in his life, "if after all I have not been simply, rather blindly, trying to explain America to myself instead of writing history! or writing agriculture, or geography, or diplomacy, or economics, land transportation, etc., or literature, or religion."[37] So he had, but he had still been studying history. For history to Turner was, as he once put it, "a complex of the social sciences." It could be made understandable only if the watertight compartments in which they had been divided could be broken down, and the One-ness of the subject brought home to investigators.[38]

He labored to break down those compartments, just as he tried to persuade other historians to do so. When, early in his career, he joined the editorial board of the *American Historical Review* his first step was to urge the acceptance of more articles that lay "on the border-land between history and its neighbors."[39] A lifetime later when in his twilight years he was asked to advise the Huntington Library on its book-buying policies, he pointed out that history was no longer a placer-mining form of narrative collecting, "but involves the use of wide agencies more like the chemical laboratories, dredging process, geological experts, quartz crushers, etc. The library extended into economic, social, literary, political, religious sources becomes necessary to the modern type of historian of

[34] Turner, "Social Forces in American History," in ibid., 331. For an excellent discussion of the originality of Turner's views in relation to other presidents of the association see Herman Ausubel, *Historians and Their Craft: A Study of Presidential Addresses of the American Historical Association, 1884–1945* (New York, 1950), 326–329.

[35] Turner to Merle Curti, August 8, 1928. HEH TU Box 39.

[36] Turner to Luther L. Bernard, November 24, 1928. HEH TU Box 40.

[37] Turner to Carl Becker, February 13, 1926. Becker Papers, Cornell.

[38] Turner to Carl Becker, December 1, 1925. Becker Papers. Cornell.

[39] Turner to J. Franklin Jameson, January 26, 1910. HEH TU Box 14.

the evolution of civilization."[40] Few men have clung so tenaciously to a belief as did Turner in the virtues of interdisciplinary studies, and few have both preached and practiced a cause so devotedly.

His own contribution to the breaking of line-fences between disciplines led him principally into the field of geography, for this was the allied subject that promised the greatest help in understanding American sectionalism. This was a complex problem; to what degree did varying physiographic features in each region—Southeast, Southwest, New England, North Central States, and the like—alter the behavioral patterns of the intruding stocks? Were the differences in economic, social, political, and cultural behavior that distinguished New England from the North Central States, or the Southeast from the Southwest due more to environmental forces or to the persistence of ethnic behavioral patterns among the settlers? This was the basic problem in the study of sectionalism, and that to which Turner devoted most of his research between 1905 and his death in 1932.

It could be solved only by devising a completely new research technique, build on methods of both geographers and statisticians. This involved the drawing of maps that would correlate physiographic features with political, social, economic, and cultural behavior. Some that he devised revealed the physiographic basis of society; they showed on a county-by-county basis the nature of soils, land values, agricultural yields, value of farm produce, and extent of improvements. Others depicted patterns of social behavior, illuminating degrees of illiteracy, levels of education, church preferences, and various cultural attainments. A third set of maps illustrated voting patterns, showing which counties were consistently Whig or Democratic, and which showed slight political allegiance. By comparing these maps, Turner was able to show to his own satisfaction that there was a direct relationship between geographic conditions and political or economic behavior. Thus he could demonstrate that areas of poor soil, high illiteracy rate, and evangelical sects in the pre-Civil War era were inclined to vote Democratic; that western counties changed their attitude on the tariff from free trade to protectionism with a change in crop emphasis from corn to wool growing; and that counties with agricultural surpluses for export were those principally supporting government-financed internal improvements.[41]

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[40] Turner to Max Farrand, March 8, 1927. HEH TU Box 36.

[41] Dozens of Turner's manuscript maps are preserved in the Turner Papers at the Huntington Library. A few of the most important were published in his last book, completed by friends after his death, *The United States, 1830–1850: The Nation and Its Sections* (New York, 1935). Turner was convinced of the value of his maps, and of their use in various social-study disciplines. "I really think," he wrote in 1925, "the maps which exhibit the correlation between physical geography (especially topography and soils), land values in 1850, illiteracy, party politics, and culture have a real merit in the line of showing the interdependence of the social studies." Turner to Carl Becker, October 3, 1925. Becker Papers. Cornell.

Today's student of statistical cartography or statistics is inclined to look at the dozens of maps so laboriously produced by Turner with a mixture of amused tolerance and contempt, for we now know that they woefully failed to accomplish their purpose. His misfortune was twofold: he lived before statisticians devised the sophisticated techniques that would endow his masses of data with significant meaning, and he was so wedded to the use of maps that he failed to take advantage of more useable means of achieving the correlations that he sought. Neither he nor his students made any serious effort to master the devices that might have solved their problems: mathematical correlations, sampling, time-series trending, and the use of punched cards for storing and sorting data. Instead Turner's faith was in a device that did not lend itself to the complex correlations that he required. As he crowded on the necessary information the result was an undecipheral maze of colors, symbols, lines, and numbers, so jumbled and crowded that they meant nothing. Even when kept simple the visual comparison of two or more maps to identify correlations was almost impossible unless the correlation was so high that it could not be missed. Today's statistical techniques allow the type of analysis that Turner sought, but not through the maps on which he pinned his faith.[42]

This latter-day criticism should not blind us to the undisputed fact that in his own time Turner's methods were accepted as irreproachable and his findings hailed as revolutionary by both geographers and statisticians. His services were sought as speaker at professional associations of geographers,[43] and when he did consent in 1914 to deliver a paper at a joint meeting of the Association of American Geographers and the American Geographical Society on "Geographical Influences in American Political History," his talk was hailed as one of the most stimulating ever given and by far the hit of the program. "Your work," he was assured by a leading geographer, Isaiah Bowman, "is so sympathetic with respect to geographic factors that it is a pity that we do not see more of you and hear a paper every year."[44] The high regard in which Turner was held by practitioners of this discipline was shown when

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[42] Richard Jensen of Washington University has graciously allowed me to use his unpublished paper on "The Development of Quantitative Historiography in America." This excellent essay, together with the same author's study of "American Election Analysis: A Case History of Methodological Innovation and Diffusion," in Seymour M. Lipset, ed., *Politics and the Social Sciences* (New York, 1969), provide the best criticism of Turner's mapping techniques, yet assign him his proper place as a pioneer in the use of statistical methodology.

[43] Ralph S. Tarr to Turner, May 25, 1911. HEH TU Box 16. Turner has written "NO" at the top of this letter. He had, however, participated in two conferences at meetings of the American Historical Association in 1907 and 1908 on "The Relation of Geography to History." Reports of these meetings are in the *Annual Report of the American Historical Association for 1907* (Washington, 1908), I, 45–48, and the *Annual Report of the American Historical Association for 1908* (Washington, 1909, I, 61.

[44] Isaiah Bowman to Turner, April 7, 1914. HEH TU Box 21.

he was elected a member of the Association of American Geographers—an honor restricted to one hundred scholars who made the most significant contributions—and chosen a fellow of the American Geographical Society.[45] His passing in 1932 was mourned as sincerely by geographers as by historians. "Professor Turner," wrote the editor of the *Geographical Review,* "was a rare combination of historical originality with geographical insight. His death is a loss no less severe to American geography than to the study of American history."[46] Clearly Turner had broken the line-fence between two of the social-science disciplines as no one had in the past.

Despite the criticism of modern sceptics who scorn his statistical techniques, he was also viewed by statisticians of its own generation as the outstanding pioneeer in applying their discipline in the field of history. When the American Statistical Association celebrated its seventy-fifth birthday in 1913, the one historian invited to participate was Turner, who was asked to give a paper on "The Importance and Service of Statistics to History." "No one," the president of the association assured him, "is better qualified to speak on this subject from the view of the historian than you are."[47] A decade later when a team of scholars began preparation of a book on the inter-relationship of the social sciences, they turned naturally to Turner for the chapter on the relationship between history and statistics.[48] Turner declined both of these invitations, for he was too deeply involved in his sectional studies to be interrupted, but the point remains: his own generation viewed him as the outstanding disciple of the use of statistical methods in historical research.

That Turner pioneered in blending historical, geographic, and statistical techniques even his enemies must concede; they insist, however, that despite his lip service to interdisciplinary studies he virtually ignored the other social sciences. Economists in particular have castigated him for distorting the past by refusing to recognize the significance of class conflicts and economic growth. If Turner is to be judged solely on the basis of his published works this charge seems warranted, for he wrote little and largely of a rural America in which economic forces played a lesser role than in the industrialized–urbanized twentieth century. But if we examine his unpublished essays, and read his letters of advice to friends, it becomes clear that he was no less aware of their impor-

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45 Isaiah Bowman to Turner, March 1, 1915. HEH TU Box 25. Turner's certificates of membership in the two associations are in HEH TU Box 53.

46 *Geographical Review,* XXII (July, 1932), 499

47 John Koren to Turner, November 18, 1913. HEH TU Box 20A.

48 William F. Ogburn to Turner, December 15, 1924. HEH TU Box 33. Turner sent his "regrets" to both of these proposals.

tance than later economic historians who built their whole interpretation of the American past on an economic foundation.

Turner's interest in economic forces and recognition of their importance in shaping human behavior can be traced to the very beginning of his career. As early as 1892 he urged that historians cease their preoccupation with politics and "interpret events from the economic point of view."[49] Until this was done, history would be superficial, and scholars would have no real understanding of the basic subsurface social and economic tides that determined political action. In adopting this point of view, Turner aligned himself with the little group of social scientists that included Lester Ward, Richard T. Ely, and John R. Commons who first recognized that modern society rested on an economic base, and that this must be understood before political actions could be understood. He saw too, as did John R. Commons, that they were linked with social and cultural forces, and that all operated together in human motivation.[50]

With this as a basic assumption, Turner would never ignore the role of economics in shaping human behavior, even though his focus on agrarian America left him little to say on the subject. When he concentrated, as he occasionally did, on a modern period, he recognized that even a Marxian interpretation had some validity. A final and very important phase of the nation's growth, he told an audience in 1908, had been "the steady stratification of our society by the development of contesting social classes. It is hard to realize how recently it has become possible to use the words proletariat and capitalistic classes in reference to American conditions."[51] In his seminars, too, he elaborated the idea of a continuous conflict between "the capitalist and the democratic pioneer" persisting from colonial times to the present.[52] Even such a latter-day critic as Charles A. Beard paid tribute to Turner as a pioneer in exploring the field that he was to make his own. "Almost the only work in economic interpretation which has been done in the United States," he wrote in 1913, "seems to have been inspired at the University of Wisconsin by Professor Turner."[53]

At one point Turner did break with Beard and his school, and we know today that Beard was wrong and Turner right. He saw,

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[49] Turner, "The School of Economics, Political Science and History," *The Aegis,* VI (April 8, 1892), 448.

[50] For an intelligent appraisal of Turner's influence in this group of thinkers see George D. Blackwood, "Frederick Jackson Turner and John Rogers Commons—Complementary Thinkers," *Mississippi Valley Historical Review,* XLI (December, 1954), 471–489.

[51] Turner, "Development of American Society," *loc. cit.,* 132–133.

[52] Merle Curti to Turner, August 13, 1928. HEH TU Box 39.

[53] Charles A. Beard, *An Economic Interpretation of the Constitution of the United States* (New York, 1913), 5–6.

as less perceptive scholars did not, that idealism played a role in human motivation, and that those tracing behavioral patterns solely to material desires were blind to the truth. Over and over again he protested to his friends, "I am not an economic determinist."[54] This broad view led to a more sophisticated—and more complex—view of history than that of Beard and his followers, but no message that he preached was more important in leading to a correct understanding of the past. "I tried," he told a friend in 1928, "to keep the relations steadily in mind; but it isn't an easy job, and the effort is sometimes conducive to unwritten books!"[55]

Frederick Jackson Turner, then, more than any historian of his generation, succeeded in merging history with geography, history with statistics, history with economics. Nor did his assault on compartmentalization end even there, for he was a welcome guest on programs of the American Sociological Association and a pioneer in introducing sociological methods into historical research. Franklin H. Giddings, one of the most eminent practitioners of that subject, in 1928 judged Turner to be "a sound sociologist, and a ground-breaking one of first rate importance."[56] In the judgment of his peers, Turner stood head and shoulders above his fellow-historians in urging interdisciplinary studies, and in proving them essential in unraveling the secrets of the past. Avery Craven, a student of Turner and himself an eminent historian, summed up the judgment of his generation in his remarks at the funeral of his master. "He is claimed by the historians," Craven said, "and the sociologists and the geographers and yet he was more than any of these. He was a student of the whole field of the social sciences, and more than any other man . . . saw the field as one and was able to integrate it."[57] No historian could deserve a more appropriate epitaph than that.

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[54] Turner to Andrew C. McLaughlin, May 29, 1915, HEH TU Box 24; Turner to Edgar E. Robinson, December 12, 1924, HEH TU Box 33; Turner to Archibald Henderson, January 29, 1930, HEH TU Box 43. On the margin of a term paper written by one of his students, Herman K. Murphy, Turner wrote: "History not all economic determinism." HEH TU Students' Papers (1).

[55] Turner to Merle Curti, August 15, 1928. HEH TU Box 39.

[56] Franklin H. Giddings to Merle Curti, August 20, 1928. HEH TU Box 39.

[57] Avery Craven, "An Appreciation of F.J.T.," HEH TU Box 57.

THE RHETORICAL HERITAGE OF FREDERICK JACKSON TURNER[1]

Goodwin F. Berquist, Jr.

Ninety-three years ago a young man named Frederick Jackson Turner became a member of the Wisconsin Academy of Sciences, Arts and Letters. Turner was at the time an instructor in rhetoric and oratory at the University of Wisconsin. He would later become Vice-President of the Academy for Letters and one of America's truly great historians.[2] Turner's fame began with a speech he delivered in Chicago in 1893 entitled "The Significance of the Frontier in American History." The purpose of this paper is to identify and explore Turner's rhetorical heritage prior to that time.

The Rhetorical Environment at Portage

Portage, Wisconsin where Fred Turner grew up a hundred years ago was a rough and ready frontier community. Indians with their ponies and dogs came to town frequently to trade furs for paint and trinkets. Lumberjacks from the pineries of central Wisconsin "took over" the town on Saturday nights. The Bierhall of Carl Haertel was a haven for local Germans as well as the town club house. Pomeranian immigrants, Irish, Scots, Welsh, Norwegians and Swiss lived about Portage, along with a few Southerners and Negroes, some Englishmen and one or two Italians. Turner's parents were among the Yankee settlers from upstate New York who came in the 1850's.[3]

In such a melting pot, not everyone could read or write English. But all could listen and speak when they had a mind to. The spoken

[1] Paper read at the Centennial Meeting of the Wisconsin Academy of Sciences, Arts and Letters, Milwaukee, Wisconsin, October 3, 1970. The author is former editor of the Academy *Transactions* and Professor of Speech, Ohio State University. Research for this paper was undertaken at the Henry E. Huntington Library and Art Gallery, San Marino, California under a grant from the Department of Speech, Ohio State University.

[2] Authority for the above statements comes from the following sources: *Transactions* of the Wisconsin Academy of Sciences, Arts and Letters, 7(1883–87), 267; biographical data dictated by Turner to his secretary, TU Box 57, Frederick Jackson Turner Papers, Henry E. Huntington Library; Merle Curti, "Frederick Jackson Turner" in *Wisconsin Witness to Frederick Jackson Turner,* O. Lawrence Burnette, Jr. comp. (Madison: State Historical Society of Wisconsin, 1961), p. 175. Turner served as an Academy Vice-President from 1896 to 1899 and remained a member of the organization until he left Wisconsin in 1910. The Council of the American Historical Association chose him as one of the two most eminent historians America has produced.

[3] The above description of Portage is based upon an account Turner himself wrote to C. L. Skinner, March 15, 1922, reprinted in Burnette, *Wisconsin Witness,* pp. 65–6, and in p. xi introducing the same work.

word was not only the most common mode of communication; it was also the necessary instrument for education, progress and enlightenment. Indeed, probably no event of importance took place in Portage without some spokesman or other urging the populace to action or stronger belief.

Fred Turner was raised in a literate household. His mother had been a school teacher and came from a long line of preachers. His father was editor of the *Wisconsin State Register* and a pillar of the community who gave talks on local history and published several manuscripts in this field.[4] Fred Turner early learned the importance of the printed word. As he wrote his future wife in later years, "I thank heaven that I have an imagination and a love of books, two things that have lifted me out of my surroundings at Portage. Life, in any case, is more or less coarse, and requires imagination to idealize it a bit, but this is especially so in such an environment as that in which my early life has been spent."[5]

Andrew Jackson Turner was much more than a literate parent. As editor of a small town newspaper, it was his duty to know what was going on in town, across the state, and throughout the nation. Contemporary affairs were part of the regular fare at mealtime in the Turner household. The elder Turner was also leader of the Republican party in Portage; he "went as delegate to state and national Republican conventions, assigned the candidates of his party to the varied nativities and towns of the county, as chairman of the Board of Supervisors, harmonized the rival tongues and interests of the various towns of the county, and helped to shepherd a very composite flock."[6] An expert hunter and fisherman, A. J. Turner often took Fred with him on his forays into the wilderness. As soon as he was allowed, Fred began to frequent the newspaper office and in time, his father let him set type for local news and edit an exchange column.[7] As a high school student, he kept a scrapbook of newspaper clippings including texts of speeches and quotations from such prominent spokesmen as Emerson, Disraeli, Ingersoll, Webster and Schuyler Colfax. Fred was

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[4] Burnette, *Wisconsin Witness*, p. 67 ; p. xi.

[5] Turner to Caroline Mae Sherwood, August 24, 1887, TU Box B.

[6] Burnette, *Wisconsin Witness*, "Turner's Autobiographic Letter", p. 66.

[7] Burnette, *Wisconsin Witness*, "Turner's Autobiographic Letter", p. 66. Turner's early experience working in a newspaper office was later to prove of great value in his work as a historian: "My practical experience in newspaper work, and in contact with politics through my father probably gave me a sense of realities which affected my work and my influence. I had to see the connections of many factors with the purely political. I couldn't view things in the purely 'academic' way . . . " Turner to Merle Curti, August 8, 1928, reprinted extract, Wilbur R. Jacobs, *The Historical World of Frederick Jackson Turner With Selections From His Correspondence* (New Haven: Yale University Press, 1968), p. 6.

also among a half-dozen students to declaim on Memorial Day in 1877 and 1878.[8]

Not much is known about Turner's day-to-day activities in these early years but we do have a document which reveals a good deal about his rhetorical development. In his senior year, Fred participated along with eighteen others in an oratory contest, held on graduation day. Fred won first place and his oration "The Power of the Press" was published soon after in his father's newspaper.[9]

The first rule in public speaking is to choose a speech topic that interests you, and this Fred obviously did.

A second rule is to speak in such a way as to interest your listeners. Fred Turner talked of native democracy, of the role of the press in educating everyone, not just a powerful elite as the Athenians did in ancient Greece. The want of education by the masses is shown by the recent rise in communism, Fred declared. Orators will continue to persuade their audiences but the press provides a new dimension, a larger audience. "The Press is an instrument of unspeakable good in the diffusion of education . . . . as the freedom of the Press increases, so does the freedom of the people"—sentiments dear to the heart of Andrew Jackson Turner as well as his son. The speech also includes timely references to the Union Army, the Christian religion, *Uncle Tom's Cabin,* and the Declaration of Independence. The people of Portage could easily identify with the young orator.

By today's standards, Fred's oration would rank "above average" but not "superior." What makes this speech significant is not its rhetorical excellence but its insight into a young mind. Journalism was Fred's intended career. His faith in American democracy, Portage style, would be lifelong. And he would be an avid reader of books to his dying day.[10] But above all else, Fred Turner excelled as a speaker in an age when oratory was usually a prompt and sure road to recognition and power.

Rhetorical Experiences at Madison

In the fall of 1878, Fred Turner matriculated at Madison. There he was exposed to two men who were to have a marked influence upon his life: President John Bascom, "a versatile scholar, and, for his day, a progressive thinker on social and economic issues," and David B. Frankenburger, newly appointed professor of rhetoric and oratory. President Bascom preached the duty of University students to improve the state which made their higher edu-

[8] *Wisconsin State Register,* May 26, 1877; June 1, 1878.

[9] *Wisconsin State Register,* July 6, 1878.

[10] Fred's conclusion is a flowery peroration to books: "the true Elysian fields where spirits of the dead converse, and into these fields a mortal may venture unappalled."

cation possible, by using the information thus acquired for the public good.[11] Professor Frankenburger was the kind of instructor who taught individuals, not classes.[12] Turner, who spent four highly successful years under his tutelage, described his rhetoric teacher as a man with a rare, questioning smile, glad expectancy, appealing sympathy, an instructor who sought only the best in his students. Frankenburger encouraged and inspired, made helpful suggestions, and gave unstintingly of his time and energy. He was himself an unusually popular reader, lecturer and speaker, a lawyer, prominent Unitarian and staunch admirer of Emerson.[13] In May of 1883, Fred Turner's oration entitled "The Poet of the Future" won the coveted Burrows Prize at the Junior Exihibition. A year later, at graduation, Turner's "Architecture Through Oppression" was chosen the best of eighteen orations delivered before a distinguished audience including the Governor, President Bascom, and members of the Board of Regents.[14] In a day when skill in oratory and debate were widely admired, young Fred Turner, the shy, quiet youth from Portage, had found the key to success and self-confidence.

Turner did not debate at Wisconsin, probably for two reasons. In the summer of 1879, Fred became seriously ill and spent the following academic year recuperating at home. In those days at Madison, being on the debate squad was a four year proposition which included an intensive period of research and apprenticeship for the underclassmen.[15] In so popular and competitive an activity, a student who missed a whole year usually missed out entirely. Secondly, Turner simply did not have a "logical mind";[16] while he would have no trouble tackling the research on a question, his forte was imagination. Avery Craven put it this way: "There was something of the poet and much of the philosopher about Turner. He had the ability to see deep into the meaning of things and the power to catch the universals. This did not weaken his capacity for scientific research nor lessen his interest in details, but it did cause him to emphasize trends and flavors, to attempt to deal

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[11] Authority for the statements in this paragraph comes from the following sources: University of Wisconsin photostat L 18 14, Turner Papers; Burnette, *Wisconsin Witness,* "Frederick Jackson Turner", p. 178; Merle Curti and Vernon Carstensen, *The University of Wisconsin: A History 1848–1925* (Madison: University of Wisconsin Press, 1949), 1, 344.

[12] The portrait of Frankenburger which follows is one Turner painted himself in a funeral eulogy to one of his favorite professors, TU Box 55.

[13] Curti and Carstensen, *University of Wisconsin,* 1, 344.

[14] Copies of both college orations appear in TU Box 54.

[15] A revealing account of the seriousness with which students took their debate responsibilities in Turner's day appears in Curti and Carstensen, *University of Wisconsin,* 1, 433–8.

[16] "Inviting us one day to consider the problem of sovereignty, he (Turner) quoted Austin's definition; said he couldn't understand it; admitted he wasn't blessed with the logical mind." Quoted in Carl Becker, "Frederick Jackson Turner", *American Masters of Social Science,* ed. by Howard Odum (New York: Henry Holt, 1927), p. 278.

with intangibles, to sweep over minor things in the effort to get at larger truths."[17]

That Turner respected the work done in debate is clear enough. An entry in his commonplace book, written apparently in September, 1887, includes notes for a speech to the debate society.[18] Debate work is important, Turner told the undergraduates, because it helps one to be a ready speaker and exposes the student to much information he might otherwise miss. There is a danger, Turner told the squad, to acquiring glibness and getting into careless habits of enunciation and gesture. "Do not let the violence of debate carry you away from rules of graceful oratory—when form becomes more prominent than the idea—the effect is lost." Don't be prejudiced in important questions by reading on only one side and hearing the opposition in a spirit of antagonism. "Fight your side for all it is worth but hold your judgment in reservation." "Young speakers are too apt to make their point as a dry resume." "Use as few notes as possible." Excellent advice today as when it was given over eighty years ago.[19]

The thrills and excitement attending the return of a winning college orator in Turner's day is nowhere more clearly documented than by Turner himself. Writing from Madison on May 3, 1879, Fred vividly describes the reception given Robert La Follette upon winning the state title at Beloit—an account Turner's father later published.[20]

Fred Turner's own rhetorical talents were substantial. Each year his grades improved in Professor Frankenburger's classes until at last he received a 98 in his senior year.[21] Turner's junior oration, "The Poet of the Future", is a philosophical eulogy of modern science and modern democracy, replete with literary allusions. In his senior year he chose a simpler theme: that great architecture is built at the cost of great toil and evil. This final college effort is a more professional composition, the best rhetorical production of his three prize-winning orations.

Undoubtedly Turner's sustained exposure to classical authors and his continuing work in journalism also contributed to his rhe-

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[17] Burnette, *Wisconsin Witness,* "Frederick Jackson Turner, Historian", p. 110.

[18] TU Vol. III (1–3), commonplace books, 1881–87, n.p.

[19] In 1892 when Turner, then a professor of history at Madison, was trying to persuade Richard Ely to leave Johns Hopkins for Wisconsin, he noted that "vigorous and deeply interested" students in the debating societies paid more attention to the department of economics than any other. Turner to Richard Ely, January 25, 1892, Box E, Ely correspondence (State Historical Society Library, Madison, Wisconsin). Turner later commended C. H. Haskins to Woodrow Wilson in these terms: "He is one of the strongest reasoners and effective debaters in our faculty meetings." Turner to W. Wilson, December 3, 1896, extract reprinted in Jacobs, *Historical World,* p. 200.

[20] *Wisconsin State Register,* May 10, 1879.

[21] Turner Papers, University of Wisconsin photostat L 18 14, uncatalogued material—Turner's undergraduate records.

torical development. At Madison, "he received a thorough classical training" and did honors work there; quite probably, Turner's sensitivity to literary style was cultivated in this way.[22] For three of his four undergraduate years, Turner was associated with *The Badger,* the student newspaper.[23] As a senior he intended to make journalism his lifetime career.

Turner's commonplace books reveal his growing awareness of style, metaphor, balance and epithet. Begun April 9, 1881, these student notebooks present a remarkable insight into the mind of a developing scholar. The materials included are varied indeed: quotations from books, essays, lectures and speeches; Greek and Latin translations; drafts of orations;[24] lists of books Turner read, concerts, operas and lectures he attended; poetry and songs Turner composed; and random asides about philosophy and religion, ideas for essays and topics for orations. Turner's favorite author was Ralph Waldo Emerson; his picture appears on the back cover of the first commonplace book. While an extended analysis of these notebooks is not appropriate here, a listing of some of the speech-related themes may suffice to suggest the whole: here are quotations about talk, the spoken word, silence, the human voice, being understood, the role of character in men of intellect, elocution, modes of style and originality of thought, rhythm and meaning, figures of speech and eloquence. Here, indeed, is documentary proof of Turner's rhetorical heritage!

Tutor in Rhetoric and Oratory

The year following graduation Fred Turner turned his attention to journalism full-time, serving as correspondent for newspapers in Chicago and Milwaukee.[25] He appears to have gotten on well enough, but something was missing; the career he dreamed of since boyhood was somehow unsatisfactory. At first, Turner thought the problem was one of locale and he toyed with the idea of joining Reuben Gold Thwaites in starting a paper out West.[26] But actually the problem lay elsewhere. In his junior year at Madison Turner had his first exposure to college history with Professor

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[22] Burnette, *Wisconsin Witness,* "Frederick Jackson Turner", p. 178. In 1880 Turner was asked to tutor a college preparatory student in Greek by his former high school principal. W. G. Clough to Turner, September 7, 1880, TU Box 1.

[23] Turner served at various times as exchange editor, secretary-treasurer, and president of the Badger Association. When Turner first joined, the paper was called *The Campus*; it received its new name in 1882. University of Wisconsin, University Archives, *The Badger,* Vols. 1–4.

[24] According to Wilbur Jacobs, "the drafts of Turner's college orations sometimes read like preliminary versions of an essay on the frontier theory, for they deal with the rise of the common man, freedom, and social evolution." *Historical World,* pp. 8–9.

[25] Wilbur R. Jacobs, *Frederick Jackson Turner's Legacy* (San Marino: Huntington Library, 1965), p. 6.

[26] Frederick Jackson Turner, "Reuben Gold Thwaites: A Memorial Address", p. 38, printed copy, Huntington Library.

William Francis Allen; he was simply never the same thereafter. A revealing entry in Turner's commonplace book at this time probably holds the key to his decision to make history his life work: "Science has revolutionized Zoology, Botany, etc. It must now take up recorded history and do the same by it. This I would like to do my little to aid, but find not the *time*. It is a very egotistical idea that haunts me that if I were to drop my detestable dishing up of newspaper flippancy, I could . . ." The sentence ends here.

But how could Turner earn a living while he pursued graduate work? There simply were no assistantships available in history. Rhetoric solved his financial problem now as it would frequently in the years to come.[27] Professor Frankenburger arranged to have Fred appointed instructor in rhetoric and oratory. From the fall of 1885 to the end of the winter term, 1888, Fred Turner tutored over a thousand students in the communication skills he had himself so recently mastered.[28]

As a speech teacher, Turner was conscientious and content-oriented. He taught twelve hours of formal speech classes each week and listened to "rehearsals" an additional hour and a half daily. Sometimes his work was made easier when the majority of a new crop of students had earlier training; sometimes, harder because, as Fred put it, "to tell the truth none of the contestants are naturally very good declaimers." When judges were overly long in rendering a decision in a speech contest on a hot day, Fred lectured them on their lack of consideration and thereby expedited matters. Turner preferred oratory to declamation "not being" he said "much of an elocutionary alchemist myself!"[29]

Like many another teacher of public speaking, Turner soon became a highly sensitive critic, reacting to speech communication wherever he found it. Whether it was poor preaching or the polished oratory Professor Allen took him to hear at a Harvard commencement, unenlightening papers read by fellow historians, President Bascom's farewell address, or merely social conversation at a Madison soiree, the critical faculties of the speech teacher came into play.[30]

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[27] Turner had "champagne" tastes impossible to satisfy on existing income. Consequently he accepted dozens of speaking engagements, before and after 1893, to supplement his salary.

[28] Turner Papers, University of Wisconsin photostat L 18 14, uncatalogued material—Turner's instructional reports.

[29] References to Turner's experiences as a speech teacher appear in the following letters: Turner to his parents, September 23, 1885, TU Box A; Turner to Caroline Mae Sherwood, June 6, 1887; June 15, 1887, TU Box B.

[30] References to Turner as speech critic appear in the following letters: Turner to Caroline Mae Sherwood, December 12, 1886, TU Box A; June 12, 1887, TU Box B; Turner to Mary O. Turner, June 30, 1887, TU Box B; Turner to William Francis Allen, December 31, 1888, TU Box 1; Turner to Caroline Mae Sherwood, May 15, 1887, TU Box B; May 5, 1887, TU Box A.

Not surprisingly, Turner was frequently called upon to speak himself. In 1885, he agreed to replace Professor Allen temporarily as "recent history" section leader for the Contemporary Club of the Unitarian Church. Later he lectured to this body on the fisheries question and with Professor Allen, on the history of the northwest. In 1887 Turner was chosen to give the address of welcome at his class reunion. On still another occasion he served as toastmaster at the annual dinner-dance of his social fraternity. As a doctoral student at Johns Hopkins in 1888–89 Turner was active in both chautauqua and extension work. Soon after his return from Baltimore, he was simply unable to satisfy all the requests he received for extension lectures throughout the state. Because Turner believed in the need for competent history teachers in the public schools, he found himself addressing teachers' conventions from time to time. Frederick Jackson Turner mastered the platform as he would later master his profession.[31]

Turner in the Classroom

Despite his many appearances off campus, it was in the classroom that Turner exerted his lasting impact. Turner's rhetorical training is clearly a part of his approach to the teaching of history. In March of 1889, for example, he complained to Professor Allen that his freshman history students experienced difficulty in reporting the results of their research in class.[32] In class, Turner himself dropped the role of polished lecturer to take up that of Socratic inquirer. As Sidney Packard, a former student recalls, "Turner was a poor lecturer in his classroom almost never getting very far from a small box of notes. When he did manage to get a few feet from those notes, or while he was on the way back to them after explaining a diagram or map, he was another man entirely and spoke with real eloquence and charm and addressed himself to large topics in an easy and relaxed manner. He seemed almost apologetic for so doing as soon as he got back to the notes."[33]

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[31] References to Turner's speaking appear in the following sources: Turner to his parents, September 23, 1885, TU Box A; Turner to Caroline Mae Sherwood, May 11, 1887, TU Box A; Curti and Carstensen, *University of Wisconsin,* 1, 723; Turner to Caroline Mae Sherwood, May 27, 1887, TU Box A; Ray A. Billington, "Frederick Jackson Turner: Biography of a College Teacher" (An unpublished manuscript Dr. Billington kindly permitted the author to examine in March, 1970); Turner to William Francis Allen, October 31, 1888, TU Box 1; March 14, 1889, TU Box 1; Turner to Herbert Baxter Adams, December 9, 1891, TU Box 1; January 18, 1892, TU Box 1; Curti and Carstensen, *University of Wisconsin,* 1, 642. In one rural Wisconsin community of six hundred inhabitants, Turner's extension lectures attracted an audience of over two hundred people.

[32] Turner to William Francis Allen, March 14, 1889, TU Box 1; Turner to Merle Curti, August 8, 1928, TU Box 39.

[33] Turner Papers, student reminiscences, August 20, 1968, L 18 14, uncatalogued material; see also Jacobs, *Turner's Legacy,* p. 14.

One should not assume that Turner went to class unprepared. Indeed, just the opposite was true. According to Ray A. Billington, Turner was never "guilty of using the yellowing notes of yester-year; every assignment was freshly prepared in endless hours of labor. This was illustrated in his last year of teaching in 1923–24. The lectures for his 'history of the West' were carefully recast, even though they had been given dozens of times and would never be given again. . . . Little wonder that a Harvard undergraduate told his tutor that the students learned more from Turner than from any other instructor, and on being asked why replied 'Turner gives all his time to us, instead of spending it writing books and articles like others!' "[34] What made Turner one of the great teachers of his time, Merle Curti maintains, is the fact that "he possessed the rare gift of inspiring students, of imbuing them with a deep love of his subject and a belief in its great importance."[35]

Along with many others, Carl Becker believed that a key ingredient in Turner's remarkable hold on others was his voice. Describing his first encounter with Turner as a college sophomore, Becker wrote "Haltingly I asked my foolish question, and was answered. The answer was nothing, the words were nothing, but the voice—the voice was everything: a voice not deep but full, rich, vibrant and musically cadenced; such a voice as you would never grow weary of, so warm and intimate and human it was. I cannot describe the voice. I know only that it laid on me a kind of magic spell which I could never break, and have never wanted to."[36] As Allyn Young, a prominent economist at Wisconsin and Harvard, wrote "My wife who is nearly blind and upon whom voice, there-fore, makes a deep impression, has said that Turner has the most pleasantly modulated voice and the most winning manner of speech that she has ever heard."[37]

In his writing as well as his speech, Frederick Jackson Turner revealed his rhetorical heritage for all to see. Some commentators were fascinated by the "compelling power" of his metaphor; others with his poetic touch. A Harvard graduate student fresh in from southwestern Oklahoma was intrigued by Turner's ability to capture the spirit of the frontier West he had recently left: "I had lived so close to all these things that they were conditions

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[34] "Why Some Historians Rarely Write History: A Case Study of Frederick Jackson Turner," *Mississippi Valley Historical Review* 50, No. 1 (June, 1963), 18–19. See also Jacobs, *Turner's Legacy,* p. 14.

[35] Burnette, *Wisconsin Witness,* "Frederick Jackson Turner," p. 201.

[36] Becker, "Frederick Jackson Turner", p. 276; see also George C. Sellery, "The Spirit of Wisconsin", baccalaureate address, June 20, 1937, TU File Drawer 15–E; and Richard Hofstadter, *The Progressive Historians: Turner, Beard and Parrington* (New York: Alfred A. Knopf, 1968), pp. 81–2.

[37] Jacobs, *Historical World,* pp. 14–15.

to be accepted as a matter of course. It had been impossible for me to see the forest for the trees, or the city for the houses. But Turner's lectures changed all this." Still others commented on Turner's philosophical insight and broad humanitarianism. Joseph Schafer summed it all up best when he wrote "Other things being equal, men and women prefer to work under a leader instinctively recognized as a supreme gentleman. But when, to that character, is added not only the profound historian and philosopher, but also the artist in speech and the poet in imaginative conception, even the unseeing feel the resulting blend as something strictly unique, to be enjoyed as a 'gift of the gods.' "[38]

Three historians clearly perceive the rhetorical spirit of Turner's work. Ray A. Billington reports that Turner "enlisted an army of propagandists who preached the gospel of the frontier in classrooms and seminars throughout the land."[39] John D. Hicks observed of Turner that "In his essays, most of which were written to be read aloud, he could rise to the heights of eloquence."[40]

A final observation comes from one who knew Professor Turner better than anyone else: "My mother's ancestors were preachers! Is *it* strange that I preached of the frontier?"[41]

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[38] The various facets of Turner's rhetoric cited above are identified in the following sources: Frederick Jackson Turner, *The Significance of the Frontier in American History,* ed. by Harold P. Simonson (New York: Frederick Unger, 1963), pp. 9–10; Turner Papers, reminiscences of Merrill Crissey, TU Box 57; Hofstadter, *The Progressive Historians;* p. 73. Edward Everett Dale, "Memoirs of Frederick Jackson Turner", *Mississippi Valley Historical Review,* XXX, no. 3 (December 1943), 340, 342; Frederick Jackson Turner, *The Frontier in American History,* foreword by Ray A. Billington (New York: Holt, Rinehart and Winston, 1962), p. xviii; Joseph Schafer, "Editorial Comment—Death of Professor Turner", *Wisconsin Magazine of History,* XV, no. 4 (June, 1932), 497. From the time he composed his junior oration, "The Poet of the Future", it was apparent that Turner was philosophically oriented, that he yearned to grasp the *significance* of events and periods rather than merely capture their details. Fulmer Mood, "Turner's Formative Period" in Everett E. Edwards, *The Early Writings of Frederick Jackson Turner* (Madison: University of Wisconsin Press, 1938), p. 6; Becker, "Frederick Jackson Turner", p. 296. Such a mind could be strongly prophetic on occasion. Thus one of Turner's speeches in the 1920's "gloomily forecast what portended for America: population pressures; diminishing food supply; the exhaustion of forest, oil, and coal reserves; the threat of war; the horror of a dreaded 'chemist's bomb'. He also lamented in his addresses the increasing tendency toward conformity with an accompanying 'decline in self-confidence' in America." Jacobs, *Turner's Legacy,* p. 42.

[39] Turner, *The Frontier in American History,* foreword by R. A. Billington, p. xiii.

[40] Review of Wilbur Jacobs, *The Historical World of Frederick Jackson Turner With Selections From His Correspondence,* by John D. Hicks, *Journal of American History,* LVI, no. 2, (September, 1969), 413. In 1920 for example Turner was persuaded to publish a collection of his essays under the title *The Frontier in American History.* Ray Billington wrote of this work in 1967, "no one volume has done more to reshape the writing of American history or to recast the popularly held image of the American past"; of the thirteen essays included, *nine were originally presented as speeches.* Turner, *The Frontier in American History,* foreword by R. A. Billington.

[41] Burnette, *Wisconsin Witness,* "Turner's Autobiographic Letter," p. 67.

THE GOSPEL OF POVERTY: THE MESSAGE OF CONSERVATIVE PROTESTANTISM TO THE POOR AT THE TURN OF THE CENTURY

Walter F. Peterson

An article simply entitled "Wealth" appeared in the *North American Review* of June 1889. The editor declared that this article written by the articulate industrialist Andrew Carnegie was "the finest article I have ever published in the *Review*."[1] The former bobbin boy detailed three "modes" by which the wealthy man could dispose of his surplus: "It can be left to the families of the descendents; or it can be bequeathed for public purposes; or, finally it can be administered during their lives by its possessors." Carnegie held that the first was "the most injudicious." The failure of man to dispose of his accumulated wealth during his lifetime marked him as selfish and lacking in foresight.

> The rich man is thus almost restricted to following the examples of Peter Cooper, Enoch Pratt of Baltimore, Mr. Pratt of Brooklyn, Senator Stanford, and others, who know that the best means of benefiting the community is to place within its reach the ladders upon which the aspiring can rise—parks, and means of recreation, by which men are helped in body and mind; works of art, certain to give pleasure and improve the public taste, and public institutions of various kinds, which will improve the general condition of the people; in this manner returning their surplus wealth to the mass of their fellows in the forms best calculated to do them lasting good.

The solution to the problem of wealth and poverty, the rich and the poor had been discovered. "Such, in my opinion," said Carnegie, "is the true Gospel concerning Wealth . . ."[2]

Few literate Americans at the turn of the century escaped exposure to Carnegie's apologia for the accumulation of wealth. The spirit of acquisitiveness abroad in the land had assumed enormous prestige and support. From 1890 to the present the upholding of this doctrine, or attack upon it, the examination and re-examination of Carnegie's and succeeding positions have led to the development of a sizable body of literature on the Gospel according to "Saint Andrew."

Studies of the Gospel of Wealth normally cite the writings of President James McCosh of Princeton and Noah Porter of Yale, Russell Conwell, whose "Acres of Diamonds" was supposed to have

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[1] Quoted in B. J. Hendrick. *The Life of Andrew Carnegie* (New York, 1932), I, p. 330.
[2] Andrew Carnegie, "Wealth," *North American Review*, 148 (June, 1889), pp. 653–664.

been repeated six thousand times throughout the East and Mid-west, and conclude with the benediction of the Right Reverend William Lawrence, Episcopal Bishop of Massachusetts.[3] But lesser men, ministers of all the major Protestant denominations, who were often closer to the people, endorsed the same general principles with equal and sometimes greater fervor. They held that wealth and civilization went together and provided man with the possibility of rest and reflection. The worshipers at Plymouth Congregational Church in Indianapolis heard that "Wealth is the rich soil in which a human soul-root unfolds its powers and becomes its possibility. God meant we should flee poverty."[4] The question of accumulation was not one that the Christian could view dispassionately. The chancellor of Nebraska Wesleyan University pointed out that it was no sin to get money provided it was done through honest methods: "Indeed to gain in this way is a Christian duty."[5]

Through the assiduous application of their Christian duty men such as George Peabody and A. T. Stewart made millions of dollars. Charles E. Bronson, pastor of the First Presbyterian Church, Saginaw, Michigan, thanked God for the noble examples of John Wanamaker and Chauncey Depew, who proved to the young men of America that it was possible to reach the highest posts in business and at the same time preserve the Christian character.[6] Of course they did not do these things alone, for God put the twelve millions of dollars in Peabody's hands. "Everybody honors him because he saved his country from financial ruin, set up institutions of learning, and because he was always looking for an opportunity to make some one happy," S. P. Long told the First Lutheran Church of Mansfield, Ohio.[7] To accomplish these good works a man had to be determined, sometimes even as harsh as A. T. Stewart when he sent a servant out of his home because she burned the two ends of a match when matches were very dear. When the girl's father found fault with the great merchant for giving a large sum to the church the next week, Stewart replied, " 'If I had not saved

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[3] See the brilliant chapter entitled "The Gospel of Wealth of the Gilded Age," by Ralph Henry Gabriel, *The Course of American Democratic Thought* (New York, 1956), pp. 151–169.

[4] Oscar C. McCulloch, *The Open Door: Sermons and Prayers* (Indianapolis, 1892), p. 145. McCulloch who was minister of Plymouth Congregational Church, Indianapolis, Indiana, made this statement in a sermon entitled "The New Vow of Poverty." John Sweet, pastor of the First Methodist Episcopal Church, Owosso, Michigan said much the same thing: "Money is power, and all power is good in the hands of those who know its proper place and use," in C. S. Eastman, ed., *The Methodist Episcopal Pulpit* (Monroe, Michigan, 1897), p. 140.

[5] D. W. C. Huntington, *Half Century Messages to Pastors and People* (Cincinnati, 1905), p. 164.

[6] Charles E. Bronson. *The Presbyterian Pulpit; a Volume of Sermons by Ministers of the Synod of Michigan* (Monroe, Michigan, 1898), p. 213.

[7] S. P. Long, *The Eternal Epistle: Sermons on the Epistles for the Church Year* (Columbus, 1908), p. 399.

the two ends of the match, I could not have given this large sum for this benevolent cause.' "[8]

The Christian benefactor was a selfless man who gave mostly to religious institutions and did so with some self-effacement. On this count even the great and generous Carnegie did not escape the chastisement of the irascible S. P. Long. When the wealthy iron-monger refused to support Wesleyan University and the Protestant Hospital of Columbus, Long concluded that he was no Christian. Long also resented the Carnegie library program. "I do not blame a man even like Carnegie for putting up a library in every city if he can get the dumb public to pay for half of his monument." He held that the difference between a man of God and a man of the world is that the man of the world wants all the glory himself while the man of God wants the glory to go where it belongs, to the God who gave him the money.[9]

While righteousness and business success normally went hand in hand, all affairs of men were seen as guided by God's unerring wisdom. "He knows when to give and when to withhold, when to check and when to impel, when to enrich and when to impoverish, when to create and when to destroy," wrote Lutheran theologian Luther Gotwald in *Joy in the Divine Government*. In short, God cannot be guilty of the slightest mistake. The students of Matthias Loy, Professor of Theology in the Evangelical Lutheran Seminary at Columbus, Ohio, were told that this same God assigns men to their place in society. One man was a merchant prince, another but a servant in his house or a mechanic in his shops. To complain, therefore, was to show a thankless heart and behave in a manner unworthy of a Christian who knows that God bestows different gifts. If his place in society was lower than that of another, he should not be envious of the man whose station was higher. Since each man receives only what is right and fair in the eyes of the Lord, each individual should be content with his lot in life.[10]

But it was not altogether likely that the poor, content in the knowledge that it was God's will, would accept a perpetual state of poverty. Many Protestant ministers at the turn of the century recognized this possibility. The revolt of the Grangers and Populists, the railway strikes and the Haymarket Riot were convincing evidence that this situation was unfortunately true. As a conse-

[8] S. P. Long, *The Great Gospel* (Columbus, 1904), pp. 571–572.

[9] S. P. Long, *The Eternal Epistle*, p. 400.

[10] Luther A. Gotwald, *Joy in the Divine Government; and Other Sermons* (New York, 1901), p. 8. Matthias Loy, *Sermons on the Epistles for the Sundays and Chief Festivals of the Church Year* (Columbus, 1900), pp. 140–141. These statements have the same tone as those of Henry Ward Beecher a half century earlier in *Life Thoughts* (Boston, 1858), p. 181. "We have aristocrats, but God made them. . . . It was designed that some should be high, some intermediate, and some low, as trees are some forty, some a hundred, and some, the giant pines, (how solitary their tops must be!) three hundred feet in height."

quence, to provide for those to whom the "Gospel of Wealth" did not apply, they built an elaborate rationale that might be called the "Gospel of Poverty." This statement did not appear as one simple and consistent declaration of good news to the poor but rather as a variety of assertions which can be seen as variations on the basic theme.

Perhaps the least acceptable answer to the question was the one proposed by the Lutheran minister, Olaf Lysnes. If you have accepted Jesus then you are independently rich even though you may be poor in this world's goods. Suddenly you belong to the nobility of the household of faith.[11] In Minneapolis the members of the First Baptist Church heard much the same message. "Talk about Poverty! He is not the poorest man who is out of money, whose buildings have gone up in smoke, whose deposit account is swallowed up in bankruptcy. The poorest man is the man who is without God, and without hope, the man from whom the Scriptures have been snatched away." Thus did the Reverend Doctor William B. Riley admonish the city's poor in *Messages For the Metropolis.*[12]

If the poor still chafed under the burden of their worldly troubles they were counselled to keep in mind that their troubles were really of no consequence. Samuel Smith Harris, Episcopal Bishop of Michigan declared that he did have a gospel for the poor which they would find soothing, for it was full of the good news of hope, love and life. This gospel proclaimed that the wants and needs, the poverty of the unfortunate man, belonged to a world that was passing away. God had another world, a real world, in store for him where all inequalities of the present life would be redressed, for God had reserved all of eternity merely to console the poor. Heaven would be

> An eternity of peace for the troubled, of rest for the weary, of joy for the afflicted, when men and women and children shall hunger no more, and thirst no more; where there shall be no more pain, neither sorrow nor crying, for God shall wipe away all tears from their eyes. Ah, yes, this begins to sound like good news indeed, like a real gospel to the poor.[13]

S. P. Long, who preached to as many as three thousand people

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[11] Olaf Lysnes. "The purpose of Jesus' Poverty," in *Pastors of the United Norwegian Lutheran Church of America, a Free Text Church Postil* (Minneapolis, 1913), pp. 36–37.

[12] William B. Riley. *Messages for the Metropolis* (Chicago, 1906), pp. 185–186. S. P. Long in *The Great Gospel,* pp. 568–569, wrote, "Who are the poor people in this city of Mansfield? The very people who are giving nothing to God."

[13] Samuel Smith Harris. *The Dignity of Man; Select Sermons* (Chicago, 1889), p. 252. Bishop Matthew Simpson of the Methodist Episcopal Church preached much the same doctrine when he said, "If I have but little treasure on earth, I can have treasure laid up in heaven. There are rich men on earth who will not be rich in eternity; and there are poor men who will be rich in the day of the Lord Jesus; and if the mind can be thrown forward thus, how this view of the future will compensate for the privations of the present!" *Sermons by Bishop Matthew Simpson* (New York, 1885), p. 232.

each Sunday in Mansfield, Ohio, addressed himself to the topic of "Plain Philosophy for Poor People" on Christmas morning, 1903. He called the attention of his congregation to "those homes in the tenement houses, dark, black, filthy rooms, drunken husbands, sometimes no clothing to wear, no bread to eat, no decent meal for the children, and it almost makes our hearts bleed." Yet there was another side to this question. Christ the Savior of the world was born not even in a tenement, but as the poorest child on earth never was born, in a low, common stable in order that the poor might have comfort.

> There is comfort for the poorest people in the world; they can live until they die, and that is all the rich can do. We are here, my friends, to live, and it does not take a great deal to exist, and when life is done there is just as much in store for the poorest man that ever lived as there is for the wealthiest. When life is over, then comes death, and let me say to all the poor this morning, that that is all the rich have; they simply live and at the end of life comes death; they take nothing with them, and how much better off are they than the poorest?

The poorest people can live and die saved. "This my friend is the true philosophy of a Christian—Plain Philosophy for Poor People."[14]

The Presbyterian leader J. G. K. McClure, President of McCormick Theological Seminary, held that people could gain an insight into the entire question of poverty by seeing how Jesus dealt with it when he told the rich young ruler to sell all that he had and give to the poor. Actually, Christ did not mean that man should take the injunction literally, for the young ruler would become forever a poor man himself and such a step would be most unwise. Christ felt so deeply for the poor that he would never do anything to weaken or hurt them. The outright gift of money would be the worst possible use of the young ruler's goods because it would discourage efforts for self-support and thus most certainly injure the poor. "What the poor always need—whether they are poor in money, or poor in strength, or poor in comfort, is stimulus and encouragement to rise above their circumstances, to struggle beyond them, to have a larger spirit, and to put forth an earnest effort."[15] This treatment of the question, an evasion of the real issue, seemed to be quite standard in Protestant circles at the turn of the century.

If man needed a stimulus to rise, as McClure suggested, no better one could be found than in poverty itself assisted by calamity.

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[14] S. P. Long. *The Great Gospel,* pp. 89–90.

[15] James G. K. McClure. *Loyalty; The Soul of Religion* (Chicago, 1905), pp. 94–95. S. P. Long in *Prophetic Pearls* (Columbus, 1913), p. 195, wrote, "We never can help this world back to God till we mingle with the poor and extend them a warm, helping hand."

In fact, it would be disastrous to do away with poverty, for it was a most valuable condition. Just as gold and silver are dug out of rugged mountains, so out of the hardships of life come some of the richest treasures of human experience and of human character. Many of the greatest men in history have come from the most humble surroundings, and had they not been faced by this challenge of poverty they might never have reached the heights of fame. The struggle with poverty and hardship developed a strength of character that could not be found in any other way. The best thing in life was to struggle with these difficulties and overcome them.[16] It was much better that a man struggle with poverty, than with wealth, for "through the liftlock *prosperity,* one man passes upward while ninety-nine pass downward. Through *adversity* one man passes downward while ninety-nine pass upward." Obviously, our society must preserve and cherish poverty to develop men of character in the future.[17]

The man who could find no consolation in adversity as a stimulus to building character and who, though striving mightily, still failed to rise above his poverty, was counselled in another fashion. As a mere "drudge" in an industrial society he must cultivate a spirit of love "ere he is perfectly at home and happy in his task." His honor was at stake to do his humble part in God's plan.[18] "The vision of someone who is helped will be his final motive to the humble and complete and glad offering up of himself." Through his faithfulness others were made rich. "The factory hand, the miner under ground, the seamstress in her chamber, the laborer by the roadside, wear out their lives for others' comfort. In the accomplishment of great enterprises how many die for the honor and the progress of mankind!"[19] Congregationalists in Wilmette, Illinois, and Presbyterians in West Bay City, Michigan, were thus admonished to give their all in the name of progress.

The new industrial society continued to widen the gap between the poor, who seemed only to become poorer, and the rich whose wealth seemed continually to accumulate. Because of the growing disparity a very definite effort was made to prove to the poor how

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[16] John Woods, Pastor of the First Presbyterian Church, Ludington, Michigan, *The Presbyterian Pulpit,* pp. 115–116.

[17] P. E. Holp, Pastor of the Congregational Church, Sioux Falls, South Dakota, in *The Golden Age and Other Sermons* (Sioux Falls, 1887), p. 177. Precisely the same point of view was expressed by the Disciples of Christ minister J. Z. Tyler in *Talks to Young People* (Cincinnati, 1896), pp. 15–16: the Presbyterian minister David Edwards Beach in *Sermons and Addresses* (Marietta, Ohio, 1890), pp. 199, 272, 276; and the Lutheran minister Luther A. Gotwald in *Joy in the Divine Government,* pp. 12, 58. These expressions were in the same vein as those of Henry Ward Beecher in *Life Thoughts* published in 1858, p. 73, when he said "How blessed, then, is the stroke of disaster which sets the children free, and gives them over to the hard but kind bosom of Poverty, who says to them, 'Work!' and, working, makes them men!"

[18] Roy Edwin Bowers. *The Wholesome Life* (Chicago, 1911), p. 67.

[19] E. K. Strong. "Life in Death," in *The Presbyterian Pulpit,* pp. 367–368.

very much they actually had to be thankful for. B. L. McElroy of the First Methodist Episcopal Church, Ann Arbor, Michigan, stressed a "doctrine of compensation," which, he said, "is calculated to be of service to all who have not made themselves utterly 'reason-proof.' " This doctrine proposed some measure of mediation between the rich and the poor. McElroy hoped that the gap between these two groups would be narrowed if men would just remember that "for everything they have missed they have gained something else."[20] Possession became only another name for relinquishment. If the poor would only open their eyes to that fact they would look without envy on the holdings of the rich. By way of illustrating this principle, the Episcopal rector in Muscatine, Iowa, notes that most wealthy men had ruined their health in the process of acquiring their riches and then would have given all their accumulated wealth if only they could have had in return the good health of the common laboring man.[21]

In the kitchen of the General Otto H. Falk mansion as it overlooks Lake Michigan from Milwaukee is a plaque hung at the turn of the century by the General for the edification of his servants. The central portion of the plaque shows a happy, care-free servant giving counsel to a troubled king. Beneath the figures an inscription reads: "Riches are always restless; 'tis only to poverty the gods give content." Falk, a good Episcopalian, and one-time President of the Allis–Chalmers Manufacturing Company, felt that this message was salutary. This argument was carried into the pulpit by Louis Buchheimer, a Lutheran pastor in St. Louis, and his statement constitutes the ultimate exposition of the Gospel of Poverty as it carried the good news concerning their condition to the poor. Buchheimer pointed out that there was really no very great distinction between the gifts of God to various men. The rich man had his park, but the poor man could look at it and enjoy it without the expense of maintaining it. Although others lived in stately mansions, they had to pay very heavily for the privilege. While the rich man may have had a valuable picture gallery, the poor man could see in the sunrise and sunset a splendor that no artist could ever capture. While the poor man did not possess some of the conveniences and delights of the more favored, in return he was free from many embarrassments to which the wealthy were subject. By the very simplicity and uniformity of his life the poor man was mercifully delivered from the great variety of cares that continually plagued his wealthy brother. Surely the plain meal eaten with

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20 B. L. McElroy. *The Methodist Episcopal Pulpit,* pp. 256–258.

21 Edward Clarence Paget, *Silence: With Other Sermons* (New York, 1896), pp. 116–117.

relish and appetite by a poor man was more delicious than the most luxurious banquet.[22]

Andrew Carnegie, addressing the Nineteenth Century Club at the close of 1887, exclaimed, "I defy any man to show that there is pauperism."[23] Those Protestant ministers who preached the Gospel of Poverty agreed completely with the author of the Gospel of Wealth. In Minneapolis, William B. Riley said that he knew for a fact that the inhabitants of "ninety-nine houses out of a hundred are in perfect comfort."[24] S. P. Long told his congregation that every man is supposed to own his own home.[25] Even evangelist Billy Sunday, the ordained Presbyterian minister who worked with the poor and downtrodden more than did most of his brethren, said that "I do not believe that there are any people beneath the sun who are better fed, better paid, better clothed, better housed, or any happier than we are beneath the stars and stripes—no nation on earth."[26]

The working man in the United States may have been better off than his counterpart elsewhere, but how prosperous was he in the decade of the nineties? Industrialization was making the United States an increasingly wealthy nation. But hours of work were long and wages were low. According to one estimate, weekly hours of work in manufacturing industries averaged sixty in 1890 and fifty-nine in 1900, and annual earnings of all wage earners except farm laborers averaged only $486 in 1890 and $490 in 1900.[27] According to the census of 1900, two-thirds of the male workers over sixteen years of age earned less than $12.50 per week.[28] It is true that prices were not high. In 1898 sugar sold for 5¾ cents a pound, coffee for 28 cents a pound, roasting beef for 14⅔ cents a pound, and milk for less than 6 cents a quart. Coal cost $6 a ton, men's heavy shoes $2 a pair, and the best ready-made suits sold for $20 or less.[29] But even with prices so low, the real income of a great many American families was very meager indeed. Without question, the condition of vast numbers of Americans at the turn of the century bordered on poverty.

Because they failed to recognize the facts of urban American industrial life as they applied to the working man, most of the Protestant clergy consistently misread the causes of poverty. The

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[22] Louis Buchheimer, pastor of the Evangelical Lutheran Church of Our Redeemer, St. Louis, Missouri, in *Faith and Duty; Sermons on Free Texts with Reference to the Church Year* (St. Louis, 1913), pp. 24, 81–82.

[23] Quoted in *Social Science Review* (December 14, 1887), p. 9.

[24] William B. Riley. *Messages for the Metropolis,* pp. 10–11.

[25] S. P. Long. *The Eternal Epistle,* p. 148.

[26] William T. Ellis. *Billy Sunday: The Man and His Message* (, 1936), p. 363.

[27] Paul H. Douglas. *Real Wages in the United States, 1890–1926* (New York, 1930), Table 147 opposite p. 392.

[28] Bureau of the Census, *Employees and Wages* (Special Report, 1900), pp. ci–civ.

[29] *Bureau of the Department of Labor,* No. 18 (September, 1898), p. 696.

catalog of reasons given for the existence of poverty included sloth and indifference, the failure to anticipate expenses through saving, and the use of liquor and tobacco.[30] Very considerable emphasis was placed on the lack of cleanliness, thrift and economy. "If they knew those things," T. G. Soares, a Baptist minister in Oak Park, Illinois, wrote, "they would not be needy. It is foolish to be impatient with the poor, because they have not the methods and virtues of the successful. If they had them they would not be poor."[31] Grinding poverty was also seen as the warning hand of God. In 1908, S. P. Long said that there were families without bread in every city in the land and the reason for it was very simple. "The good Lord cannot bear it any longer to see families go to hell with full stomachs and no knowledge of Him. So He now pulls the bell of famine and rings into our ears: 'Prepare to meet thy God!' Oh, what an unthankful world! You unthankful souls, I am surprised that God has not starved you long ago!"[32] A far easier solution was not to resort to reason or explanation but simply write off the poor as did J. G. K. McClure. "People are not alike. Those who grow up in slums and are foul with evil from their youth are different from those who grew up clean and wholesome in religious homes."[33]

But this was the period also of the rise of the Social Gospel. At the turn of the century Walter Rauschenbusch, Washington Gladden, Shailer Mathews, Harry F. Ward and Charles Stelzle were issuing a clarion call to the churches to accept their social responsibilities and reorient the pattern of Protestant thought and action to meet the challenge of a rapidly developing urban, industrial society. The impetus within the churches for a Social Gospel was provided, however, by only a small but articulate group. These liberal Protestant leaders represented the religious part of the Progressive period in American history. The *Social Creed of the Churches* adopted by the Federal Council of the Churches of Christ in America in 1912 was the high point of the Social Gospel.[34] But it had little or no impact on the average Protestant minister in Beaver Dam, Wisconsin, or Mansfield, Ohio, largely because the Protestant church had, by the turn of the century, been captured

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30 B. L. McElroy, "Compensation, A Law of Life," in *The Methodist Episcopal Pulpit*, p. 358. S. P. Long, *Prophetic Pearls*, p. 102. Billy Sunday, *Billy Sunday's Sermons in Omaha* (Omaha, 1915), p. 114.

31 Theodore Gerald Soares, *The Supreme Miracle and Other Sermons* (Chicago, 1904), pp. 35–36.

32 S. P. Long, *Prepare to Meet Thy God* (Columbus, 1908), p. 62.

33 James G. K. McClure, *Loyalty; The Soul of Religion*, pp. 98–99.

34 See Harry F. Ward, ed., *Social Creed of the Churches* (New York, 1912), for not only the Creed itself but also the official definition of each of the articles. Article 16 was the most far-reaching, "For a new emphasis upon the application of Christian principles to the acquisition and use of property, and for the most equitable division of the product of industry that can ultimately be devised."

by the middle class and because most Protestant ministers simply did not understand the age in which they lived.

The clergy were not prepared to meet the new problems of the city and industry directly, for they had no contact with them. Only very rarely did ministerial candidates come from those classes produced by modern industrial society—the very rich and the urban, industrial poor. Charles Stelzle once observed that the average Protestant minister believed that having come from a poor home he was in a position to sympathize with the unfortunate. At the same time these ministers completely failed to comprehend the problems of industrial and urban poverty and unemployment. Stelzle made a survey of ministers to study this matter and found that fully ninety per cent of the men that he interviewed in city churches had been born and reared in what might be classed as rural areas. The poverty to which they referred was the simple life of the small town or of the farm which was quite a different thing from the pangs of cold and hunger which he had experienced in city tenements. Leaving their rural areas for college and the seminary, they had no occasion to encounter the realities of city life as they affected the urban poor. The result was an ever-widening rift between the American worker and Protestantism.[35]

To an increasing extent, the great American middle class came to sustain the churches of the major Protestant denominations as the nineteenth century progressed. Clearly the upper and lower strata of society, both from an economic and educational point of view, had by the turn of the century ceased to actively support these denominations. Now the "solid" and "responsible" middle class, including the employers, salaried persons, small tradesmen and farmers, came to be identified with the major Protestant denominations. Among them were also included those who had a personal or sympathetic attachment to this class or were engaged in personal service. Some ministers candidly admitted that their churches ministered primarily to the middle class.[36]

What was the answer of Protestantism to the new age that was emerging at the turn of the century? The great mass of the Protestant clergy, conservative in temper and philosophy, beholden to

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[35] Charles Stelzle, *A Son of the Bowery; The Life of an East Side American* (New York, 1926), pp. 82–83. In a sample of 1800 ministers taken in 1930 it was found that only 12 per cent were reared in cities over 100,000 population and 48 per cent came from communities of less than 1000. In this same sample, less than 1 per cent reported the economic status of their parents as wealthy, about 4 percent said their parents were poor. Well over half stated that their fathers were farmers or small tradesmen. Mark A. May, "Theological Education," in Samuel McCrea Cavert and Henry Pitney Van Dusen, eds., *The Church Through Half a Century: Essays in Honor of William Adams Brown* (New York, 1936), p. 257.

[36] Andreas Bard, *The Dawn of To-Morrow and Other Sermons* (Burlington, Iowa, 1911), p. 30. Lewis O. Brastow, *The Modern Pulpit: A Study of Homiletic Sources and Characteristics* (New York, 1906), p. 321.

their middle class congregations, beat a dismal retreat in the face of growing problems. This trend can be seen in Manhattan where, in the period before 1900, 40 Protestant churches left the district below 20th Street while 300,000 immigrants and workers moved into the same area.[37] Most ministers were not conscious of society as a whole except to resent the intrusion of new problems on their peace of mind. The course of least resistance was to maintain the old individualistic approach and respond to the new questions with the same old answers. The Gospel of Poverty was the message of conservative Protestantism to the poor at the turn of the century. Perhaps it was just as well that few of the class for which this gospel was intended ever heard the sermons preached ostensibly for their benefit to middle class congregations. However, the development of this message was an interesting intellectual exercise for many a conservative Protestant clergyman and provided peace of mind for the middle class parishioner.

[37] Charles Howard Hopkins, *The Rise of the Social Gospel in American Protestantism, 1865–1915* (New Haven, 1940), p. 250.

THE BROWN RAT IN EARLY WISCONSIN

A. W. Schorger

Rats have been the greatest plague of all animals to mankind. On account of their destruction of provisions, property, and as carriers of disease, they have been universally detested. The two most common rats in the United States are the brown or Norway rat *(Rattus norvegicus)* and the black rat *(Rattus rattus)*, the former being by far the most abundant.

It is commonly stated on the authority of Pallas that the brown rat entered Europe in 1727 at which time vast numbers swam the Volga. According to Baumann (1949) this species arrived in Europe in the 15th century and not in the 18th. The dates of its arrival in several European countries are given by Barrett-Hamilton (1910): Denmark, 1716; Norway, 1762; Sweden, 1790; France, 1750; England, 1728 or 1729 (Pennant, 1761–66).

An attempt to determine the dates of arrival of the two species in North America is made extremely difficult since usually only "rats" are mentioned without specific information for identification. The black rat was the first to arrive. Both species were brought by ships. Port Royal, Nova Scotia was founded in 1605. Lescarbot (1914:226) was present from July, 1606 to July, 1607. In the meantime rats had increased greatly and had traveled a distance of over 400 paces to the Indian lodges. At Jamestown, Virginia, in April, 1609, the corn imported for the colonists was almost totally destroyed by decay and the "many thousand rats" (Smith, 1910). To have reached this abundance, rats must have arrived on the ships of 1607. Lawson (1907:129) came to North Carolina in 1700, and nine years later wrote that they had the same house rat as in Europe. When Kalm (1772:348) was in New Jersey in January, 1749, he observed that the rats were of the same size as those in Sweden but differed in color, being "grey or blue-grey." Both brown and black rats may have been present. The black rat was frequently called the blue rat in Pennsylvania at the beginning of the present century (Rhoads, 1903). Pennant (1761–66) was assured by several natives of Scandinavia that the Norway rat was unknown there and stated that Linnaeus failed to take notice of it; hence Kalm may have referred only to the black rat.

Methods of Distribution

Rats were distributed mainly by boats such as sailing vessels, steamers, and the large barges and scows of traders. They were carried inland, from waterways by freighters, and in the wagons of emigrants which usually carried seeds for planting and goods protected from breakage by packing in straw. Cook stoves were brought to Fort Wayne, Indiana, in 1836. The parts, wrapped in straw, were packed in crates. When these were opened several rats escaped to form the first colony (Griswold, 1917). At this time nearly all freight arrived by water. The railroad did not come until much later. About 1811, Audubon (1851) observed several Norway rats escape from a barge from New Orleans which was unloading freight at Henderson, Kentucky. The Norway rat appeared at Brookville, on the White River, Franklin County, Indiana, the summer of 1827. The black rat, which was numerous at the time, disappeared in a year or two (Hammond, 1869). Both species undoubtedly arrived by way of the Ohio River.

A few migrations of the brown rat in large numbers have been recorded (Lantz, 1909). Since it is mainly nocturnal, the movements of individuals in frequency and distances overland are difficult to determine. Migration appears to be induced by a shortage of food or an unfavorable environment. Rats usually remain in the vicinity of buildings but in summer and fall sometimes move away from them.

When Maximilian (1906, 2:235) was at Fort Clark in 1833 the Norway rat had not yet reached the Indian villages but the Indians killed on the prairie seven that were on their way from the fort. The Minitari villages were at the mouth of Knife River, Mercer County, North Dakota and Fort Clark was on the Missouri eight miles below them. Lyon (1936) mentions that he had taken this rat on a wild island in the Potomac. It could be reached only by a swim of at least 100 yards. In September, 1899, Snyder (1902) observed one running along the beach at Fox Lake, Dodge County, Wisconsin, fully a mile from any building. Some of the marked rats released in New Orleans were subsequently trapped four miles distant (Nelson, 1917).

The fall movement is usually to cornfields. In Rock County Jackson (1908) found them in these fields, the only localities at a distance from buildings. Errington (1935) in the early winter of 1930–31 found them living in holes in the banks of Lake Kegonsa where they subsisted on dead fish, ducks, and other animal matter. For the most part they attempted to winter in corn shocks but few if any survived the season. When the old sandpit near University Bay was used as a refuse dump, it was infested with rats.

In winter I saw much sign of them in the corn shocks in an adjacent field. The great horned owl is one of the most important predators on wintering rats (Errington, 1932). On May 29, 1914, a rat was found in the nest of a bank swallow, a considerable distance from any building, on the Yahara River near Upper Mud Lake (Betts, 1914; Schorger, 1937).

Spread of the Brown Rat

It is impossible to state definitely when the brown rat first arrived in North America. Harlan (1825) was informed by an eye witness that the *Norway* rat did not appear in what is now the United States until shortly before 1775. The commander of the Spanish Fort Panmure (Rosalie), on the site of present Natchez, Mississippi, complained bitterly in 1779 of the damage done to grain by the enormous number of rats (Delavillebeuve, 1932). The species is unknown. Michaux (1805) mentioned that the "grey European rats" had not yet reached Cumberland (the western two-thirds of Tennessee) but were common at the white settlements elsewhere in the country. I do not know when rats arrived in Chicago, but their presence in 1854 is graphically described by Carl Schurz (Schafer, 1928): "Chicago has 'wooden sidewalks' under which live millions of rats. These rats regard the streets at night as their domain, and in my presence made great use of their freedom. Rats of all sizes and colors, old and young, white and gray, played charmingly about my feet. And when I stepped on one and it squeaked, it seemed to me as if I ought to beg pardon." The presence of the white phase is to be noted. The black rat is not mentioned for Cook County by Kennicott (1855).

Strangely, Nuttall (1950) reported that there were no rats in or around Detroit in 1810. The earliest references to rats in the Upper Great Lakes region are to be found in the papers of the American Fur Company. On April 16, 1827, Robert Stuart wrote from Mackinac to J. J. Astor that he did not consider it advisable to keep furs over winter on account of the destruction by rats. Damage by rats is also mentioned in a letter of June 2, 1827.

Rats were present in the states of the upper Missouri far earlier than Silver (1927) indicates. They infested the trading posts and forts and were highly destructive to the stored corn. The earliest reference found to rats at St. Louis is 1846. At that time Pancoast (1930) was operating a boat on the Missouri and when docked at St. Louis several rats went ashore. Rats must have been present much earlier for the boats which plied the Missouri started from St. Louis. When Luttig (1920) was ascending the Missouri in the fall of 1812 he mentioned the abundance of mice on his boat but does not mention rats. The first steamboat to ascend the Missouri beyond Council Bluffs went to Fort Union in 1832. However, in 1833, Maximilian (1906, 3:13) found Norway rats abundant at Fort Clark. At this fort, which was not built until 1831, Chardon (1932), between August, 1834 and May, 1839, killed nearly 5000 rats by tally. In 1858 rats were not only a scourge to the fort but also to the Indian villages (Boller, 1868).

Norway rats were so numerous in 1833 at Fort Union in extreme eastern Montana that the daily loss of corn was estimated at 250 pounds (Maximilian, 1906, 2:235). Oddly, Kurz (1937) wrote at Fort Union in 1851 that "there are no rats in the fort any more than at Fort Berthold." The ambiguity may be due to translation. Sackett (1866) who subsequently visited Fort Berthold found it free of rats. He also inspected forts Randall, Sully and Rice where rats swarmed. At Fort Rice 90,000 pounds of the 237,000 pounds of stored corn had been destroyed, and the remainder so defiled that only the Indians would eat it. The rats at Fort William, located at the junction of the Laramie and the Platte, in 1837 had cut to pieces the old epichimores (Russell, 1914). No large boats could ascend the Platte.

The Black Rat

The black rat does not appear to have entered Wisconsin. Lapham (1853) mentions it as having occurred at Racine, and Kessinger (1888) as "very frequent" in Buffalo County. These were without doubt melanistic brown rats. Smith (1958) found that 19 percent of the Norway rats in southeastern Georgia were melanistic, and Rohe (1961) captured five in the black phase at Pasadena, California. J. L. Diedrich of the Milwaukee Public Museum has informed me that the Museum does not have a specimen of the black rat; however they do have several melanistic brown rats which were obtained in the late 1930's at the old Washington Park zoo site where there was a quite large population.

Arrival in Wisconsin

It is logical to assume that the brown rat arrived in eastern Wisconsin from vessels on Lake Michigan and in the western part of the state from boats on the Mississippi. The dates when rats are mentioned for some of the counties in the state are shown in Fig. 1.

Rats were probably at Prairie du Chien by 1823 for on September 10 of that year R. Stuart wrote to Joseph Rolette at Prairie du Chien that the deer skins shipped by the Upper Mississippi Outfit were badly damaged by moths, rats, and dampness (Am. Fur Co.). The headquarters of the Upper Mississippi Outfit were at St. An-

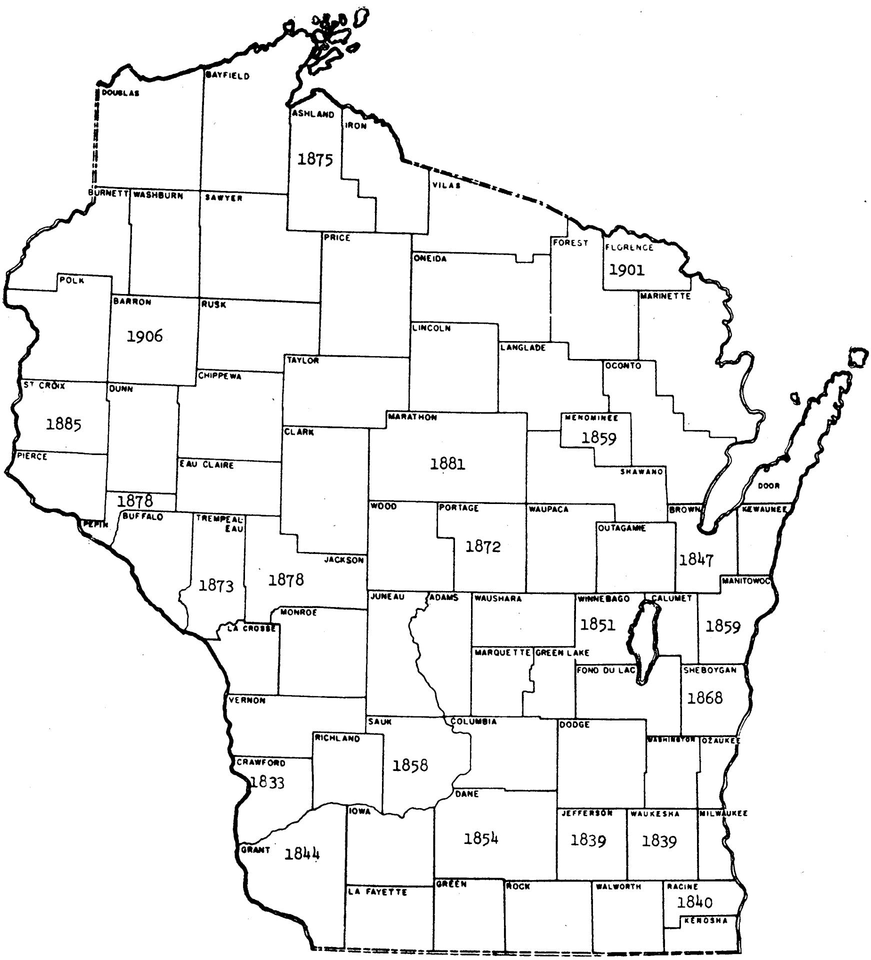

FIGURE 1. Dates when the brown rat was first mentioned.

thony Falls near St. Paul. According to Atwater (1893) rats and mice were unknown at Minneapolis until about 1852. They certainly were present much earlier. The invoices inward of the American Fur Company show that of the "House Rat Traps" supplied in 1833, 18 traps remained with the Upper Mississippi Outfit and 7 at Prairie du Chien.

Grant County had rats at least by 1844. In June of this year about 30 were killed in demolishing an old log stable (Lancaster, 1844). On April 5, 1847, 225 rats were killed by a Mr. Nordyke and sons living near Lancaster (Lancaster, 1847). Jones (1857), residing near Platteville, entered in his journal on January 29, 1857: "I cleaned wheat and killed rats." Two dogs killed 63 large rats at Boscobel in June, 1873 (Boscobel, 1873).

The first rat ever seen at Taylor, Jackson County was killed in September, 1878. It was supposed to have arrived in a freight car (Merrillan, 1878). The first rat ever seen, supposedly, at Merrillan was found on July 21, 1882 (Merrillan, 1882). A correspondent at nearby Alma Center promptly wrote that "we count ours by such numbers that we should not miss a small colony" (Merrillan 1882.1). After a rat was caught in 1880 in Black River Falls, it was stated that this pest had yet to become a permanent resident of the village (Black River Falls, 1880). The first rat for Bloomer, Chippewa County, was caught November 9, 1899 (Bloomer, 1899).

Rats were seen daily in Galesville, Trempealeau County, in August, 1873 (Galesville, 1873). Durand, Pepin County, was overrun by rats in 1878 (Durand, 1878); and in 1885 they were multiplying rapidly at New Richmond, St. Croix County (New Richmond, 1885). In September, 1906, 42 rats were killed under one stack of grain while threshing on a farm near Barron, Barron County. They had been around only a year or two but were "making excellent progress" (Barron, 1906).

The brown rat arrived in central Wisconsin later apparently than along Lake Michigan and the Mississippi. Jackson (1961:255) was informed that it was present at Milton, Rock County, prior to the arrival of the railroad in 1852. Chase (1858) spent the winter of 1839–40 in an old log cabin three miles from Watertown, Jefferson County, in which were rats which he looked upon as better than no company at all. They lived under the floor. Welch (1881) understood that rats were unknown in the interior of Dane County until the arrival of the railroad in 1854. By 1860 Madison (1860) had rats in abundance and contests were scheduled to see which dog could kill ten rats in the shortest time. An advertisement was run offering ten cents apiece for rats. One contest did not materialize as the rats escaped (Madison, 1860.1). The Capital House had been nearly freed of rats by "Costar's celebrated vermin exterminator" (Madison, 1862). While at DeForest Stoner (1938) wrote in his diary on August 27, 1862, that he was disturbed most of the night by a large rat. The following night he caught one. In 1858 the first rat ever seen in Baraboo, Sauk County, was killed by boys (Western Hist. Co. 1880). Rats were observed in Reedsburg in 1873 (Reedsburg, 1873).

While at Menasha, Winnebago County in 1851, Mackinnon (1852) intended to dine with some Indians. The squaw put in the kettle several species of squirrels and undressed fish, then "to cap the climax, some rats were pulled from a heap of rubbish and actually added to the stew. My stomach began to mutiny, and I was peremptorily compelled to run off." At Neenah in 1857, rats and mice were a great nuisance (Neenah, 1857). The Peters House in Oshkosh was overrun by rats in 1869 (Oshkosh, 1869). It was announced in April, 1872, that rats had at last arrived in Stevens Point, Portage County (Stevens Point, 1872). They did not appear in Colby, Marathon County until the spring of 1881 (Colby, 1881). While at Keshena, Menominee County, in 1859, Father Gachet wrote: "In order to make ourselves a little soup, the brother ferreted out the chapel and produced some ends of old tallow candles which the teeth of rats had spared." In 1874 it was stated that it was about seventeen years since rats had become "acclimated" to Lake Superior (Ashland, 1874); however, when six rats were killed in Ashland the following year, they were pronounced to be the first ever found in the village (Ashland, 1875).

The first wheat raised near Racine was purchased by Charles Wright the fall of 1840. While in storage a large amount of it was destroyed by rats and mice (Western Hist. Co., 1879). Subsequently Lapham (1853) listed the brown rat as a resident of Racine. The fall of 1839, H. Vail of the town of Vernon, Waukesha County, stored his corn in the loft of the house of Almon Welch only to have it purloined by rats, mice, and squirrels (Western Hist. Co. 1880.1). Between October, 1868 and the end of April, 1869, the watchman at Rock Mills, Sheboygan, killed between 400 and 500 rats (Sheboygan, 1869). By 1859 rats had become an intolerable nuisance at Manitowoc (Manitowoc, 1859). Mrs. A. B. Williams came to DePere, Brown County in 1847. The following year she moved into the Frontier House. It had been occupied so long by "rats, bats, swallows and pigeons" that it took three men a week to make it livable (French, 1876). Florence, Florence County, could say in 1901 that there was neither a rat nor a mouse in the city (Florence, 1901). On the night of October 4 of the following year the first rat was killed at the pumping station (Florence, 1902).

Eradication

There is no hope of eliminating the brown rat. The most that can be expected is to keep the population at a low level. Shortly after the discovery by Karl P. Link of Warfarin as a rodenticide, it was used in an eradication campaign in the village of Middleton in the fall of 1950. Bait, consisting of a mixture of corn meal and Warfarin, was widely distributed on November 4 (Madison, 1950). Dr. Link has informed me that in the spring of 1951 it was difficult to find a rat but it was not exterminated.

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THE INFLUENCE OF DRUMLIN TOPOGRAPHY ON FIELD PATTERNS IN DODGE COUNTY, WISCONSIN

Charles W. Collins

The influence exerted by drumlin topography on field patterns is readily apparent to those persons who have the opportunity to fly over the drumlin fields of southeastern Wisconsin. Marschner,[1] in his classic work on land use and patterns, observed that land use in Dodge County, Wisconsin, is controlled by both the rectangular land divisions and the orientation of the drumlins. It was observed by this writer that the relationship between field patterns and drumlins is not only complex, but also systematic. It is the purpose of this paper to demonstrate that a combination of factors, including drumlin trends and height as well as the township and range grid, are responsible for systematically varying sizes, shapes and orientations of the field patterns in Dodge County.

Dodge County lies in the southeastern portion of Wisconsin, approximately 30 miles northwest of Milwaukee. (See Figure 1.) The county is nearly homogeneous insofar as farm type, farm size and crop combinations are concerned. In general, the farms are between 130 and 150 acres in size.[2] Although the majority are dairy operations with hay, corn and oats occupying a large percent of the cropland, some specialized operations such as beef, chicken and turkey ranches are occasionally encountered. Woodlands and unimproved pasture generally are found on the steeper slopes. Pasture, farmsteads, farm gardens and a few specialty crops, such as green peas and sweet corn, account for most of the remaining cropland. In several instances wetlands are found in the lowland areas between drumlins. Occasionally these wetlands are used as unimproved pasture, although more often they would fall into the category of wasteland.

Soils vary considerably throughout the drumlin area with sandy loams and silt loams commonly found on drumlin sides and tops.[3] Peat and muck soils are commonly found in the depression between drumlins even though actual swamp or marsh conditions may be absent due to the implacement of drain tile.

Drumlins are present in approximately ¾ of the country. These elongated hills, with their major axes orientated in the direction of the flow of the ice sheet that created them, vary in their axial orientations from almost true north–south in south central Dodge

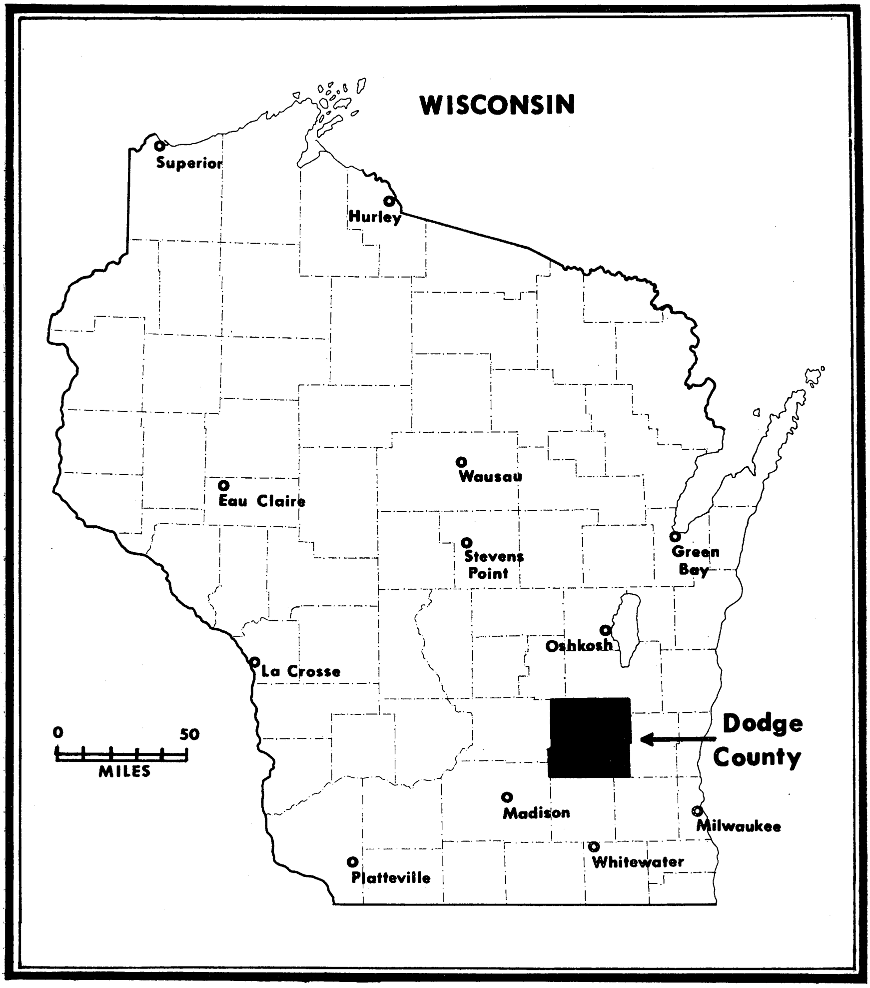

FIGURE 1. Index Map.

County to northeast–southwest at the western border. The major non-drumlin area is located in the north–central section, where typical swell and swale topography is found. Horicon Marsh, one of Wisconsin's largest wetland areas, is also located in this north–central area.

METHOD

In order to study in detail the relationships between drumlin topography and field size, shape and orientation, a method by which these phenomena could be measured and evaluated had to be developed. Because the large number of fields presented a problem in handling the data, four areas of nine square miles each were selected as sample areas. These areas were chosen by visual examination of the topographic maps of Dodge County. They were selected because they represent four types of topography characteristic of the non-wetland areas of the county. (See Figure 2.) These areas include the following types of topography:

Elba Area —High drumlins oriented northeast–southwest.

Lowell Area —Low drumlins oriented north–northeast south–southwest.

Lebanon Area—High drumlins oriented nearly true north–south.

Trenton Area —Non-drumlin area with local relief generally less than 40 feet.

Field patterns were studied through the use of large scale aerial photographs (eight inches to the mile) provided by the Dodge County Office of the Agricultural Stabilization and Conservation Service. Maps of the field patterns, roads and farmsteads were constructed by tracing these elements directly from the aerial photographs. (See Figure 3.) As in a recent study by Hart dealing with field patterns, changes in the tone or texture of the photos were considered to be an indication of a boundary.[4] Field checking in the study areas corroborated Hart's conclusion that this method is indeed accurate. For the purposes of this study, farmsteads were not considered to be fields, and minor drainage lines were not considered to be field boundaries unless they coincided with a tone or texture change on the photo. True wetlands were observed in only a few instances. They were delineated, but for the purposes of the study were not considered to be fields. Woodlots, which occupied less than 10% of the study areas, were considered to be fields for the purposes of this study. In the case of strip cropping, each strip was treated as a separate field.

It was desirable, for the purposes of this study, to measure the degree of topographic orientation in such a way so that a statistical, yet visual, presentation could be made. A grid with four lines to the inch was constructed and randomly placed over the topographic maps of each square mile of the nine-square-mile units. Each intersection of a contour line and the grid was then noted and the bearing of the contour line was measured. In some instances contour lines were observed to bend toward a grid line, touching it, but not crossing. These cases were disregarded due to the difficulty of obtaining an accurate angular measurement. A frequency diagram of the angles was then constructed. The angles

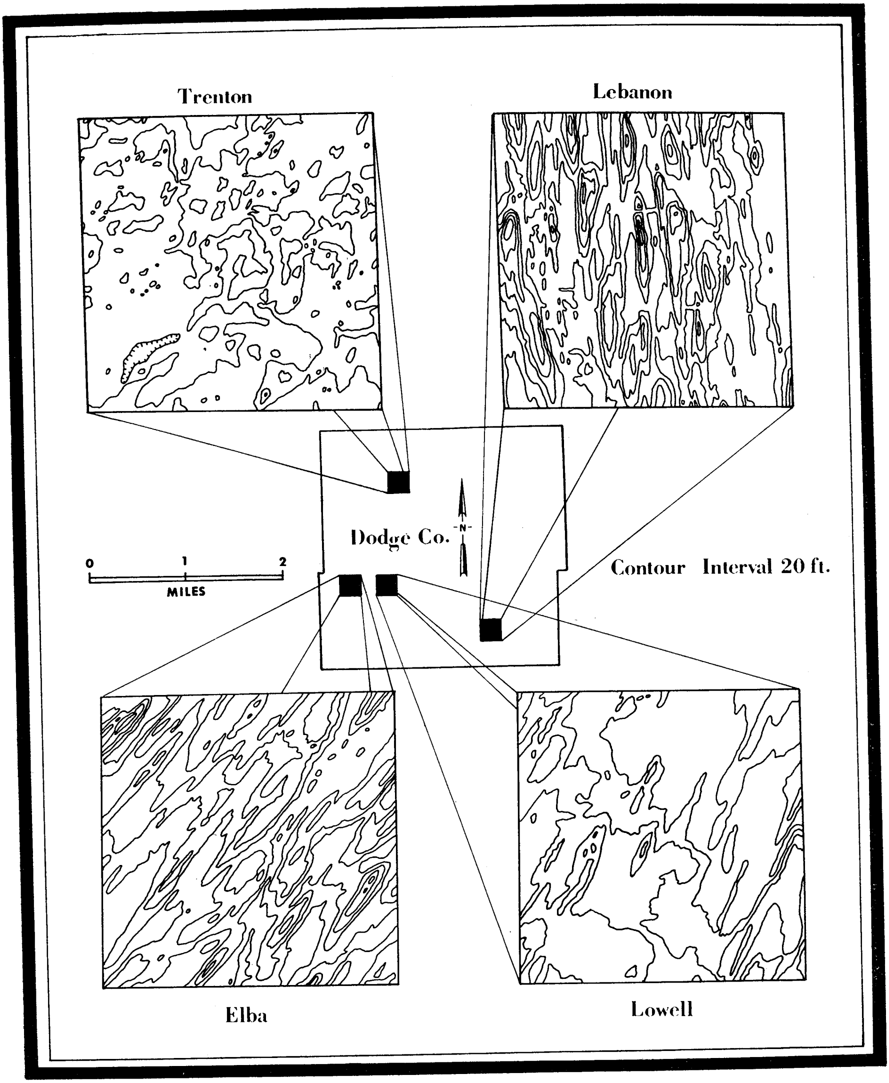

FIGURE 2. Topography in the four study areas.

were grouped for convenience into ten-degree units. The results were plotted on the compass roses shown in Figure 4.

In the analysis of field shape, all fields were considered. Each was put into one of the following nine categories: squares, rectangles, parallelograms, trapezoids, clipped figures, triangles, complex polygons, trapeziums and irregulars. Of these nine categories,

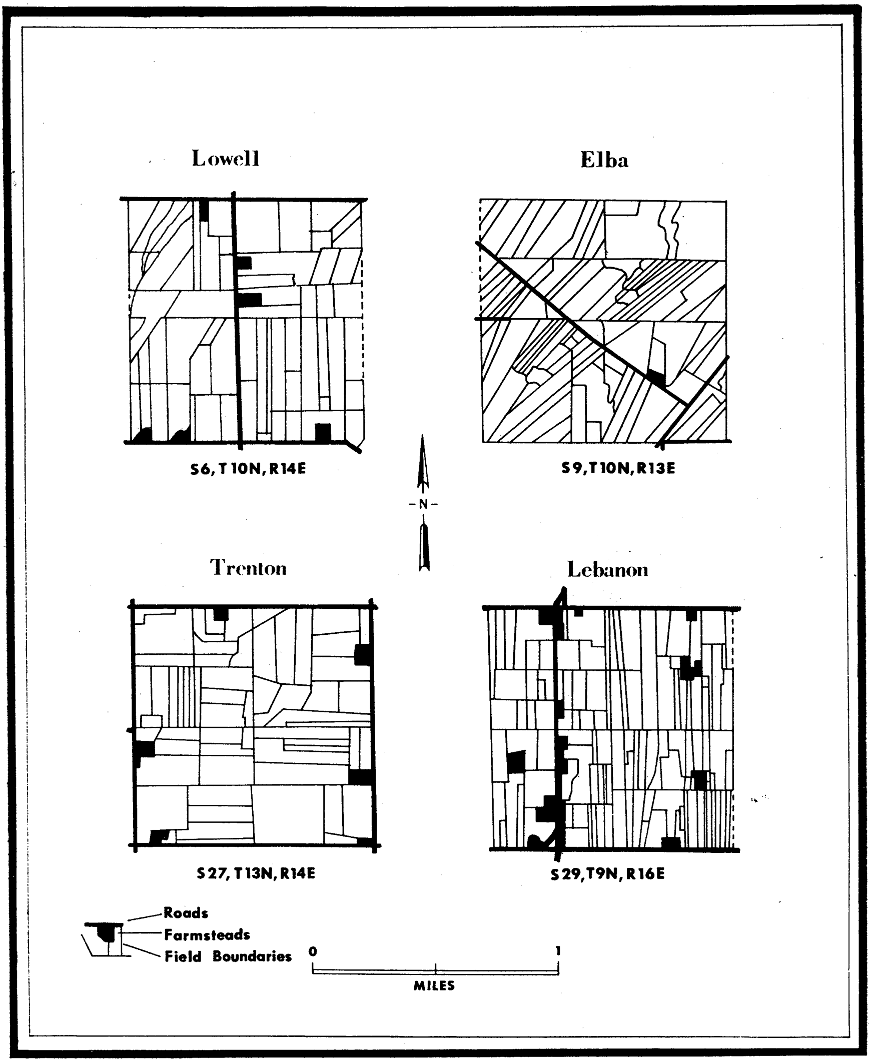

FIGURE 3. Field patterns in one section of each of the four study areas.

perhaps clipped figures, complex polygons, trapeziums and irregulars are in need of further explanation. The clipped figure is a five-sided field which has two parallel sides which were, in turn, generally parallel to drumlin trends. The other three sides were usually coincident with some elements of the township and range grid. Two of these three sides were generally parallel. The complex polygon category included fields having five or more sides, all of

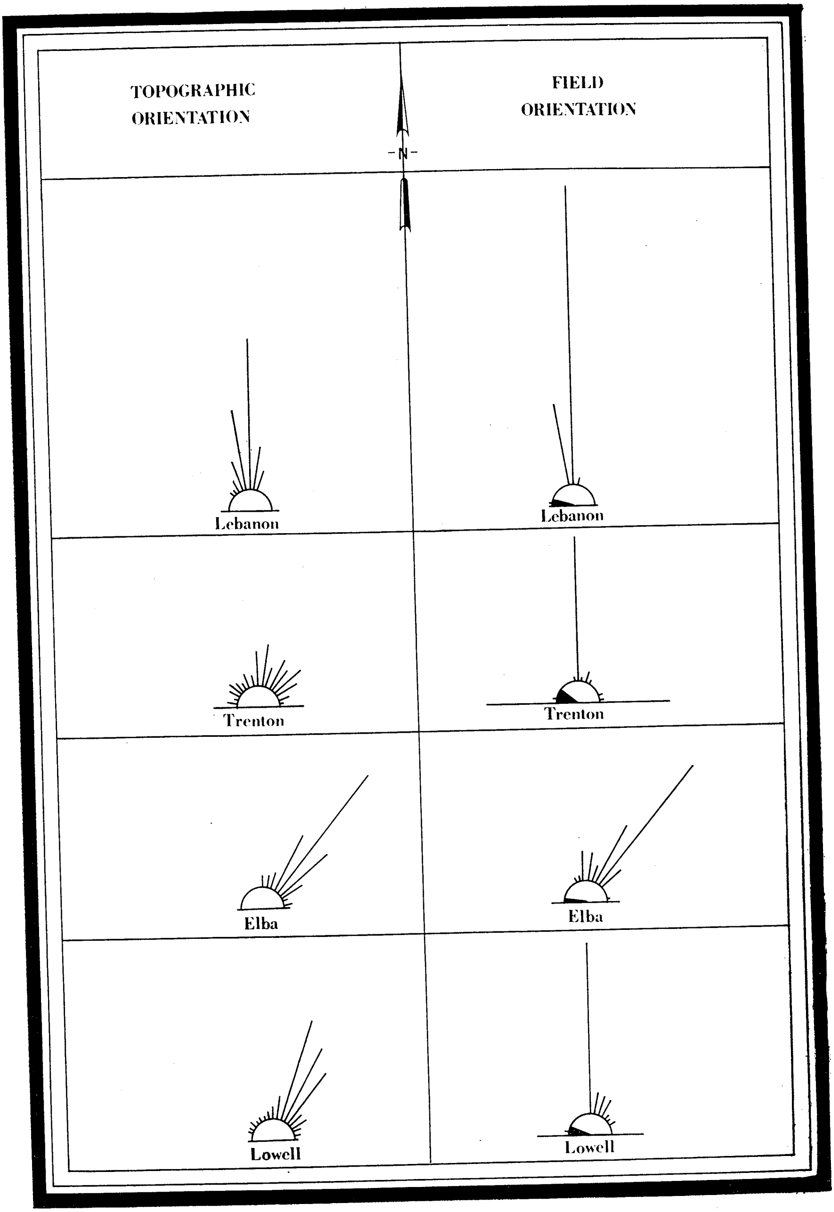

FIGURE 4. Topographic and Field Orientation. Lengths of the shafts are proportional to the percent of orientation in that direction. Data are grouped into ten-degree units. The dark portions of the semi-circles are proportional to the percent of fields having no definite orientation.

which were straight lines. Trapeziums included four-sided fields where all sides were straight, but where no two sides were parallel. Fields where one or more sides were not straight lines were placed in the irregular category.

The fields to be used in determining field orientation and size were selected with the use of a random dot sample. The size of each sample field was measured with a planimeter. Some subjectivity was involved in the measurement of field orientations since the determination of orientation was entirely visual. This visual analysis was chosen because of difficulties encountered in attempting to develop a non-subjective method. The method employed herein involved the simple placing of a line parallel to the general direction of field orientation as computed by the operator. Although this method involves some degree of subjectivity, it should be noted that in a test six geography graduate students at the University of Wisconsin–Milwaukee agreed as to the orientation of test fields within two degrees, ninety-eight percent of the time. Therefore, although some subjectivity is certainly involved in this measurement it is the belief of the writer that it is minimal. Field orientation data, like topographic orientation, was grouped into ten degree units and plotted on compass roses. (See Figure 4.)

Field Patterns

Several interesting relationships come to light when topographic orientation and field orientation data are compared. For instance, if Figure 4 is examined, it is evident that the two roses representing the nine square miles in Elba Township display a strong and nearly identical northeast–southwest orientation. Thus, drumlins and field orientation are nearly identical in the Elba Area. In the Lowell Area, however, although drumlins have a similar orientation to that of the Elba Area, the majority of the fields display a north–south or east–west orientation. This leads one to believe that topographic orientation alone will not produce the angular fields seen in Elba, and that the lower relief of Lowell is most certainly a factor. Note also that in the Trenton area, where low relief is coupled with little or no general topographic orientation, most of the fields are oriented with the township and range grid. Lebanon with its nearly north–south drumlins, displays an exceptionally high degree of north–south field orientation.

When field shape was compared to the topographic orientation of the four study areas, it was discovered that Elba and Lowell, where drumlins were oriented north–east to south–west, displayed the greatest variety of field shapes. It was also in these areas where the greatest number of fields with acute and obtuse angles were observed. Field shapes, such as trapezoids, clipped figures, parallelograms and triangles were common. In Elba, for example, over 36% of the fields are trapezoids. If we add to this, 7% parallelograms, 3% clipped figures, and 8% triangles, we include 54% of the sample fields. (See Figure 5.) Compare this to less than 10% of these four shapes in Trenton where there is little topographic orientation, 12% in Lebanon and 24% in Lowell.

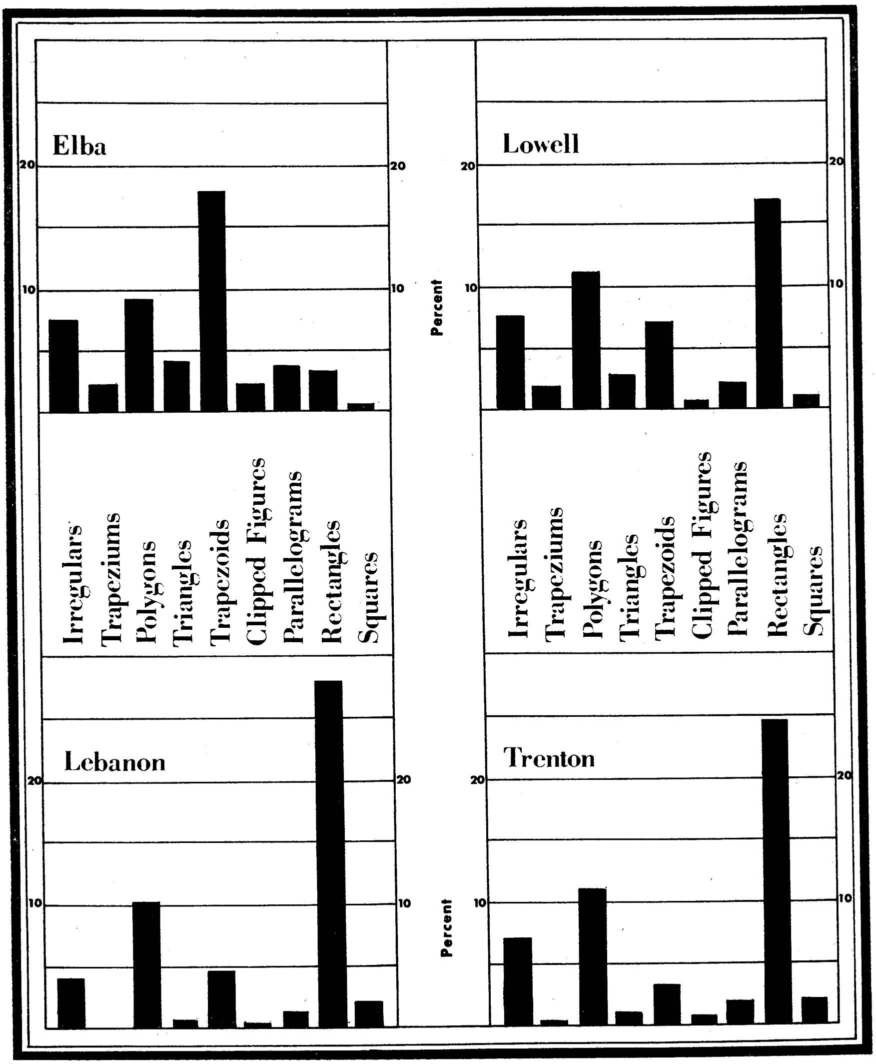

FIGURE 5. Field shapes, percents.

In Lebanon, where high drumlins give a strong north–south orientation to the topography, 56% of the fields were found to be rectangular. Compare this figure to that of Elba with 6%, Lowell with 34% and Trenton with 49% rectangles. Given these data only, one might be led to believe that the Trenton and Lebanon areas are similar. It is field orientation, however, that is the important difference, since Lebanon displays a high degree of north–south field orientation which is parallel to the drumlin trends, while Trenton has as many fields oriented east–west as north–south. A further difference in the nature of the rectangular fields of these two areas can be seen when the field pattern maps of sections in Trenton and Lebanon (Figure 3) are compared. In Lebanon the closely spaced high north–south oriented drumlins impose a restriction on field width, the ratio between the length and width of fields is considerably greater than in Trenton.

In Elba the low figure of 6% rectangles is related to both the high degree of topographic orientation in a direction not parallel to elements of the township and range grid, and the relatively high relief. The Lowell Area, with the intermediate figure of 34% rectangles again emphasizes the importance of lower relief in governing field shapes. Here, although topographic orientation is strongly northeast–southwest, fields are preferentially oriented north–south or east–west, resulting in the larger percentage of rectangular fields for Lowell.

In the case of Lebanon, two other factors regarding field shapes stand out. They are, the almost complete absence of square and the relatively lower number of irregular fields. The latter can be perhaps explained by the absence of streams and swamps in the Lebanon area, since these hydrographic features are responsible for many of the irregular field boundaries. The absence of streams and swamps can be attributed in part to the implacement of drain tiles in many of the lower areas between drumlins. Consequently, straight line drainage ditches frequently serve as field boundaries in the lower intra-drumlin areas. The near absence of square fields can be related to the parallelism of the high north–south drumlins. This parallelism seems to make the elongated rectangle so practical for cultivation as to exclude squares.

In Hart's study of field patterns in Indiana,[5] field shapes were related to differences in farm types. This, however, does not seem to be the case in Dodge County where the scale of the study is larger and the study areas are much closer together. Furthermore, field study revealed that the only significant difference in farm type or farming practices throughout the four study areas was that strip cropping was practiced more in those areas of higher relief.

Field Size

Field size differs considerably throughout the four study areas. The smallest fields were located in Lebanon where 8.33 acres was the mean size of those fields sampled. The smaller field size in Lebanon is undoubtedly partly attributable to the greater use of strip cropping in this area of relatively higher relief. The largest fields were found in Trenton with a mean of 15.0 acres. Here, lower relief and the absence of topographic orientation have resulted in fewer restrictions on field size than in the other three regions. An examination of the bar charts in Figure 6, further demonstrates the field size differences between the study areas. For example, in Lebanon 86.5% of the fields sampled were below 13 acres, which was the median field size in Trenton. This compares to 65% below 13 acres in Lowell and 54.5% in Elba. Insofar as large fields, Trenton and Elba both had approximately 20% of their fields over 20 acres in size, while the Lowell area had 15% over 20 acres, and the Lebanon area only 3% in this larger size category. It is further interesting to note that the "forty-acre field" is missing in all four of the study areas.

Conclusions

It is the opinion of the writer that this study bears out the stated hypothesis that drumlin trends and heights as well as the rectangular land division are largely responsible for the varying field sizes, shapes and orientations in Dodge County. Four significant facts regarding drumlin and fields can be drawn from the study. First, the presence of drumlins in portions of Dodge County appears to be an important limiting factor with regard to field size. Second, the relief in the drumlin areas is an important factor in determining field orientations, in that the fields in the regions of higher drumlins tend to show a greater degree of parallelism to the topographic orientation. Third, more complex field shapes are found in areas where drumlins cross elements of the rectangular land division at acute and obtuse angles. Fourth, in the area where high drumlins are parallel to elements of the rectangular land division fields were found to have the highest degree of topographic orientation and the smallest size.

Although the conclusions listed above only apply to the four nine-square-mile study areas in Dodge County, Wisconsin, relationships uncovered in this study may apply to other drumlin areas. Obviously this paper represents only a preliminary study and more work is needed before the relationships between drumlins and field patterns are completely understood. It is the hope of this

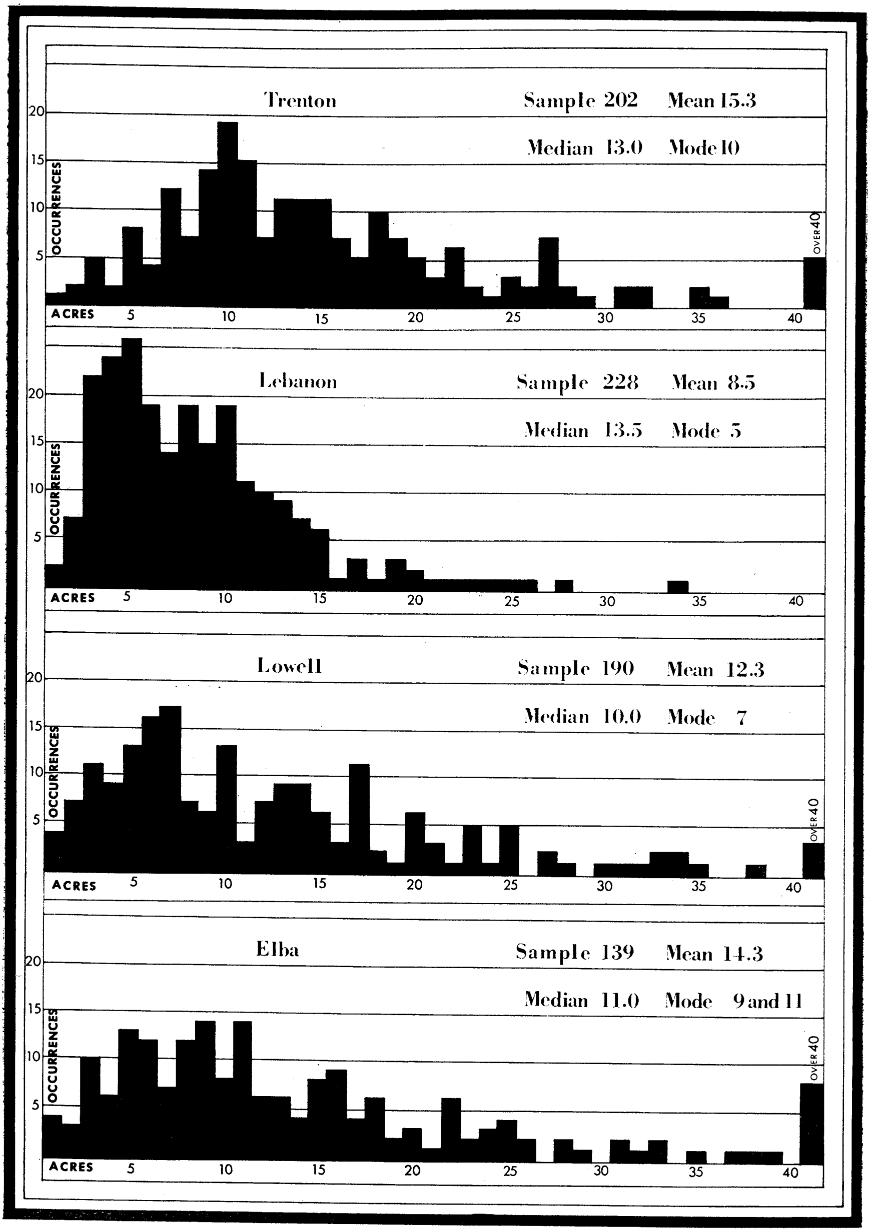

FIGURE 6. Field sizes in the four study areas.

writer that more studies of field patterns in all types of topography will be undertaken by geographers and other scholars so that we may one day more fully understand the fields upon which our very existence depends.

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5. *Ibid*, p. 471.
6. I would like to thank Professor Canute Vander Meer of the Department of Geography, University of Wisconsin–Milwaukee for the encouragement necessary to continue this study. Professors Dale Fatzinger and Lloyd Flem of the Department of Geography at Wisconsin State University–Platteville read the first draft and offered valuable comments. The final paper remains, of course, my responsibility.

SEDIMENTOLOGICAL AND CHEMICAL PARAMETERS OF THE LAKE SUPERIOR NERITIC ZONE, SOUTH SHORE, WISCONSIN

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INTRODUCTION

In October, 1967, a group of faculty members at the Wisconsin State University, Superior, began to analyze the opportunities oceanography offered by their location on the shore of Lake Superior. An area was selected for examination for the purpose of establishing baseline studies. Parameters selected for study included; sediment sieving analysis, turbidity, pH, electrical conductivity, dissolved oxygen, and total dissolved solids. Development of techniques and procedures was a primary objective of the pilot study and, as anticipated, the exploratory traverses exposed several errors.

While Lake Erie has been classified by investigators as either "dead" or in a semi-permanent state of contamination, Lake Superior is usually classified as in a near-pristine condition. In an effort to avoid such generalized terminology it is necessary to conduct analyses of Lake Superior in a manner to establish bases from which the degree of contamination may be determined, particularly along the Wisconsin portion of the south shoreline where there is definitely a problem of shoreline erosion (Red Clay Interagency Report, 1967). With these baseline studies, studies of water quality may then be compared in qualitative as well as quantitative terms. These baseline studies are particularly important because there are significant quantities of non-natural materials being discharged into the lake at the present time. From these baseline studies it is hoped that the study of the physical–chemical factors of the environment will lead to studies of the producer–consumer dynamics of the area discussed in the present paper. These baseline studies are in addition to other baseline studies which have been and are being conducted in the western Lake Superior region by the National Water Quality Standards Laboratory (Duluth) and by the University of Minnesota (Duluth and Minneapolis).

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In October of 1967 an area was selected for the purpose of establishing baseline studies of the Lake Superior neritic zone, south shore, Wisconsin. This research work was the beginning of studies which have culminated in the establishment of the Center for Lake Superior Environmental Studies at Wisconsin State University, Superior.

The area selected for study extends for two miles along the south shoreline from the eastern end of Wisconsin Point immediately east of the City of Superior in Section 35, Township 49 North, Range 13 West (figure 1). The eastern end of the study area is 500 yards east of the mouth of Morrison Creek in Section 36, Township 49 North, Range 13 West.

Factors considered in selection of the study area included accessibility by land for convenience in establishing triangulation stations, proximity to the University, an open or unprotected coastal area, and a variety of onshore topography ranging from marsh to wooded and actively undercut clay banks. Two streams flow into the lake within the study area, Dutchman Creek and Morrison Creek, with their mouths periodically blocked with sediment.

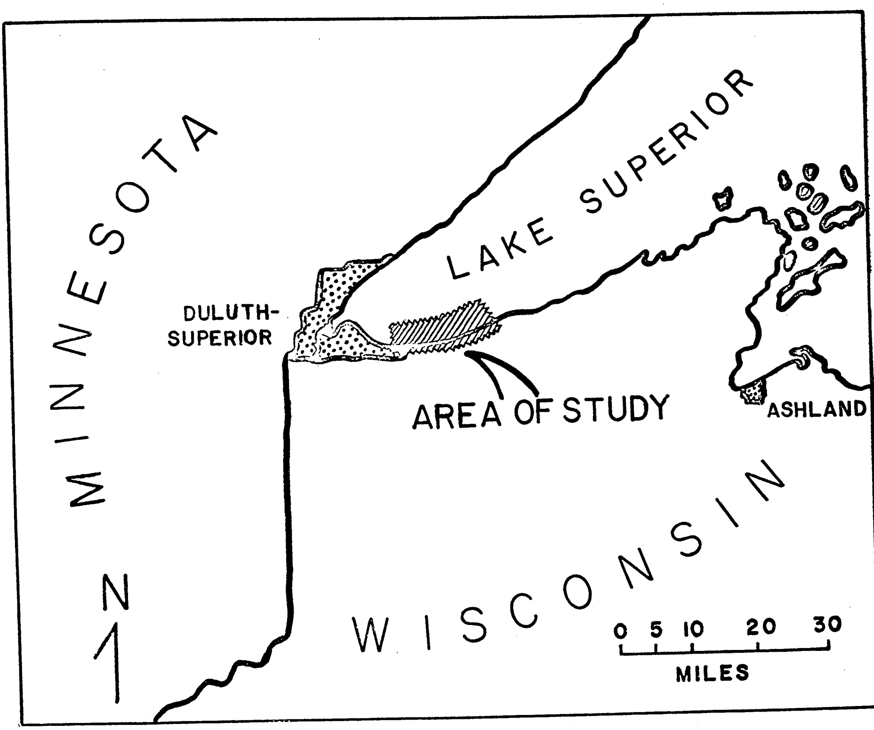

FIGURE 1. Area of Study in Western Lake Superior.

Five data collecting stations were established at equal intervals along the shore as indicated in figure 2. Triangulation points for use by the boat party in positioning along the traverse lines were located using the 1954 1:24,000 Superior Topographic Quadrangle Sheet, Aerial Photographs, and Hydrographic Charts.

The five traverse lines were oriented at right angles to a line parallel to the shoreline at the appropriate station. Standard plane table triangulation methods were utilized to map the location of the offshore stations along the traverse lines. The traverse lines were spaced at half-mile intervals and extended offshore to a water depth of thirty feet, the operational limit of the equipment.

Four data collecting stations were located along each traverse line: at the shore, and where the depth of the bottom was ten, twenty, and thirty feet. Samples were taken along the traverse lines at water depth intervals of ten feet, from surface to bottom, to a maximum depth of thirty feet. A set of ten samples of water and four sediment samples were obtained per traverse. Maximum distance offshore at the thirty foot depth was 0.8 miles while minimum distance was 0.4 miles.

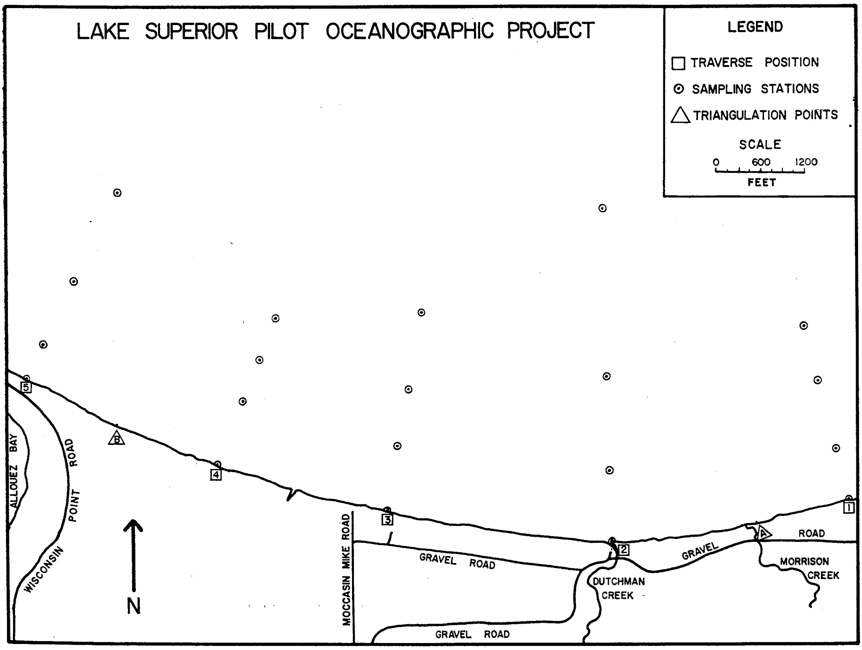

FIGURE 2. Data Collecting Stations.

METHODS

A seventeen foot boat with ten horsepower motor was available. The boat crew maintained position along the traverse lines by visual alignment of markers previously erected on shore and oriented using a Brunton Pocket Transit. The positions of the sample collecting stations were then plotted on the base maps.

Water samples were taken at the surface, at depths of ten foot intervals, and at the bottom. For example, at the thirty-foot depth station along each traverse, one bottom sediment sample and two sets of water samples were collected. Separate samples were obtained for dissolved oxygen analysis. Each suite of water samples thus consisted of four aliquots collected; from the surface, at a depth of ten feet, twenty feet, and at the bottom.

The size distribution of sands along the South Shore of Lake Superior was examined. Significant qualitative changes in the lithology were noted. Sediment samples were obtained at each traverse station with a Peterson Dredge. These bottom samples were oven dried and 100 gram aliquots were retrieved from a Jones Sediment Splitter. This sample was passed through a nest of ten U. S. Standard Sieves and Ro-Tapped for a period of five minutes. The various size fractions were regarded as percentages of the total weights of each aliquot.

A grain-size frequency distribution of material from each sample station was then plotted as a comparative curve of cumulative frequency. From these curves the significant parameters of median diameters, coefficient of sorting, skewness and kurtosis (the latter two representing the first and second moments of dispersion) were calculated.

Water turbidity was measured at each offshore station by use of a Secchi Disk. All observations were made under conditions of direct sunlight and within a three-week period in October 1967. Sunlight was of approximately the same intensity during all observations.

The pH of the water samples was obtained by means of a Beckman Model G pH Meter with Sargent No. S-30072-15 combination electrode. Freas type conductivity cells with cell constants of approximately 0.3 reciprocal ohms were used in conjunction with a Model RC Conductivity Bridge from Industrial Instruments Incorporated operating at 1000 Hz to determine the specific conductance.

Dissolved oxygen in parts per million was determined by the Iodometric Method, not using the azide modification (Standard Methods, 1965). Values for total dissolved solids were determined by evaporation of a 25.00 milliliter water sample at 105° C. in a platinum crucible.

RESULTS

The sediment groups identified by median size analysis are derived from three sources. The first is continental clastic glacial till of Wisconsin age (minimum age of 10,000 ± 2,000 years) which forms the surface stratigraphic unit throughout much of the Great Lakes Region. The second source consists of the rather extensive Keweenawan Sandstones (age greater than 500 million years) found adjacent to the shoreline in the Apostle Island area. The third source is the Valders Red Clay which outcrops along the South Shore of Lake Superior from the Duluth–Superior area eastward to the Apostle Islands. Loy (1962) reported that while this material appears to be pure clay, sieve analysis reveals a consistency of approximately five-percent boulder to sand-sized particles. Valders Clay was deposited as a result of sedimentation in glacial Lake Duluth and is of post-Wisconsin age.

Median grain size of the lake sediments ranged from a negative 2.70 ϕ (small pebbles) to a positive 3.05 ϕ (very fine sand) value (figure 4.). Along the typical traverse, medium-sized sand particles were found high on the beach and in the littoral zone. Fine sand particles were recorded at the ten foot and twenty foot depths and very fine sand particles were dredged at the thirty foot depth.

Using Trask statistics (Trask, 1932), the quartile deviation (coefficient of sorting) varied from 1.51 ϕ to 0.69 ϕ indicating well sorted clastics with all calculations based on phi scale ($-\log_2$) (see figure 3). The skewness (symmetry) ranged from a negative 2.21 to a positive 1.09, while the kurtosis (peakedness) ranged from a negative 0.42 to a negative 0.2.

On this basis bottom contours were mapped and the areal distribution pattern of the median diameter size grades of the lake bottom sediment indicated (see figure 4). Translated into the Wentworth Grade Scale (1922) lake bottom material in the study area ranged from granules to very fine sand.

This wide range in particle size reflects the active erosion presently existing in the area studied. As figure 4 indicates, the coarse sediment is located adjacent to the shoreline and sediment size decreases with an increase in distance offshore. The division between fine and very fine sand occurs approximately one-half mile offshore.

Isolated pockets of pebbles are found occasionally along the South Shoreline. These pockets are residuals resulting from the reworking of banks of Valders Red Clay which as indicated above contains a small percentage, by weight, of boulders. Large volumes of this clay are eroded and reworked during periods of lake storms

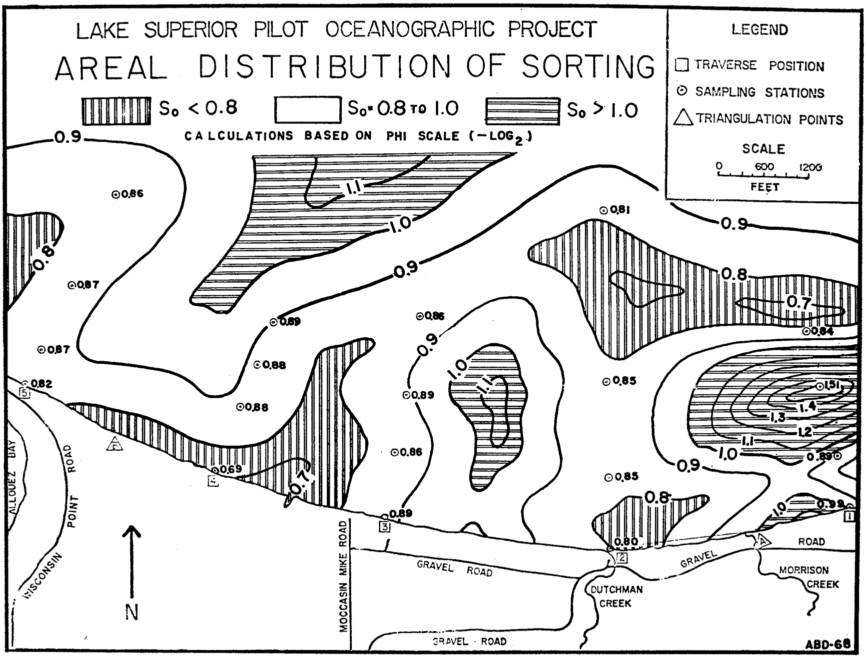

FIGURE 3. Areal Distribution of Sedimentary Particles (calculations based on Phi Scale, $-Log_2$).

and frost heaving. After the fine clay is transported offshore by lake currents the boulders are concentrated in pockets and slowly transported parallel to the shoreline by longshore currents.

Dispersion of a fraction of these gravels occurs by a process described by Dickas and Lunking (1968). Blocks of clay eroded from the banks and carried into the lake are reworked into tri-axial ellipsoids. The tri-axial "mudball" acquires a layer of pebble armour. The armoured mudballs are then carried by the current and cast upon the beach where the armour plate of gravel and sand spalls off as the hydrous clay mud-ball core desiccates. The result is a small residue of pebbles on an otherwise finely-sorted beach sand. It should be emphasized that these small pebble residuals are not the same as those of much greater volume caused by longshore current sorting along the beach.

Anticipated exceptions to the offshore median diameter particle size decrease occur adjacent to the mouth of Morrison Creek (see figure 4). At this location a submerged sand bar trends 55 degrees west of north. The highest portion of this bar is composed of granules and pebbles and is centered approximately 1800 feet

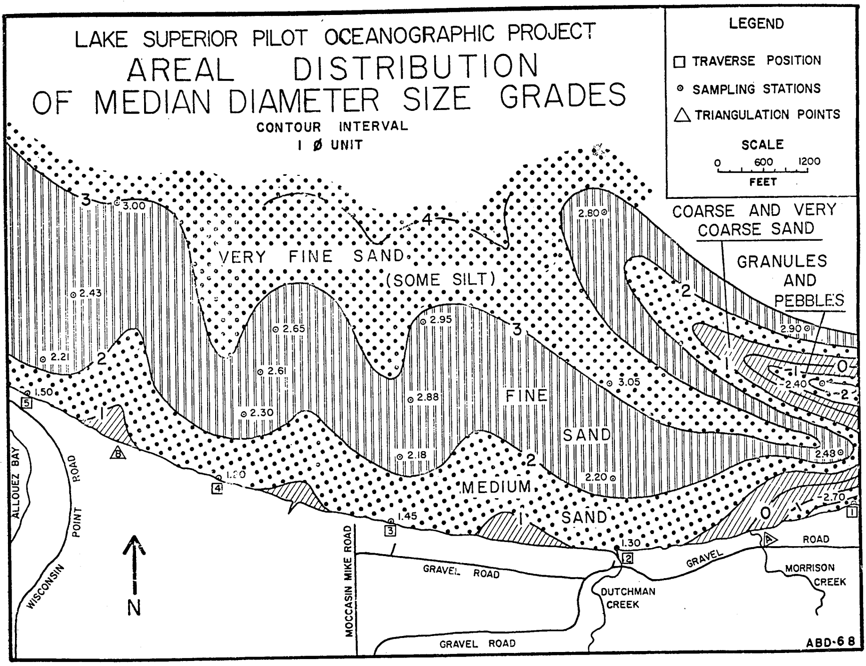

FIGURE 4. Areal Distribution of Median Diameter Size Grades of Sands Particles.

offshore. The shallowing water over the bar permits westerly-moving longshore currents to winnow out the finer clastic elements leaving the coarse sediment. This winnowing activity is also related to the increase in turbidity noted in the vicinity of the bar (figure 5).

The orientation of this bar cannot, at this time, be attributed to any particular type of lake currents. A more complete understanding of surface current activity requires a thorough study of the variable wind patterns in the immediate vicinity of the Lake Superior study area.

The average depth of visual extinction of the Secchi Disk at all stations was 2.95 meters (8′ 3″) and ranged from a minimum value of 1.67 meters (5′ 6″) to a maximum of 3.81 meters (12′ 6″) (figure 5). These data indicate that wave action and longshore currents hold enough sediment in suspension to decrease the water transparency below that determined in mid-lake where Loy (1962) reported values of 14 meters. Figure 5 indicates an apparent increase of water transparency to the northwest which may be due to the lessening influence of the sand bar which is crossed by traverses one and two.

pH ranged from a low value of 7.49 to a high of 8.40 (see table 1). The average value was 7.89. These appear to be in agreement with the Silver Bay study from which results of 7.8 pH units were reported (Swain and Prokopovich, 1957.) The higher values as compared with samples obtained at Silver Bay, Minnesota, may be due to increased leaching of alkaline earths from the red clays along the South Shore of Lake Superior. Average pH unit values for all sample stations by depth were 7.91 at the surface, 7.88 at ten feet, 7.88 at twenty feet, and 7.85 at thirty feet.

Specific conductance (k x 10^6 ohm $^{-1}$ Cm $^{-1}$ at 25°C.) had values ranging from 96.5 to 126.3 (see table 2). The average was 102.3. Homogeneity was within reasonable limits and indicated that samples from depths to thirty feet were within the active mixing zone. Averaging values by depth were 105.1 at the surface, 100.9 at ten feet, 100.9 at twenty feet, and 98.5 at thirty feet.

Dissolved oxygen values ranged from an average of 10.8 parts per million at the surface layer to 10.5 parts per million at the thirty foot level. Thus, there was no significant variation in parts

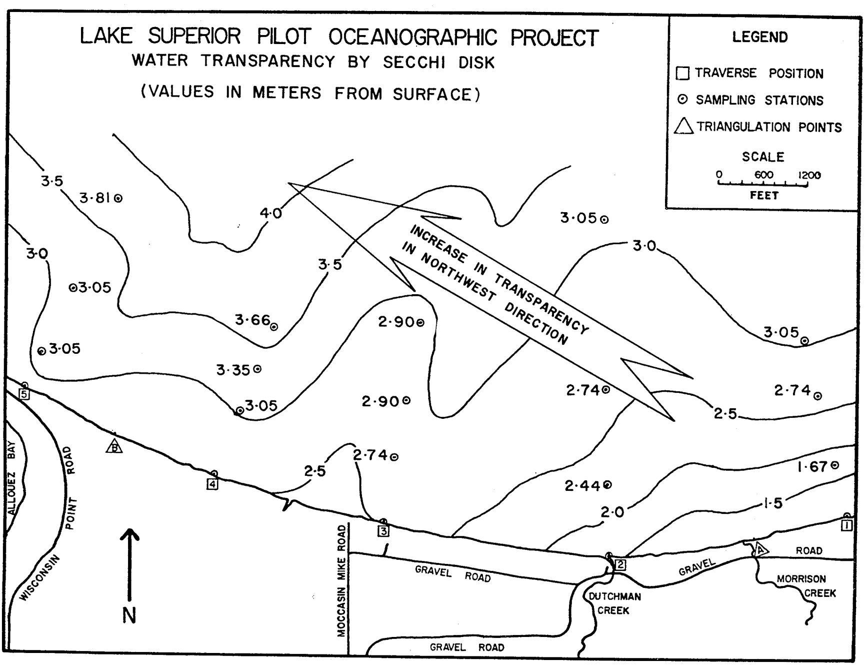

FIGURE 5. Water Transparency by Secchi Disk (values in meters from surface).

TABLE 1. *pH* OF LAKE WATER.

SAMPLE STATION[1]	TRAVERSE POSITION				
	1	2	3	4	5
0–1	7.90	8.05	7.68	8.40	7.49
10–a	8.31	7.89	7.98	7.91	7.97
10–b	7.88	7.85	7.72	8.06	7.97
20–a	7.68	7.82	7.58	7.94	7.93
20–b	7.72	7.86	7.96	7.68	7.88
20–c	7.80	8.10	7.61	7.73	7.66
30–a	7.89	7.82	8.02	7.90	8.00
30–b	7.83	8.14	7.84	7.87	7.92
30–c	7.83	8.07	8.21	7.81	8.00
30–d	7.85	7.90	7.59	8.14	7.78

[1]The number of the sample station is the maximum depth at the station. The letter 'a' is the surface sample; 'b' is at 10′ depth; 'c' is 20′ depth; etc.

per million from one depth to another and apparently the samples were all obtained from the mixing zone. However, the slightly higher surface readings in parts per million of dissolved oxygen concurs with the findings of Putnam and Olson (1960), that parts per million of dissolved oxygen and oxygen saturation (%) were both higher at the surface. With one exception shore surface readings were higher than from offshore samples.

Putnam and Olson's observations further indicate that during a sampling period at Knife River Station (L-16), Lake Superior on September 16, 1959, the parts per million of dissolved oxygen were approximately comparable with results obtained in the present study ranging from sampling station averages of 10.6 to 11.3.

TABLE 2. SPECIFIC CONDUCTANCE OF LAKE WATER.
(VALUES IN K x 10^6 OHM^{-1} CM^{-1})

SAMPLE STATION	TRAVERSE POSITION				
	1	2	3	4	5
0–a	107.8	121.6	105.3	126.3	104.2
10–a	107.8	100.0	104.2	98.1	104.5
10–b	104.7	99.6	102.1	104.8	97.3
20–a	99.2	100.5	104.2	99.1	109.7
20–b	104.7	102.1	104.2	100.5	96.5
20–c	100.0	102.2	99.2	102.4	100.8
30–a	99.9	104.2	100.4	104.5	99.9
30–b	100.0	98.9	102.2	99.4	96.6
30–c	100.2	99.6	104.4	100.2	99.6
30–d	99.4	99.7	98.9	97.0	97.6

Putnam and Olson also found oxygen saturation for September 10, 1959, to be near or greater than 100% for the zone covered by the present study.

Beeton (1966) found the dissolved oxygen content of Lake Superior, except in certain bays, to be near saturation at all depths. It is therefore presumed that dissolved oxygen is near or greater than 100% saturation in the study area.

Total solids determined by evaporation of a 25.00 milliliter water sample at approximately 105° C. in a platinum crucible averaged 71.5 parts per million.

CONCLUSIONS

Data indicates a standard distribution of the Lake Superior clastics within the area studied which is not unusual considering the high energy conditions of the lake shoreward of the six-fathom depth. The few anomalous zones recorded are attributed to small lake floor surface pockets of clay being transported to lower depths. Derived from gravity slumping along the South Shoreline, such clays were initially deposited in the area as lacustrine sediments during the Wisconsin sub-epoch in Lake Duluth, the ancestral glacial high-watermark of Lake Superior.

Generally the specific conductance average value decreases slightly from shoreline to the thirty foot area and also decreases from surface to bottom. The specific conductance values are approximately equivalent to the specific conductance of a 7×10^{-4} M KCl solution.

pH unit values obtained were quite uniform except for a few anomalies which may have some significance. The highest and lowest values occur at the shoreline which may be indicative of leaching. An average of pH unit values at each sample station indicates that the area is quite homogeneous.

Dissolved oxygen values were nearly constant with average values ranging from 10.5 to 10.8 parts per million. There was no significant variation in parts per million from one depth to another and apparently the samples were all obtained from the mixing zone. Highest values were obtained from shoreline stations which are the sites of greatest water agitation.

The average of random samples for total dissolved solids was determined to be 71.5 parts per million.

Ultimate conclusions are difficult to assess. It was not possible to locate the mixing zone utilizing the data obtained. While much more information should be gathered, the data collected are assumed to be normal considering the near-pristine condition of Lake Superior.

The project has served as an initiation into the field of water study for an interdisciplinary group and has established a base line for further investigation.

The findings presented apply only to the study area and are not intended to indicate an interpretation of the entire dynamic processes operating in Lake Superior. Since, however, the study was along and adjacent to open lake shoreline, it is expected that the findings may validly be employed in a comparative study of other unprotected shoreline sectors of Lake Superior.

Acknowledgments

The authors are grateful to the late Mr. Edward Moyer, who was dedicated to the protection and conservation of Lake Superior, and who provided the boat and motor for use in this study.

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VEGETATIONAL PATTERNS AND ORDINATION IN CEDARBURG BOG, WISCONSIN

Thomas Foster Grittinger[1]

INTRODUCTION

Cedarburg Bog, located only 25 miles north of Milwaukee, is one of the largest bog areas in southern Wisconsin. This bog, occupying the basin of a postglacial lake, lies in sections 20, 21, 28, 29, 31, 32, and 33, in the township of Saukville (T11N, R21E) in Ozaukee County (Figure 1). An aerial photograph of this 2,000 acre bog reveals numerous patterns throughout its surface (Figure 2), which reflect differences in the vegetation. The peripheral portions of the bog generally appear dark in tone and of coarse texture, whereas around the margins of the lakes the tone is lighter and the texture finer. Large areas near the center of the bog appear to be composed of alternating dark and light bands. Other parts are sharply distinct from nearby areas, often giving a rectilinear effect, and still other regions have less well defined patterns. Since preliminary observations on the ground confirmed these patterns, and the only previous research in Cedarburg Bog concerned plant species and associations encountered (Cutler, 1935) and water level changes (Cutler, 1936), further study was indicated.

The first objective concerned a description of the vegetation types which form these patterns and the mapping of the major cover types present within the bog. The second objective involved the quantitative analysis of the vegetation and the communities present by utilizing an ordination of these communities within the bog.

METHODS

Pattern Analysis and Mapping of Major Cover Types

To map vegetational patterns within Cedarburg Bog, several aerial observations were made during the summer and fall of 1966.

[1] Contribution No. 2 from The University of Wisconsin–Milwaukee Field Station. This paper represents a portion of a thesis submitted in partial fulfillment of the Doctor of Philosophy Degree, University of Wisconsin–Milwaukee, 1969, and it represents a portion of a paper presented at the 99th annual meeting of the Wisconsin Academy of Sciences, Arts and Letters. The author wishes to express appreciation to P. B. Whitford for advice and counsel throughout the course of this work, to M. L. Heinselman for positive identification of the string bog, to P. J. Salamun and A. L. Throne for taxonomic assistance, to G. W. Argus for identification of willows, to W. H. Ellis for identification of red and silver maple hybrids, and to J. H. Zimmerman for identification of sedges and grasses. Financial aid was provided by a National Science Foundation Summer Fellowship for Graduate Teaching Assistants, a University of Wisconsin–Milwaukee Graduate Fellowship in Botany and The University of Wisconsin, University Center System. The author is Assistant Professor of Botany and Zoology at the University of Wisconsin, Sheboygan County Campus.

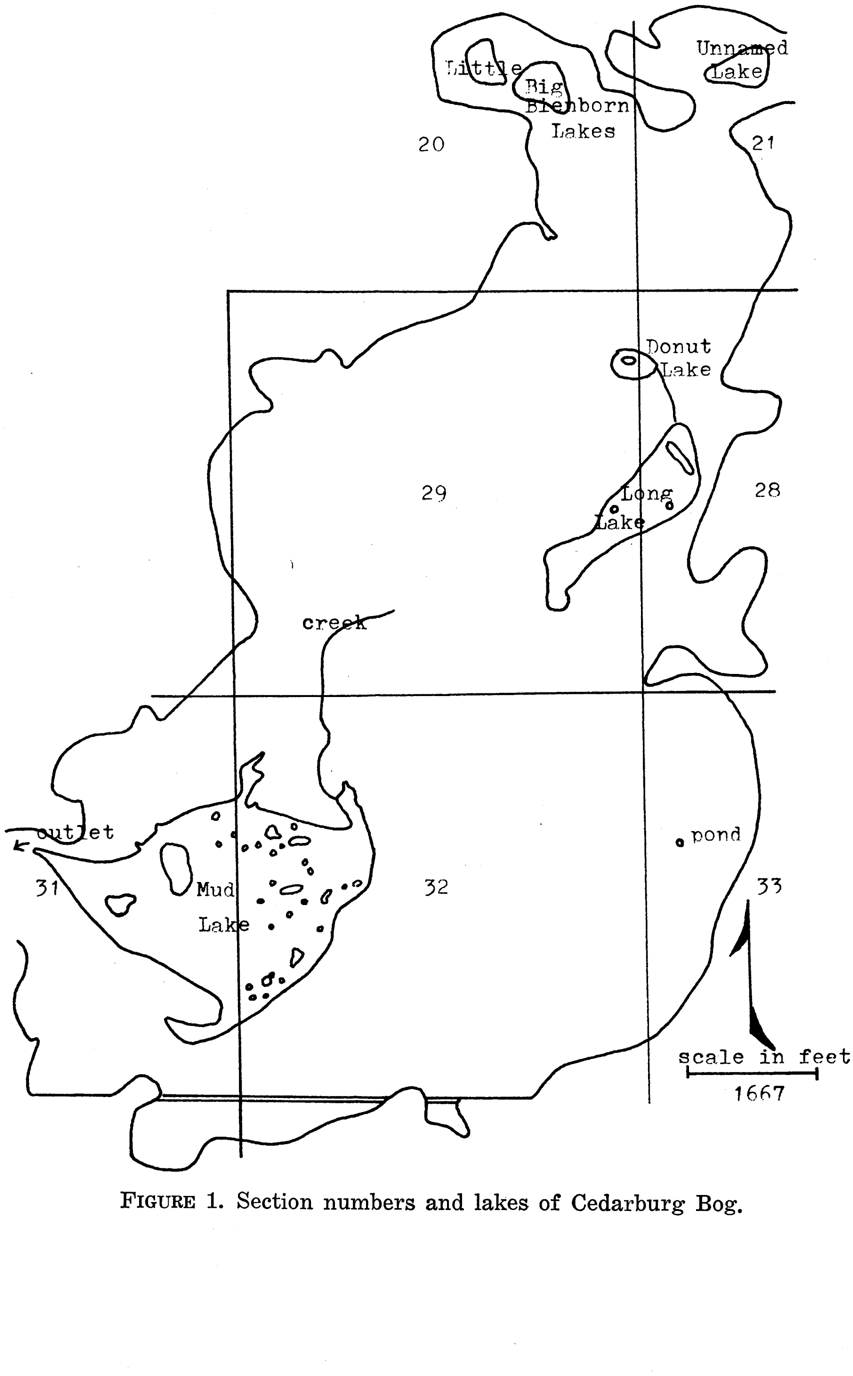

FIGURE 1. Section numbers and lakes of Cedarburg Bog.

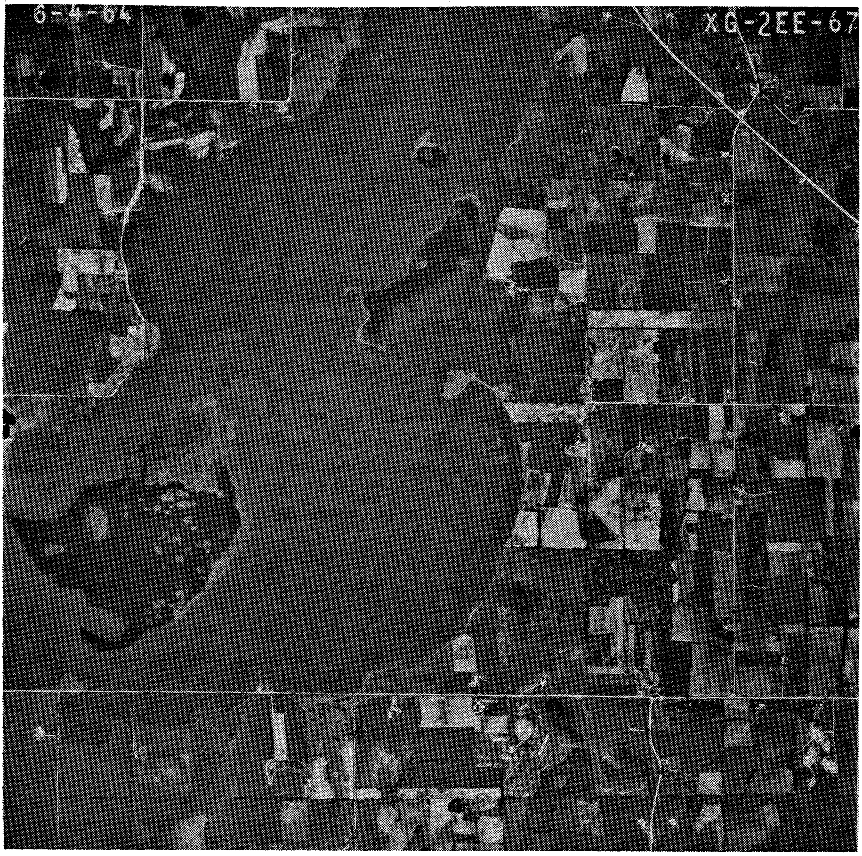

FIGURE 2.

Also, numerous ground reconnaissance trips were carried out during the winters of 1966–67 and 1967–68. References were constantly made to aerial photographs and to topographic maps to corroborate these observations.

Under stereoscopic examination, two aerial photographs taken from slightly different angles reveal both the topography and vegetational characteristics (Losee, 1942). The characteristics of the vegetation, other than height, were analyzed by examination of photographic tone, texture, shadow, and the shape and size of crowns as suggested by Spurr and Brown (1946).

Vegetational Sampling

After the bog area had been mapped, the general vegetation types were studied quantitatively, using the transect method for cover values and the quarter method for trees and saplings. Sampling lines were laid out independently of the aerial map. Thus they served to check on the accuracy of the mapping and to amplify and refine the description of the vegetation types.

Cover values for trees of all sizes, shrubs, woody vines, and some of the more conspicuous herbaceous material, e.g. the cattails and sedges, were measured by the line intercept method (Canfield, 1941; Buell and Cantlon, 1950). Such methods are useful where differences in the vegetation are evident and are to be compared with one or several factors that change between two points (Oosting, 1956). The transect method has been used to study vegetation and some environmental factors by Bauer (1936), Penfound and Hathaway (1938), and Pierce (1953).

East–west lines (lines 2, 3, 5, and 6) were placed every half mile to insure thorough coverage of the bog (Figure 3). A north–south line near Mud Lake (line 1) was added to supplement coverage in this area and terminated at the south shore of the lake. The short east–west line (line 4) was used to gain additional data since it was most accessible and had water level sampling devices for other work (Grittinger, 1969); this line ended at the creek north of Mud Lake. All of these lines were laid out by compass.

The six lines were divided into 100 foot segments, resulting in a total of 236 segments. Cover in each segment was measured by placing a tape on the ground and estimating the vertical projection of the canopy. Since the segment was 100 feet long, the total intercept of any given species could easily be expressed in per cent cover. This was converted to relative cover by dividing the total intercept of a species within the 100 feet by the total intercept of all species and multiplying by 100.

Relative density, relative frequency, and relative dominance of trees and saplings were determined by the quarter method. The merits of the quarter method are discussed by Cottam and Curtis (1956). This method had been employed by Curtis (1950) based on a system of recording "witness trees" used by the Federal Land Survey in the last century (Cottam, 1949; Stearns, 1949). A point was placed at the center of every 100 foot segment.

Ordination and Compositional Index

Ordination has been defined as the "arrangement of data of a continuous and non-discrete sort into an orderly spatial pattern" (Curtis, 1959). This method, unlike classification techniques, relies less on subjective judgement for placing vegetational types in a successional pattern. While the general classification and mapping permits an introduction to the problem, the ordination of data

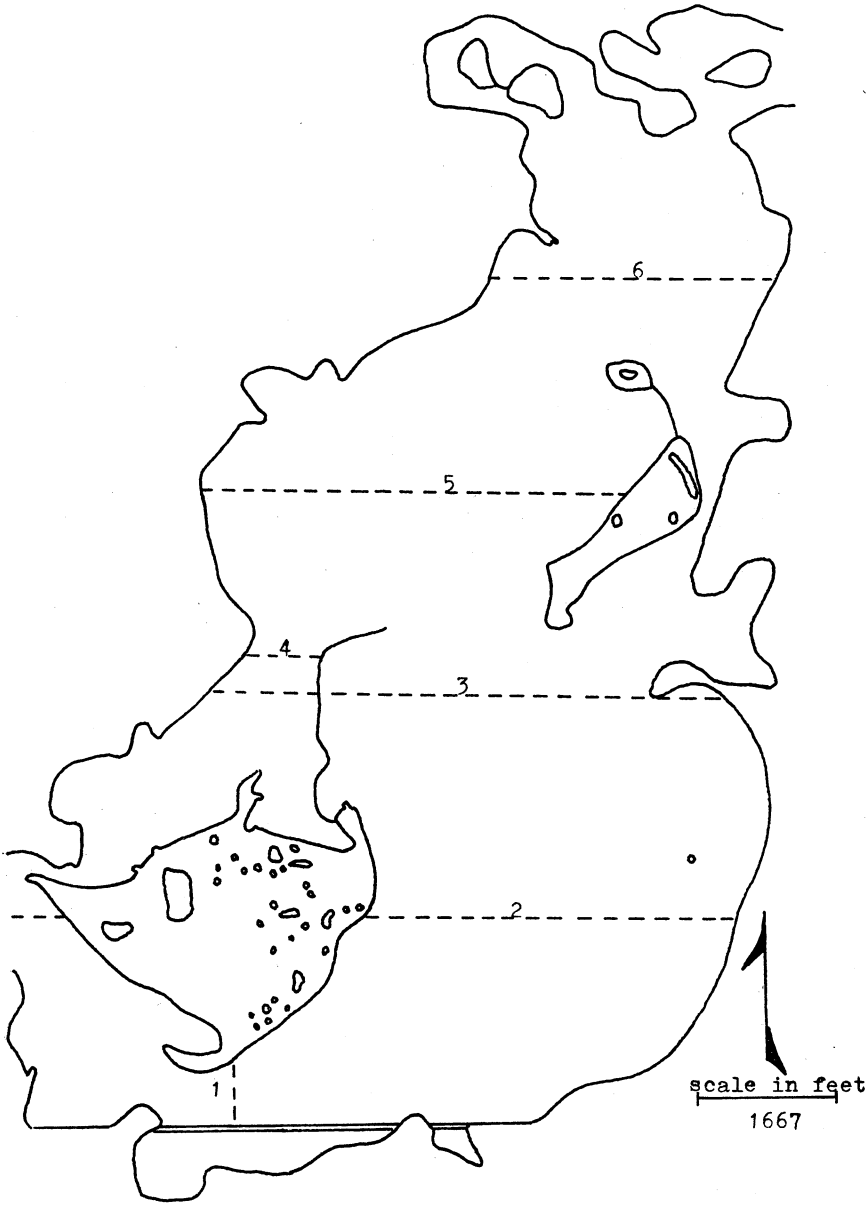

FIGURE 3. Line intercepts.

will, it is hoped, permit a more thorough and objective study of the variation within Cedarburg Bog.

To use an ordination technique, it was necessary to establish adaptation numbers for the woody and the major herbaceous species in the bog. Curtis and McIntosh (1951) used a similar method with upland forest trees. An index of joint occurrence was used in ranking all species according to their ecological responses. This index, used by Swindale and Curtis (1957), was calculated by finding the number of quadrats in which two species occur together as a percentage of the number of quadrats of occurrence of the less common species of this pair. In the present study, 100 foot segments of the line intercepts were used rather than quadrats. The species were then placed in an order based on similarity of behavior (Guinochet, 1955). As in Swindale and Curtis (1957), the species with high indices of joint occurrence are placed close together and those with low indices are placed far apart in the order.

To facilitate ordination, additional information gathered from field experience and the literature was used. This involved the knowledge that some species have fairly predictable ecological requirements, i.e. a given species will be more important on the mesic end rather than the wet end of a continuum ranging from emergent aquatics to a mesic situation, or vice versa. Reference species were chosen as follows: white birch (*Betula papyrifera* Marsh.)* was arbitrarily used to represent a more mesic condition than bog birch (*Betula pumila* L. var. *glandulifera* Regel) or the emergent aquatic sedge (*Carex* spp.) mat, and the emergent sedges were used to represent the most wet situation since they were abundant next to the edge of the water. The white birch is typical of the dense forest nearer the outer edges of the bog. Bog birch lies midway between the two extremes. All other species were compared to these three on the basis of indices of joint occurrence. For the sake of clarity, three different lines were used with one of these three species as a reference point on each line. All of the other species were placed along these lines in an order determined by their joint occurrence indices. For example, one line had white birch as a reference point, another had bog birch, and the third had emergent sedges. Each species was compared to each of these three species, and then placed an appropriate distance from the reference point. A linear scale was computed by subtracting the index from one and multiplying by 20, an arbitrary number. The results were then measured out in centimeters along the line. Thus two species with an index

* The nomenclature used here is according to Fernald (1950).

of 0 (never occurring together) would be placed 20 centimeters apart, and two species with an index of 1 (always together) would be placed on the same spot on the line.

A scale was devised, similar to that of Curtis and McIntosh (1951), but with emergent aquatics at one end and the mesic upland hardwoods at the other. A scale from 1 to 10 was used with the low value to represent those species most likely to be found at the edge of the water with the emergents and 10 to represent those species likely to be present in an upland forest. In addition to the three original species, yellow birch (*Betula lutea* Michx.), cedar (*Thuja occidentalis* L.), tamarack (*Larix laricina* (DuRoi) K. Koch), and a flat, open sedge mat area referred to as the *Rhynchospora–Carex* mat (dominated by *Rynchospora alba* (L.) Vahl and *Carex lasiocarpa* Ehrh. var. *americana* Fern.) were found to lie in a similar sequence on all three of the ordination lines. An adaptation number was then assigned to each of the five species and two associations based on their distance from each other and from the ends of the 20 centimeter lines. The emergent aquatic mat was given a value of 1.0, the *Rhynchospora–Carex* mat 2.0, bog birch 3.5, tamarack 5.0, cedar 6.0, white birch 7.0, and yellow birch 8.0. Sugar maple (*Acer saccharum* Marsh.), an infrequent species in the bog, was assigned a value of 10.0.

The rest of the species were then assigned adaptation numbers on the basis of comparisons with the species and groups designated above. For example, winterberry (*Ilex verticillata* (L.) Gray) has a joint occurrence of 0.062 with respect to the emergents, 0.325 compared to *Rhynchospora–Carex,* 0.698 compared to bog birch, 0.875 compared to tamarack, 0.830 compared to cedar, 0.610 compared to white birch, and 0.470 compared to yellow birch. Thus, the winterberry was given an adaptation number which would place it between tamarack and cedar, i.e. 5.5. In a few cases the indices were high over a wide scale, and an adaptation number was assigned on the basis of field experience and literature.

A compositional index for each segment was calculated by summing the products of the adaptation number and the relative cover value for each species in the segment. For example, a 100 foot segment with 60% cedar, 30% tamarack, and 10% dogwood would have these relative cover values multiplied by 6.0, 5.0, and 5.0 respectively to produce a compositional index after summation of 560. The possible range of these index numbers is from 100 for a segment of pure cattail or emergent sedges to 1,000 for a segment of pure sugar maple. Thus each segment with its accompanying point had a value that was determined by the relative cover and the ecological response of the individual species found along that particular segment. According to Curtis (1959), this method of summing weighted values, which combines a measured value of plant quantity with an estimate of plant response, has been used by a number of ecologists (Whittaker, 1952; Ellenberg, 1952) and has been discussed by Whittaker (1954).

The ecological response of the individual species was analyzed by plotting the relative cover of a single species against the ordination after arranging all segments by numerical order of the compositional index. These figures were made by plotting the moving averages of the averages of the relative cover within each 30 units of the ordination. The moving average was calculated by the formula:

$$B = \frac{n_1a + 2n_2b + n_3c}{n_1 + 2n_2 + n_3}$$

where B is the smoothed average of b, and n_1, n_2, and n_3 are the number of segments included in the averages a, b, and c respectively. This formula has been used in upland ordination by Brown and Curtis (1952). This procedure was carried out for many of the woody species and some of the more important herbaceous species.

The data from the relative cover analysis of each 100 foot line segment were combined for each 100 unit interval of the compositional index scale, so that all of the 100 foot line segments falling within each 100 unit interval were used to obtain the mean relative cover values for each species of tree, shrub, and some of the herbs. One hundred unit intervals were arbitrarily used for convenience.

The tree and sapling data obtained by the quarter method were computed on the basis of the same 100 unit intervals of the compositional index.

Comparison of Ordination with Mapped Patterns

Each transect segment was plotted on an overlay of an aerial photograph by its compositional index. All of the segments with compositional index values ranging from 100 to 200 were plotted with one color, those with values from 200 to 300 were plotted with another color, and so on until all of the segments were represented on the overlay. These plotted segments were then compared to the vegetational patterns and cover types. Since an extremely large aerial photograph and overlay (40″ by 40″) would be required to adequately show the mapped indices, this could not be included. However, all of the segments within each pattern given on the vegetational pattern map were summed and the mean and range of compositional index values for each type were calculated.

Results

Pattern Analysis and Mapping of Major Cover Types

On the basis of the aerial photographs and ground reconnaissance, eight major vegetational cover types were recognized within Cedarburg Bog:

1. Emergent aquatics
2. String bog or Strangmoor
3. Bog birch–leatherleaf shrub area
4. Dogwood–willow shrub area
5. Dead tamarack area
6. Conifer forest
7. Conifer–swamp hardwood forest.
8. Upland hardwood forest

These zones outlined on the map (Figure 4) are necessarily somewhat arbitrary since cover types blend one into another throughout the bog. In addition, within any larger area there are frequent cover types too small to be shown on a map of the scale given here (1 inch = 1667 feet). Where there is an obvious and intimate mixing of cover types over a given area two or more numbers are used to indicate the nature of the mixture, e.g. 4,6 indicates a dogwood–willow shrub and conifer forest mixture.

Vegetational Sampling, Ordination, and Compositional Index

The adaptation numbers assigned to the woody and the major herbaceous species of the bog are listed in Table 1.

The compositional index numbers for the 236 segments of the six transect lines in Cedarburg Bog range from 99.9 to 799.9. There are 6 segments in the 100–200 range, 16 in the 200–300 range, 28 in the 300–400 range, 53 in the 400–500 range, 117 in the 500–600 range, 13 in the 600–700 range, and only 3 in the 700–800 range, indicating that the major part of the bog is in shrub or early swamp forest stages of succession.

The ecological responses of 13 of the species are illustrated on Figures 5–7, and some of the more important ones are discussed. The results of the relative cover analysis are included on Tables 2–4 and those of the mean importance values for trees and saplings are found on Tables 5 and 6.

Comparison of Ordination with Mapped Patterns

The correspondence between the areas mapped within the bog and the compositional index values are listed in Table 7. For each cover type there is a mean compositional index value and a range of values.

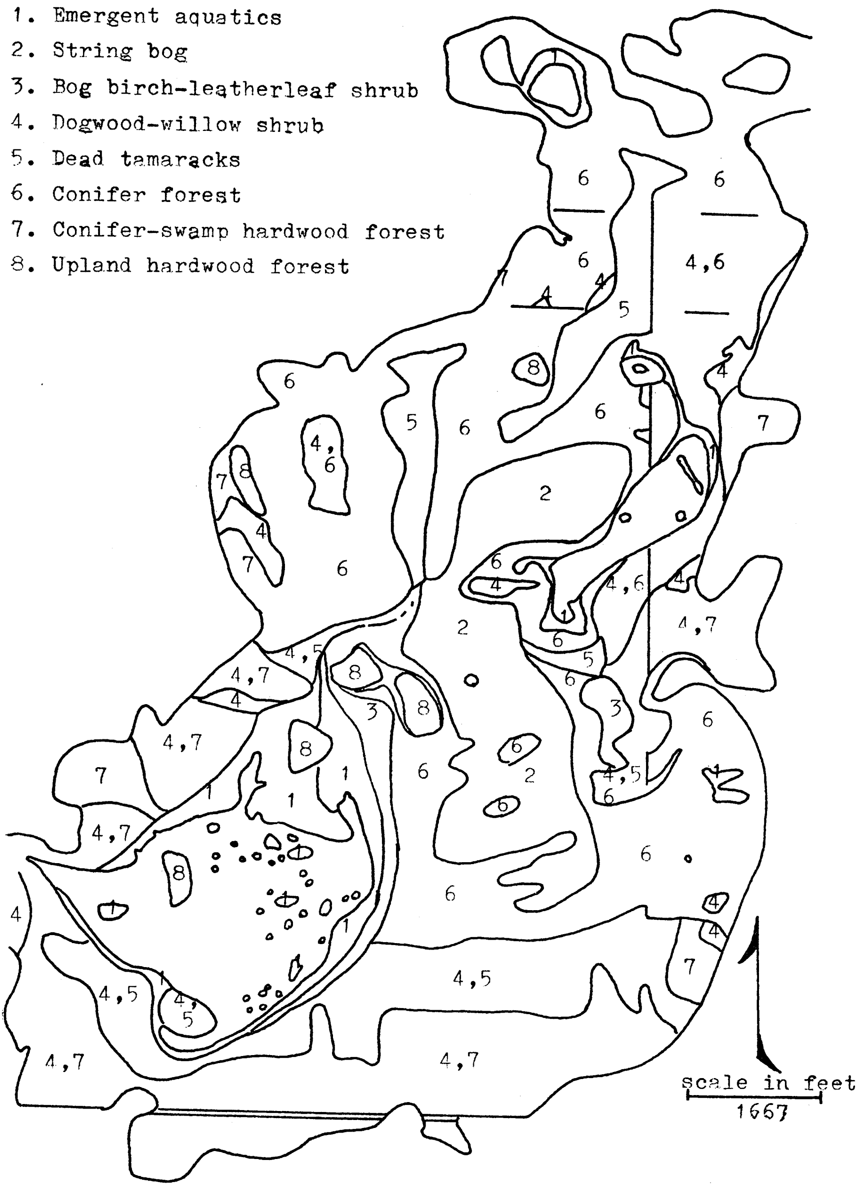

FIGURE 4. Vegetational patterns of Cedarburg Bog.

TABLE 1. ADAPTATION NUMBERS OF SPECIES IN CEDARBURG BOG.

Carex aquatilis Wahlenb.	1.0
Sagittaria sp.	1.0
Scirpus validus Vahl var. *creber* Fern.	1.0
Typha spp.	1.0
Andromeda glaucophylla Link	2.0
Phragmites communis Trin. var. *Berlandieri* (Fourn.) Fern.	2.0
Rhynchospora alba (L.) Vahl	2.0
Sarracenia purpurea L.	2.5
Betula pumila L. var. *glandulifera* Regel	3.5
Chamaedaphne calyculata (L.) Moench var. *angustifolia* (Ait.) Rehd.	3.5
Salix pedicellaris Pursh	3.5
Salix candida Flügge	4.0
Salix gracilis Anderss.	4.0
Salix serissima (Bailey) Fern.	4.0
Cornus racemosa Lam.	4.5
Gaylussacia baccata (Wang.) K. Koch	4.5
Rosa palustris Marsh.	4.5
Salix discolor Muhl.	4.5
Spiraea alba Du Roi	4.5
Alnus rugosa (Du Roi) Spreng. var. *americana* (Regel) Fern.	5.0
Amelanchier spp.	5.0
Cornus obliqua Raf.	5.0
Cornus stolonifera Michx.	5.0
Larix laricina (Du Roi) K. Koch	5.0
Lonicera dioica L.	5.0
Lonicera oblongifolia (Goldie) Hook.	5.0
Lonicera villosa (Michx.) R. & S.	5.0
Nemopanthus mucronata (L.) Trel.	5.0
Pyrus melanocarpa (Michx.) Willd.	5.0
Rhus Vernix L.	5.0
Vaccinium myrtilloides Michx.	5.0
Viburnum trilobum Marsh.	5.0
Ilex verticillata (L.) Gray	5.5
Juniperus communis L. var. *depressa* Pursh	5.5
Lonicera canadensis Bartr.	5.5
Parthenocissus sp.	5.5
Picea mariana (Mill.) BSP	5.5
Rhamnus alnifolia L'Her	5.5
Ribes sp.	5.5
Salix Bebbiana Sarg.	5.5
Solanum Dulcamara L.	5.5
Viburnum Lentago L.	5.5
Vitis riparia Michx.	5.5
Populus tremuloides Michx.	6.0
Rhamnus cathartica L.	6.0
Rhamnus Frangula L.	6.0
Rubus sp.	6.0
Thuja occidentalis L.	6.0
Acer rubrum L.	7.0
Acer rubrum L. x *A. saccharinum* L.	7.0
Betula papyrifera Marsh.	7.0
Fraxinus nigra Marsh.	7.0
Fraxinus pennsylvanica Marsh. var. *subintegerrima* (Vahl) Fern.	7.0
Ulmus americana L.	7.0
Betula lutea Michx.	8.0
Fraxinus americana L.	8.0
Taxus canadensis Marsh.	8.5
Prunus virginiana L.	9.0
Tilia americana L.	9.0
Acer saccharum Marsh.	10.0
Ostrya virginiana (Mill.) K. Koch	10.0
Viburnum acerifolium L.	10.0

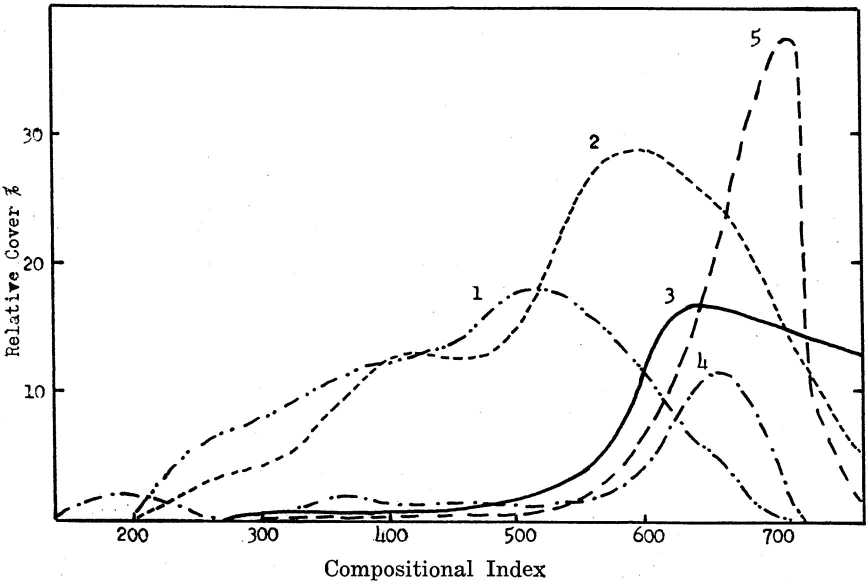

FIGURE 5. Behavior of the major bog trees along compositional gradient. 1, tamarack; 2, cedar; 3, white birch; 4, black ash; 5, elm.

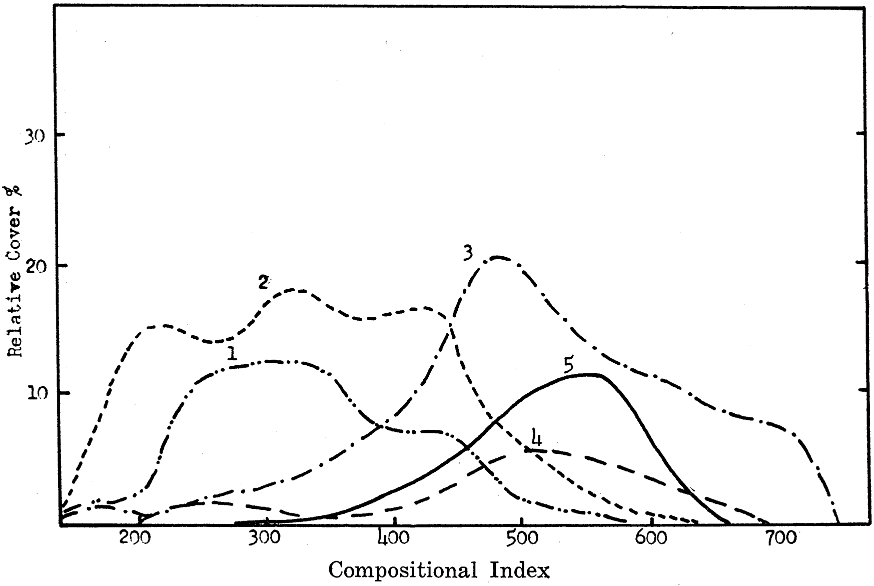

FIGURE 6. Behavior of the major bog shrubs along compositional gradient. 1, leatherleaf; 2, bog birch; 3, red osier dogwood; 4, poison sumac; 5, winterberry.

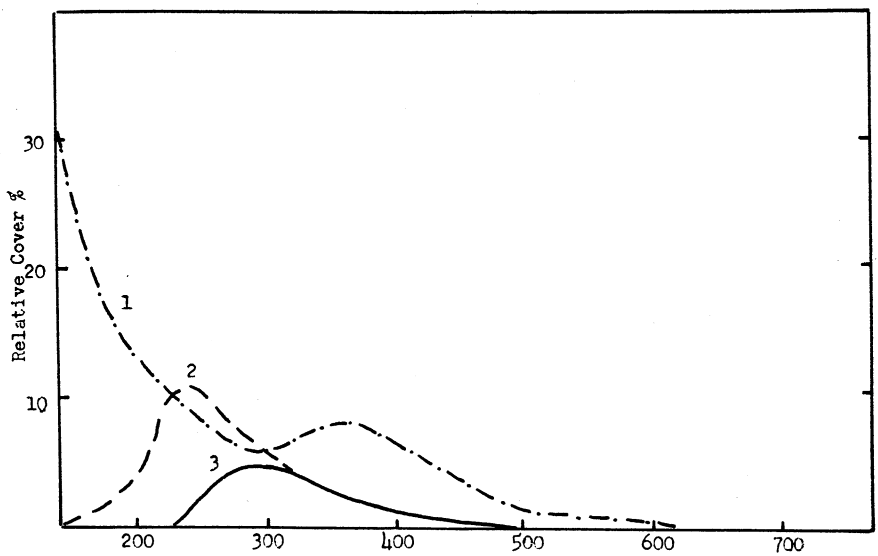

FIGURE 7. Behavior of selected bog herbs along compositional gradient. 1, cattail; 2, reed grass; 3, pitcher-plant.

TABLE 2. RELATIVE COVER MEANS OF TREES IN 100 UNIT COMPOSITIONAL INDEX INTERVALS.

SPECIES	100–200	200–300	300–400	400–500	500–600	600–700	700–800
Larix laricina		5.79	9.46	13.93	16.50	6.44	
Thuja occidentalis		3.10	7.25	13.69	22.18	24.90	7.50
Fraxinus nigra	1.22		1.35	.74	1.79	9.34	4.90
Ulmus americana			.26	.23	1.74	17.75	3.73
Betula papyrifera			.42	.76	3.05	16.85	15.87
Betula lutea					.28	2.76	2.13
Fraxinus americana						.44	20.53
Tilia americana					.02	1.72	12.33
Acer saccharum							13.80
Ostrya virginiana							8.03
Subtotal*	1.22	8.89	18.85	29.82	46.77	81.39	88.99

*Subtotal includes trees with less than 1.0% relative cover in any interval:
Acer rubrum
Acer rubrum x *Acer saccharinum*
Fraxinus pennsylvanica var. *subintegerrima*
Populus tremuloides

TABLE 3. RELATIVE COVER MEANS OF SHRUBS IN 100 UNIT COMPOSITIONAL INDEX INTERVALS.

SPECIES	100–200	200–300	300–400	400–500	500–600	600–700	700–800
Chamaedaphne calyculata	1.70	8.53	11.10	5.50	.98		
Betula pumila	.50	13.97	17.91	14.00	2.43	.18	
Salix serissima		1.19		.51	.10		
Salix gracilis	1.03	1.79	2.96	5.56	1.42	.15	
Salix discolor		.82	2.95	4.07	2.17		
Alnus rugosa	.30		.08	2.78	2.76		
Cornus obliqua			.78	.67	1.13		
Rhus Vernix		1.55	.55	2.97	4.75	.62	
Cornus stolonifera	.60	1.79	5.87	15.07	15.83	6.39	4.13
Juniperus communis		.14	.55	1.53	1.45		
Ilex verticillata		.06	.09	4.92	10.72	.93	
Solanum Dulcamara	.60		.40	1.03	2.73	2.72	
Salix Bebbiana		.24	.65	.82	1.32	1.98	
Rubus sp.			.31	.03	.15	1.06	
Rhamnus Frangula			.02	.01	.10	1.04	.17
Taxus canadensis					.12	.07	2.03
Prunus virginiana					.04	.88	3.63
Viburnum acerifolium							1.00
Subtotal*	5.16	32.15	47.59	62.26	52.51	18.36	10.96

*Subtotal includes shrubs with less than 1.0% relative cover in any interval:

Amelanchier spp.
Andromeda glaucophylla
Cornus racemosa
Gaylussacia baccata
Lonicera canadensis
Lonicera dioica
Lonicera oblongifolia
Lonicera villosa
Nemopanthus mucronata
Parthenocissus sp.
Pyrus melanocarpa
Rhamnus alnifolia
Rhamnus cathartica
Ribes sp.
Rosa palustris
Salix babylonica
Salix candida
Salix humilis
Salix pedicellaris
Sambucus canadensis
Spiraea alba
Vaccinium myrtilloides
Viburnum Lentago
Viburnum trilobum
Vitis riparia

TABLE 4. RELATIVE COVER MEANS OF SELECTED HERBS IN 100 UNIT COMPOSITIONAL INDEX INTERVALS.

SPECIES	100–200	200–300	300–400	400–500	500–600	600–700	700–800
Carex aquatilis	46.48	8.80	4.98				
Scirpus validus	13.17	.06					
Sagittaria sp.	5.68						
Typha sp.	28.45	5.04	8.55	3.06	.55	.15	
Phragmites communis		6.71	2.88	.38			
Rhynchospora alba and *Carex lasiocarpa*		33.70	15.35	3.89	.18		
Sarracenia purpurea		4.54	1.76	.52			
Subtotal*	93.85	58.85	33.52	7.85	.73	.15	

*Subtotal includes herbs with less than 1.0% relative cover in any interval: *Hypericum* sp.

TABLE 5. MEAN IMPORTANCE VALUES OF TREES BY QUARTER METHOD FOR 100 UNIT COMPOSITIONAL INDEX INTERVALS.

SPECIES	100–200	200–300	300–400	400–500	500–600	600–700	700–800
Larix laricina		134.5*	107.9	166.5	116.1	59.4	
Thuja occidentalis		165.5*	122.3	94.6	111.7	85.3	
Fraxinus nigra	300.0*		32.8	14.8	20.4	26.6	29.4
Fraxinus pennsylvanica var. *subintegerrima*			6.3	4.7			
Ulmus americana			30.3	19.2	17.4	57.4	
Acer rubrum					5.3		
Betula papyrifera					19.1	52.6	88.7
Betula lutea					3.4	6.7	
Fraxinus americana							79.3
Tilia americana						12.2	23.1
Acer saccharum							23.7
Ostrya virginiana							55.7
Total relative cover of trees %	1.2	8.9	18.8	29.8	46.8	81.4	89.0
Total trees per acre	32.6	31.4	60.6	65.4	160.0	170.2	395.1
Total basal area in square inches per acre	847.6	493.0	1502.9	1497.7	3936.0	9718.4	12801.2

Species with importance values less than 5 in any interval:
Acer rubrum x *Acer saccharinum*
Populus tremuloides
Salix Bebbiana

*It should be noted that the Importance Value is based on relative values among trees only so that, where tree cover is less than 10% of the total cover, importance value has little meaning.

TABLE 6. MEAN IMPORTANCE VALUES OF SAPLINGS BY QUARTER METHOD FOR 100 UNIT COMPOSITIONAL INDEX INTERVALS.

SPECIES	100–200	200–300	300–400	400–500	500–600	600–700	700–800
Betula pumila		6.8	3.3	3.3			
Salix gracilis				11.8	2.6		
Salix discolor		7.3	8.2	17.6	6.3		
Larix laricina	98.3	119.4	142.1	102.1	85.1	8.7	
Alnus rugosa			3.4	10.1	7.8		
Rhus Vernix			3.5	8.5	22.7	5.8	
Cornus stolonifera					0.7	11.4	
Picea mariana		6.9					
Salix Bebbiana		6.9	8.3	13.4	13.6	9.8	
Viburnum Lentago						6.3	
Thuja occidentalis		140.5*	91.9	112.0	106.6	98.3	
Fraxinus nigra	201.6*		24.5	5.0	8.9	61.4	33.9
Acer rubrum					5.2	5.6	
Ulmus americana		12.3*	8.2	1.6	9.9	22.0	
Betula papyrifera			6.7	7.4	14.6	27.7	48.4
Betula lutea					4.3	14.2	
Fraxinus americana							106.3
Tilia americana						22.9	22.6
Prunus virginiana						5.7	41.2
Acer saccharum							47.6
Total trees per acre	65.4	78.8	283.2	514.6	774.4	235.5	228.7
Total basal area in square inches per acre	281.2	220.6	934.6	1698.2	3097.6	1083.3	1166.4

Species with importance values less than 5 in any interval:
Acer rubrum x *Acer saccharinum*
Cornus obliqua
Fraxinus pennsylvanica var. *subintegerrima*
Ilex verticillata
Populus tremuloides

*It should be noted that the Importance Value is based on relative values among saplings only so that, where sapling cover is less than 10% of the total cover, importance value has little meaning.

TABLE 7. CORRESPONDENCE BETWEEN THE MAPPED AREAS WITHIN THE BOG AND THE COMPOSITIONAL INDEX VALUES.

VEGETATIONAL PATTERN	COMPOSITIONAL INDEX	
	Mean	Range
1. Emergent aquatics	159.0	99.9–277.8
2. String bog	367.6	258.1–507.1
3. Bog birch—leatherleaf shrub	394.3	267.7–543.0
4. Dogwood—willow shrub	466.4	373.8–510.6
5. Dead tamaracks	461.1	422.8–499.8
6. Conifer forest	526.7	294.9–610.4
7. Conifer—swamp hardwood forest	604.7	500.8–651.0
8. Upland hardwood forest	772.0	693.9–799.9
4, 5.	424.9	293.1–529.0
4, 5, 6.	499.8	482.7–513.3
4, 6.	519.2	464.5–565.0
4, 7.	529.6	345.2–632.3

DISCUSSION

Pattern Analysis and Mapping of Major Cover Types

The patterns and zonation of the vegetation types of Cedarburg Bog form a mosaic (Figure 2). Some of these types, such as the upland hardwoods, dead tamarack area, string bog, and, to some extent, bog birch–leatherleaf shrub zone and emergent aquatic zone are usually distinct from each other. Others, such as the conifer forest, the conifer–swamp hardwood forest, and the dogwood–willow shrub areas, are often indistinct, blending into one another. This blending seems greatest where disturbance such as lumbering or wind-throw of trees has occurred. Clearly the classification of vegetation by general types, while useful in mapping the general vegetational cover, is not sufficiently discriminating. Although sequential, concentric zones representing different stages of successional development are present throughout much of the bog, i.e. the northeast shore of Mud Lake, the mosaic effect demonstrated by aerial photograph suggests more complex relationships.

The first zone to be considered on the vegetation map is that of the emergent aquatics (Figure 4, Number 1). It is finely textured and very light in tone on the aerial photograph (Figure 2). This zone is found at the margins of the lakes, especially northern and eastern Mud Lake, northern and southern Long Lake, and northern Donut Lake. It can be found along the several creeks between the lakes as well. It lies between the open water and the successional shrub zone (Number 3). The emergent aquatic zone is composed mostly of bulrushes (*Scirpus validus* Vahl var. *creber* Fern.), sedges (chiefly *Carex aquatilis* Wahlenb.), and cattails (*Typha* spp.), while locally water willow (*Decodon verticillatus* (L.) Ell.) and arrowhead (*Sagittaria* sp.) may dominate at the water's edge. The appearance of this zone is very open—almost marsh like. This is referred to as the emergent aquatic mat or association.

The center portion of the bog (Figure 4, Number 2) is distinct from all other zones in that it appears as dark gray, more or less parallel bands on a finer, lighter background on aerial photographs. There are larger islands of dark gray vegetation, similar to the narrower bands, scattered in this zone too. Ground studies, observations from an airplane, and stereoscopic analysis reveal this to be string bog or "Strangmoor" composed of ridges and islands of tamarack and cedar, usually very stunted on the smaller ridges, lying on an open, flat sedge mat. When seen from the ground or at lower elevations, this area has the appearance of open meadows separated from one another by ridges or hedgerows of conifers. Sometimes the ridges are small with little woody vegetation. The larger, darker islands are stands of fairly dense conifer forest.

This part of the bog is of special interest since it is the southernmost location of "patterned organic terrain" of the northern type. The previous known limit for such patterns is about 200 miles northward, near Seney, Upper Michigan (Heinselman, 1965). Dr. M. L. Heinselman states that the areas "west and southwest of Long Lake clearly constitute a 'string bog' or 'strangmoor' complex" (personal communication). His identification was made on the basis of an examination of an aerial photograph and a description of the area.

The *Rhynchospora–Carex* mat (called "flarks" by Swedish workers) forms the relatively flat, open mat; the area is dominated by *Rhynchospora alba* (L.) Vahl, a short, fine sedge, with lesser amounts of *Carex lasiocarpa* Ehrh. var. *americana* Fern., pitcher-plants (*Sarracenia purpurea* L.), bogbean (*Menyanthes trifoliata* L. var. *minor* Raf.), water horsetail (*Equisetum fluviatile* L.), bladderwort (*Utricularia* spp.), arrowgrass (*Triglochin maritima* L.), dense clones of reed (*Phragmites communis* Trin. var. *Berlandieri* (Fourn.) Fern.), sundew (*Drosera linearis* Goldie and *D. rotundifolia* L.), some orchids (*Pogonia ophioglossoides* (L.) Ker. and *Calopogon pulchellus* (Salisb.) R. Br.), and some cattails (*Typha latifolia* L. and *T. angustifolia* L.). This mat is very soft and treacherous to tread upon, and though it appears to float, seems to lack some of the resiliency of the emergent aquatic mat.

The ridges of the string bog are elevated from a few inches to a foot or more above the surrounding mat, and range in width from a foot or so to twenty or more feet. The ridges may be more than one hundred feet long before attenuating into the mat or fusing with another ridge, thus forming a net like structure. Within each ridge or island there is a miniature ecotone, grading from low *Rhynchospora–Carex* mat to bog birch, leatherleaf (*Chamaedaphne calyculata* (L.) Moench var. *angustifolia* (Ait.) Rehd.), and some bog-rosemary (*Andromeda glaucophylla* Link), along with *Sphagnum* spp., cranberry (*Vaccinium Oxycoccos* L.), and sundew (*Drosera rotundifolia* L.), to cedar and tamarack with numerous shrubs beneath. The shrubs are especially frequent on the edges of the larger ridges and islands and in openings within; included here are bog birch, leatherleaf, poison sumac (*Rhus Vernix* L.), red osier dogwood (*Cornus stolonifera* Michx.), black chokeberry (*Pyrus melanocarpa* (Michx.) Willd.), juniper (*Juniperus communis* L. var. *depressa* Pursh), winterberry, and dwarf alder (*Rhamnus alnifolia* L'Her.). Beneath the dense cedar and tamarack of the larger ridges and islands, velvet-leaf bilberry (*Vaccinium myrtilloides* Michx.) and winterberry may be found.

The bog birch–leatherleaf or successional shrub zone (Figure 4, Number 3) appears quite fine in texture and a medium gray in tone on the aerial photograph. This zone is found near lakes, streams, and the edges of the low islands within the lakes. It lies shoreward of the emergent aquatics. Near the edge of Mud Lake it is up to several hundred feet wide and ranges from almost pure bog birch to a bog birch–tamarack mixture. A dense cover of leatherleaf is present on some of the low islands within the lakes where stunted tamaracks are found.

The dogwood–willow shrub areas are very numerous in the bog (Figure 4, Number 4). Their appearance on the aerial photographs is very similar to that of the previous zone, but ground observations reveal some differences. Near the west shore of Mud Lake it has the characteristics of a shrub carr, with a dense, almost pure and impenetrable stand of slender willow (*Salix gracilis* Anderss.). In other areas red osier dogwood and several species of willow are important with lesser amounts of winterberry. Another form of this cover type occupies large areas near Mud Lake, where there are many dead or dying elm (*Ulmus americana* L.), black ash (*Fraxinus nigra* Marsh.), and tamarack. Here red osier dogwood and cattail are abundant. These shrub areas are often mixed with other types, especially where the trees were cut or wind thrown.

The zone of dead tamaracks (Figure 4, Number 5) occupies principally two disjunct, but very similar areas. On aerial photographs it is similar to the previous two types, and again can be best distinguished by its location within the bog and by ground observations. This zone is characterized by dead tamaracks, many of which are still standing, though free of bark and most branches. It is an open area with some young cedar, large amounts of bog birch, some red osier dogwood, and lesser amounts of poison sumac, willows, winterberry, and juniper. Old stumps are found scattered here and there.

The sixth cover type, that of the conifers (Figure 4, Number 6), has a coarse texture and a mottled gray tone. Throughout most of the bog this cover type is composed of both cedar and tamarack, but white birch is often found near the peripheral portions of this cover type. Near the bog birch–leatherleaf shrub zone almost pure stands of tamarack may occur and between Mud Lake and the east side of the bog black spruce (*Picea mariana* (Mill.) BSP.) occurs. In still other locations, small thickets of cedar may exclude almost all other species.

The conifer–swamp hardwood forest (Figure 4, Number 7) is more heterogeneous than the conifer forest due to the increased number of hardwood trees. This forest type tends to be found on the peripheral portions of the bog, especially the northwestern and western parts of the bog, and around the southern parts of Mud Lake. The latter example has been subjected to disturbance, however. This forest is composed of cedar, tamarack, black ash, elm, white birch, with lesser amounts of red maple (*Acer rubrum* L.), and red–silver maple hybrids (*A. rubrum* L. x *A. saccharinum* L.). The latter hybrid was corroborated by Dr. W. H. Ellis of Austin Peay State University. This cover type, as represented by the conifer and white birch mixture blends freely with the pure conifer forest. There are areas near the edge of the bog, e.g. south of Mud Lake, where there is a preponderance of swamp hardwoods. However, since these areas are relatively small and blend freely with the conifer–swamp hardwood mixture, they are included in the conifer–swamp hardwood forest.

The most mesic cover type in the bog is the upland hardwood forest (Figure 4, Number 8). On the aerial photographs, the vegetation appears to be of a very coarse texture, mottled gray in tone, and composed of large flat tree crowns. This type of cover occupies the upland mineral soils of the islands within the bog. Stereoscopic examination indicated that these tree tops are at a higher elevation than any others within the bog. One island is found in Mud Lake, three are north of Mud Lake, and another is surrounded by bog northwest of Long Lake. Upland hardwood forest also covers the high ridge that is near the western edge of the bog. These upland areas appear to be formed of glacial debris, mostly limestone boulders and gravel and as such are elevated above the surface of the surrounding peats. The upland hardwood forest is composed mainly of sugar maple, white ash (*Fraxinus americana* L.), basswood (*Tilia americana L.)*, ironwood *(Ostrya virginiana* (Mill.) (K. Koch), and other mesic species.

Vegetational Sampling, Ordination, and Compositional Index

The ecological responses of members of a plant community have been widely applied for ordination in Wisconsin. Adaptation numbers (Curtis and McIntosh, 1951) have been used for forest trees (Curtis and McIntosh, 1951; Brown and Curtis, 1952; Ware, 1955; and Christensen, Clausen, and Curtis, 1959). In these cases actual joint occurrences of species served as a guide in setting up a Classification system based on ecological responses of trees (Curtis, 1959). They all found sugar maple to be the most mesic species, with other tree species at the opposite extremes of the adaptational series (Curtis, 1959). In all cases a scale of adaptation numbers was set up ranging from 1 to 10. The most mesic species, sugar maple, was assigned a value of 10.0, and the least mesic in either wet or dry sites, a value of 1.0.

Bray (1955) assigned adaptation numbers to southern Wisconsin savanna trees on the basis of mutual occurrences. According to Curtis (1959), the results gave a compositional gradient based on moisture rather than moisture and light as was the case with the forest trees.

Vegetation other than trees has been similarly treated in order to set up a classification based on ecological response. Curtis (1955) evolved five indicator groups for Wisconsin prairie species based primarily on the moisture gradient. The scale of numbers ran from 1 for the wet indicators to 3 for the mesic and finally on to 5 for dry indicators.

In this study, adaptation numbers (Table 1) based on an index of joint occurrence were obtained for all of the woody and some of the important herbaceous species present. A compositional index for trees alone was inadequate since many areas in the bog are treeless and, in other areas, the relatively uniform tree composition precluded an ordination based on joint occurrence of trees.

The series of adaptation numbers represents a range in vegetation from cattail to sugar maple. The higher the number of any given species, the greater the likelihood that that species will be found on mesic areas, dominated by sugar maple. As might be expected for a wet area with little topographic variation, many species encountered in Cedarburg Bog have adaptation numbers below the middle of the scale. The species with higher numbers are found mostly on upland areas; sugar maple and ironwood do not grow in the bog proper.

The adaptation numbers assigned in this bog continuum may differ considerably from those in the upland continuum for several reasons. First, the scale utilized here is wider than that of the upland ordination since it ranges from emergent aquatics to mesic upland hardwoods rather than only from pioneer trees to mesic upland hardwoods. Second, a given species may exhibit a somewhat different response in a bog as compared to the uplands.

The string bog area presents a unique problem in ordination. Since the string bog is composed of two distinct cover types, i.e. islands and ridges with conifers and shrubs on a matrix of *Rhynchospora* and *Carex,* the data from the line intercepts represents a "hybrid" cover type. Since 100 foot segments in the string bog include both cover types, the *Rhynchospora–Carex* mat will have a very high joint occurrence index with any of these woody species. For example, the joint occurrence index value between the *Rhynchospora–Carex* mat and tamarack or bog birch is 1.00, and between the mat and cedar it is 0.925. Thus, it is difficult to substantiate the assignment of an adaptation number of 2.0 to *Rhynchospora alba* on one hand, and 3.5 to bog birch, 5.0 to tamarack, and 6.0 to cedar on the other, on the basis of the above comparisons. Of course when tamarack is compared to cedar or to bog birch, a more meaningful relationship is seen: 0.842 and 0.862 are the respective joint occurrence indices. Although this suggests that the *Rhynchospora–Carex* mat does not fit into the ordination, the desirability of including this extensive cover type on a standard ordination precluded its elimination, while the sampling method using 100 foot segments precluded treating the ridges and open mat separately.

The ecological response curves for most of the species (Figures 5–7) show an intergrading similar to that found in upland forests by Curtis and McIntosh (1951). No species is distributed entirely at random. Each species is present in more than one section of the continuum but showed a tendency to a normal curve of relative cover values, with a peak in one section of the continuum. This would be expected from the general knowledge of species' responses to environmental factors. It is unfortunate that there are not enough samples of segments with higher values present to enable a complete study including examples from the 800 to 1000 range, but the paucity of mineral islands in the bog and their abrupt nature, precluding a gradual transition from island to bog, made a complete study impossible.

White birch proved relatively mesic, reaching a maximum cover value in segments between 600 and 800 (Figure 5 and Table 2). White birch was found in situations ranging from conifer–swamp hardwood forest to the lower slopes of the mineral soil islands where it appeared to reach maximum size. Mixed with cedar and tamarack in the bog forest, it often occurs in areas where stumps show evidence of cutting. This pattern is corroborated by Curtis (1959), who mentions that this species is often found as a gap-phase tree in small openings in the forest, and shows intermediate shade tolerance.

Elm and black ash have high relative cover values in the segments from 600 to 700 (Figure 5 and Table 2). Both species were once abundant near Mud Lake, but now only a few isolated trees survive. Although elm (Eyre and Zillgitt, 1953) and ash (Curtis, 1959) appear able to sprout from the bases of nearly dead trees, the black ash seems to recover better after flooding. This is probably due to the additional effect of the Dutch elm disease on the elm population. The increase in relative cover for black ash in the segments near 200 is due to the survival of a few isolated trees on hummocks near Mud Lake.

Cedar has a high relative cover value over a wide range on the compositional index scale (Figure 5 and Table 2), with highest values in the 500 to 700 range. There is a wide range in size and growth-form in the bog, with stunted and gnarled trees in the string bog and larger trees on slopes of the mineral soil islands. Curtis (1959) reported cedar stumps over 4 feet in diameter on an island in Cedarburg Bog. The only areas that do not contain this species are the emergent aquatic, some of the dogwood–willow, and the bog birch–leatherleaf areas near the lakes. Cedar is considered tolerant by Baker (1949) and Zon and Graves (1911), but only intermediate by Curtis (1959). It is sometimes seen in almost pure thickets in the conifer forest area, as a result of layering following wind throwing of this shallow rooted species. This means of reproduction is common in swamps (Curtis, 1959; Curtis, 1944; and Rudolf, 1949). Cedar has been considered as a climax species in boggy areas (Gates, 1942). Clausen (1957) found cedar to be important in the wet-mesic conifer swamps, where its optimum presence is attained (Curtis, 1959).

Tamarack, though less mesic than cedar, also has a wide ecological response (Figure 5 and Table 2), ranging far and wide in the bog. Unlike cedar, it sometimes occurs very near the emergent aquatic areas. It is more frequent than cedar in the bog birch–leatherleaf shrub, and less frequent than cedar in the more mesic conifer–swamp hardwood forest. According to Conway (1949), Cooper (1913), and Gates (1942), tamarack is usually the first forest tree to invade the hydrosphere in bogs. As an intolerant tree (Curtis, 1959), it is replaced by black spruce, cedar, balsam fir, and swamp hardwoods, in about that order, on better drained less acid swamps (Soc. of American Foresters, 1954). Tamarack is a major species in the wet conifer forests of Wisconsin (Clausen, 1957), and attains its optimum presence in this forest type (Curtis, 1959).

Winterberry has quite mesic requirements (Figure 6 and Table 3). It frequently forms small, dense thickets in the conifer forest areas; it is especially common on the conifer islands and larger ridges in the string bog where it may be found beneath cedar and tamarack.

Red osier dogwood and poison sumac are typical of disturbed areas in the bog (Figure 6 and Table 3). They often occur in the dogwood–willow areas in the bog (Figure 3, Number 4). Red osier dogwood can assume high relative cover values in the segments in the 400 to 600 interval, but is really very common elsewhere, too. It is probably the most frequent woody species in this bog. It may be found in the smallest openings, but develops best in large, open areas such as under dead elm and black ash near Mud Lake. Poison sumac has almost a bimodal curve since it is frequent in small open but otherwise more mesic areas resulting from disturbance as well as on some ridges and islands in the string bog.

Bog birch and leatherleaf both reach maximum relative cover values in the 300 to 400 interval of the compositional index scale (Figure 6 and Table 3). Gates (1942) places bog birch in the "High Bog Shrub Association" which succeeds the "Chamaedaphne Association." On the other hand, Conway (1949) considers both species part of the "Moss–heath Association." In Cedarburg Bog, both species often occur together, showing similar ecological requirements. As mentioned previously, these species, especially the bog birch, are dominant over large portions of the bog as the bog birch–leatherleaf shrub areas (Figure 3, Number 3). Leatherleaf and the more common bog birch appear in an apparent successional sequence between the emergent aquatics and the tamaracks, in the string bog areas, and in the dead tamarack areas.

Pitcher-plant is common in the *Rhynchospora–Carex* portions of the string bog (Figure 7 and Table 4). However, it is also found on the ridges under a light canopy of cedar and tamarack; its greatest cover is in the 200 to 300 range.

Reed grass finds optimum ecological conditions in the low-indexed segments in the string bog (Figure 7 and Table 4). Here it is usually found in the open, very wet flarks of the *Rhynchospora–Carex* mat, where it may form dense clones.

Cattail is typically a member of the emergent aquatic community, but is often found in wet depressions caused by wind-thrown trees in the 300 to 700 range (Figure 7 and Table 4). Most of this cattail is *Typha latifolia* L., though some *T. angustifolia* L. is present.

The ecological responses of other bog species are graphed and discussed elsewhere (Grittinger, 1969).

The mean importance values of the trees and saplings generally parallel the results seen with the relative cover treatment, i.e. those species with low adaptation numbers usually have high importance values in the lower compositional index intervals and those species with high adaptation numbers have high importance values in the higher intervals (Tables 5 and 6). Some exceptions should be noted, however. In the tree class (Table 5), black ash attains the importance value of 300 in the compositional index intervals of 100 to 200. In the interval of 200 to 300, tamarack and cedar have importance values of 134.5 and 165.5 respectively. Likewise in the sapling class (Table 6), black ash is important in the 100 to 200 range (201.6) as are cedar and elm in the 200 to 300 range (140.5 and 12.3 respectively). In all of these cases the small sample is probably a factor, as there are only 6 segments in the 100 to 200 range, and 16 in the 200 to 300 range. Furthermore, the importance value is based on relative values among tree species only, so that in relatively treeless areas, where shrubs and herbs make up most of the cover, the importance values of the few scattered trees have little meaning. In the 100 to 200 range the sum of the relative cover of the trees is only 1.2 and in the 200 to 300 range, it is 8.9. In such situations one accidental tree on a hummock among cattails would give that species an importance value of 300 if no other tree species were present, even though its contribution to the total cover is insignificant.

Comparison of Ordination With Mapped Patterns

The plotted segments matched the original patterns on the aerial photographs. There is a progressive increase in mean compositional index, with a few slight exceptions, in going from the mapped emergent aquatic areas to the upland hardwood forests. The areas where large amounts of dogwood–willow are found mixed with other cover types also fit into this progression. For example, the mixture of dogwood–willow and conifer forest give a mean that is higher than the "pure" dogwood–willow but lower than "pure" conifer forest.

The uniformity with which the compositional indices of the transect segments correspond to their expected localities on the aerial photograph seems to indicate that the adaptation numbers assigned to the plant species are valid for such ordination.

The range of compositional indices within a given pattern type is indicative of several factors. First, as in the case of the conifer forest with a wide range of indices, it is probably due to the mixture of stunted conifer forest within the string bog at one extreme and the existence of dense stands of tall cedar and tamarack with a few scattered white birch trees at the other. Another situation of note is the wide range of the mixture (4, 6) of dogwood–willow shrub and conifer–swamp hardwood forest. Here the segments with lower compositional indices are found in disturbed areas, especially near Mud Lake, and in some cases approach being a shrub–carr or even an aquatic emergent area, while the segments with higher compositional indices are represented by conifer–swamp hardwood forest and shrubs near the edges of the bog.

CONCLUSIONS

Cedarburg Bog is composed of a mosaic of vegetational patterns that may be arbitrarily classified and mapped into eight major cover types based on aerial and ground studies. The major cover types are: emergent aquatic, string bog or strangmoor, bog birch–leatherleaf shrub, dogwood–willow shrub, dead tamarack, conifer forest, conifer–swamp hardwood forest, and upland hardwood forest areas. The string bog is an area of particular interest since it represents the southernmost reported example of this type of patterned terrain. In addition to the major cover types, mixtures of some of these types exist, especially where disturbance occurred.

Adaptation numbers were assigned to the plant species on the basis of an index of joint occurrence, and these numbers were used to weight relative cover values to obtain a compositional index for each 100 foot segment of the line intercepts. The compositional indices strongly correspond to the vegetation patterns or cover types suggesting that the adaptation numbers assigned are valid for this ordination. The ordination of the communities within the bog was related to the ecological responses of the individual species as shown by the graphed curves of relative cover on the compositional index scale. Of the eight major cover types, only the string bog does not lend itself to this ordination.

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THE LITTORAL MACROPHYTE VEGETATION OF LAKE WINGRA

An example of a *Myriophyllum spicatum* invasion in a southern Wisconsin lake.

Stanley A. Nichols and Scott Mori

ABSTRACT

Over the past century the aquatic vegetation of Lake Wingra, Dane Co., Wisconsin has changed from a vegetation type which was probably dominated by *Vallisneria americana* and *Potamogeton spp.* to one which is 68% *Myriophyllum spicatum. M. spicatum* is a European species that appears to be a very aggressive invader. The value of *M. spicatum* to the aquatic plant community is low. The time or mechanism of the invasion could not be precisely determined.

To provide a basis for assessing the role of *M. spicatum* in the present community, and to provide a basis for continued research on the lake, the submerged aquatic plants were sampled by the line intercept method. Forty lines, approximately perpendicular to the shoreline and extending to the depth at which growth of submerged aquatic plants ceased, were sampled. All plants intercepting the line were recorded within consecutive 5 m segments of the line. Depth data, shore vegetation and soils data were taken relative to the transect lines. For descriptive and mapping purposes the vegetation was divided into five communities. The data are summarized in map and tabular form.

INTRODUCTION

Over the past century a striking change has occurred in the vegetation of Lake Wingra. Up to this time no quantitative work has been done on the aquatic plants of the lake. The purpose of this study was to assess the change in the vegetation during the past hundred years, and to describe and map the present vegetation for current research and future vegetational studies.

In the 1870's Lake Wingra, or Dead Lake as it was known then, was shallower and larger. Rowley (in Sachse, 1965) described the lake as marshy on all sides with a good bit of wild rice *(Zizania aquatica)* and wild celery *(Vallisneria americana)*. "The shores of the lake were shallow and one had to push a boat through a hundred yards or more of weeds and cattails before reaching open water."

A hydrographic survey in 1904 revealed a maximum depth of 14 feet. Beginning in 1905 and continuing through 1920 considerable filling and dredging of the lake took place. Today the majority of the shoreline is controlled by the University of Wisconsin Arboretum.

The shore vegetation of the lake today is considerably different than the broad *Typha* marshes with *Z. aquatica* as described by Rowley. A more striking change occurred in the submerged vegetation, with the disappearance of *V. americana* and the almost complete dominance by *Myriophyllum spicatum.*

Description of the Area

Lake Wingra is a natural, shallow basin on an outwash terrace overlying a feeder stream of the preglacial Yahara River. The Lake lies in central Dane Co. (T-7-N, R-9-E), within the city limits of Madison. Poff and Threinen (1962) report the surface as 139.6 ha and the maximum depth as 6.4 m.

Two small streams and numerous springs are the chief source of water supply. The outlet, at the northeastern corner of the lake, drains into Lake Monona via Murphy's Creek. A dam on Murphy's Creek maintains a 0.6 m head of water.

Methods

Field Methods

Lake Wingra was sampled using the line intercept method as described by Lind and Cottam (1969). A plastic coated rope, marked in five meter intervals, was used as the intercept line. The intercept lines (Fig. 1) ran from shore toward the center of the lake at approximately 100 m intervals. Because of dense vegetation and unsure bottom it was found easiest to run the lines with a canoe. On the first trip the rope was taken out and anchored to a float in deep water. The line was run a second time with one paddler calling off the plant species intercepting the line, one paddler taking depth measurements, and a third investigator acting as a recorder. By using different symbols on the data sheet it was noted whether the plant species was present (less than one plant per meter), scattered (non-continuous), or continuous (a solid, unbroken stand of plants) in each 5 m segment of line. Depth was recorded in 0.5 m intervals until the end of the vegetation. A sounding rod was used for depths up to 2.5 m and a weighted line after this depth. For mapping purposes the azimuth of each line was taken with a Brunton Compass.

In the case that a community obviously ended between intercept lines, the community was sketched. Notes referring to its position

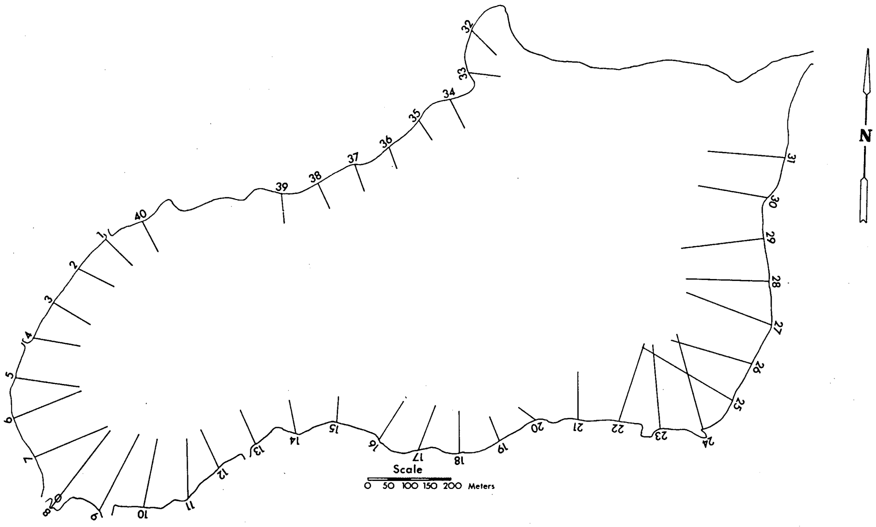

FIGURE 1. Map of Lake Wingra showing transect sampling lines.

by distance and azimuth from the enclosing intercept lines were taken.

The soil was examined 5 m from shore at the beginning of each transect. Shore vegetation for each transect was noted.

From the line intercept data, five macrophyte communities were recognized. Using SCUBA apparatus, 20, one meter square quadrats were harvested from each community. The number of stems of each species in each quadrat was tallied for density data. In every fourth quadrat the species were dried and weighed to give an estimate of the standing crop.

Two areas along the north shore of the lake were not considered in this survey. An area between transects 31 and 32 and transects 39 and 40 were deleted because of a great amount of disturbance to the plant community due to mechanical harvesting and chemical poisoning with Aquathol. The ponds and lagoons entering the lake were also disregarded.

Plant species were collected during the summers of 1968 and 1969. Voucher specimens are on file at the University of Wisconsin Herbarium.

Computations

Each five meter interval of every transect was used as a basic sampling unit (BSU). The percent occurrence of each community type and the frequency of each species was calculated on the basis of 872 BSU containing vegetation.

The outer limit of the littoral zone was calculated as the mean $\pm 2\sigma$ of the end point depth of the 40 transects. The open area in the littoral zone was computed as the percentage of BSU under 2.3 m ($\bar{x} - 2\sigma$) containing no vegetation.

Swindale and Curtis (1957) devised an ordination of aquatic communities based on the relative frequency and joint occurrence of each species. Only nine species in the Wingra study were given joint occurrence numbers by Swindale and Curtis. Therefore, the following modification was devised to calculate a compositional index (CI) value.

$$CI = \frac{\Sigma \text{ relative frequency of joint occurrence } \#4 \text{ spp.} \times 100 + 300}{\Sigma \text{ relative frequency of joint occurrence } \#3 + \text{joint occur. } \#4 \text{ spp.}}$$

The modification can be used because the greatest percentage of the relative frequency is concentrated in species with joint occurrence numbers, therefore only minor species were eliminated. The Swindale and Curtis (1957) scale goes from 100–400. The low end of the scale indicates oligiotrophic conditions and the high end represents eutrophic conditions. Lake Wingra is a highly eutrophic lake, therefore few, if any, species with a joint occurrence number of less than 3 would be expected.

Results

Depth, Lacustrine Soils, and Shore Vegetation

A hydrographic map of the littoral zone is presented in Fig. 2. The outer limit of the vegetation is controlled by depth. The mean depth of the end of the littoral zone is 2.7 ± 0.4 m. Because of the extreme turbidity of the water, it was often hard to ascertain the absolute end of the vegetation, even with SCUBA gear. It is assumed that one could find vegetation beyond the limits indicated on the vegetation map (Fig. 3). If so it would be scattered and highly stunted plants of *M. spicatum*. For more complete hydrographic data, one should consult Noland (1951).

Marl composes the major part of the littoral zone soil. 68% of the 40 transects had a marl bottom 5 m from shore, 20% had sand and 12% had an organic bottom.

The organic bottom is found on the north, south, and west sides of the lake. It is found extensively in areas of water lily vegetation and areas where the shore vegetation is cattail marsh.

Sand beach is found along a road fill on the south shore of the lake, and in an area centrally located along the north shore line. The remainder of the areas have a marl bottom. All the beach soil types grade into a black, organic "ooze" before the limit of the littoral zone.

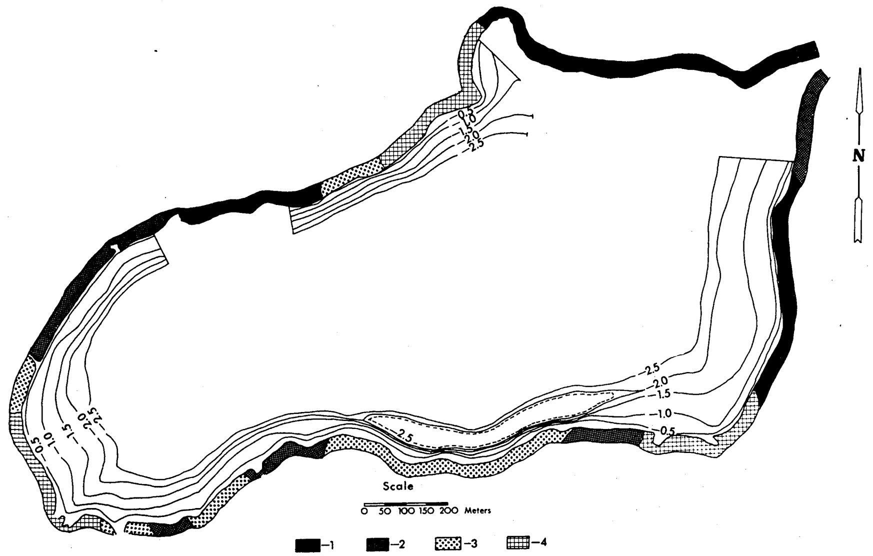

FIGURE 2. Map of Lake Wingra showing shore vegetation and depth in meters. Shore vegetation: 1-developed land, 2-lowland shrub, 3-lowland forest, 4-cattail marsh.

FIGURE 3. Map of Lake Wingra showing the location of plant communities. Plant communities: 1-*Nymphaea* community, 2-shallow water *Myriophyllum* community, 3-deep water *Myriophyllum* community, 4-*Nuphar* community, 5-*Potamogeton-Myriophyllum* community, 6-*Scirpus* beds.

No obvious correlations could be made between shore vegetation and aquatic macrophyte communities. Figures 2 and 4A depict the vegetation types bordering the lake.

Flora of Lake Wingra

Fassett (1930) divided aquatic macrophytes into four different life forms: forms with long lax stems and flexous leaves; forms with basal rosettes and unbranched stems; forms with vegetative stems and horizontal floating leaves; and forms that are rooted underwater but have photosynthetic parts emergent. In considering Lake Wingra a fifth category should be added to include small, free floating plants.

Naming of species, except for *M. spicatum* follows Fassett, 1960. For a history of the naming of *M. spicatum* one should consult Fernald, 1919 and Fernald, 1945.

Four species, *Lemna minor* L., *L. trisulca* L., *Spirodela polyrhiza* (L.) Schleid, and *Wolfia columbiana* Karst., of the small, free floating plants were collected.

Nymphaea tuberosa Paine and *Nuphar variegatum* Engelm. represent forms with vegetative stems and horizontal floating leaves.

Three species, *Typha latifolia* L., *T. angustifolia* L. and *Scirpus Validus* Vahl. represents forms that are rooted underwater but have photosynthetic parts emergent.

No species with a basal rosette and unbranched stems were found.

The remainder of the species, *Potamogeton pectinatus* L., *P. nodosus* Poir, *P. Richardsonii* (Benn.) Rydb., *P. zosteriformis* Fern., *P. crispus* L., *P. foliosus* Raf., *P. natans* L., *Zanichellia palustris* L., *Najas flexilis* (Willd.) Rostk., Schmidt, *Anacharis canadensis* (Michx.) Planchon. *Heteranthera dubia* (Jacq.) MacM., *Ceratophyllum demersum* L., *Utricularia vulgaris* L., *Ranunculus longirostris* Godron., and *Myriophyllum spicatum* L. are plants with long lax stems and flexous leaves.

Table 1 shows the relative frequency each major species occupies in the flora of the lake. *M. spicatum* is the most dominant member with a relative frequency of 68.4%. No other species exceeds a relative frequency of 10%.

An examination of herbarium sheets in the University of Wisconsin Herbarium has revealed specimens of *Potamogeton freisii* Rupr., *P. illinoinensis* Morong., *P. amplifolius* Tuckern., *P. praelongus* L., and *V. americana* Michx. which were not recollected by the authors in this study. None of these species have been collected later than 1929.

M. spicatum and *P. crispus* are European introductions.

TABLE 1. SPECIES COMPOSITION AND COMPOSITIONAL INDEX OF THE PLANT COMMUNITIES IN LAKE WINGRA.

Species	Joint Occur.	Shallow Myr.		Pot.-Myr.		Deep Myr.		Nuphar		Nymphaea		Total Lake	
		% F	rel F	% F	rel F	% F	rel F	% F	rel F	% F	rel F	% F	rel F
M. spic.	4	97.3	87.9	88.2	39.1	100	95.1	40.0	23.1	64.3	40.9	92.7	68.4
P. pect.	4	3.8	3.4	50.7	22.5	—	—	4.4	2.5	—	—	11.0	8.1
P. nat.	3	1.3	1.2	43.1	19.1	—	—	8.8	5.0	—	—	8.4	6.2
N. var.	—	0.6	0.6	6.3	2.8	—	—	97.7	56.5	4.5	7.1	6.5	4.8
P. nod.	—	1.3	1.2	18.8	8.4	—	—	4.4	2.5	—	—	4.1	3.0
C. dem.	4	5.2	4.7	1.4	0.6	1.7	1.6	4.4	2.5	—	—	4.0	2.9
N. tub.	—	2.2	2.0	4.9	2.2	—	—	—	—	85.7	54.6	3.6	2.6
S. val.	—	1.3	1.2	1.4	0.6	—	—	2.2	1.3	—	—	1.1	0.8
A. can.	3	0.2	0.2	4.9	2.2	—	—	—	—	—	—	0.9	0.7
H. dub.	3	1.1	1.0	1.4	0.6	—	—	—	—	—	—	0.9	0.7
P. crisp.	—	0.4	0.4	—	—	3.5	3.4	—	—	—	—	0.7	0.5
P. zost.	4	0.4	0.4	1.4	0.6	—	—	—	—	—	—	0.5	0.4
R. long.	—	—	—	—	—	—	—	6.6	3.8	—	—	0.3	0.2
N. flex.	3	—	—	0.7	0.3	—	—	4.4	2.5	—	—	0.3	0.2
P. fol.	—	—	—	0.7	0.3	—	—	—	—	—	—	0.1	0.1
T. ang.	—	0.4	0.4	—	—	—	—	—	—	—	—	0.2	0.1
T. lat.	—	0.1	0.1	—	—	—	—	—	—	—	—	0.1	0.1
P. Rich.	4	—	—	1.4	0.6	—	—	—	—	—	—	0.2	0.1
C I.		398		374		400		379		400		391	

Vegetation of Lake Wingra

For mapping and descriptive purposes five communities were recognized in Lake Wingra. The shallow water *Myriophyllum* community constituted 68.4% of the total vegetation. The *Potamogeton–Myriophyllum* community constituted 16.5% of the total vegetation. The deep water *Myriophyllum* community constituted 13.3% of the total vegetation. The *Nuphar* community constituted 5.2% of the vegetation and the *Nymphaea* community constituted 1.6% of the vegetation. Figure 3 shows the location of each of these communities in the lake.

The shallow water *Myriophyllum* community (Fig. 4B, 4F) is a solid stand of *M. spicatum* with other species scattered or present, and not more than one species of *Potamogeton* scattered in any BSU. The stand is characterized by an average of 253 stems/m^2 and a standing crop of 385 g/m^2. All species combined, except for *M. spicatum,* constitute less than 1% of the density or the standing crop. The frequency, relative frequency and CI value are given in Table 1. With a CI value of 398, the shallow water *Myriophyllum* community is an example of a community in a stage of advanced eutrophication.

At a point (about 2.4 m) with increasing depth the *Myriophyllum* community changes from a solid stand to scattered plants. This is the dividing line between the deep water and shallow water *Myriophyllum* communities. The deep water community is more monotypic; *P. crispus* and *C. demersum* (Table 1) are the only species occurring with *M. spicatum*. With a scattering of plants the density and standing crop drops considerably. The average density was 70 stems/m^2 and the average standing crop was 142 g/m^2. Virtually 100% of the density and standing crop was composed of *M. spicatum*. *M. spicatum* colonizes the deepest portions of the littoral zone. It has enough of a competitive advantage to exclude virtually all other species.

The *Potamogeton–Myriophyllum* (Figure 4C) community is difficult to define. For mapping purposes it was defined as an area having one *Potamogeton* sp. continuous through the sampling unit or at least two species scattered or present. The difficulty arises in the fact that there is tremendous variety in this area. There were many small associations of one or two species of *Potamogeton* spatially located very near one another, but mutually exclusive. A very intensive mapping technique would be required to separate them, but the physiognomic difference was obvious in the field. On the other hand, much of the *Potamogeton–Myriophyllum* community appeared to be an ecotone between a narrow, shallow water *Potamogeton* community and the somewhat deeper, shallow water *Myriophyllum* community. The community is characterized by an

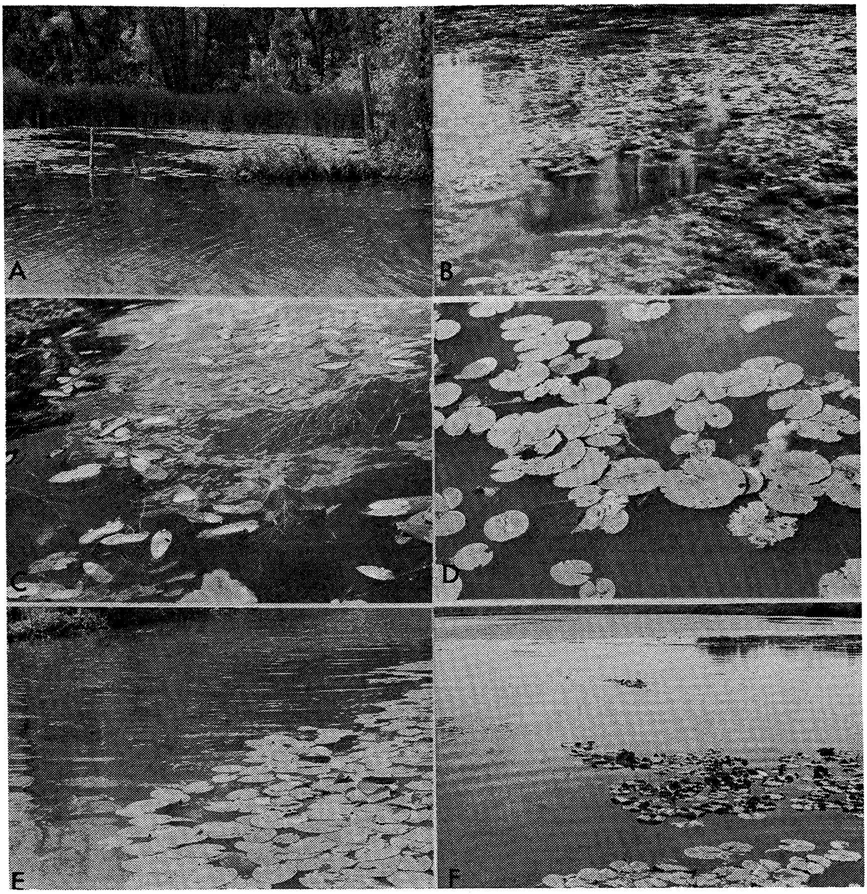

FIGURE 4. Aquatic communities of Lake Wingra: A. *Nymphaea tuberosa* community with *Typha* shore vegetation, B. Shallow water *Myriophyllum* community, C. *Potamogeton-Myriophyllum* community, D. *Nymphaea tuberosa* community, E. *Nuphar variegatum* community, F. Foreground: *Nymphaea* and *Nuphar* communities showing close proximity. Background: Shallow water *Myriophyllum* community showing broad, dense expanse of plant material.

average density of 192 stems/m^2 and a standing crop of 196 g/m^2. *P. natans, M. spicatum* and *P. pectinatus* were the three most common species (Table 1). Monotypic stands of *N. flexilis, P. natans, P. nodosus,* and *P. pectinatus* could be found. *C. demersum,* although not wholly a member of the *Potamogeton–Myriophyllum* community, was also observed in pure stands. These stands never exceeded 10m^2 and were not mapped as a separate community. The CI value of 374 indicates a lower level of eutrophication in this community. This is a direct reflection on the importance of *M. spicatum* in the community.

Usually *Nymphaea tuberosa* and *Nuphar variegatum* are lumped into a floating leaved community (Fassett, 1930). Again from field observations, it was obvious that these two species occur spatially close together, but mutually exclusive of one another (Fig. 4F). An attempt was made, therefore, to separate the two communities. With analysis the difference between the communities is striking. The average density in the *Nymphaea* community (Fig. 4D) was 13 stems/m^2 compared to 114 stems/m^2 in the *Nuphar* (Fig. 4E) community. The average standing crop was 49 g/m^2 in the *Nymphaea* community compared with 183 g/m^2 in the *Nuphar* community. *M. spicatum* was the only other species to occur commonly in the *Nymphaea* community. It occurred only where *N. tuberosa* became widely scattered. *N. variegatum* had a variety of species (Table 1) associated with it. The species difference reflects the CI differences in Table 1.

The emergents, *S. validus, T. latifolia,* and *T. angustifolia,* because of their minor importance, were not analyzed as a separate community. *S. validus* beds are indicated on the vegetation map (Fig. 3).

Discussion

Over the last century, and more particularly the last few decades, the submerged aquatic vegetation of Lake Wingra has changed drastically from a community that was probably dominated by *Potamogeton* spp. and *V. americana* to a type strongly dominated by an European invader, *M. spicatum.* This change has not been documented, but has most likely been paralleled in other areas.

M. spicatum was first collected in the Chesapeake Bay Region in 1902 (Steenis et al, 1961). By 1962 the plant covered 200,000 acres and was considered a serious aquatic pest. Currituck Sound, North Carolina illustrates the rapidity of the *M. spicatum* invasion. First reports of the plant from here were received in 1965. At this time approximately 100 acres were in the infestation stage and 500–1,000 additional acres showed initial establishment. By the summer of 1966 these figures had risen to 8,000 and 67,000 acres respectively (Crowel et al, 1967).

By 1967 *M. spicatum* was established in the Northeast in Vermont, New York, Pennsylvania, New Jersey and Delaware. In the Midwest it had been reported in Ohio, Indiana, Illinois and Wisconsin. Its presence has been noted in the states of Maryland, Virginia, North Carolina, Georgia, Florida, Alabama, Louisiana, Texas and California.

Lake Mendota (also within the city of Madison) has been studied and can be used for comparison. Denniston (1921) listed *Vallisneria spiralis* L., *Najas flexilis, P. Richardsonii, P. zosteriformis* and *P. pectinatus* as the most abundant species in the order given. Today even the most uncritical observer would have to rank *M. spicatum* as the most abundant Lake Mendota aquatic vascular plant. In a study by Rickett (1921) the average dry weight of *Myrophyllum* per square meter in University Bay of Lake Mendota was given as 12.6 g. This differs sharply with the value of 172 g/m^2 reported by Lind and Cottam (1969).

Andrews (1946) states, "By late June or early July, the long-stemmed pondweeds have risen above it *(M. exalbescens Fern.)*, and it is no longer conspicuous." By contrast, in 1967, the peak growth of *Myriophyllum* was in June and July (Lind and Cottam, 1969). Within the last fifty years there has been a startling change in the abundance of *Myriophyllum* in Lake Mendota.

The invasion of *M. spicatum* appears to be a very recent occurrence in Lake Mendota. Voucher specimens of *M. spicatum* were identified for the authors by John Steenis in the summer of 1969. The bulk of the plant material in 1969 was *M. spicatum*. Andrews (1946) found no *M. spicatum*. Voucher specimens of *M. exalbescens* were collected as late as 1962 on Lake Mendota. The earliest recorded specimen of *M. spicatum* was collected in the state in 1936 by J. J. Davis in the Tomahawk region.

Like many other pests *M. spicatum* ranks high in uselessness. It is of greatest public concern because it restricts man's recreational and aesthetic activities. The concern in this report is directed toward its effect on the biological system.

M. spicatum is a very aggressive plant with a wide ecological amplitude. Initially it appears beneficial to fish and wildlife. These appearances are deceiving, and, as in the case of Lake Wingra, the plant soon crowds more desirable aquatic plants. How stable the *Myriophyllum* communities are, is yet to be determined. A monotypic community is ecologically unhealthy. It is felt that *M. spicatum* has reached the maximum extent of its growth in Lake Wingra. The *Myriophyllum* communities have also reached the maximum extent of eutrophication as described by Swindale and Curtis (1957). Although *M. spicatum* has a competitive edge in the deep water, soft bottom areas of the lake, the effect is less intensive in the shallow water, sandy bottom areas. There, other species constitute a more substantial portion of the vegetation.

Curtis (1959) defines terrestrial weeds as plants of open or disturbed habitats. The last major disturbance took place in Lake Wingra in 1920. John H. Steenis (personal communication) reported no *M. spicatum* in Lake Wingra from a date in the 1930's, at least ten years after the last disturbance.

Much research is being expended on control measures for *M. spicatum* by means of chemical poisoning and mechanical harvesting. Little has been discovered about natural control, the role the plant plays in the natural community, or the invasion mechanism the plant uses to become established in the community.

Lake Wingra is the ideal location for continued research on the community relations of *M. spicatum*. Up to this time only a small portion of the lake has been disturbed by man's control efforts. By continued resampling of the lake and by using this report as a base, questions on the role of *M. spicatum* in the community, and questions on the course of community succession after maximum eutrophication as described by Swindale and Curtis (1957) might be answered.

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VARIABILITY IN WISCONSIN IN *TRIENTALIS BOREALIS* RAF.

Roger C. Anderson[1]

In North America *Trientalis borealis* extends from the Great Slave Lake to the east coast. Its distribution approximates that of the boreal forest in Canada and the northern conifer hardwoods in the United States. Its range extends into the Appalachian Mountains and on to the New Jersey coastal plain (Anderson, 1968).

During an autecological study of *Trientalis borealis* in Wisconsin, the great morphological plasticity of this species became apparent. Studies were undertaken to examine the range of variability of *Trientalis* in Wisconsin and compare it with the variability reported for the European species of *Trientalis* (*Trientalis europaea* L.). A further objective was to determine if morphological differences existed between different sectors of the state, specifically between the area north of the tension zone (Curtis, 1959) and the southern portion of the state. The tension zone divides the state into two floristic provinces, the prairie forest and the northern hardwoods. *Trientalis* has been reported for all but 6 of 72 counties in Wisconsin; however, it is most abundant north of the tension zone (Anderson, 1968).

The morphological variation of *T. europaea* in Great Britain has been discussed by Matthews and Roger (1941) and in Poland, Norway, and Finland by Medwecka–Kornas (1963). In Canada, Lepage (1946) delineated three forms of *T. borealis* based largely on leaf shape and plant growth form, and Curtis (1959) comments on the variability of *T. borealis* in Wisconsin.

Methods and Materials

Pressed specimens from the University of Wisconsin herbarium were used to obtain the variability data across the state. Data pertaining to the fruits and seeds was obtained from material collected at a single site, the University of Wisconsin Arboretum Finnerud Forest, in Oneida County. The information collected from the herbarium specimens included the stem length in centimeters (from the point on the stem where it would be out of the soil to the major leaf whorl), the number of leaves in the major whorl, the number of flowers per plant, and the number of floral

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parts. For any one flower, the number of stamens, sepals and petals was constant. However, multi-flowered plants occasionally had flowers with different numbers of floral parts so that each flower had to be counted separately. For some specimens it was not possible to obtain all the information due to lack or damage of stem, leaves or flowers. For each specimen, collection north or south of the northern tension zone boundary was noted. Chi-square tests were used to determine whether there were significant morphological differences between northern and southern specimens. Fruit and seed size were determined by measuring the longest dimension with the aid of a microscope ocular micrometer.

RESULTS

Figure 1 shows the results of several measures of variability on Wisconsin *Trientalis*. Plant height is the only measured feature that does not differ significantly between northern and southern specimens. In Figure 1a plant height has been divided into five stem height classes (4–8 cm, 9–10, 11–12, 13–14, 15–19). Northern plants tend to be slightly taller, whereas the southern specimens have more individuals that are in the shortest group and proportionately fewer tall plants, Figure 1a. The average height of the northern specimens was 11.9 cm compared to 11.1 cm for the

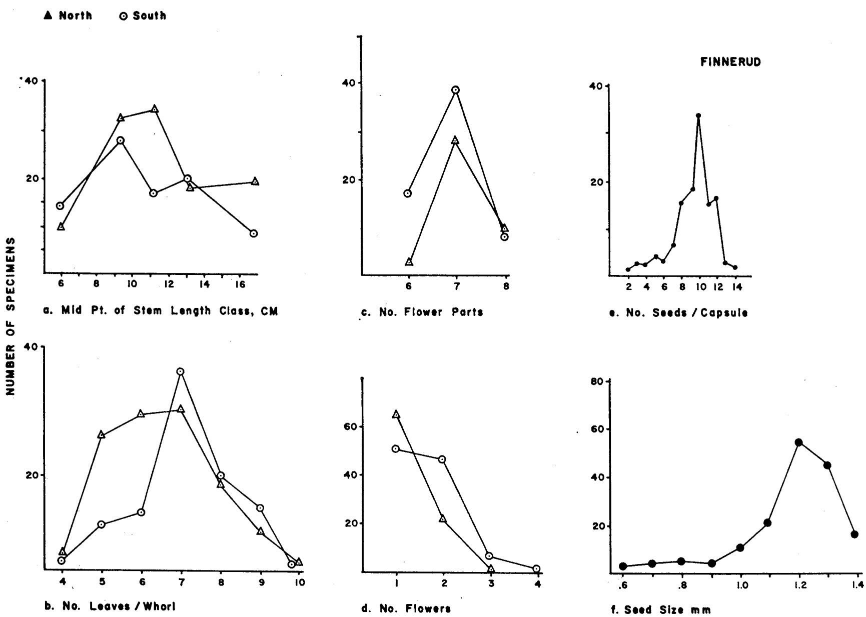

FIGURE 1. Some aspects of the variability of *Trientalis borealis*.

southern plants. Considering all the specimens, plant height ranges from 4 cm to 19 cm with an average of 11.6 cm.

The number of leaves on the major whorl varied from 4 to 10 leaves with an average for the complete sample of 6.8 and a mode of 7 leaves. Figure 1b shows that for the northern specimens six leaves was as common as seven. The average number of leaves for the northern specimens was 6.5 leaves compared to 7.1 for the southern. A chi-square test indicates that there is a significant difference (.01 level) in the number of leaves between locations of collection. For the test statistics, specimens having five leaves or fewer per whorl were combined. Similarly those with nine or more leaves were grouped, because of the smaller number of specimens in these groups.

A significant difference (.005 level) in the number of flowers and the number of floral parts (.025 level) was found between northern and southern specimens. Figure 1d shows that northern plants commonly produced only a single flower (75 per cent of the specimens) and the usual number of flowering parts was seven (77.6 per cent), Figure 1c. In the south, specimens with 6 flower parts were more numerous, accounting for 22.9 per cent of all the southern specimens, compared to 4.0 per cent for the northern plants.

The capsules of *Trientalis* vary in size from 1.66 mm to 2.66 mm with an average of 2.2 mm. The capsules contained from 2 to 14 seeds, Figure 1e, with a mode of 10 and an average of 9.4 seeds. Seed length, Figure 1f, ranged from .56 mm to 1.43 mm with an average of 1.18 mm. The weight of 233 air dried seeds was 111 mg with an average weight of .476 mg.

Discussion

The variability described by Matthews and Roger (1941) for *T. europaea* in Great Britain was largely variation in plant height and the number of leaves per whorl. They report that plants with 6 leaves are most frequent, accounting for 42.4 per cent of all the specimens examined. For Wisconsin specimens, 20.1 per cent of the plants had 6 leaves per whorl, while plants with seven leaves per whorl were the most common, 30.6 per cent of the specimens. Table 1 compares the number of leaves per plant for the Wisconsin specimens with *T. europaea* as reported by Matthews and Roger (1941).

The table shows that all three groups differ in the number of leaves per whorl, with the southern Wisconsin *T. borealis* plants having the most leaves. However, the variation between the two *T. borealis* groups is less than that between the species. Medwecka–Kornas (1963) reports that in northern Europe the number of

TABLE 1.

NUMBER OF PLANTS	No. LEAVES PER WHORL							
	3	4	5	6	7	8	9	10
T. europaea	3	40	277	488	212	115	13	2
North Wis. *T. borealis*		3	27	29	29	19	8	1
South Wis. *T. borealis*		1	11	13	35	20	13	1
Combined Wisconsin		4	38	42	64	39	21	2
Average North—6.5 leaves.								
Average South—7.1 leaves.								
Average combined—6.8 leaves (Wisconsin).								

leaves per whorl varies from 4 to 11, but Hegi (1927) gives a range of 5 to 12 leaves for *T. europaea*. In Wisconsin, plants of *T. borealis* with 12 leaves have been observed. Thus, the variation in number of leaves between the two species is about the same.

For *Trientalis europaea* in Great Britain the variation in stem length was 3 to 20 cm (Matthews and Roger, 1941), and for northern Europe .6 to 27.5 cm (Medwecka–Kornas, 1963) compared with 4 to 19 cm for the Wisconsin plants. The height of the European species is influenced by environment; plants exposed to severe environments are smaller. In Wisconsin, plant height is also related to environment, with shorter plants generally associated with drier habitats.

Iltis and Shaughnessy (1960) indicate that the star-shaped flowers of *T. borealis,* 12–20 mm in diameter, are usually 7-merous. In this study the southern specimens were more variable than the northern. The 7-merous flowers were found to be the most common throughout the state, but the 6-merous flowers were more frequent south of the tension zone.

For the Eurasian species, the number of seeds per capsule ranged from one to eighteen with an average of eight seeds per capsule (Matthews and Roger, 1941). Capsules of *Trientalis borealis* contain two to fourteen seeds with an average of 9.4. Matthews and Roger (1941) report the average seed weight to be .680 mg, 30 per cent heavier than *T. borealis* seeds, .476 mg.

Another variation in *Trientalis* is the "ramose" form that is characterized by having an additional verticel of leaves above the main whorl. The earliest published record of this growth form is by Hegi (1927). Lepage (1946) recognized three forms of *T. borealis* in Canada, one of which is the "ramose" form. Three morphological forms were delineated by Medwecka–Kornas (1963) in northern Europe: a normal form distributed south of the tree line, a diminutive form with a northern range beyond the limits of the boreal forest of the fjeld field of Lapland, and a "ramose" form growing on the peripheries of the distribution of the normal form in disturbed or open habitats. The morphological forms intergrade, and she suggests that the forms are the results of environmental modifications. Individuals of the normal form were found to develop additional verticels of leaves after being transplanted to an open garden (Hiirsalmi, 1960). In Wisconsin, plants with this form were occasionally encountered in the field, but they are more common among plants grown under greenhouse conditions.

Because of the morphological variability of *Trientalis* in Wisconsin and the diverse habitats in which it grows, Curtis (1959) suggested that there may be ecotypes within the population of *Trientalis borealis* in Wisconsin. Some of this variation may be due to environmental differences. However, near the edge of a species range it seems likely that there may be selection for genetic combinations that are better adapted to conditions that differ from those in the main part of the range. In Wisconsin the tension zone delineates areas that have climatic and edaphic differences. When plants collected north and south of the tension zone are examined, significant morphological variations between the two are found. However, the differences are quantitative rather than qualitative, and nearly all the variability found in Wisconsin *Trientalis* occurs both north and south of the tension zone. The Wisconsin specimens of *Trientalis* appear to be a single taxon displaying the same kind of variation from north to south within the state.

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THE INSECT PARASITES OF THE INTRODUCED PINE SAWFLY, *DIPRION SIMILIS* (HARTIG) (HYMENOPTERA: DIPRIONIDAE), IN WISCONSIN, WITH KEYS TO THE ADULTS AND MATURE LARVAL REMAINS

James W. Mertins and *Harry C. Coppel*

The introduced pine sawfly, *Diprion similis* (Hartig), was first discovered in North America in 1914, in a nursery at New Haven, Connecticut (Britton, 1915). The larvae collected may have been the first progeny arising from foreign stock which probably entered this country on nursery material. Rapid spread of the insect resulted in reports of infestations throughout the northeastern states and as far south as Virginia by 1923 (Middleton, 1923). In 1931, *D. similis* appeared in Canada at Oakville, Ontario (Munro, 1935), and was reported from Wisconsin near Menomonie by 1944 (Coppel, 1962).

The hosts of the sawfly include species of the genus *Pinus*. In North America the favored host is eastern white pine, *Pinus strobus* L. Other species of pines commonly attacked in Wisconsin are Scotch pine, *P. sylvestris* L., and red pine, *P. resinosa* Ait. Trees of all ages are defoliated, but feeding is particularly severe in the most exposed locations and in the overstory, where stripping of foliage may result in branch mortality. Tree mortality occasionally results when a large second generation of larvae destroys the buds set for the following year. Although the sawfly is primarily a pest of plantations, nurseries, and ornamentals, its habits in Wisconsin make it a serious threat to the production of eastern white pine forests.

The data, accumulated since 1957 on the parasite complex of the introduced pine sawfly in Wisconsin, were organized in 1965. This information was compiled from both field collections and laboratory studies of material collected during the summers of 1957–68 in northwestern Wisconsin; principally in Polk, Burnett, and Washburn Counties.

This paper, the third in a continuing but unnumbered series concerning the insect parasites of Wisconsin forest insect pests, deals with the known parasites of *D. similis* in Wisconsin. Keys are presented both for the separation of the adult parasites, and for the remains left in the host cocoon after the parasite has emerged. Descriptions of the adults, final larval instar cephalic structures and spiracles of Hymenoptera, and buccopharyngeal apparatuses and stigmal plates of Diptera are given. Notes on the biology of the parasites are also included.

METHODS

The keys are based on the adult parasites, and the host and parasite remains positively associated with them. The information used for preparation of the key to parasite remains consisted of the host cocoon itself, especially the size, position, and type of emergence hole made by the parasite; the absence or presence, and appearance of the parasite cocoon or puparium; the cast larval skin of hymenopterous parasites and the buccopharyngeal armature of dipterous parasites. Cocoons from which parasites had emerged were cut open with a razor blade to observe the location and appearance of the contents. Cast larval skins of hymenopterous parasites were removed, softened in warmed 10% KOH for 20–30 minutes, and rinsed in distilled water. While rinsing, the skins were spread under the dissecting microscope with two insect pins, and then mounted on microscope slides in non-resinous mounting medium (Turtox CMC-10). The final instar buccopharyngeal armature of each dipterous parasite was removed from the inside of the puparial case, softened in KOH, cleaned of extraneous membranes in distilled water, and mounted. Posterior spiracular plates of Diptera were taken from the puparial cases, softened, and mounted.

Illustrations of adults and gross characters of larval remains were made with the aid of Bausch and Lomb binocular dissecting microscope fitted with 10x eyepieces and a 2x enlarger lens. Fine details of immature remains were added through the use of an Ernst Leitz binocular compound microscope. Measurements were made with a Reichert ocular micrometer calibrated with a stage micrometer (American Optical Co.) on each microscope.

Terminology used for the parts of the cephalic structures and spiracles of final instar hymenopterous larvae and the buccopharyngeal armature of the Diptera is the same as that assembled by Finlayson (1960) from various authors.

PARASITES OBTAINED

The following 21 species of Hymenoptera and 4 of Diptera were reared from *D. similis* cocoons in Wisconsin:

HYMENOPTERA

Ichneumonidae: *Scambus hispae* (Harris), *Delomerista japonica* (Cushman), *D. novita* (Cresson), *Itoplectis conquisitor* (Say), *Exenterus amictorius* (Panzer), *E. canadensis* Provancher, *Gelis tenellus* (Say), *Agrothereutes lophyri* (Norton).

Eulophidae: *Dahlbominus fuscipennis* (Zetterstedt), *Tetrastichus coerulescens* Ashmead, *Elasmus apanteli* Gahan.
Eupelmidae: *Eupelmus spongipartus* Foerster, *Eupelmella* (=*Macroneura* of Peck, 1963) *vesicularis* (Retzius).
Torymidae: *Monodontomerus dentipes* (Dalman).
Pteromalidae: *Amblymerus verditer* (Norton), *Tritneptis scutellata* (Muesebeck), *Dibrachys cavus* (Walker), *Catolaccus cyanoideus* Burks, *Habrocytus thyridopterigis* Howard.
Eurytomidae: *Eurytoma pini* Bugbee.
Chalcidae: *Spilochalcis albifrons* (Walsh).

DIPTERA

Tachinidae: *Spathimeigenia spinigera* Townsend, *Bessa harveyi* (Townsend), *Diplostichus lophyri* (Townsend), *Euphorocera edwardsii* (Williston).

Two keys have been prepared for the separation of the aforementioned species. The first allows separation of the parasite species on the basis of the remains left in the host cocoon after adult emergence. The second separates the adult parasites.

KEY TO THE PARASITES OF *D. similis* BASED ON PARASITE REMAINS

1. Host cocoon containing parasite puparium or cocoon ____2
   Host cocoon not containing parasite puparium or cocoon_14
2.(1) Host cocoon containing puparium, exit hole at tip of cocoon ____3
   Host cocoon containing parasite cocoon ________________6
3.(2) Exit hole usually with edges of tapering thickness, ragged and bent outward in appearance; no lid attached (Fig. 144) ___________________*Spathimeigenia spinigera* Tnsd.
   Exit hole sharply cut, with or without lid attached ______4
4.(3) Exit hole usually with hinged lid (Fig. 146); mandibular hooks fused with intermediate sclerite (Figs. 99, 100) __5
   Exit hole without lid (Fig. 145); mandibular hooks separate from intermediate sclerite (Fig. 98) ______________ ________________________________*Bessa harveyi* (Tnsd.)
5.(4) Length of mandibular hooks plus intermediate sclerite less than one-half the total length of buccopharyngeal apparatus (Fig. 99) ____________*Diplostichus lophyri* (Tnsd).
   Length of mandibular hooks plus intermediate sclerite greater than one-half the total length of buccopharyngeal apparatus (Fig. 100) ____*Euphorocera edwardsii* (Will.)
6.(2) Parasite cocoon abortive, seldom more than a crude tangled covering of silk over host remains ________________7
   Parasite cocoon complete ______________________________9

7.(6) Epistoma complete, labial sclerite open dorsally, mandibles without teeth (Fig. 80) ----*Itoplectis conquisitor* (Say)
Epistoma incomplete, labial sclerite closed dorsally, mandibles each with two rows of fine teeth on blade and a large posteromedial tooth (Figs. 76, 77) ------------------8
8.(7) Labial sclerite angular dorsally, resembling either an acute or truncate peak (Fig. 76) ----*Delomerista japonica* Cush.
Labial sclerite rounded dorsally (Fig. 77) ---------------------------------------*Delomerista novita* (Cress.)
9.(6) Labral sclerite present; epistomal arch incomplete or very lightly sclerotized so as to appear incomplete (Figs. 75, 81, 82) --10
Labral sclerite absent; epistoma complete (Figs. 78, 79) -13
10.(9) Labial sclerite with a group of dome-like protuberances ventrally (Fig. 75) -*Scambus (Scambus) hispae* (Harris)
Labial sclerite with no such protuberances -------------11
11.(10) Labial sclerite open dorsally ---------------------------12
Labial sclerite closed dorsally ------------------------8
12.(11) Spiracle short and broad, closing apparatus constituting about one-half of its total length (Fig. 112) ------------------------------------*Agrothereutes lophyri* (Nort.)
Spiracle longer, funnel shaped, the closing apparatus constituting only about one-third of its total length (Fig. 111) ------------------------------------*Gelis tenellus* (Say)
13.(9) Atrium of spiracle wider than deep, usually elliptical in outline (Fig. 110) ----------*Exenterus canadensis* Prov.
Atrium of spiracle almost as deep as wide, widest at top and tapering toward its stalk (Fig. 109) ------------------------------------*Exenterus amictorius* (Panz.)
14.(1) Exit hole very nearly at tip of host cocoon, edge slightly ragged or irregular; diameter 1.3–2.0 mm ------------15
Exit hole in various positions, often on side of cocoon; edges smoothly cut or slightly scalloped; diameter 0.4–1.2 mm --17
15.(14) Exit hole large, 1.5–2.0 mm in diameter (Fig. 128) ------------------------------*Itoplectis conquisitor* (Say)
Exit hole smaller, about 1.3 mm in diameter -----------16
16.(15) Remains of parasite consisting of exuviae and buccopharyngeal apparatuses of the first two instars of dipterous larva within host cadaver; exit hole as in Fig. 145 ------------------------------*Bessa harveyi* (Tnsd.)
Parasite remains other than within host cadaver contained within the host cocoon; cephalic structure as in Fig. 95 ------------------------*Spilochalcis albifrons* (Walsh)

17.(14) Cast skin of last larval instar with long hairs or setae --18
Cast skin of last larval instar without conspicuous long hairs or setae --22

18.(17) Skin densely covered with long (0.4 mm) setae; antennae dome-like; blades of mandibles straight (Fig. 88) ---------------------------*Monodontomerus dentipes* (Dalm.)
Skin sparsely covered with setae; antennae peg-like; blades of mandibles curved ----------------------------------19

19.(18) Mandibles each with a large tooth (Fig. 94) --*Eurytoma pini* Bugbee
Mandibles without large tooth -----------------------20

20.(19) Clypeus absent ------------*Catolaccus cyanoideus* Burks
Crescent-shaped, toothed clypeus present (Figs. 86, 87) -21

21.(20) Clypeus with 7 or 8 well-formed teeth (Fig. 86) --------------------------------*Eupelmus spongipartus* Foerst.
Clypeus with 3–5 well-formed teeth (Fig. 87) ------------------------------------*Eupelmella vesicularis* (Retz.)

22.(17) Atrium of spiracle with at least 10 chambers (Figs. 113, 114, 115) --23
Atrium of spiracle with 4–8 chambers; antennae cone-like ---25

23.(22) Cephalic structure of last larval instar showing mandibles, pleurostoma, hypostoma, superior and inferior mandibular processes (Fig. 84) -----*Tetrastichus coerulescens* Ashm.
Cephalic structure of final larval instar with only mandibles visible --24

24.(23) Cast pupal skins dark brown; ventral process of mandible much longer than dorsal process; teeth on blade of mandible prominent (Fig. 85) -------*Elasmus apanteli* Gah.
Cast pupal skins golden-yellow; ventral process of mandible but little longer than dorsal process; teeth on blade of mandible obscure (Fig. 83) --*Dahlbominus fuscipennis* (Zett.)

25.(22) Cephalic structure of final larval instar with mandibles, epistoma, pleurostoma, hypostoma, superior and inferior mandibular processes (Figs. 90, 91); atrium of spiracle with 4 or 5 chambers (Figs. 120, 121) ---------------26
Cephalic structure of final larval instar with only mandibles and sometimes a lightly sclerotized articulation visible (Figs. 89, 93); atrium of spiracle with 5–8 chambers (some may appear sub-divided) (Figs. 119, 123) -----27

26.(25) Ratio of mandibular width: length $\leqq 0.8$ (Fig. 90); exit hole diameter 0.5–0.6 mm; usually secondary parasite -------------------------*Tritneptis scutellata* (Mues.)

Ratio of mandibular width: length >0.8 (Fig. 91); exit hole diameter 0.7–0.8 mm; usually primary parasite ---------------------------------- *Dibrachys cavus* (Walk.)

27.(25) Antennae usually with sockets visible (Fig. 93); total length of spiracle 2.8–3.0 times length of closing apparatus (Fig. 123) ------------ *Habrocytus thyridopterigis* How.

Antennae with no visible antennal sockets (Fig. 89); total length of spiracle 2.3–2.5 times length of closing apparatus (Fig. 119) --------------- *Amblymerus verditer* (Nort.)

KEY TO ADULT PARASITES OF *D. similis*

1. Antennae 3 segmented, the third bearing an arista; body bristly (Diptera) ---------------------------------- 2

Antennae with at least 8 apparent segments; body without bristles (Hymenoptera) ---------------------------- 5

2.(1) Vein M_{1+2} rounded distally, not angular (Fig. 68); only 2 bristles at base of vein R_{4+5}; posterior tip of abdomen red-brown ----------------- *Spathimeigenia spinigera* Tnsd.

Vein M_{1+2} distinctly angular distally (Figs. 70, 72, 74); 4–8 bristles at base of vein R_{4+5}; posterior tip of abdomen black or gray ------------------------------------ 3

3.(2) With a pair of small, usually cruciate bristles on apex of mesoscutellum (Figs. 72, 74); palpi yellow ----------- 4

Without small pair of bristles at apex of mesoscutellum; palpi dark brown (Fig. 70) ------ *Bessa harveyi* (Tnsd.)

4.(3) With a pair of bristle-like hairs on the mesoscutellar disc larger than the others; vein M_{1+2} pronouncedly recurved distally (Fig. 72) ---------- *Diplostichus lophyri* (Tnsd.)

All the hairs on the mesoscutellar disc of equal size; vein M_{1+2} forming an obtuse angle, with little or no tendency towards recurvation (Fig. 74) -- *Euphorocera edwardsii* (Will.)

5.(1) Antennae geniculate (Chalcidoidea) ----------------- 13

Antennae filiform (Ichneumonidae) ------------------ 6

6.(5) Clypeus with a median apical notch (Figs. 1, 5, 9) ----- 7

Clypeus rounded or angular apically, never with a median notch -- 9

7.(6) Tarsal claws of female with a large basal tooth (Fig. 4); front below antennal sockets black in male --------------------------------- *Scambus (Scambus) hispae* (Harris)

Tarsal claws of female without basal tooth; front below antennal sockets creamy white in male -------------- 8

8.(7) Ovipositor with a strong dorsal curve apically (Fig. 8); hind tibia of male not as long as the femur and trochanters combined ------------------ *Delomerista japonica* Cush.

Ovipositor without a strong dorsal curve apically (Fig. 12) ; hind tibia of male as long as femur and tronchanters combined ------------------ *Delomerista novita* (Cress.)

9.(6) Ovipositor short and inconspicuous, mostly concealed within the abdomen (Figs. 17, 20) ; mesoscutellum yellow -- 10

Ovipositor longer, extending beyond the tip of the abdomen and at least one-third as long; mesoscutellum white, black or brown --------------------------------------- 11

10.(9) With a large yellow spot on either side of propodeum; all yellow margins of abdominal tergites less than one-third the length of the tergite ----- *Exenterus canadensis* Prov.

No yellow spot on sides of propodeum; yellow margins of tergites I and II broad, one-third to four-fifths the length of the tergite ------------ *Exenterus amictorius* (Panz.)

11.(9) Eyes prominently emarginate at the level of antennal sockets (Fig. 13) ---------- *Itoplectis conquisitor* (Say)

Eyes not emarginate ----------------------------------- 12

12.(11) Forewings with two broad, transverse dark bands (Fig. 23) ------------------------------- *Gelis tenellus* (Say)

Forewings evenly dusky hyaline --------------------- ------------------------ *Agrothereutes lophyri* (Nort.)

13.(5) Mesofemur dorsoventrally flattened; mesotarsus short, broadened and spinous beneath (Figs. 37, 39) -------- 20

Mesothoracic legs not so modified ------------------ 14

14.(13) Metafemora greatly enlarged and toothed ventrally (Fig. 64) -------------------- *Spilochalcis albifrons* (Walsh)

Metafemora not so modified ------------------------- 15

15.(14) Metacoxae at least 3 times as large as procoxae (Figs. 33, 41) -- 16

Metacoxae only slightly larger than procoxae --------- 17

16.(15) Tarsi 4 segmented, extremely long; radius attached only proximally (Fig. 33) ----------- *Elasmus apanteli* Gah.

Tarsi 5 segmented, normal length; radial vein apparently forming a complete semicircle attached to front margin of wing at both ends (Fig. 41) ------------------------- -------------------- *Monodontomerus dentipes* (Dalm.)

17.(15) Pronotum large and rectangular when viewed dorsally; antennae with 10 segments, last 3 fused (Figs. 60, 62) -------------------------------- *Eurytoma pini* Bugbee

Pronotum narrowed, at least dorsomedially; antennae with 8 or 13 segments ---------------------------------- 18

18.(17) Antennae with 8 segments; tarsi 4 segmented -------- 19

Antennae with 13 segments, the last 3 of which may be more or less fused; tarsi 5 segmented ---------------- 21

19.(18) Forewings infumate centrally (Fig. 28); male antennae with 3 branch-like projections (Fig. 29) ______________________________________ *Dahlbominus fuscipennis* (Zett.)
Forewings hyaline ______ *Tetrastichus coerulescens* Ashm.
20.(13) Wings reduced to non-functional vestiges (Fig. 39) ____ ________________________ *Eupelmella vesicularis* (Retz.)
Wings normally developed ____ *Eupelmus spongipartus* Foerst.
21.(18) Antennal sockets about one-half way up the front (Fig. 56) __________________ *Habrocytus thyridopterigis* How.
Antennal sockets lower, usually about even with lower margin of eyes (Figs. 43, 47, 50, 53) ________________ 22
22.(21) Forewings infumate centrally (Fig. 48) _____________________________________ *Tritneptis scutellata* (Mues.)
Forewings hyaline ________________________________ 23
23.(22) Head disproportionately large; cheeks deeply grooved or excavated (Figs. 53, 54) ____ *Catolaccus cyanoideus* Burks
Head of normal proportions; cheeks not hollowed out __ 24
24.(23) Postmarginal vein about as long as radius (Fig. 51); body very dark green ______________ *Dibrachys cavus* (Wlkr.)
Postmarginal vein distinctly longer than radius (Fig. 44); body bright metallic green __ *Amblymerus verditer* (Nort.)

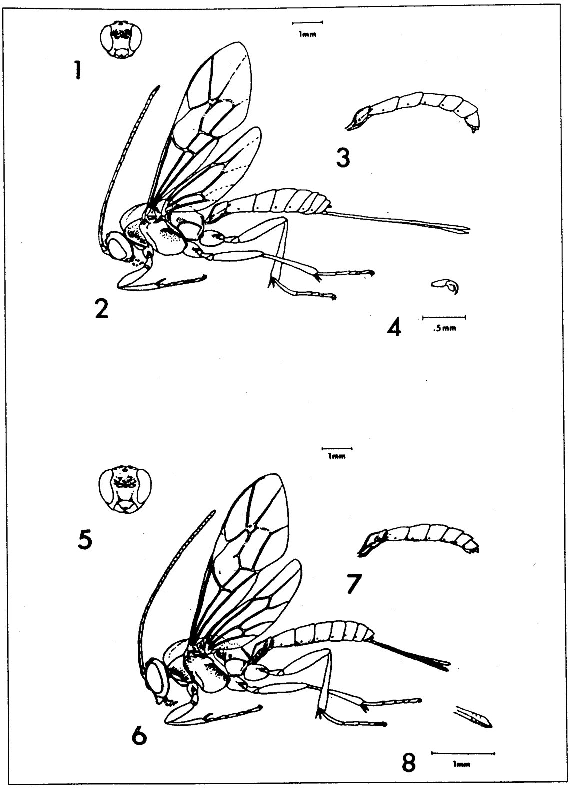
Notes on Biology and Descriptions of Parasites

Hymenoptera
Ichneumonidae

Scambus (Scambus) hispae (Harris)
Figs. 1, 2, 3, 4, 75, 105, 126

S. hispae was reared sporadically from *D. similis* during the present study. It has not been reported previously from this host. It is a solitary, usually internal feeder on *D. similis,* attacking and emerging from the cocoon, and is usually a primary parasite.

The round, sharply cut emergence hole (Fig. 126) is slightly to the side of one end of the host cocoon and is 1.5–1.9 mm in diameter. The parasite cocoon is semi-opaque, thick, and is made of tough tan silk. It is nearly the size and shape of the host cocoon. The host remains are appressed to the inside of the host cocoon but are outside of the parasite cocoon. In the end of the parasite cocoon opposite the emergence hole are a number of hard, shiny black pellets of larval meconium. These are flattened-oval in shape and are usually fused together in a mass. The translucent pale white pupal skin of the parasite is loose within the parasite cocoon. The skin of the female shows a prominent and characteristically long ovi-



FIGURES 1–8. Adult hymenopterous parasites of *D. similis*. 1–4, *Scambus (Scambus) hispae;* 1, head capsule, frontal view; 2, female, lateral view; 3, male abdomen, lateral view; 4, tarsal claw of female. 5–8, *Delomerista japonica;* 5, head capsule, frontal view; 6, female, lateral view; 7, male abdomen, lateral view; 8, tip of ovipositor, lateral view.

positor sheath. White pellets of adult parasite meconium often are found within the cocoon.

The final larval skin is light brown and is heavily pigmented about the head capsule. It usually does not shrink completely, but remains distended, at least lengthwise. Under magnification it is densely covered with blunt conical papillae and scattered short setae. The cephalic structure (Fig. 75) has a weakly sclerotized epistoma which is usually broken in molting, and prominent labral and suspensorial sclerites. The mandibles each have 2 rows of fine teeth. The stipital sclerites are elongate and straight. The most easily identifiable feature of the structure is the group of dome-like protuberances on the ventral portion of the labial sclerite.

Although usually a primary parasite, *S. hispae* was reared once as a secondary through *I. conquisitor* and once through *E. amictorius*. In one case, both *S. hispae* and *G. tenellus* emerged from the same cocoon, and in another instance, a female *I. conquisitor* shared a sawfly cocoon with a female *S. hispae;* both reached maturity, but only *S. hispae* emerged successfully. The sex ratio of specimens reared was 48 females:7 males. Males differ from females in their narrower abdomen without an ovipositor (Fig. 3), and in the absence of a basal tooth on the tarsal claw.

Delomerista japonica Cushman
Figs. 5, 6, 7, 8, 76, 106, 127

D. japonica is a fairly common and occasionally abundant parasite of *D. similis,* with some being reared every year. The insect attacks and emerges from the host cocoon. It is a solitary primary parasite.

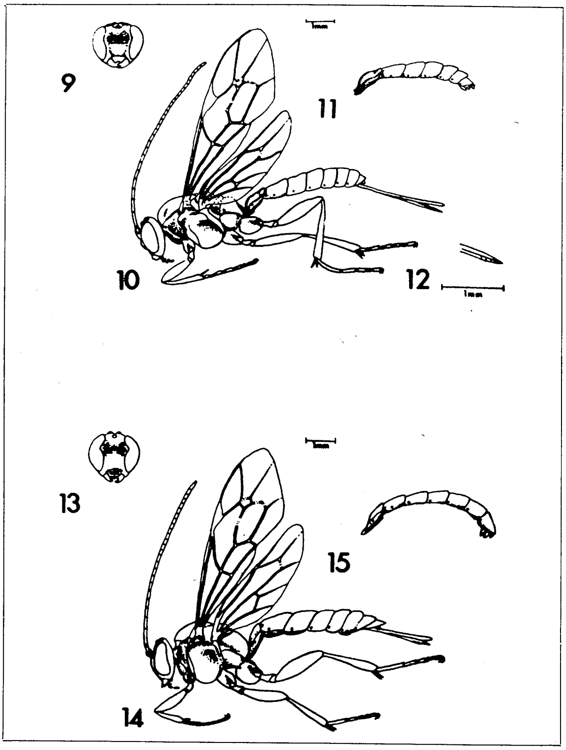
The exit hole (Fig. 127) is slightly off the tip of the host cocoon, round, but irregularly cut, and 1.8–2.2 mm in diameter. The host cocoon contains the flattened sawfly remains against a side wall, and usually walled off with a layer of coarse tan or white silk. Sometimes the silk is extended to form a nearly complete inner lining of the host cocoon. The hardened, deep red-brown to black larval meconium is in the end of the cocoon opposite the exit hole and may be in the form of pellets. The shrunken, shiny pale yellow pupal skin is loose within the cocoon. Several chalky white pellets of adult meconium usually are also present.

The skin of the final instar is loose in the cocoon and is light yellow with brown, strongly sclerotized cephalic structures. It is covered densely with minute conical papillae and intermittently with setae 0.13 mm long. The epistoma of the cephalic structure is incomplete (Fig. 76). A prominent bow-shaped labral sclerite is present. The mandibles each have 2 rows of fine teeth on the blades, and 1 large posterior medial tooth. The stipital sclerites are short and broad.

The sex ratio of reared specimens favored females 37:28. Males can be differentiated from females by the absence of an ovipositor, and the presence of a white face and white pro- and mesothoracic legs.

Delomerista novita (Cresson)
Figs. 9, 10, 11, 12, 77, 107, 127

D. novita is a rare parasite of *D. similis,* only 4 females and possibly 1 male having been reared, and it has not been reported previously from this sawfly. Its life history is similar to *D. japonica,* and all the life stages are comparable to that species. The adult



FIGURES 9–15. Adult hymenopterous parasites of *D. similis*. 9–12, *Delomerista novita;* 9, head capsule, frontal view; 10, female, lateral view; 11, male abdomen, lateral view; 12, tip of ovipositor, lateral view. 13–15, *Itoplectis conquisitor;* 13, head capsule, frontal view; 14, female, lateral view; 15, male abdomen, lateral view.

female may be separated readily from *D. japonica* by the gentler dorsal curve in the tip of the ovipositor (Fig. 12). According to Townes and Townes (1960) the males of the two species may be separated by the relative lengths of the metatibia (couplet 8 of the key to adult parasites), but the single specimen at hand is certainly borderline. The immature stages of the two species are as difficult to separate. In the specimens examined, the cephalic structure of *D. novita* was larger and more heavily sclerotized than that of *D. japonica,* but this could be due to individual variation. The best differentiating character seems to be the difference in the shape of the labial sclerite (Fig. 77). That of *D. japonica* is somewhat angular, especially dorsally, whereas in *D. novita* it is smoothly rounded. In addition, the ratio of width to length of the spiracle of *D. novita* is 0.7:1, whereas that of *D. japonica* is about 0.6:1, although a number of *D. japonica* specimens have spiracles similar in shape to those of *D. novita* (Figs. 106, 107).

Itoplectis conquisitor (Say)
Figs. 13, 14, 15, 80, 108, 128

I. conquisitor was a common and sometimes abundant parasite of *D. similis*. It nearly always functioned as a primary, solitary, internal feeder in the cocoon.

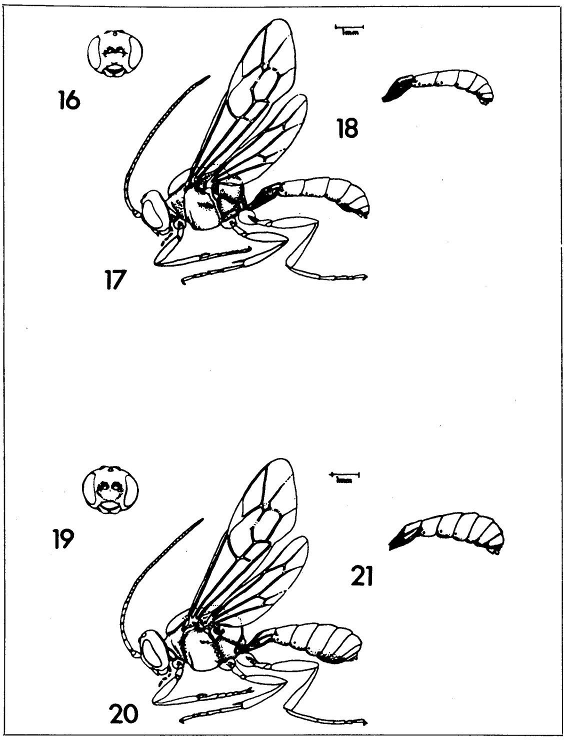
The emergence hole (Fig. 128) is close to the tip of the host cocoon, 1.55–2.0 mm in diameter, usually round, but with ragged edges. The host remains consist either of larval integument, or occasionally a pupal skin. The remains are flattened solidly against the cocoon wall and usually partitioned off with at least a crude mat of rough brown silk, which may be expanded to a semi-complete lining of the host cocoon. A tan to red-brown pellet mass of larval meconium adheres to the side of the cocoon opposite the exit hole, and occasionally one to several elongate white pellets of adult meconium are present within the cocoon. The last larval and pupal skins are free in the end opposite the exit hole. The pupal skin is pale, translucent and often fragmented.

The final instar skin is yellow to light brown with a prominent, strongly sclerotized cephalic structure. It is covered with minute spines, and a few inconspicuous setae. The cephalic structure (Fig. 80) cannot be confused with that of any other parasite of *D. similis*. It appears as a complete circle broken only by the labial sclerite; the hypostomal arms are lacking; the mandibles are large and usually show 15 or 20 rounded protuberances medially; the area above the silk press is densely covered with sharp spines. The disc-like antennae are small and inconspicuous. The spiracle (Fig. 108) is short and oval-shaped.

The adult is easily recognized by the prominent light and dark bands on the posterior tibiae and tarsi. The sex ratio of reared specimens favored females by 4.5:1. Males are separated easily from females by the absence of an ovipositor (Fig. 15). The single instance of *I. conquisitor* as a hyperparasite found it as a secondary through *E. amictorius*, and in one case, both *I. conquisitor* and *G. tenellus* emerged from the same host cocoon.

Exenterus amictorius (Panzer)
Figs. 16, 17, 18, 78, 109, 129

This European species was not recorded from *D. similis* in Wisconsin until 1961, and has increased steadily in abundance since that time to rival *Monodontomerus dentipes* as the most important



FIGURES 16–21. Adult hymenopterous parasites of *D. similis*. 16–18, *Exenterus amictorius;* 16, head capsule, frontal view; 17, female, lateral view; 18, male abdomen, lateral view. 19–21, *Exenterus canadensis;* 19, head capsule, frontal view; 20, female, lateral view; 21, male abdomen, lateral view.

species in the parasite complex (Mertins and Coppel, 1968). It is a solitary, primary parasite of the sawfly larva, and emerges from the cocoon.

The exit hole (Fig. 129) is near the end of the host cocoon, round and jaggedly cut. Except for *E. canadensis,* which makes an equally large hole, the exit hole is the largest of the parasites emerging from *D. similis* cocoons, being 2.1–2.5 mm in diameter. The parasite cocoon is about the size and shape of the host cocoon, thin, translucent, shiny, and white to pink in color. The host remains adhere to the lateral wall of its cocoon and outside that of the parasite. The partially embedded, empty chorion of the egg from which the parasite larva emerged can frequently be seen along its dorsum, usually in the thoracic region. At the end of the cocoon opposite the exit hole are found several flattened, oval brown pellets of larval meconium; the shrivelled yellow to tan larval skin; the transparent, whitish cast pupal skin; usually a large mass of white adult meconium; and numerous pieces of cocoon cut from the exit hole.

To separate the larvae of the species of *Exenterus* a perfect mount is necessary, and even then identification is not always certain (Finlayson, 1960). The cast skin of the final instar is covered with minute needle-like spines and a few short setae. The narrow epistoma of the cephalic structure (Fig. 78) is complete, but lightly sclerotized in most specimens. The stipital sclerites are large and bend dorsally along the margins of the U-shaped labial sclerite. The blade of the mandible is long, slender and pointed. The spiracular atrium (Fig. 109) is about as deep as it is wide, and tapers towards its base.

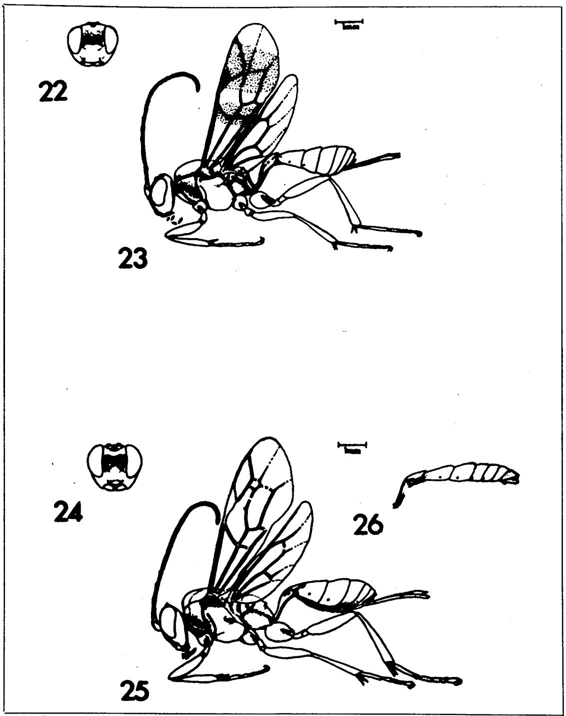
Adults are black with yellow markings, and a greenish sheen to the eyes in life. Living males can be separated readily from females. Females have a single large hypopygial plate and males have two, the anterior of which is margined with yellow giving the appearance of a narrow yellow line across the black ventral apex of the abdomen. In pinned specimens, collapse of the abdominal sternites makes microscopic examination of the genitalia necessary for proper sex determination. The sex ratio of reared specimens was 6 females:5 males.

Since becoming an important parasite of *D. similis, E. amictorius* has become the focal host of the complex of hyperparasites found associated with the sawfly, being attacked by no fewer than 10 species. The appearance of several native species of hyperparasites not previously reared from *D. similis* cocoons may be the result of the increased abundance of *E. amictorius,* the species with which they have become commonly associated. Functioning as a multiparasite, *E. amictorius* emerged from the same host cocoon with *M. dentipes, G. tenellus, D. fuscipennis, D. cavus,* or *T. scutellata.*

Exenterus canadensis Provancher
Figs. 19, 20, 21, 79, 110, 129

A rare parasite of *D. similis* in Wisconsin, *E. canadensis* has been reared about a dozen times, and in recent years has been encountered only once by dissection. The appearance and life history are, in general, similar to *E. amictorius.*

The exit hole (Fig. 129) is similar to *E. amictorius,* as are the remains left in the host cocoon, except that the silk of the parasite cocoon is never pink. The larval skin is best separated from *E. amictorius* by the shape of the spiracular atrium which is oval and wider than deep (Fig. 110). In addition, well mounted cephalic structures show both a lower epistomal arch, and shorter, more robust lacinial sclerites (Figs. 78, 79).



FIGURES 22–26. Adult hymenopterous parasites of *D. similis*. 22, 23, *Gelis tenellus;* 22, head capsule, frontal view; 23, female, lateral view. 24–26, *Agrothereutes lophyri;* 24, head capsule, frontal view; 25, female, lateral view; 26, male abdomen, lateral view.

Gelis tenellus (Say)
Figs. 22, 23, 81, 111, 130

G. tenellus is a common though not abundant parasite of *D. similis*. It is a solitary, external feeder, and functions as either a primary or secondary parasite. In three cases two individuals emerged from the same host cocoon.

The exit hole (Fig. 130) is just to one side of the tip of the host cocoon, round, smoothly cut, and 1.0–1.3 mm in diameter. The parasite cocoon adheres tightly to the inside of the host cocoon along its length on the side where the exit hole occurs. It is about one-fifth to one-fourth the volume of the host cocoon, thin, and loosely woven of light gray silk which is shiny on both sides. Host remains, which are excluded from the parasite cocoon, indicate that frequently the host pupa is attacked, as well as the prepupa. A fused clump of hard brown pellets of larval meconium is found opposite the exit hole within the parasite cocoon, and lying loose nearby is the pale, transparent pupal skin with its long ovipositor sheath.

The pale, transparent final larval exuvium lies in close proximity to, and often is tangled with, the pupal skin. It is covered with minute bump-like protuberances and scattered setae. The cephalic structure (Fig. 81) has a complete, unsclerotized epistoma; the stipital sclerites are long, extending almost to the hypostomal arms; the blades of the mandibles are straight with two rows of fine teeth; a widely arched labral sclerite turns down over the mandibles; a U-shaped suspensorial sclerite occurs dorsally and posterior to the mandibles. The funnel-shaped spiracle has 10–12 annulations (Fig. 111).

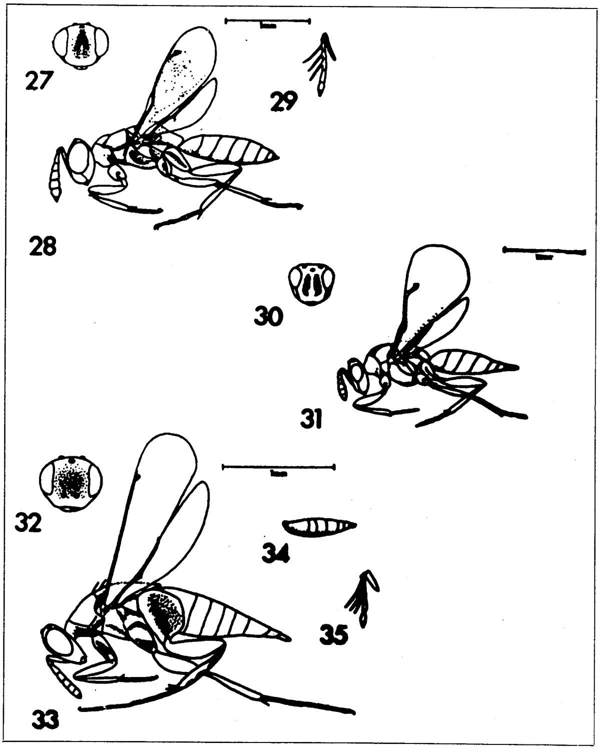
In the years before *E. amictorius* became prevalent, *G. tenellus* was most always a primary parasite. Recently, however, it has been found frequently as a secondary through *E. amictorius.* It also parasitizes through *I. conquisitor.* In addition, six instances in which both *Gelis* and *E. amictorius* emerged from the same cocoon were encountered, and it also exhibited a similar multiparasitic relationship with *M. dentipes, S. hispae, I. conquisitor, T. scutellata,* and *H. thyridopterigis. G. tenellus* is the only parasite with two dark bands on each forewing. Of nearly 600 specimens reared from the sawfly, no males have been encountered.

Agrothereutes lophyri (Norton)
Figs. 24, 25, 26, 82, 112, 131

A. lophyri was reared consistently, although not in great numbers from *D. similis.* It was always a primary, solitary, external parasite of the sawfly within its cocoon.

The emergence hole (Fig. 131) is slightly off the tip of the host cocoon, round with slightly ragged edges, and 1.5–2.0 mm in diameter. The parasite cocoon is complete and nearly the size and shape of the sawfly cocoon. It is white, papery, and brittle, and made up of two to several layers. Its outside layer is rough and sometimes has a brownish tinge, whereas the inside is smooth and shiny. The end of the parasite cocoon opposite the emergence hole contains a layer of hardened red-brown larval meconium, in or on which lie the pale whitish, shrivelled pupal skin, the yellowish shrunken larval skin, and small particles of cocoon from the exit hole.

The head capsule of the larval skin is brown, and the skin is covered with minute, sharp, conical spines and scattered setae. The epistoma of the cephalic structure is unsclerotized but appears complete (Fig. 82). The structure is similar to *G. tenellus,* but is



FIGURES 27–35. Adult hymenopterous parasites of *D. similis*. 27–29, *Dahlbominus fuscipennis;* 27, head capsule, frontal view; 28, female, lateral view; 29, male antenna, lateral view. 30, 31, *Tetrastichus coerulescens;* 30, head capsule, frontal view; 31, female, lateral view. 32–35, *Elasmus apanteli;* 32, head capsule, frontal view; 33, female, lateral view; 34, male abdomen, lateral view; 35, male antenna, lateral view.

larger, has stronger teeth on the mandibles, a sclerotized prelabium, and widened dorsal arms on the labial sclerite. The spiracle has a tapering reticulate atrium, a short stalk of two or three annuli, and a large closing apparatus (Fig. 112).

The adults are readily identified by the wide red-brown to orange band around the abdomen. Males differ from females in the lack of an ovipositor (Fig. 26), and the absence of a white band around each antenna. The sex ratio of 48 reared specimens was 3:1 in favor of females.

Eulophidae

Dahlbominus fuscipennis (Zetterstedt)

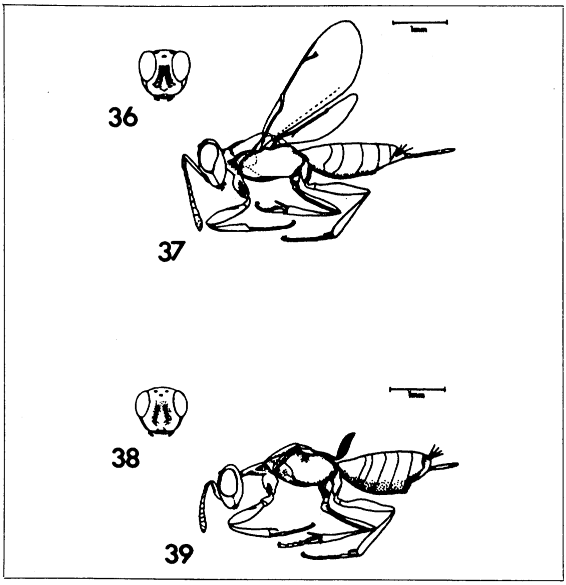
Figs. 27, 28, 29, 83, 113, 132

The European *D. fuscipennis* is established on *D. similis* in Wisconsin, is reared regularly, but is never very numerous. In all examined instances but one, the insect was a primary, gregarious, external parasite of the sawfly prepupa. It attacks and emerges from the host cocoon.

Emergence is most often via a hole (Fig. 132) slightly off one end of the host cocoon, but the hole may be anywhere along the side, and occasionally two holes are cut at opposite ends. The hole is irregularly round and about 0.6–0.7 mm in diameter. No parasite cocoons are present. The host remains are shrivelled and frequently unrecognizable. Careful dissection usually reveals that the host remains are located in the center of the cocoon, surrounded on all sides by the parasite remains. This arrangement is seen most easily before emergence, when the parasite larvae are lined up against the walls facing in one direction before pupation. After emergence the inside of the cocoon is a dishevelled mass of shiny, golden-yellow broken pupal skins, and dead larvae. The larval meconium is a hard dark-brown to gray mass occasionally made up of small ovoid pellets.

The minute last larval skin is often found adhering to the meconial mass, or sometimes to the posterior end of the pupal skin. Because of their small size it is sometimes easier to use a dead larva for identification purposes rather than a skin. One or two dead larvae are commonly found in the cocoon, and may be recognized by their shiny brown color, and the fact that broken pieces of pupal skins frequently adhere to them. The larvae are softened in KOH, punctured with a needle, and the contents squeezed out before mounting in the normal manner. Mounted skins are smooth and without structure other than mandibles, antennae and spiracles. The mandibles are triangular with a long, straight blade (Fig. 83). A row of minute teeth along the blade are usually very difficult to discern. The antennae are dome-like with two sensoria each. The spiracle is funnel-shaped, with at least ten chambers and a long stalk (Fig. 113).

D. fuscipennis is usually a primary parasite, but in one instance it apparently developed hyperparasitically through an *A. lophyri* larva. In one other case both *D. fuscipennis* and *E. amictorius* emerged from the same cocoon. The average number of individuals emerging per cocoon was 28 (range 3–59), and the overall sex ratio of insects reared was 4.3 females:1 male. Males differ from females in the shape of the antennae (Fig. 29), and their nearly hyaline forewings.



FIGURES 36–39. Adult hymenopterous parasites of *D. similis*. 36, 37, *Eupelmus spongipartus;* 36, head capsule, frontal view; 37, female, lateral view. 38, 39, *Eupelmella vesicularis;* 38, head capsule, frontal view; 39, female, lateral view.

Tetrastichus coerulescens Ashmead
Figs. 30, 31, 84, 114, 133

The hyperparasite, *T. coerulescens,* was encountered only twice during the study, and has not been reported previously from *D. similis*.

In the single example of emergence available, 2 exit holes were cut in the host cocoon on the side near one end. Probably 1 hole is cut normally, as this is the usual case in other parasites which develop gregariously on the sawfly. The hole (Fig. 133) is oblong (.47 x .40 mm). The chalcid pupae parasitized by *T. coerulescens* turned dark brown as opposed to the orange color of unparasitized pupae. Emergence from the host pupa is characteristically via a large irregular round hole cut in the ventral portion of the abdomen, usually completely destroying the abdominal tergites. The host pupa is hollow except for a dark, shiny gray or brown deposit of larval meconium in the head capsule, and the yellow parasite larval skin and yellow-brown pupal skin which lie on the meconium.

The skin of the final instar is extremely small and thread-like. Under magnification the only visible features are the spiracles and the cephalic structure (Fig. 84), which has an incomplete epistoma, large and prominent superior mandibular processes, and a ventral sclerotized bridge apparently formed from the fused inferior mandibular processes. The mandibles are bulbous ventrally and lack teeth on the blades. The spiracle (Fig. 114) has 15–18 chambers and a small closing apparatus.

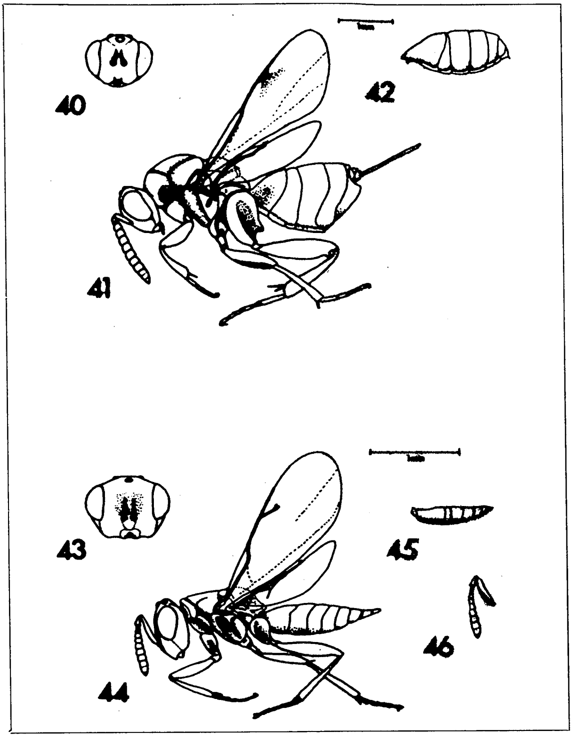
When this insect emerged from a *D. similis* cocoon it was a secondary parasite through *A. verditer*. Three female parasites emerged from the cocoon, each having matured as an internal solitary parasite of a single pupa of *A. verditer*. The second occurrence of *T. coerulescens* was revealed by dissection, and was part of the most complex association of insects found in a single sawfly cocoon. Dissection of a cocoon which had produced two adult female *M. dentipes*, revealed in addition to the *M. dentipes* and sawfly remains, those of an *E. amictorius* larva, one adult female *H. thyridopterigis*, one dead *H. thyridopterigis* pupa, and one adult female *T. coerulescens*. In this instance *T. coerulescens* was a tertiary parasite through *H. thyridopterigis* on *E. amictorius*. *T. coerulescens* was the smallest parasite reared from *D. similis* and can be identified easily by the blunt-tipped shape of the wings (Fig. 31). No males were encountered, but according to Burks (1943) they differ from the female both in having long setae on the antennal funicle segments, and in having the first segment of the funicle only three-fourths as long as the second.

Elasmus apanteli Gahan
Figs. 32, 33, 34, 35, 85, 115, 134

E. apanteli is a rare parasite of *D. similis* cocoons. It was encountered only twice, during the late summer of 1968, once by emergence and once by dissection. It is a gregarious secondary parasite through *E. amictorius*. This is a new host record.

The nearly circular exit hole (Fig. 134) is located at the tip of the host cocoon. It is about 0.6 mm in diameter and the edges are slightly scalloped. No parasite cocoons are present. The contents of the sawfly cocoon are the same as those described for the primary parasite, *E. amictorius*. The *E. amictorius* pupa is shrivelled and dark brown. The *Elasmus* remains are within the *Exenterus* cocoon, and include several dark brown pupal cases, which are virtually intact, save the head and pro- to mesothoracic region; several dead larvae or pupae; clusters of small, brown ovoid larval meconium pellets; and the pale yellow, thread-like larval exuvium, which is usually attached to the posterior tip of the pupal case abdomen.

The mounted exuviae (Fig. 85) closely resemble those of *D. fuscipennis*. In general, the row of fine teeth along the blade of the man-



FIGURES 40–46. Adult hymenopterous parasites of *D. similis*. 40–42, *Monodontomerus dentipes;* 40, head capsule, frontal view; 41, female, lateral view; 42, male abdomen, lateral view. 43–46, *Amblymerus verditer;* 43, head capsule, frontal view; 44, female, lateral view; 45, male abdomen, lateral view; 46, male antenna, lateral view.

dible is more distinct in *E. apanteli,* and in addition, the postero-ventral process of the mandible is much longer than the dorsal process as compared to those of *D. fuscipennis* which are about equal in length. Perhaps the easiest separation may be made on the basis of the color of the cast pupal skins which are brown in *Elasmus* and golden-yellow in *Dahlbominus.*

The recent rearings of *E. apanteli* from *D. similis* cocoons may be the result of the increasing importance of its primary host, *E. amictorius,* in recent years. In addition to *E. apanteli, Catolaccus cyanoideus* and *Tritneptis scutellata* have also been found recently, and nearly exclusively, associated with *E. amictorius.* The adults of *E. apanteli* are distinctive (Fig. 33). The hind coxa is enormously enlarged and flattened and the tarsus is elongate and four segmented. Males may be distinguished by the shape of the antennae (Fig. 35). The sex ratio of reared adults was 5 females:1 male.

Eupelmidae

Eupelmus spongipartus Foerster
Figs. 36, 37, 86, 116, 135

One female *E. spongipartus* has been reared from *D. similis* in Wisconsin, and it was a solitary, secondary cocoon parasite through *D. cavus*. It is undoubtedly an insignificant member of the parasite complex.

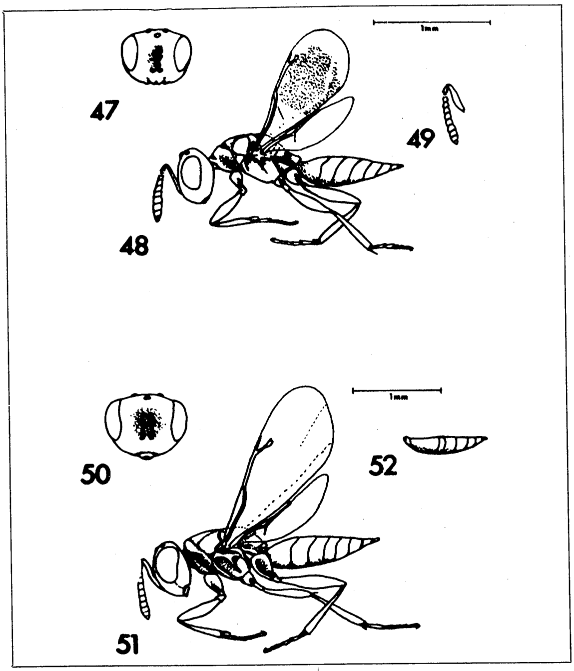
The exit hole (Fig. 135) is on the side of the host cocoon near the tip, round, smooth, and 1.0 mm in diameter. No cocoon is spun, but the small, white, fibrous egg mat noted by Muesebeck and Dohanian (1927) is attached to the inside of the host cocoon. The parasite remains are loose within the cocoon and consist of a group of dark red-brown ovoid pellets of larval meconium; the small, pale yellow larval skin which is covered with long setae; and the fragile, golden-yellow pupal skin, whose abdomen retains its shape.

The cast skin of the last instar is smooth except for a sparse covering of long setae. The most prominent feature of the cephalic structure is the large, crescent-shaped, 8-toothed clypeus (Fig. 86). The inferior mandibular articulations occur as depressions on a lightly sclerotized, transverse ventral bar, and the superior articulations (one of which is hidden in Fig. 86) are separate and lightly sclerotized as well. The mandible is large and sclerotized, bulbous basally, and has a curved toothless blade. The spiracle (Fig. 116) is funnel-shaped with 14–19 chambers, a prominent closing apparatus, and an annulated stalk. An irregular line occurs around the first chamber.

Eupelmella vesicularis (Retzius)
Figs. 38, 39, 87, 117, 136

Reared in small numbers every year, this insect can act as either a primary or secondary parasite of *D. similis* cocoons. It is a solitary, external feeder.

The exit hole (Fig. 136) is on the side of the host cocoon near the tip, is smooth and oblong (0.8 x 1.0 mm). As in *E. spongipartus* no cocoon is spun, but one to several white fibrous mats (0.6 x 0.3 mm) are found on the inside of the host cocoon. Clausen (1940) believed these fibrous mats which cover the eggs serve as protection from primary parasites upon which the developing *Eupelmella* larvae will prey. The parasite remains are similar to those of *E. spongipartus* except that they are slightly smaller and the last larval exuvium is darker yellow.



FIGURES 47–52. Adult hymenopterous parasites of *D. similis*. 47–49, *Tritneptis scutellata;* 47, head capsule, frontal view; 48, female, lateral view; 49, male antenna, lateral view. 50–52, *Dibrachys cavus;* 50, head capsule, frontal view; 51, female, lateral view; 52, male abdomen, lateral view.

The sparsely setate skin of the final instar presents features nearly identical to *E. spongipartus* under magnification. However, the clypeus usually has only five well-developed teeth (Fig. 87) with two or three imperfect ones laterally; the inferior mandibular articulations are less sclerotized and more distinctly separated from each other, and the superior articulations are not discernible. Contrary to the findings of Finlayson (1962), in our material it was not possible to distinguish *E. spongipartus* from *E. vesicularis* by the number of chambers in the spiracular atrium. In both species the number ranged from 14–19, although the prominent wavy line around the first chamber in *spongipartus* is not as evident in *vesicularis* (Fig. 117). In any case, because of the rarity of *E. spongipartus*, one can be fairly certain that a parasite exhibiting a cephalic structure such as that in Figs. 86 or 87 is *E. vesicularis*.

E. vesicularis is most commonly secondary, especially through *D. fuscipennis*, as noted by Morris (1938), but also matured on a number of other parasite species, and in a number of instances was a primary parasite. In 2 instances 2 individuals of this species emerged from a host cocoon, both utilizing the same exit hole, and in 3 cases an *E. vesicularis* and several *M. dentipes* emerged from the same sawfly cocoon. The *E. vesicularis* had functioned as a secondary parasite, but had apparently failed to destroy all of the primary parasites within the cocoon before completing its development. No males of this species are known (Gahan, 1933).

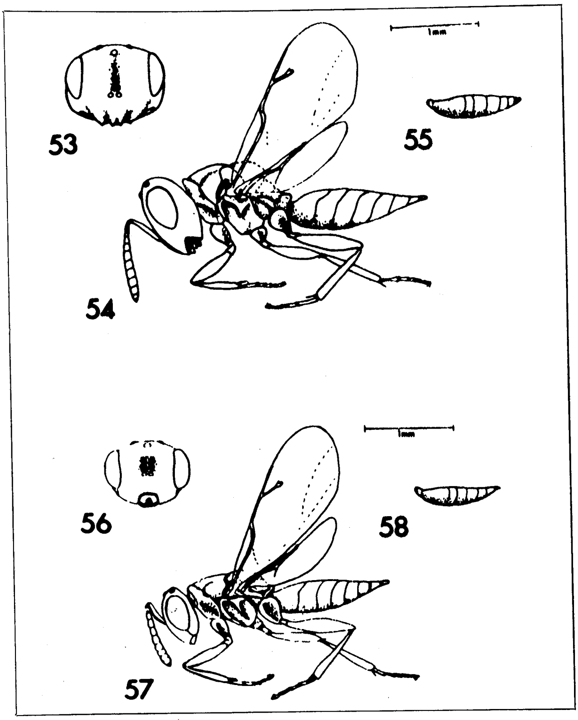
Torymidae

Monodontomerus dentipes (Dalman)
Figs. 40, 41, 42, 88, 118, 137

M. dentipes is one of the two commonest parasites of *D. similis* in Wisconsin. It is nearly always reared from every collection of cocoons made in the field, and is frequently observed in the process of oviposition. It is a gregarious, external parasite of *D. similis,* attacking and emerging from the cocoon.

The exit hole is usually located slightly to one side of the tip of the host cocoon, and is round with jagged edges (Fig. 137). It is normally 1.1 mm in diameter, but may be as large as 1.3 mm, or as small as 0.6 mm if only small males are produced. In about 3% of the cocoons examined, 2 emergence holes were cut, and occasionally the hole is cut on the side of the cocoon. The arrangement of the inside of the cocoon is similar to that left by *D. fuscipennis,* with the host remains and meconia of the parasites in the center, and the parasite pupal and larval skins layered against the walls. This is a result of the tendency of the mature parasite larvae to line up in a single layer around the host cocoon walls all facing in one direction before pupation. There are no cocoons. The larval meconium consists of numerous single or massed brown or black ellipsoid pellets located usually at the end opposite the exit hole. The yellow larval skins are covered with long hairs, and are loose within the cocoon. The ovipositor sheath of female pupal skins is long and conspicuously curved antero-dorsally. Many times the flattened, banana-shaped egg chorions adhere to the host remains.

The skin of the last instar is smooth, but densely covered with long (0.4 mm) setae. The cephalic structure (Fig. 88) has an incomplete epistoma, short hypostomal arms, large superior mandibular processes and greatly elongate inferior processes upon which the mandibles rest. The mandibles have a straight blade without teeth. The antennae are prominent dome-like structures each bearing two sensoria apically. The spiracle (Fig. 118) is large, reticulate, funnel-shaped with thick walls, and has 8–10 chambers.



FIGURES 53–58. Adult hymenopterous parasites of *D. similis.* 53–55, *Catolaccus cyanoideus;* 53, head capsule, frontal view; 54, female, lateral view; 55, male abdomen, lateral view. 56–58, *Habrocytus thyridopterigis;* 56, head capsule, frontal view; 57, female, lateral view; 58, male abdomen, lateral view.

The adults of *M. dentipes* are large and robust. They are dark green with red eyes. Males are distinguished easily by the absence of an ovipositor (Fig. 42). The average number of adults emerging from a host cocoon was 8 (range 1–32), and the sex ratio was 1.1 females : 1 male.

The host relations of *M. dentipes* are complex. Dissections indicate that the insect is most often a primary parasite, but it was found as a secondary through *I. conquisitor, E. amictorius, D. fuscipennis,* and *D. lophyri.* This relationship is probably facultative. In other instances it was the successful competitor in a multiparasitic situation, although it apparently did not act as a secondary. Instances of secondary and multiparasitism by this species are most common in second generation sawfly cocoons which are most heavily attacked by the large numbers of *M. dentipes* present in the fall.

The insect seems to be a successful multiparasite more often than it is unsuccessful, for it is seldom found dead in cocoons attacked by other species. *M. dentipes* has emerged from the same cocoons with the following species: *E. amictorius, E. vesicularis, G. tenellus, H. thyridopterigis,* or *A. verditer.*

Pteromalidae

Amblymerus verditer (Norton)

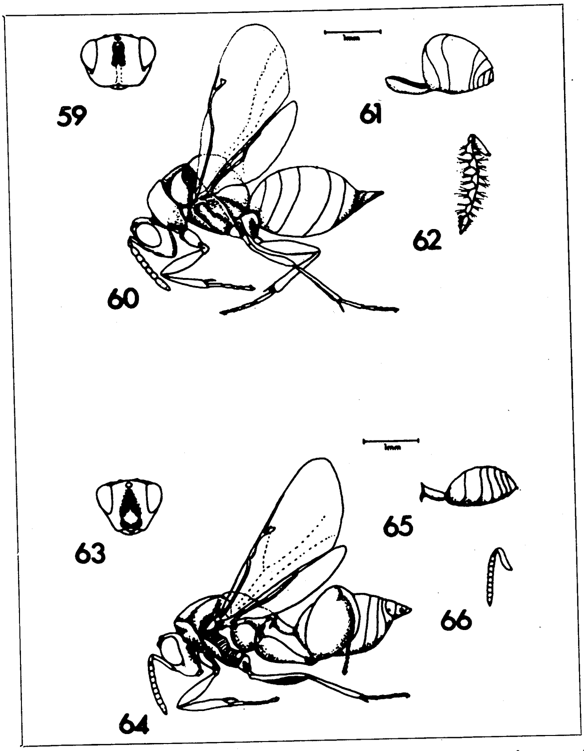
Figs. 43, 44, 45, 46, 89, 119, 138

A. verditer was reared sporadically, but not in great numbers from *D. similis.* It is a gregarious, external feeder in the cocoon, and in nearly every case acted as a primary parasite.

The exit hole is on the side of the host cocoon, often near the tip, but sometimes in the middle. Occasionally more than 1 hole is cut. The hole (Fig. 138) is small, round and regular, and 0.8 mm in diameter. No parasite cocoons are present. The parasite remains include numerous small shiny brown to black pellets of larval meconium, numerous tiny white larval skins resembling twisted threads, and fragmented shiny golden-yellow pupal skins, all loose within the cocoon. Dead and shrivelled parasite larvae and pupae are sometimes present. All 5 members of the Pteromalidae which parasitize *D. similis* leave remains similar to those described above, and therefore cannot be separated from each other without making slides.

The last larval skin is nearly featureless, except for a few inconspicuous widely scattered setae, the spiracles, and the cephalic structure which consists only of the mandibles and lightly sclerotized articulations (Fig. 89). The antennae are nearly as large as the blades of the mandibles, though not as pointed, and are without antennal sockets. The spiracle (Fig. 119) is funnel-shaped with 5–8 chambers, some of which appear subdivided, and has a narrow closing apparatus.

Although commonly a primary parasite, *A. verditer* occasionally was found to develop at the expense of *E. amictorius.* In one instance, individuals of both *A. verditer* and *M. dentipes* emerged from the same host cocoon. The adult is recognized most easily by its coloration which is brilliant metallic green in the female, and metallic yellow–green with a yellow band around the abdomen in the male. In addition, the male abdomen (Fig. 45) is shorter and narrower than that of the female. The scape of the male antenna (Fig. 46) is thicker than that of the female, and shows an anterior depression. An average of 22 individuals emerged per cocoon (range 6–40), and the sex ratio of reared individuals was 2.6 males: 1 female.



FIGURES 59–66. Adult hymenopterous parasites of *D. similis*. 59–62, *Eurytoma pini;* 59, head capsule, frontal view; 60, female, lateral view; 61, male abdomen, lateral view; 62, male antenna, lateral view. 63–66, *Spilochalcis albifrons;* 63, head capsule, frontal view; 64, female, lateral view; 65, male abdomen, lateral view; 66, male antenna, lateral view.

Tritneptis scutellata (Muesebeck)
Figs. 47, 48, 49, 90, 120, 132

T. scutellata was reared from 16 host cocoons collected during the summers of 1967 and 1968. *D. similis* has not been previously reported as its host. It is usually a secondary gregarious parasite, attacking and emerging from the sawfly cocoon.

The emergence hole is on the side of the host cocoon near the tip, round, and has slightly irregular edges (Fig. 132). It is 0.5–0.6 mm in diameter. In 2 cases more than 1 hole was used in emerging. No parasite cocoons are formed, and the other remains are similar to those described for *A. verditer*.

The exuvium of the last instar also resembles that of *A. verditer*, but may be separated by the cephalic structure and the spiracles.

The cephalic structure (Fig. 90) has, in addition to the mandibles, an incomplete epistoma, pleurostoma, hypostoma, superior and inferior mandibular processes, and shorter antennae. The atrium of the spiracle has but 4–5 chambers (Fig. 120). It is especially difficult to separate the parasite remains of *T. scutellata* from those of *D. cavus,* but the characters used in the key should allow reasonable certainty in most cases.

T. scutellata is usually a secondary parasite, and in most cases was found to be associated with *E. amictorius*. In 2 cases both *T. scutellata* and *E. amictorius* adults emerged from the same cocoon; in 10 cocoons *T. scutellata* developed as a secondary parasite through *E. amictorius,* and from 1 of these an adult *G. tenellus* also emerged. In 4 other cocoons, *T. scutellata* was secondary through *I. conquisitor* in 1, shared a sawfly host with *A. lophyri* in another, and was a primary parasite in the others.

The average number of individuals emerging per cocoon was 8 (range 3–15), and the sex ratio of reared specimens favored females 3:1. Males differ from females in their smaller abdomen and broader antennal scape (Fig. 49).

Dibrachys cavus (Walker)
Figs. 50, 51, 52, 91, 121, 139

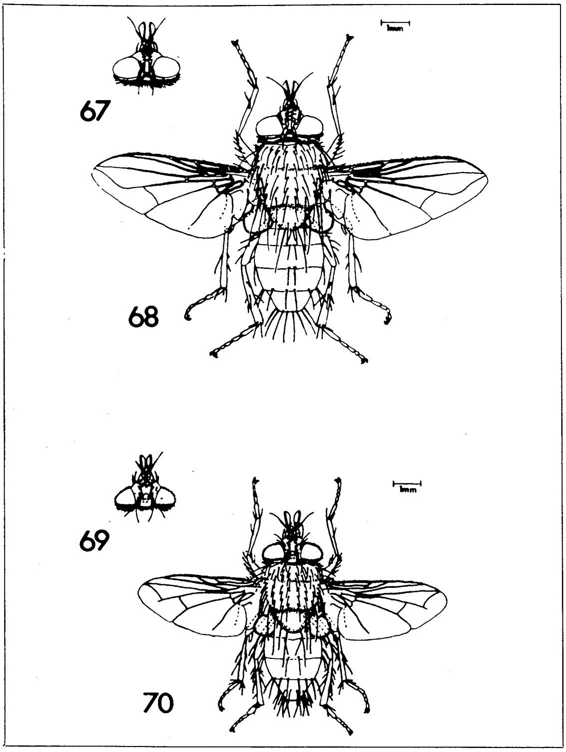
D. cavus is an occasional parasite of *D. similis,* with only a few individuals reared each year. It is a gregarious, external parasite in the cocoon, and most often functions as a primary.

The exit hole is as in *A. verditer,* 0.7–0.8 mm in diameter, and may have scalloped edges (Fig. 139). More than 1 hole is sometimes cut. The contents of the cocoon are similar to those described for *A. verditer*. The skin of the last instar is similar to *A. verditer* and the cephalic structure (Fig. 91) and spiracle (Fig. 121) resemble those of *T. scutellata*. The characters used in the key are sufficient to separate these species in the majority of cases.

D. cavus is usually a primary parasite, but in several cases it was found to develop at the expense of *E. amictorius*. In 1 instance both *D. cavus* and *E. amictorius* emerged from the same cocoon. An average of 12 individuals emerged per cocoon (range 1–24), and the sex ratio of reared insects was 17.3 females: 1 male. The adult is dark green, approaching black, and a light yellow band encircles the abdomen of the male. The male abdomen (Fig. 52) is shorter and narrower than that of the female.

Catolaccus cyanoideus Burks
Figs. 53, 54, 55, 92, 122, 140

C. cyanoideus was encountered 12 times, all from cocoons collected during the summer of 1967. It was always a solitary sec-



FIGURES 67–70. Adult dipterous parasites of *D. similis*. 67, 68, *Spathimeigenia spinigera;* 67, head of male, dorsal view; 68, female, dorsal view. 69, 70, *Bessa harveyi;* 69, head of male, dorsal view; 70, female, dorsal view.

ondary parasite through *E. amictorius*, a previously unreported host.

The exit hole (Fig. 140) is on the side of the host cocoon usually near the tip, but in one case was located in the middle of the side. It is round with slightly scalloped edges, and for the females was 0.9–1.0 mm in diameter. The exit hole of males was 0.7 mm in diameter. No parasite cocoon is formed. The parasite remains include the dark brown, shiny pupal skin which remains with little breakage, usually only the head and part of the thorax being destroyed. The last larval exuvium is often still attached to the dorso-posterior end of the pupal skin at one end, and to the hard, dark-brown, pellet-like meconial mass of the parasite larva at the other.

The last exuvium is smooth and bears some scattered setae 0.02–0.05 mm long. The cephalic structure (Fig. 92) is similar to *A. verditer,* and the spiracle (Fig. 122) resembles that of *H. thyridopterigis* except for the lack of prominent lines on the first chamber of the atrium.

The disproportionately large head is an obvious characteristic of the metallic blue–green adult (Fig. 54). The cheek area on either side of the head is excavated. The sex ratio of the specimens reared was 5 females: 1 male. Males are about one-half the size of females and have a proportionately smaller abdomen (Fig. 55).

Habrocytus thyridopterigis Howard
Figs. 56, 57, 58, 93, 123, 141

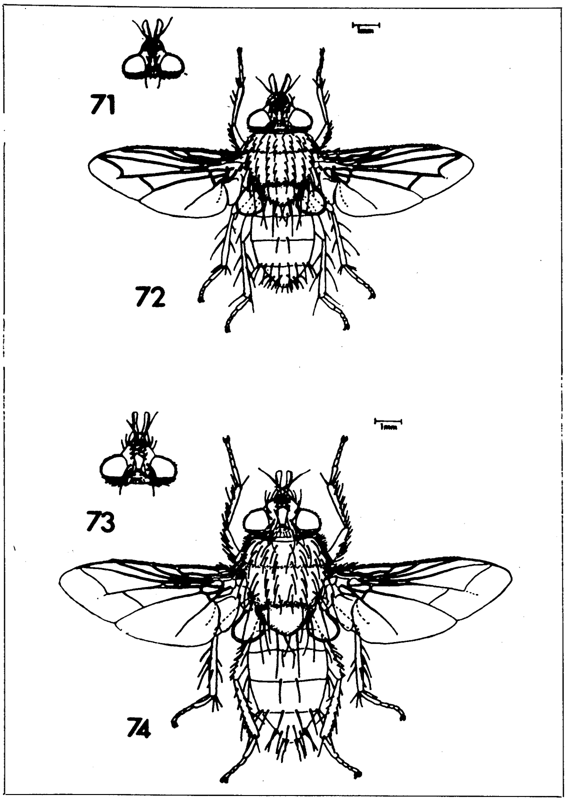
H. thyridopterigis is an occasional parasite of *D. similis* and has never been reared more than 4 or 5 times in a season. It is a gregarious external parasite in the host cocoon, and is usually primary.

The exit hole (Fig. 141) is similar to *A. verditer,* but slightly larger, and is 0.7–0.9 mm in diameter. The contents left in parasitized cocoons are like those left by *Amblymerus, Dibrachys,* and *Tritneptis,* except that the average sizes of the parasite remains are somewhat larger, and the pupal skins are yellow–brown.

The cast skin of the last instar may be differentiated from the aforementioned species by the lack of the partially developed cephalic structures found in *D. cavus* and *T. scutellata,* and the presence of large antennae set in usually distinct antennal sockets (Fig. 93). In addition, the row of fine teeth on the blade of the mandible is usually more distinct than in the other species of pteromalids. The spiracle (Fig. 123) is usually reticulate apically, and the closing apparatus is usually shorter and broader than in *Amblymerus, Dibrachys,* and *Tritneptis.*

Although normally primary, *H. thyridopterigis* was reared several times as a secondary parasite through *I. conquisitor.* In one instance, both it and *G. tenellus* emerged from the same cocoon. Other cases of successful multiparasitism involving *H. thyridopterigis* included *G. tenellus* (with both species as primary parasites), *M. dentipes,* and *E. vesicularis.* The hyperparasitic relationship of *H. thyridopterigis* to *I. conquisitor* is apparently common (Cushman, 1927; Langston, 1957; Balduf, 1937).

The adults are metallic green, and slightly larger than the other pteromalids, except the equally large *C. cyanoideus.* An average of 5 adults emerged per cocoon (range 1–22), and the sex ratio of reared adults was 10.6 females: 1 male. In its role as a secondary parasite only 1 or 2 adults were produced per cocoon, but as a primary, the average was 6 per cocoon.



FIGURES 71–74. Adult dipterous parasites of *D. similis.* 71, 72, *Diplostichus lophyri;* 71, head of male, dorsal view; 72, female, dorsal view. 73, 74, *Euphorocera edwardsii;* 73, head of male, dorsal view; 74, female, dorsal view.

Eurytomidae

Eurytoma pini Bugbee

Figs. 59, 60, 61, 62, 94, 124, 142

E. pini is a rare parasite of *D. similis* in Wisconsin, only 6 having been reared from a single study plot during 1958 and 1959. It is a primary, solitary parasite of the prepupa in the cocoon.

The emergence hole is cut in the side of the host cocoon, frequently near one end (Fig. 142). It is round, smoothly cut, and 0.9–1.2 mm in diameter. There is no parasite cocoon. The parasite remains consist of a mass of hard brown globular meconial pellets, a yellow larval skin with a sparse covering of long hairs, and a shiny golden-yellow pupal skin, all loose within the host cocoon.

The setae of the last larval skin are about 0.2 mm long, and are scattered sparsely over its surface. The cephalic structure (Fig. 94) has an incomplete epistoma, large superior mandibular processes, long inferior mandibular processes, and narrow trailing hypostomal arms. The mandibles have curved blades and a large medial tooth. The antennae are conspicuously sclerotized. The large funnel-shaped spiracle (Fig. 124) has about 15 chambers and a distinctive closing apparatus. The apical chamber is reticulate.

The adult (Fig. 60) is robust and shiny black, and is the only parasite of *D. similis* with 10 segmented antennae. Males differ from females by their pediculate abdomen (Fig. 61) and their unusual setate antennae (Fig. 62). The sex ratio favored females 2:1.

Chalcidae

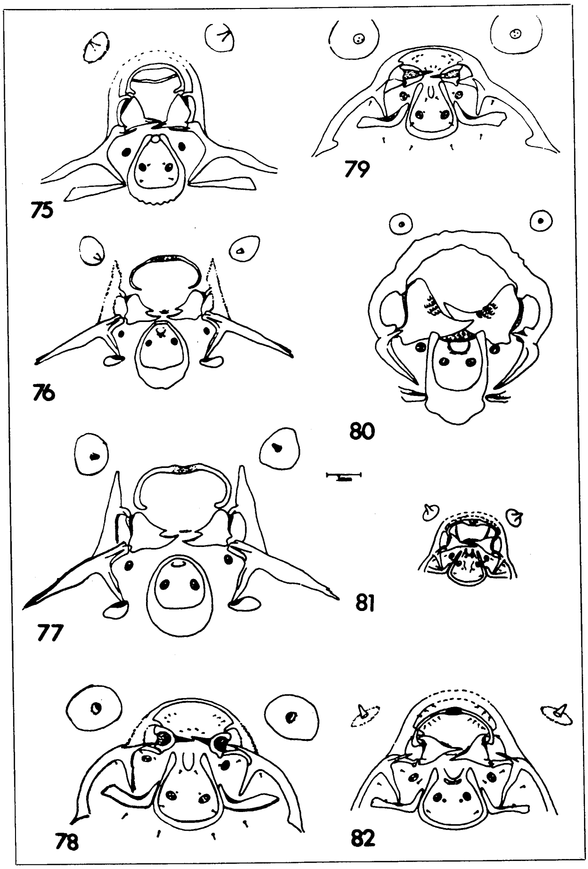
Spilochalcis albifrons (Walsh)
Figs. 63, 64, 65, 66, 95, 125, 143

S. albifrons is a rare, and apparently not very successful parasite of *D. similis;* it has not been previously reported from the sawfly. In all, 11 adults and 1 larva have been obtained from *D. similis* cocoons: 10 by dissection and 2 by emergence. All adults were females, and all were solitary, primary parasites. The larva was a secondary through *E. amictorious.*

The emergence hole (Fig. 143) is slightly off the tip of the host cocoon, round with irregular edges, and is about 1.3 mm in diameter. There is no parasite cocoon. The parasite remains consist of 1 large sub-spherical brown meconial deposit opposite the exit hole, the tan or light brown larval skin which is almost always attached to the posterior end of the dark brown, and shiny pupal skin, and numerous fragments of cocoon cut from the opening.

The cast skin of the final larval instar is smooth except for 2 or 3 short inconspicuous setae. The cephalic structure (Fig. 95) has an incomplete epistoma, well-developed superior mandibular processes, long narrow inferior mandibular processes, and very long hypostomal arms. An indistinct silk press is present, and the lightly sclerotized labral sclerite is vacuolate at the ends. The long sharp blades of the mandibles show faint indications of a row of small teeth. Antennae could not be located. The spiracle (Fig. 125) has about 7 annulations, and is widest at the second and narrowest at the fifth annulation. The closing apparatus is large and marked with a dark ring.

It appears that the adult parasites have little success in cutting through the tough silk of the host cocoon for emergence, as only 2 of the 12 individuals encountered managed to escape normally.



FIGURES 75–82. Cephalic structures of final instar ichneumonids; frontal view. 75, *Scambus (Scambus) hispae;* 76, *Delomerista japonica;* 77, *Delomerista novita;* 78, *Exenterus amictorius;* 79, *Exenterus canadensis;* 80, *Itoplectis conquisitor;* 81, *Gelis tenellus;* 82, *Agrothereutes lophyri.*

The black and yellow marked adults are easily recognized by the greatly enlarged, toothed metafemur. Two males of this species from another host were examined, and can be easily distinguished by their small abdomen (Fig. 65) which is about the size of the metafemur, and their swollen antennal scape (Fig. 66).

DIPTERA

Tachinidae

Spathimeigenia spinigera Townsend
Figs. 67, 68, 96, 101, 144

S. spinigera is a rare parasite of *D. similis* in Wisconsin, having been reared only twice. It has not been previously reported from this sawfly. It is a primary, solitary parasite, attacking the larva and emerging from the cocoon.

The emergence hole is on the tip of the host cocoon (Fig. 144), is nearly round, and about 2 mm in diameter. The thin, tapered edges are ragged and pushed outward. The host remains consist of little more than a hollow integument appressed to the lateral wall of the cocoon. Next to the host is the puparium of the parasite, about 6 mm in length, red-brown, semi-transparent, and brittle. The end of the puparium near the exit hole is broken into two semicircles and the inside is lined with a thin whitish membrane. The mouth-hooks of the third instar larva are attached securely to one of the broken semi-circles under the membranous lining.

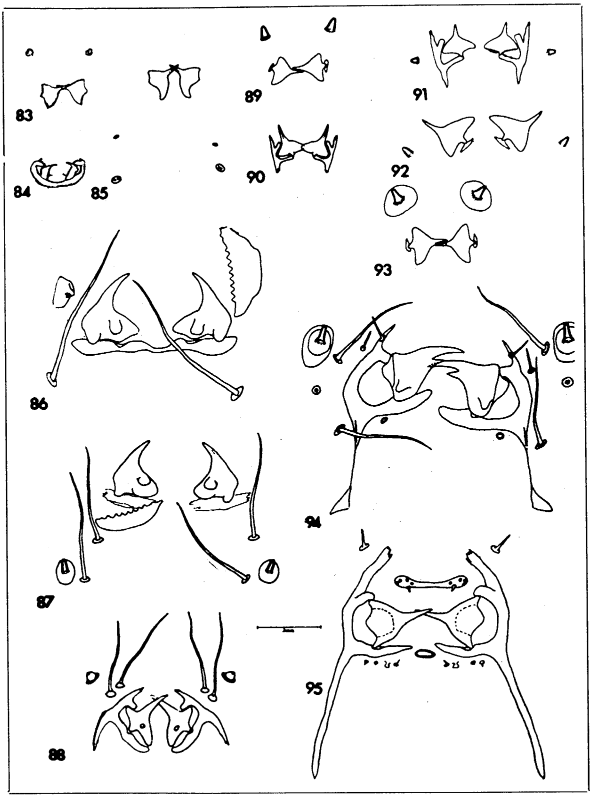
The buccopharyngeal armature (Fig. 96) has heavily sclerotized mandibular hooks with a strong antero-dorsal curve, and postero-dorsal and ventral points. The intermediate sclerite is distinct and heavily sclerotized. The basal sclerite is heavily sclerotized anteriorly, but its dorsal and ventral wings are less so, the lower trailing portion of the ventral wings becoming membranous. The posterior spiracular plates of the puparium (Fig. 101) are sharply elevated, wedge-shaped, and each is surrounded by a heavily sclerotized band.

The adult insect is most readily identified by the reddish markings on the tip of the abdomen and on the legs. The pulvilli and tarsal claws are decidedly longer than the fifth tarsal segment in the male, but of equal length in the female. Orbital bristles are lacking (Fig. 67) in the male, and present (Fig. 68) in the female.

Bessa harveyi (Townsend)
Figs. 69, 70, 97, 98, 102, 145

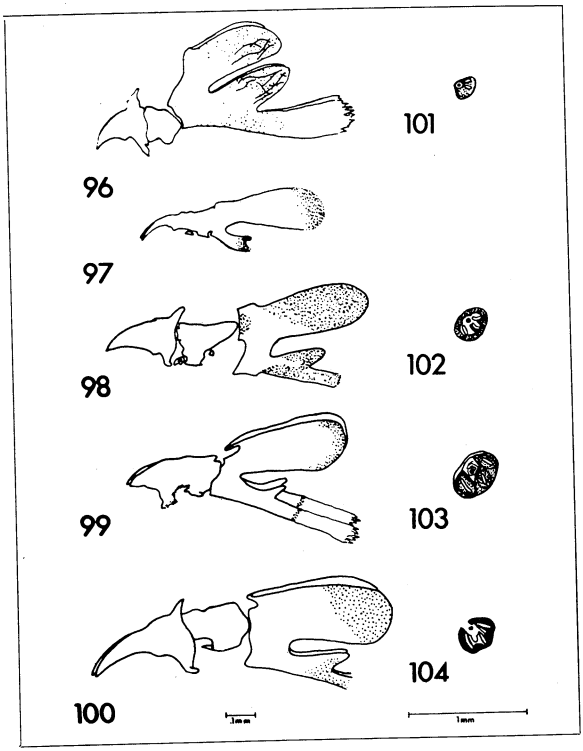
Bessa harveyi is an uncommon parasite of *D. similis* in Wisconsin, having been obtained only 16 times. *D. similis* is apparently one of the species "occasionally" attacked by *B. harveyi* (Turnock and Melvin, 1963), but has not been reported previously as a host in the literature. It is a solitary, primary parasite, attacking the host larva and emerging from the cocoon. In about half of the instances observed, the mature parasite larva emerged from the host cocoon before forming its puparium.

The oval emergence hole (Fig. 145) is on the tip of the host cocoon and about 1.3 mm in diameter. Some of the edges may



FIGURES 83–95. Cephalic structures of final instar chalcidoids; frontal views. 83, *Dahlbominus fuscipennis*; 84, *Tetrastichus coerulescens;* 85, *Elasmus apanteli;* 86, *Eupelmus spongipartus;* 87, *Eupelmella vesicularis;* 88, *Monodontomerus dentipes;* 89, *Amblymerus verditer;* 90, *Tritneptis scutellata;* 91, *Dibrachys cavus;* 92, *Catolaccus cyanoideus;* 93, *Habrocytus thyridopterigis;* 94, *Eurytoma pini;* 95, *Spilochalcis albifrons.*

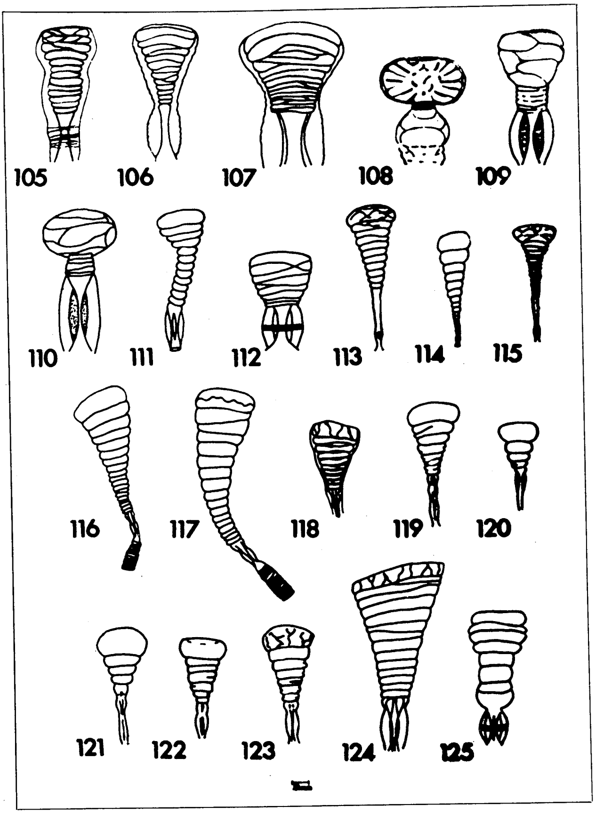
appear slightly pushed out. When the parasite larva emerges from the cocoon to pupate, the only remains are the mouth-hooks and exuvia of the first and second instars. The buccopharyngeal apparatus of the second instar (Fig. 97) is 0.5 mm long and is fused into a single structure. The mandibular hooks are long, narrow and sharp, the dorsal wings are elongate and less sclerotized posteriorly, and the ventral wings are short and simple. A small salivary sclerite occurs below the intermediate region.



FIGURES 96–104. Remains of immature dipterous parasites. 96–100, Buccopharyngeal apparatuses, lateral views; 96, *Spathimeigenia spinigera*, third instar; 97, *Bessa harveyi*, second instar; 98, *Bessa harveyi*, third instar; 99, *Diplostichus lophyri*, third instar; 100, *Euphorocera edwardsii*, third instar. 101–104, Right posterior spiracular plates of third instar dipterous larvae; 101, *Spathimeigenia spinigera;* 102, *Bessa harveyi;* 103, *Diplostichus lophyri;* 104, *Euphorocera edwardsii.*

When the parasite pupates within the host cocoon, the remains include the puparium in addition to those remains described previously. The puparium is formed with its anterior end toward the exit hole, and lies side by side with the host remains. It is similar in appearance to that of *S. spinigera,* but is only 5 mm in length. A creamy-white meconium is usually present in its posterior end. The mouth-hooks are attached to the open end of the puparium under the membranous lining.

The buccopharyngeal armature of the third instar (Fig. 98) is separated into three distinct parts. The mandibular hooks are



FIGURES 105–125. Spiracles of final instar Hymenoptera. 105, *Scambus (Scambus) hispae;* 106, *Delomerista japonica*; 107, *Delomerista novita;* 108, *Itoplectis conquisitor;* 109, *Exenterus amictorius;* 110, *Exenterus canadensis;* 111, *Gelis tenellus;* 112, *Agrothereutes lophyri;* 113, *Dahlbominus fuscipennis;* 114, *Tetrastichus coerulescens;* 115, *Elasmus apanteli;* 116, *Eupelmus spongipartus;* 117, *Eupelmella vesicularis;* 118, *Monodontomerus dentipes;* 119, *Amblymerus verditer;* 120, *Tritneptis scutellata;* 121, *Dibrachys cavus;* 122, *Catolaccus cyanoideus;* 123, *Habrocytus thyridopterigis;* 124, *Eurytoma pini;* 125, *Spilochalcis albifrons.*

heavily sclerotized, curved on the antero-dorsal margin, and are equipped with postero-dorsal and ventral processes. The intermediate sclerite has a large posterior lobe. The basal sclerite is heavily sclerotized anteriorly and lightly so posteriorly on both the dorsal and ventral wings. Two small sclerites are present below the intermediate sclerite. The posterior spiracular plates (Fig. 102) are slightly elevated and each is completely surrounded by a black ring of roughly circular form.

The sex ratio of adults reared was 1.7 females: 1 male. Adult *B. harveyi* are the smallest dipterous parasites of *D. similis,* and are quickly recognized by their size, dark-brown palpi, and the lack of a pair of cruciate bristles on the apex of the scutellum. Males are separated most easily from females by the absence of orbital bristles (Fig. 69).

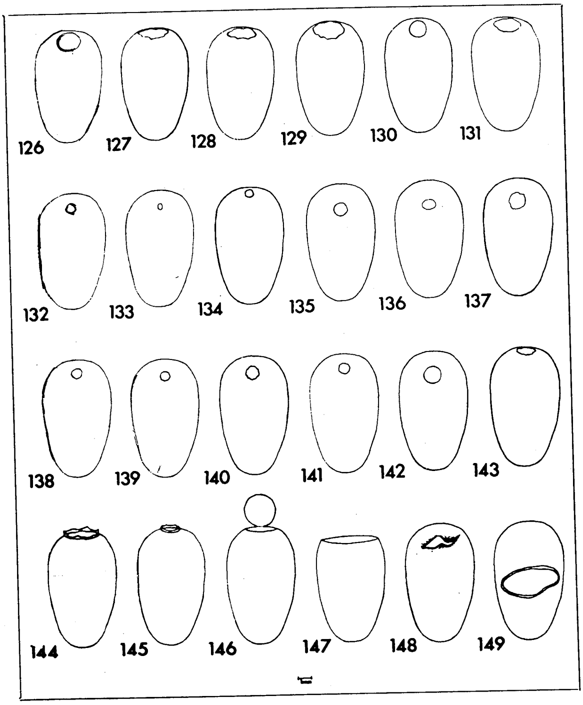
Diplostichus lophyri (Townsend)
Figs. 71, 72, 99, 103, 146

D. lophyri was by far the commonest dipterous parasite of *D. similis* in Wisconsin. It was reared in small numbers every year. The insect attacks late instar larvae and is a primary, solitary parasite. It emerges from the cocoon.

The distinctive emergence hole is at the tip of the host cocoon (Fig. 146). It is round with smoothly cut edges, and a flap that remains attached by a small hinge of uncut silk. The hole is 2.4 mm in diameter. Within the cocoon the host remains lie next to the puparium which faces the exit hole. The puparium is 6 mm long and similar to those described for *S. spinigera* and *B. harveyi.*

The buccopharyngeal armature (Fig. 99) of the third instar is attached to the inner open end of the puparium. It consists of the heavily sclerotized mandibles which are completely fused to the intermediate sclerite, and the basal sclerite which is closely articulated with, but separate from, the intermediate sclerite. The mandibular hooks are broad and have a postero-ventral projection. The heavily sclerotized intermediate region also has a ventral process. The basal sclerite is strongly sclerotized centrally, but becomes less so posteriorly on its dorsal and ventral wings. The ventral wings show an antero-dorsal projection. The posterior spiracular plates (Fig. 103) are large, with only the areas immediately surrounding the spiracular openings being elevated. The spiracular openings are long and narrow, and the black ring surrounding each plate is incomplete medially.

Probably any housefly-sized Diptera reared from *D. similis* can be safely called *D. lophyri* because the other Diptera are so uncommon. Specifically the insect may be identified by the pronounced distal recurvation of vein M_{1+2} (Fig. 72) and the pair of enlarged hairs on the mesoscutellar disc. Males lack the orbital bristles of females, and also have greatly elongate tarsal claws and pulvilli. In one instance, a puparium of *D. lophyri* served as a food source for several individuals of *M. dentipes.*



FIGURES 126–149. *D. similis* cocoons showing sawfly and parasite emergence holes, and holes made by predators. 126, *Scambus (Scambus) hispae;* 127, *Delomerista japonica* or *D. novita;* 128, *Itoplectis conquisitor;* 129, *Exenterus amictorius* or *E. canadensis*; 130, *Gelis tenellus;* 131, *Agrothereutes lophyri;* 132, *Dahlbominus fuscipennis* or *Tritneptis scutellata;* 133, *Tetrastichus coerulescens;* 134, *Elasmus apanteli;* 135, *Eupelmus spongipartus;* 136, *Eupelmella vesicularis;* 137, *Monodontomerus dentipes;* 138, *Amblymerus verditer;* 139, *Dibrachys cavus;* 140, *Catolaccus cyanoideus;* 141, *Habrocytus thyridopterigis;* 142, *Eurytoma pini;* 143, *Spilochalcis albifrons;* 144, *Spathimeigenia spinigera;* 145, *Bessa harveyi;* 146, *Diplostichus lophyri;* 147, *Diprion similis;* 148, bird predation; 149, rodent predation.

Euphorocera edwardsii (Williston)
Figs. 73, 74, 100, 104

E. edwardsii is a rare, and apparently unsuccessful parasite of *D. similis*. It was encountered 13 times in Wisconsin (8 of these in 1967), and then only by dissection. No adults have been reared.

Since no adults of the species emerged, the position and appearance of the exit hole are unknown. It is probably large, and because of the near relationship of the species to *D. lophyri,* it may have a hinged cap. Pupation probably occurs within the host cocoon as with *D. lophyri.*

The buccopharyngeal armature of the third instar is large and heavily sclerotized (Fig. 100). The mandibular hooks are long, slender, and show a definite constriction at their juncture with the intermediate sclerite. They have both dorsal and ventral processes posteriorly. A small sclerite projects anteriorly below the intermediate region. The basal sclerite is freely articulated with the intermediate sclerite, and is heavily sclerotized anteriorly. The posterior portions of both the dorsal and ventral wings are lightly sclerotized. The ventral wings have an anterior projection. The posterior spiracular plates of the third instar larva (Fig. 104) are large, elevated, and somewhat irregular in outline. Each is surrounded incompletely by a black ring. The spiracular openings, especially the two outside ones, are long and slender.

The adult specimens borrowed from the U. S. National Museum for the purposes of illustration ranged to 8.9 mm in length, which is larger than any of the other dipterous parasite of the sawfly, and almost equal to the length of a large sawfly cocoon. The mouthhooks of the third instar are one-half again as large as any of the other dipterous parasites. It may be that eggs deposited on *D. similis* larvae are incapable of maturing on the sawfly because it provides an insufficient amount of food. Only dead third instars and several puparia with completely devoured hosts have been encountered in cocoons. In any case, *E. edwardsii* is successful insofar as it kills a small number of sawflies, but it is rare and insignificant in its overall effects.

The size of the adults will set them apart immediately if they should ever be reared. In addition, the presence of apical cruciate bristles on the mesoscutellum, but absence of a pair on the disc, is characteristic. Males (Fig. 73) lack the orbital bristles of females, and also have pulvilli and tarsal claws twice the lengths of those from the females.

SUMMARY

Twenty-five species of parasites, 21 Hymenoptera and 4 Diptera, have been reared from *Diprion similis* (Hartig) in Wisconsin. Nine of these species are reported here for the first time as parasites of this sawfly. Two illustrated keys have been prepared to aid in the separation of these parasites. The first is designed to separate the species on the basis of remains left in the host cocoon,

while the second will allow identification of the adults. Brief notes on the biology of each species, and descriptions of their final instar cephalic structures are also presented.

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