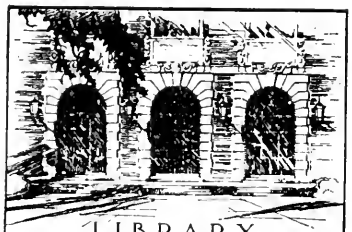

ILLINOIS NATURAL HISTORY SURVEY

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A Century of Biological Research

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FOREWORD

THE record of one hundred years of the scientific progress of the Illinois State Natural History Survey inspires us to reflect on its origin and brilliant achievements. We pay the highest tribute to those early educators and scientists who had vision beyond the exigencies of the moment.

And we express the highest commendation to the present Chief, Dr. Harlow B. Mills, and all of his staff for their contributions to the well-being and pleasure of our citizens. The important results of their research extend well beyond the borders of Illinois.

In contemplating the future, we are confident that this group of dedicated men and women will meet the increasing demands for assistance in the problems of the production of the necessities of life, that they will continue their research on the development and protection of our natural resources. In the future we may be dependent for our very existence on scientists such as these. We know they will meet the challenge.

Illinois is justly proud of the century of progress of one of its own agencies.

Congratulations!

VERA M. BINKS, *Director*
Department of Registration
and Education

The original building of the Illinois State Normal University, Normal, Illinois, spring, 1880. In this building the Illinois Natural History Society was founded and its museum was housed. Here the Illinois State Laboratory of Natural History had its headquarters from its founding in 1877 until late in 1884, and here the fourth State Entomologist was located for approximately 2 years.

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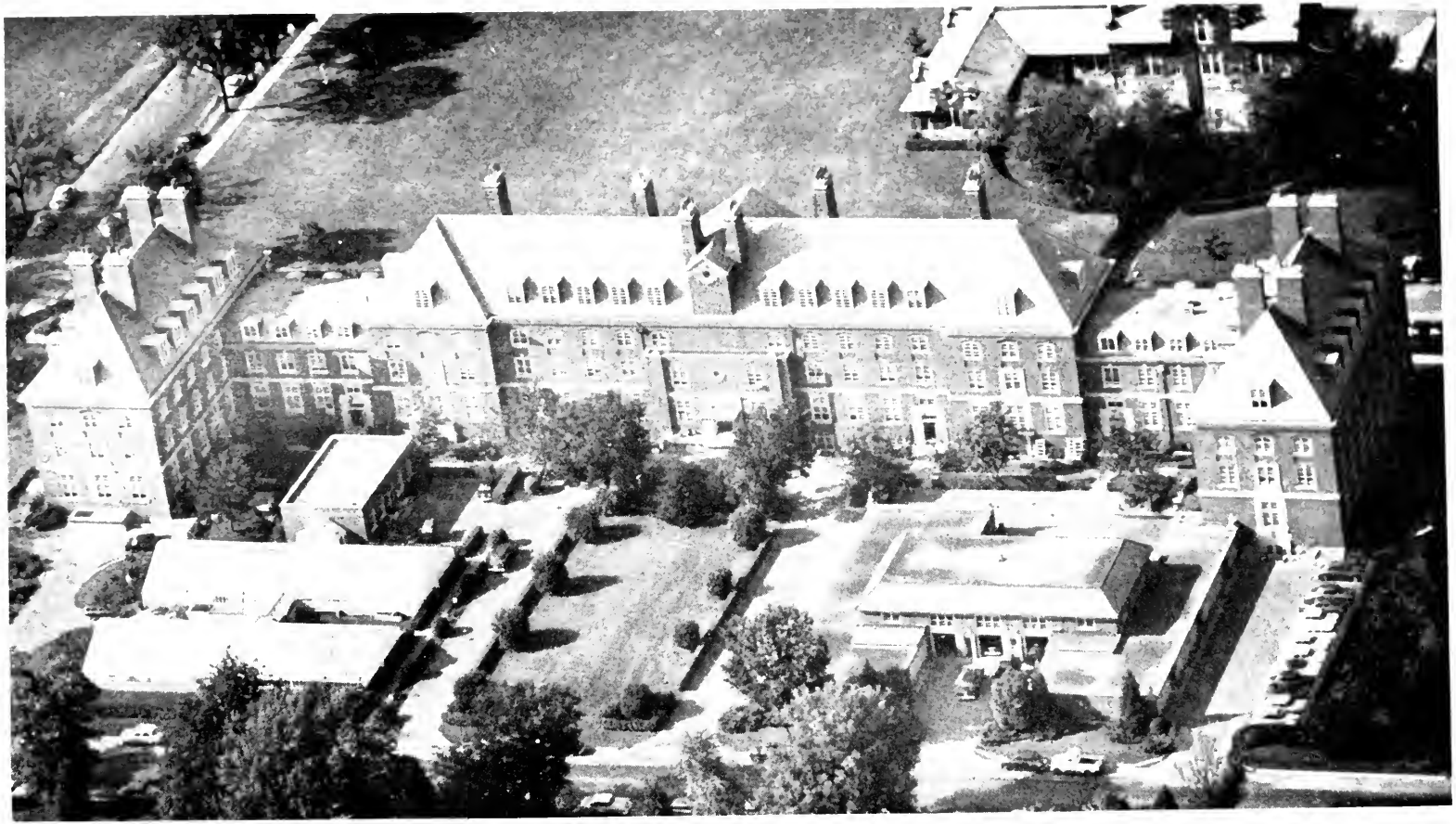


Aerial view, from the south, showing the Natural Resources Building on the University of Illinois campus in Urbana-Champaign. The central part of the building was completed in 1940, the two wings in 1950. The main offices and laboratories of the Illinois Natural History Survey occupy most of the west half of the building. The experimental greenhouse and its service building are shown in the left foreground.

From 1858 to 1958

HARLOW B. MILLS

THE mid-point of the nineteenth century in the United States was marked by ferment, by excitement, by great ideas. River traffic was at a peak; railroads had been built and were being extended. New areas were becoming more easily accessible to settlers. The point of departure to the exciting and mysterious Far West was on the Mississippi River, and two things happened just before 1850 which focused attention on that vast and largely unexplored area —the movement of the Mormons from Nauvoo, Illinois, on the banks of the Mississippi, to the Great Salt Lake, and the discovery of gold at Sutter's Mill in California.

The United States tried its muscles in the Mexican War in its first international conflict since its last test with England, and it ended Mexican dominance in California with the assistance of the Bear Flag Revolution.

Politically the young country was going through the series of events which ultimately led to the Civil War. On August 27, 1858, the most important of the Lincoln-Douglas debates, according to the estimate of some historians, took place at Freeport, Illinois. This debate is said to have won for Judge Douglas the Senatorship in his contest with Lincoln, but at the same time it lost the Presidency for the Judge in a later contest with the same adversary.

At the debate, there was a boy of fourteen who wormed his way to the front of the crowd and gained some renown by vocally taking issue with Douglas at one point in this historically climactic discussion. The youngster was considerably chagrined by reproof from those around him, but perhaps he was caught by the character of that meeting, for it is reported by George W. Smith (1927: 410) that

> There was much confusion—some real disorder. . . . It appears from the reports that orators, reception committees, invited guests, and newspaper reporters all engaged in a hand-to-hand conflict for seats and in some cases for standing room.

This boy who had the courage to challenge Judge Douglas was Stephen Alfred Forbes, later to be the person most responsible for the development of the Illinois State Natural History Survey, the centennial of which this number of the *Bulletin* commemorates.

Not only was this point in history one of swift movement and of critical importance in the politics and development of the country; it also brought science into clearer focus. Many scientific societies were organized. Darwin's *Origin of Species* appeared in 1859. Scientists were just beginning to play with the idea that their field was not a mental toy, that it could be put to practical use; and some scientists were announcing that they were interested in the practical application and popularization of their knowledge, much to the distress of most of their colleagues.

As an illustration, there is a rather long apology which Walsh (1868*b*:9) felt constrained to include in his *First Annual Report of the Acting State Entomologist.* Apparently this comment was written for the eyes of Walsh's scientific confreres; in part it says:

> In a Memoir intended for publication in the Proceedings of some grave Scientific Society, it would, of course, be highly indecorous to break the dreary monotony of scientific hair-splitting by a single remark, which had the slightest tendency towards exciting that convulsive movement of the midriff, which the vulgar herd of mankind call "laughter." . . . Four hundred years ago Martin Luther said, that "he could see no reason why the Devil should run away with all the good tunes." I can see no reason, in the year 1867, why the pestilent yellow-covered literature of the day should monopolize all the wit and humor. If there is one thing which I have at heart more than another, it is to popularize Science—to bring her down from the awkward high stilts on which she is ordinarily paraded before the world—to show how sweet and attractive she is when the frozen crust, in which she is usually enveloped, is thawed away by the warm breath of Nature— . . . If I merely succeed in enticing away a single young woman from her

mawkish novelettes and romances into the flowery paths of Entomology, or if I can only induce a single young man, instead of haunting saloons and lounging away his time at street-corners, to devote his leisure to studying the wonderful works of the Creator, as exemplified in these tiny miracles of perfection which the people of the United States call "bugs," I shall think that I have not written altogether in vain.

The growth of the population of Illinois resulted in the bringing together, within the state's boundaries, of people with common interests in natural history. This field of knowledge had not gone unnoticed in this general geographical area, but the investigators here were individuals and worked pretty much alone. Just across the Wabash River to the east, Thomas Say had earlier done research on insects and other animal groups. Across the Ohio River to the south, John James Audubon had studied birds.

NATURAL HISTORY SOCIETY

Because by mid-century people interested in natural history had become more numerous in the state, Cyrus Thomas of Carbondale was able to propose to the December, 1857, meeting of the State Teachers' Association in Decatur that a Natural History Society of Illinois be formed (Bateman 1858*a*). The next year, on June 30, 1858, the Society was organized at Bloomington in the office of the Illinois State Normal University (Bateman 1858*b*:258–9). It was given official sanction and notice when it was chartered by an act of the state legislature approved February 22, 1861 (Illinois General Assembly 1861:551–2).

Immediately after its organization the new Society began the development of a museum and the collection of scientific literature.

Among its active members mentioned by Forbes (1907*c*:893–4) were C. D. Wilber, who later became a consulting mining engineer; Dr. J. A. Sewall, who later became President of the University of Colorado at Boulder; Major J. W. Powell, who was to gain renown as an explorer in the West; Dr. George W. Vasey, for many years botanist with the United States Department of Agriculture; A. H. Worthen, head of the first Illinois State Geological Survey; Cyrus Thomas, Benjamin D. Walsh, M. S. Bebb, Dr. Oliver Everett, James Shaw, Dr. Henry M. Bannister, Dr. J. W. Velie, Professor J. B. Turner, Dr. Edmund Andrews, Dr. Frederick Brendel, and Newton Bateman. The above list indicates a great breadth of interest and no lack of intelligence on the part of the original members of the Society.

The first officers of the Society included a General Agent, among whose duties were the collection and exchange of specimens (Batemen 1858*b*:258). C. D. Wilber was named to this office. The Society's original constitution (Bateman 1858*b*: 258) and the revised constitution of 1859 (Francis 1859*b*:662–3) provided that all specimens should be deposited in the Museum of the State Normal University.

The constitution as revised on June 20, 1859 (Francis 1859*b*:662–3), dropped the General Agent, gave most of his duties to a newly created Superintendent, and added a Curator, whose duties were to receive and arrange specimens. Cyrus Thomas, who was elected Curator, lived in Jackson County, many miles from the Museum, and the elected Superintendent, Wilber, who taught geology at the State Normal University, according to Marshall (1956) acted as unofficial curator.

At the 1860 meeting, R. H. Holder of Bloomington was named both Curator and Treasurer (Wilber 1861*a*:538).

The state charter of 1861 gave the Society authority to establish its own Museum at the State Normal University (Illinois General Assembly 1861:551), and officers of the Society set December 25, 1861, as the date on which the Museum was to be "dedicated, with appropriate exercises, as a FREE OFFERING TO THE CITIZENS AND SCHOOLS of Illinois" (Wilber 1861*c*:675).

Forbes (1907*c*:893) listed Sewall, Powell, Vasey, and himself as curators of the Society's Museum, Vasey serving only nominally as Powell's deputy. Powell was named Curator by the State Board of Education on March 26, 1867. His appointment was ratified and consented to on the same day by the Directors of the Natural History Society (Bateman 1867:

8). Forbes was appointed to the same office on June 26, 1872, the day Powell's resignation was offered and accepted (Bateman 1872:6).

Because the Natural History Society was composed principally of people who were prosecuting natural history investigations as sidelines to other activities, and because it was not a strong cohesive agent, it finally reached the point where it could no longer sustain itself. Forbes (1907*c*: 898) said of the times, "It should be remembered, in this connection, that this was a time when college men, as a rule, worked like dray-horses and were paid like oxen, . . ."

The Society turned to the state for aid, and by an act approved February 28, 1867, $2,500, to be paid annually to the State Board of Education, was appropriated by the General Assembly for the salary of a curator and "for the necessary expenses of improving and enhancing the value" of the Museum (Illinois General Assembly 1867:21). Major Powell was the first curator to receive state aid. The state appropriations, according to Forbes (1907*c*:895), "were largely drawn upon to outfit and maintain the Powell expeditions to the far west." As a condition upon receiving further state aid, as provided by legislative act approved April 14, 1871, the Society had to turn its Museum over to the state (Illinois General Assembly 1872:152). On June 22, 1871, the Society agreed to the transfer and when, on June 28, 1871, the Board of Education accepted the transfer, the Museum officially became state property (Bateman 1871:9; Forbes 1877:324–5).

On December 15, 1875, the State Board of Education passed the following resolution (Etter 1876:17):

> *Resolved,* That we regard the Museum as a State institution, devoted to the prosecution of a natural history survey of the State, to the encouragement and aid of original research, and to the diffusion of scientific knowledge and habits of thought among the people.

Forbes, who in 1872 had been appointed by the State Board of Education as Curator of the Museum, remained in that capacity until July 1, 1877, when by legislative act approved May 25, 1877, a State Historical Library and Natural History Museum were established at Springfield, and the Illinois Museum of Natural History at Normal was "converted into a State Laboratory of Natural History" (Illinois General Assembly 1877:14–6).

STATE LABORATORY OF NATURAL HISTORY

The act that established the State Laboratory of Natural History relieved Forbes of the necessity of developing museum exhibits and allowed him to turn more of his attention to research. Shortly after the establishment of the Laboratory, Forbes' title was changed from Curator to Director (Etter 1877:25).

Forbes had not been occupying his time completely in the preparation of museum material while he was Curator of the Illinois Museum of Natural History. He had taught classes in zoology at Illinois State Normal University and he had started a series of bulletins reporting on research and investigation. The first number of the series is dated December, 1876, and carries the title, *Bulletin of the Illinois Museum of Natural History*. From the appearance of No. 2 of the first volume, in June, 1878, until the beginning of Volume 13, in 1918, the title was the *Bulletin of the State Laboratory of Natural History*, and from that time to the present it has been the *Bulletin of the Illinois State Natural History Survey* or *Illinois Natural History Survey Bulletin*. The volumes have been numbered serially from December, 1876, to the present time.

The work of the Laboratory and its young Director attracted the attention of the new Illinois Industrial University at Urbana. Not only had Forbes been publishing actively, but in 1882 the duties of State Entomologist had fallen on his capable shoulders. Shortly afterward the University made an offer of employment to the Director of the Laboratory and State Entomologist. Forbes faced the choice of declining the offer, of abandoning the Laboratory, which had been established at the Illinois State Normal University by legislative act, or of moving the Laboratory with him.

Apparently at his suggestion, the matter was taken up with the State Board of Education by the Trustees of the Illinois Industrial University, and an agreement

was made that the law be changed to allow for the move. In a report addressed to the Regent and dated December 12, 1884, Forbes made known his needs at the University (Burrill 1887*a*:10). He stated:

> As you are doubtless aware, I have for some time held the position of Director of the State Laboratory of Natural History, located in the Normal University building at Normal, and, indeed, still remain in nominal charge of that establishment, having received from the State Board of Education a leave of absence, without pay, from January 1 to June 30, 1885, in order to enable me to enter upon my duties in the University here. If I believed that my acceptance of a chair in this University necessarily involved an interruption or serious modification of the work which I have organized as Director of the State Laboratory of Natural History, I should keenly regret it; and, indeed, I did not express my acceptance of that position until I had arranged a plan of readjustment which I thought adequate to prevent such a contingency.

Later in the same meeting, Trustee Alexander McLean offered the following resolutions (Burrill 1887*a*:18):

> *Resolved*, That the Trustees of the Illinois Industrial University have heard with great satisfaction the suggestion that the State Laboratory of Natural History may be united with the University under their charge.
>
> *Resolved*, That in case such a union shall be accomplished they will, to the extent of the means intrusted to them, aid in carrying forward the valuable work of the laboratory, by assigning to it suitable apartments in the building of the University, and by providing such conveniences as the nature of the work may require, to the end that it may enjoy a commodious and perpetual home within, and the generous coöperation of, an institution founded and maintained for the promotion of scientific research and the dissemination of practical knowledge.

Forbes officially took over his duties at Urbana on January 1, 1885 (Forbes 1886*b*:LX).

In the following March the Regent, Dr. Selim H. Peabody, had the following comment (Burrill 1887*a*:19–20):

> The unsuccessful effort of three years ago to secure for the University the presence and aid of Prof. S. A. Forbes for the organization of the instruction of Zoology was renewed last year, and has been crowned with better fortune. Since the opening of the new year the Zoological laboratory has become an active agency in this department of physical science, and its success is well assured. A new interest has been aroused in this science. The office of the State Entomologist has found a home, it is to be hoped permanent, where it naturally belongs. The governing board of the Normal University has unanimously resolved that the State Laboratory of Natural History should find its proper abode here at the State University, and has consented that the property peculiar to the work of that [laboratory] may be transferred hither. This change requires only legislative action before it can legally go, as it has practically gone into effect, and there appears to be little doubt that such action will be taken during the present session.

The legislature approved the action, and everything was legal.

On July 1, 1885, the appointment of Forbes as Professor of Zoology and Entomology at the University of Illinois (previously Illinois Industrial University) at an annual salary of $1,160 was approved by the Board of Trustees, which also appointed Forbes Director of the State Laboratory of Natural History and authorized him to receive laboratory property transferred by the State Board of Education (Burrill 1887*a*:50). It is interesting to note the size of the Laboratory staff at that time. On September 8, 1885, the Trustees approved the following appointments (Burrill 1887*a*:55–6):

Entomological Assistants	
Thomas F. Hunt	$40 a month
Clarence M. Weed	$40 a month
Botanical Assistant	
Charles F. Hart	$45 a month
Amanuensis	
Miss Mary J. Snyder	$45 a month
Services relating to botanical survey	
Prof. T. J. Burrill	$300 for the year
F. S. Earle	$83 1/3 a month
Such other miscellaneous assistants as might be required and within the funds available	

The State Laboratory of Natural History continued under that name until 1917.

STATE ENTOMOLOGIST

The rapid settlement of Illinois during the middle of the nineteenth century brought in a great number of agriculturists. The country was new, and the breaking down of the original vegetation for the establishment of fields in which crops were grown brought about great losses from insects. These losses, while

seen and experienced, were not well understood. Official entomology was born during this period. The agriculturists felt the need of assistance and cried out to the government for it.

At the end of the Civil War, the President of the young Illinois State Horticultural Society, John P. Reynolds, spoke vigorously on the subject at the December 19, 1865, meeting of the Society at Normal. In his retiring address, Reynolds (1866:8) said:

> And, first, the appointment of a STATE ENTOMOLOGIST. The time has been in this State when it required some moral courage for any one to advocate the appointment and *compensation from the treasury* of an officer to look after the bugs, but I venture the opinion that there is no subject in which you, as amateur or professional horticulturists, have a more direct, immediate or larger pecuniary interest, than in Entomology— . . . No one who has given the subject any attention will question the truth of the statement that the people of Illinois are to-day many millions of dollars poorer by reason of noxious insects; nor the additional statement that a very large proportion of this loss might have been averted by the labors of a competent Entomologist with a little means at his disposal.

In 1866 the Horticultural Society, meeting at Champaign, passed the following resolution (Deyo 1867:58):

> *Resolved*, That we most urgently pray the honorable legislature of our great state to appoint a State Entomologist, that Agriculturists and Horticulturists may not quite despair of ever overcoming the giant insectiforous [*sic*] difficulties in the way of success in their professions. As one eminently qualified, and the highest in his profession in the whole west, we most hopefully mention the name of Benjamin D. Walsh, of Rock Island.

The Horticultural Society was not alone in this movement. At a meeting of the executive committee of the Illinois State Agricultural Society on January 3, 1866, G. W. Minier offered the following

University Hall on the University of Illinois campus. This building, completed in 1874 and razed in 1938, was headquarters for the Illinois State Laboratory of Natural History and the Office of State Entomologist for a few years after they were moved from Normal to Urbana.

specific and forthright resolution (Reynolds 1868:18):

> *Resolved*, That whenever a sum of fifteen hundred dollars ($1,500) shall have been obtained, by legislative action or otherwise, for an annual salary, this Board will then appoint a competent scientific man as State Entomologist.
>
> *Resolved*, That Mr. B. D. Walsh be and he is hereby appointed State Entomologist, subject to the preceding resolution.

The legislature listened to these pleas and in 1867 passed a law which authorized the Governor, with the consent of the Senate, to appoint a state entomologist. The work of this officer was considerably handicapped. While he was voted a salary, he was given no work fund, and the first three persons to hold the position maintained their offices in their homes or in offices devoted to other purposes. The job was a difficult one, and Forbes (1915: 7–8) once rather facetiously wrote:

> He [Walsh] performed as well as he could his various duties of private, captain, colonel, adjutant, and major-general of this new force—and in two years he was dead. He had two successors enlisted for the war on precisely the same terms, the first of whom, Dr. Wm. Le Baron, of Geneva, Illinois, maintained for five years the unequal contest, when he also died; and the second, Dr. Cyrus Thomas, of Carbondale, abandoned the field in despair after seven years of diligent service, going then to Washington for work in another department of science, where he lived to the good old age of eighty-five. I have sometimes wondered if his long survival was

Benjamin Dann Walsh, State Entomologist, 1867–1869.

not largely due to his fortunate escape from an untenable situation.

Forbes set out to disprove this contention, and carried the duties, however with more help than his predecessors had, from 1882 to 1917, a span of 35 years.

Let us now look at the four men who carried the title and responsibility of Illinois State Entomologist.

Benjamin Dann Walsh

Although the resolutions passed by the State Horticultural Society and the State Agricultural Society in 1866 mentioned specifically Benjamin D. Walsh as a potential State Entomologist, Walsh did not obtain this title without some complications. An act providing for this officer was passed by the legislature and was approved on March 9, 1867 (Illinois General Assembly 1867:35–6). No appointment was made at that time. However, a special session was called on June 11 of the same year, and at that time the name of Walsh was presented for the Senate's approval. The session was called for specific purposes, of which the approval of an appointee as State Entomologist was not a part. Therefore, the Senate decided that constitutionally it could not act on this matter.

Walsh acted as State Entomologist, without legal status, and with an assignment of $500 by the Horticultural Society, until the legislature passed an act "for the relief of the state entomologist," March 25, 1869 (Illinois General Assembly 1869:53–4). This act legalized what Walsh had been doing for nearly 2 years. It is interesting to note that Walsh's first annual report was made to the Horticultural Society and not to the Governor, and was signed by Walsh (1868*b*:3) as Acting State Entomologist.

Walsh was a most interesting person. He was born in Frome, Worcestershire, England, September 21, 1808 (Weiss 1936:234). He was well educated, and, about 1830, received a Master of Arts degree from Trinity College, Cambridge, where he was a classmate of Charles Darwin. He was married in England, and in 1838 he came to America. His wife had relatives in Henry County, Illinois, and he purchased a 300-acre farm in that part of the state. He operated the farm until 1851, when he moved to Rock Island and entered the lumber business.

He was not a politician, but in 1858, when he suspected that the city was being cheated by the city council, he placed his name in contention for alderman. His purpose was to get at the city's books. This action did not endear him to some elements of the city, and his life was threatened. Undaunted, he went ahead with a successful campaign, exposed the frauds, and resigned.

Although he had made a small collection of insects in England, he publicly had shown no deep interest in entomology until January, 1860, when he lectured for 2 hours to the State Horticultural Society. Thereafter he contributed regularly to the *Prairie Farmer* and other agricultural journals. Further, in the proceedings of scholarly societies, he published several excellent scientific papers on insects. He collaborated with E. T. Cresson, A. R. Grote, and J. W. McAllister in the publication of a monthly called the *Practical Entomologist,* which lasted for only 2 years, until September, 1867. In September of the following year, Walsh and C. V. Riley started the *American Entomologist.*

On November 12, 1869, as Walsh was walking down a railroad track, busily engrossed in reading a letter, a train approached. When he saw the train, he was too late to clear himself completely, and his left foot was badly injured. The foot was amputated, and to console his wife he said, "Why, don't you see what an advantage a cork foot will be to me when I am hunting bugs in the woods: I can make an excellent pin-cushion of it, and if perchance I lose the cork from one of my bottles, I shall simply have to cut another one out of my foot" (Riley 1869–70:65).

He published an article exonerating the engineer from all blame in the accident.

He appeared to be recovering well from the accident when suddenly he began to decline, apparently from some internal injury. He passed away on the 18th of November, 1869.

William Le Baron

In 1870 Governor John M. Palmer requested William Le Baron to take over the position left vacant by the unfortunate

death of Walsh. This request was quite unexpected, for entomology was only an active side interest of this competent physician.

Things which are half-said in history pique the imagination. We find that Dr. Goding (1885:123), in a biographical sketch of Le Baron, had the following to say:

> In 1870 two candidates appeared for the office of Illinois State Entomologist made vacant by the untimely death of the lamented Walsh—Dr. Henry Shimer of Mt. Carroll and Mr. Emery of the *Prairie Farmer*, both of whom were well qualified for the position. For reasons that cannot be given at this time, Gov. Palmer refused to appoint either, but named *Dr. Le Baron* for the place, taking him entirely by surprise.

Le Baron was a native of North Andover, Massachusetts, where he was born October 17, 1814. He came from a line of New England professional people; his father was a medical doctor and his maternal grandfather was Dr. Thomas Kittredge, a well known and highly respected surgeon of his day.

Le Baron's calling was decided at an early point in his life. After studying medicine under an uncle, Dr. Joseph Kittredge, he practiced for several years in his home town. Later he completed his medical studies and was graduated from the

William Le Baron, State Entomologist, 1870–1875.

Harvard Medical College. In 1844 he moved to Geneva, Illinois, where he continued a successful career as a physician.

As a child he was greatly interested in nature, moving from ornithology to botany to entomology. In 1850, after 6 years in Illinois, he published his first article, a treatise on the chinch bug, in the *Prairie Farmer*. This study was so exhaustive that Asa Fitch, the New York State Entomologist, republished it in his Second Report. In 1865 Le Baron was made the entomological editor of *Prairie Farmer*.

In the position of State Entomologist he labored diligently until his health gave way. He died on October 14, 1876. The excellence of his four reports is a measure of the high ability that Le Baron possessed.

Cyrus Thomas

The third State Entomologist did not attend college (Goding 1889:106). The competence Cyrus Thomas attained was the result of his own personal labors. He was a versatile and practical person. He was born in Tennessee, July 27, 1825, and his mother had hoped that he would become a physician. In 1849 he moved to Jackson County, Illinois, where he studied law and taught school. In 1851 he

Cyrus Thomas, State Entomologist, 1875–1882.

was admitted to the bar and was elected county clerk. About 1864 he dropped law and entered the ministry.

For some time, Thomas had considered entering the field of science and, as evidence of his practicalness, in 1856 he deliberately began the study of entomology as being a field which was inexpensive and in which there was an abundance of material close at hand upon which he could work. He became an authority on the Orthoptera. He wrote many articles on entomology, some of which he contributed to farm journals.

From 1869 to 1874 he was associated with the federally sponsored Hayden Geological Survey, paying special attention to the entomology and agricultural resources of the West. During this period he published many reports of entomological significance.

In 1874 Thomas was elected to the Professorship of Natural Sciences at Southern Illinois Normal University, whereupon he severed his relationship with the federal survey. The next year, 1875, he was appointed by Governor Richard J. Oglesby to take the place of Dr. Le Baron as State Entomologist. Six reports were published by Thomas and his collaborators.

On March 3, 1877, the United States Entomological Commission was authorized by Congress. Thomas found time, along with his regular work, to become a member of this Commission. Other members of the Commission were C. V. Riley and A. S. Packard, Jr. Thomas was not collaborating with amateurs when he joined these two men on the Commission. Both were giants in the profession—names that still command respect. Riley was State Entomologist for Missouri, as well as a member of the Commission, and the real originator of entomological research in the federal government. Packard was a scholarly gentleman, a member of the National Academy of Sciences and other learned groups, and an author of note in his field.

Thomas was a man of real capability, holding, as he did simultaneously, a professorship at Southern Illinois Normal University, the State Entomologist's responsibility, and membership on the historic federal Entomological Commission.

Thomas was interested in many things, and in July, 1882, he resigned his various Illinois positions and accepted employment in the Smithsonian Institution's Bureau of Ethnology, leaving a brilliant and uncompleted career in entomology. He was to gain further laurels in archeology and to become an authority on the Mayan language.

About some things he was adamant. He published a review of Darwin's works from an orthodox view, which so impressed the officials of Gettysburg College that they hastened to award him an honorary Ph.D. degree.

Thomas lived to be 85 years old, passing away on June 27, 1910.

He bears a peculiar relationship to the Natural History Survey, for he is credited with having first proposed an Illinois Natural History Society in 1857, and he was a State Entomologist.

Thomas was a man of multiple aptitudes, as the above sketch indicates. He moved his intellect in many fields: school teacher, lawyer, county official, minister, entomologist, explorer, college professor, and archeologist.

Stephen Alfred Forbes

No one has molded the character of the Natural History Survey so much as Dr. Forbes, a man of irrepressible intellect and insatiable curiosity, and the fourth and last Illinois State Entomologist.

Forbes was born of pioneer parentage on May 29, 1844, in Stephenson County, Illinois. He was one of a large family. His father died when he was 10, and a brother assumed the responsibility for an invalid mother, Stephen, and a younger sister. Stephen attended district school until he was 14, and his brother carried on his education for 2 more years. For a short time in 1860 he attended Beloit Academy. He had an innate interest in language, and on his own he learned to read French, Spanish, and Italian.

When the Civil War broke out in 1861, Forbes was 17. He joined Company B, 7th Illinois Cavalry, in September of that year. He rapidly advanced from orderly to sergeant to lieutenant to captain, reaching the last rank when he was 20. In 1862 he was captured while carrying dispatches near Corinth, Mississippi, and

Stephen Alfred Forbes in the 1880's, while State Entomologist and Director of the State Laboratory of Natural History at Normal.

was in Confederate prisons for 4 months. During this period of enforced idleness he studied Greek from books he managed to buy at Mobile. He participated in 22 military engagements, and, other than suffering from scurvy and malaria while in prison, he emerged from the war unscathed.

At the end of hostilities he entered Rush Medical College in Chicago. Because of lack of funds and certain psychological difficulties revolving around surgery without anesthesia, he never finished the course. After leaving Rush, he taught school and, on the side, studied natural history. His first publications appeared in 1870, and these led to his appointment in 1872 as Curator of the Museum established by the State Natural History Society at Normal. He held this position until 1877, when he was appointed to head the State Laboratory of Natural History, the child of the Museum.

After the resignation of Thomas as State Entomologist in 1882, Governor Shelby M. Cullom appointed Forbes to that position. In 1884 Indiana University awarded Forbes the Ph.D. degree "by thesis and examination." He did not have a bachelor's degree. In 1885 he moved to

the University of Illinois, where he was Professor of Zoology and Entomology, Director of the State Laboratory of Natural History, and State Entomologist. He was Professor of Zoology for 25 years, Professor of Entomology for 13 years, and Dean of the College of Science for 16 years.

He was especially interested in the interactions of organisms and has been called "the father of ecology." His interests covered all of biology. He investigated or directed investigations of the food of fishes and birds, the fishes of the state, and the biology of the Illinois River, and he directed the first forest surveys of Illinois. These represent only a few of his innumerable interests.

He was a member of many learned societies and the recipient of many honors.

Stephen Alfred Forbes in about 1915, shortly before being named Chief of the Illinois Natural History Survey at Urbana.

Beyond this, he was active in his church, helped organize the first golf club at the University, was a member of a hiking club, and late in life delighted in driving an automobile. On his eightieth birthday he was arrested for speeding, an incident which gave him some pleasure.

When the State Laboratory of Natural History and the State Entomologist's Office were united in 1917 to form the Nat-

ural History Survey, Forbes became the first Chief of the new organization. He held this position until his death, March 13, 1930, when almost 86 years of age.

The four sketches above cannot do justice to the entomological pioneers who are their subjects, but they will give some indication of the high quality of the men. All were competent individuals with high standards, even though they came from widely different backgrounds and possessed widely different trainings.

(Among the sources of biographical material on Forbes are Anon. 1930, E. B. Forbes 1930, Ward 1930, Howard 1932, Van Cleave 1930, 1947, and Marshall 1956.)

The Natural History Building on the University of Illinois campus. About 1894 headquarters and laboratories of the Illinois State Laboratory of Natural History and of the State Entomologist were moved into this building. From July 1, 1917, until the middle of 1940 it housed the main offices and most of the laboratories of the Illinois Natural History Survey.

Reorganization

Forbes administered the State Laboratory of Natural History and the State Entomologist's Office as a unit, interchanging personnel and materials. Further, he made these agencies available to the University of Illinois in many ways, and considerable publishing was done in the State Laboratory *Bulletin* by University staff members.

The State Entomologist's responsibilities changed as time went on, and the agency became responsible for the administration of some laws, as well as for research (Forbes 1909:64–5). With the discovery of the San Jose scale in Illinois in 1896, there was concern over the possible spread of other pests into the state. In 1899 legislation was passed giving the State Entomologist large powers in inspection, certification, and quarantine. Other duties were added in 1907.

According to Forbes (1909:55, 66), in 1909 the staffs of the two agencies consisted of the following:

State Laboratory of Natural History
- 1 Director
- 1 Entomologist
- 2 Zoological Assistants
- 1 Artist
- 1 Secretary
- Special assistants from time to time

State Entomologist's Office
- 1 State Entomologist

10 Assistants
1 Draftsman
1 Chief Inspector
4 Temporary Inspectors
1 Foreman
12 Laborers

Forbes' interest was primarily in research and not in administering laws.

During the reorganization of state government under Governor Frank O. Lowden's administration, the chance came to make changes which would bring Forbes' interests into clearer focus. The State Laboratory of Natural History and the research activities of the State Entomologist were brought together in 1917 under a new name, the Natural History Survey. This Survey was placed in the Department of Registration and Education along with the two other scientific surveys, Geological and Water. The administration of quarantine laws and the like was transferred to the State Department of Agriculture.

NATURAL HISTORY SURVEY

We have followed the meanderings of organization from the Illinois Natural History Society of 1858 through the So-

Theodore Henry Frison, Acting Chief, 1930–1931, Chief, 1931–1945, Illinois Natural History Survey.

ciety's Museum to the Illinois State Laboratory of Natural History. We have also discussed the development of the State Entomologist's Office from 1867 and have seen this office united with the State Laboratory in their research duties to form the State Natural History Survey in 1917.

A new type of administrative responsibility was set up in the Civil Administrative Code of 1917, which has remained essentially unchanged to the present time. The Code (Illinois General Assembly 1917:34) stated that:

> Unless otherwise provided by law, the functions and duties formerly exercised by the State entomologist, the State laboratory of natural history, the State water survey and the State geological survey and vested by this Act in the department of registration and education, shall continue to be exercised at the University of Illinois in buildings and places provided by the trustees thereof.

Within the Department of Registration and Education was established a Board of Natural Resources and Conservation; this Board is the responsible agent for the activities of the Natural History, Geological, and Water Surveys. The charge (Illinois General Assembly 1917:34) under which this group has worked through the years has been to

1. Consider and decide all matters pertaining to natural history, geology, water and water resources, forestry, and allied research, investigational and scientific work;
2. Select and appoint, without reference to the State civil service law, members of the scientific staff, prosecuting such research, investigational and scientific work;
3. Co-operate with the University of Illinois in the use of scientific staff and equipment;
4. Co-operate with the various departments in research, investigational and scientific work useful in the prosecution of the work in any department.

The Board consists of the Director of the Department of Registration and Education, who is chairman, the President of the University of Illinois or his representative, the President of Southern Illinois University or his representative, all of whom are *ex officio* members, and, in addition, experts in the fields of geology, biology, chemistry, forestry, and engineering who must have had a minimum of 10 years of experience in their professions. Expert members are appointed by the Governor and they have traditionally held long appointments. The biological scientists who have given or are giving of their time in this important state activity were or are William Trelease, John M. Coulter, Henry Cowles, Ezra J. Kraus, Carl G. Hartman, Lewis H. Tiffany, and Alfred E. Emerson.

The present Board consists of Director Vera M. Binks, Dean William L. Everitt (the representative of President David D. Henry of the University of Illinois), President Delyte W. Morris of Southern Illinois University, Dr. Walter H. Newhouse, Dr. Roger Adams, Mr. Robert H. Anderson, Dr. Lewis H. Tiffany, and Dr. Alfred E. Emerson.

The Board meets quarterly, receives reports from the Chiefs, counsels with them on their research programs, appoints their scientists, and examines and approves their budgets.

To return now to 1917: When the reorganization took place, Forbes, who was Director of the State Laboratory of Natural History and State Entomologist, was retained as Chief of the Natural History Survey. He remained as Chief until his death in 1930, and was extremely alert mentally until 9 days before his death.

Not long after the turn of the century, Dr. J. W. Folsom of the University of Illinois Department of Entomology was walking down a street in Urbana when he discovered a youngster who was engrossed in observing a colony of ants. Folsom engaged the boy in conversation and was impressed with his interest and knowledge. Thus began a close and personal relationship between Dr. Folsom and young Theodore Henry Frison.

Frison was born in Champaign, Illinois, on January 17, 1895, and was educated in the schools of that city. Through Dr. Folsom he became acquainted with Dr. Forbes, and these two scientists allowed the boy to attend University courses prior to high school graduation (Campbell 1946). Frison was in the army for a short time in 1918, after which he returned to the University, which awarded him all of his degrees. After short professional appointments in Wisconsin and New Jersey, and upon receiving his Ph.D. degree, he joined the staff of the Natural

History Survey as Systematic Entomologist. This was in 1923. Upon Forbes' death in 1925 Forbes was made Acting Chief and on July 1, 1931, he was appointed Chief.

Forbes was an indefatigable worker, becoming a specialist in bumble bees,

Dr. Percy Tetlow, Acting Chief, Illinois Natural History Survey, 1946–1947

agriculture, and insects. His tenure as Chief was marked by growth in staff and facilities. In the 1920's the growth of the organization was such that it was difficult to find space for the personnel in the rooms which the University could devote to use of the Natural History Survey. Dr. Forbes and Dr. M. M. Leighton, Chief of the Illinois Geological Survey, concerned in the problems of space and concluded that it would be essential that they attempt to obtain funds for a separate building. In this attempt they were successful. The University assigned an area for the building, and in 1940 the two Surveys began the move into a new Natural Resources Building, built for their occupancy. The building, and subsequent wings which were completed in 1958, were given to the University and added to that organization's inventory. For the first time the Natural History Survey had a home which it could really call its own.

Forbes had wide interests, and immediately upon becoming Chief he began the development of wildlife research. This

field, as a separate discipline, was new. He was instrumental in organizing the Midwest Wildlife Conference, the initial meeting of which was held in Urbana in 1935. Also he was a charter member of the Wildlife Society.

The staff of the Natural History Survey increased from 16 in 1930 to 38 at the beginning of World War II.

In intellect and aggressive enthusiasm, Frison was a worthy successor of Forbes. He made many contributions to knowledge. He was a member of many learned societies and was given positions of responsibility in them. Beyond that, he was a golf and tennis player, a fine violinist, and had a great interest in art, history, and current affairs.

It was a loss to the Natural History Survey, and to science, when he passed away December 9, 1945, after 15 profitable years as Chief.

On December 10, 1945, Dr. Leo R. Tehon was appointed Acting Chief, a position which he held until February 28, 1947. Tehon was a meticulous scholar. He was not only a fine plant pathologist and mycologist, but also a good linguist and musician (Carter 1955, Ayars 1956).

On March 1, 1947, Dr. Harlow B. Mills, the present incumbent, took over the duties of Chief.

THE FUTURE

Throughout its century of existence, this organization has attempted to meet the needs of the economy of Illinois with an eye to the state's future requirements. The Board has appointed scientists with broad views and excellent training, men who were not satisfied with the present but who had a strong interest in the future. A half century ago Forbes (1907*c*:892) wrote, "I shall be governed by the reflection that we are to-day looking forward and not back—that we are preparing for the future and not studying the past— . . ." The same fresh view should govern us at the end of 100 years. The problems in nature are ever changing, or, rather, our needs from and approach to nature are ever changing. There are new demands and new approaches. New research techniques require re-evaluation of what has been done. In agriculture there are new crops and new methods of raising them. New plant diseases appear. New insect pests invade the state. New demands are made for recreation. New advances in pure scientific knowledge must be made. All of these demands and approaches require the attention of the research specialist. All are inextricably bound up in the future. A scientist who looks only to the past is professionally dead.

Perhaps the greatest challenge of the future lies in the indisputable fact that human populations in the world — and that includes Illinois — are increasing. The demands which these people make on their environment are increasing more rapidly than are the people themselves! For most of our food and living room we are dependent on that surface which marks the boundary between the earth and the atmosphere, on that surface upon which the sun's rays strike. We are dependent on it for our food and for our relaxation. More people mean greater food demand and greater need for removing ourselves periodically from the intricacies of a complex civilization. More people mean a reduction in space for both of these necessities. This is the dilemma of the future. As the years roll by and the population statistics pile up, our dependence for existence on our living resources constantly becomes greater, and our dependence on the research scientist in fields of interest to the Natural History Survey becomes a complete necessity.

Now, in 1958, we are concerned about the great strides made by the physical sciences. These advances have great potential for good and tremendous potential for human destruction. International scientific competition has raised its head. If the deleterious side of this physical science development is kept in check, we can be sure that the need for sustaining humanity, both physically and spiritually, will be colossal in the years ahead.

We hear in 1958 of "crash programs" to develop in the shortest possible time certain phases of physical science application. When the collective human population of the United States has to tighten its collective belt just one small notch, we will hear of a "crash program" the like of which has not as yet even been

Harlow Burgess Mills, Chief, Illinois Natural History Survey, 1947 to date.

conceived. And when that time comes, the Natural History Survey will be called on for even greater activity.

In closing this discussion, it would be well to call attention to a House Joint Resolution introduced in the Seventieth General Assembly of the State of Illinois by Representatives Ora Dillavou, Charles Clabaugh, and Leo Pfeffer (Illinois House of Representatives 1957). The Resolution reads as follows:

WHEREAS, On June 30, 1858, a group of far-sighted citizens of this State met at Bloomington and organized the Illinois State Natural History Society which was incorporated in 1861 by an Act of the legislature; and

WHEREAS, In 1877 the name of the society was changed to the State Laboratory of Natural History, and in 1885 the laboratory was moved to Urbana where it was placed under the direction of the Board of Trustees of the University of Illinois; and

WHEREAS, The State Laboratory of Natural History and the research activities of the State Entomologist's office were united in 1917 to form the State Natural History Survey Division of the Department of Registration and Education; and

WHEREAS, The Natural History Survey has rendered outstanding service in the field of natural history, especially in regard to the control of noxious insects, the control of

diseases attacking floricultural and ornamental plants, the development of forestry in Illinois, the management of fishes in ponds and streams, the foods and movement of waterfowl in this State, the problems of upland game species, and the periodic report of species which are especially endangered, such as the prairie chicken and wood duck; and

WHEREAS, The following world recognized scientists and scholars have been associated with the wonderful work of the Natural History Survey: Stephen A. Forbes, Robert E. Richardson, David S. Jordan, Frank C. Baker, Charles A. Kofoid, Robert Ridgway, Benjamin D. Walsh, Wesley P. Flint, Victor E. Shelford, Theodore H. Frison, and Leo R. Tehon; and

WHEREAS, Since 1858 the Natural History Survey has received wide recognition for its contributions to society, has gained the respect of scientists throughout the world, has brought considerable prestige to this State, and, above all, has contributed immeasurably to the welfare of all the people of this State; and

WHEREAS, The 100th anniversary of the Natural History Survey will be celebrated in 1958; therefore, be it

Resolved, By the House of Representatives of the Seventieth General Assembly of the State of Illinois, the Senate concurring herein, that this General Assembly, on behalf of all the people of this State, extend heartiest congratulations and sincere appreciation to the staff, members and employees of the State Natural History Survey Division, on the occasion of their 100th anniversary, for the outstanding contributions they have made toward the growth and development of this State; that we extend to them a wish for continued success and progress in the future, and that a suitable copy of this preamble and resolution be forwarded to the chief of the State Natural History Survey Division, Mr. Harlow B. Mills.

Economic Entomology

GEORGE C. DECKER

WHEN settlers moved into the Illinois country, established homesites, and began to till the virgin soil, they found that hundreds of species of insects native to the area readily transferred their affections from wild plants to cultivated crops, at times in hordes sufficient to destroy the crops completely. It was inevitable that the Illinois settlers, like the eastern colonists, had brought certain pests along with them. The hitch-hiking pests included the codling moth in apple barrels, the hessian fly in straw used as packing material, bedbugs in bedding, and lice on the bodies of the settlers. As if these were not enough, other migrants, such as the Colorado potato beetle, the imported cabbage butterfly, the cotton leafworm, the San Jose scale, the Norway rat, and the fleas thereon, invaded the area. They were followed in later years by such notorious insect pests as the oriental fruit moth, the European corn borer, the sweet clover weevil, the Mexican bean beetle, and the Japanese beetle.

The early Illinois settlers were a hardy, self-sufficient, and determined lot, generally not rich but for the most part thrifty and aggressive. They took pride in the fact that they were skilled in the agricultural arts of their day. At the same time, they admitted that the problem of coping with the many insect pests that damaged their crops, annoyed their livestock, and invaded their homes was beyond their comprehension. They sought the aid of neighbors, school teachers, doctors, and local amateur naturalists, who in turn sought the counsel and advice of Fitch, Harris, and other entomologists located in the far-off New England and Atlantic coastal states. When these sources of information proved inadequate, the settlers appealed to the state legislature to appropriate funds and to appoint a state entomologist to study what appeared to be the most perplexing of all their problems. On February 27, 1867, the Illinois General Assembly created the office of State Entomologist.

EARLY HISTORY

Pleasant surprises await the curious who attempt to assay the extent and usefulness of man's knowledge of insects, their habits, and control measures in the 1850's and 1860's. It is gratifying to note that local, self-trained entomologists such as Walsh, Le Baron, Thomas, Shimer, and Riley had collected and identified hundreds of species and that they possessed a remarkable knowledge of the life cycle and ecology of perhaps three-fourths of the economic species ordinarily included in any current list of noxious insects in the Midwest. Le Baron (1871:5–6) summarized the situation as he saw it at that time:

> The history of many of our noxious insects, and especially the most notorious of them, has been pretty thoroughly traced, not only by the entomologists expressly employed by several of the States for this purpose, but also by many other active gleaners in this field. Still, any one who enters upon the study of this extensive subject, soon finds work enough upon his hands. It cannot be said that the history of any insect is perfectly and absolutely known, and it is a notorious fact that some of the insects which have been longest known and studied, such as the Plum Curculio and the Apple Worm, are the very ones which are causing the most damage to the horticulturist at the present day; and if we take into account the multitude of insects which are preying upon our shade and ornamental trees and shrubs, which, in the estimation of many, are scarcely inferior in value to the fruit bearing trees, we may safely conclude that the prospect is very remote when the work of the practical entomologist will cease or materially diminish. And the force of this view is greatly enhanced by the [occurrence], every year, to a greater or less extent, of new species of noxious insects, or rather of insects which, having existed here or elsewhere in moderate numbers, from time immemorial, have suddenly sprung into destructive profusion in consequence of an abundant supply of congenial food, or the absence of their natural enemies, or other conditions favorable to life, some of which are known, and some of which are obscure or in-

scrutable. The Colorado Potato-beetle, the Currant Saw-fly, the Asparagus-beetle, and the *Bruchus granarius*; to which we might add the Pear-caterpillar (*Callimorpha Leconteï*), and the Lesser Apple-leaf folder (*Tortrix malivorana,*) treated of in the following report, were all unknown here as noxious insects until within the last few years. It is true that some noxious insects, on the other hand, have greatly diminished, and some, which have been the sorest scourges of the orchardist, such for example, as the notorious Bark-louse of the apple tree, seem to be in the process of extinction.

Walsh and the others acquired much of their knowledge through their own observations and experience, but obviously they were familiar with most of the world literature on the subject. Furthermore, it seems reasonably certain that then, as now, much unpublished knowledge on the subject was transmitted from individual to individual through correspondence and conversation, some of it even as tradition. We know that pioneer naturalists obtained considerable information from the Indians. For example, the English explorer, Jonathan Carver (1778:493–4) wrote of his travels among the American Indians in 1766:

> I must not omit that the LOCUST [grasshopper] is a septennial insect, as they are only seen, a small number of stragglers excepted, every seven years, when they infest these parts and the interior colonies in large swarms, and do a great deal of mischief.

One may be more than a little surprised to discover that several local amateur naturalists—doctors, lawyers, college professors, orchardists, and agriculturalists, never referred to as or considered to be entomologists—knew many of the common insects by name and possessed a knowledge of their biology and habits adequate to permit these men to engage in lengthy and intelligent discussions on the subject at meetings of agricultural and horticultural societies. For example, Dr. E. G. Mygatt (1855), a physician, wrote an essay, "Bark Louse of the Apple Tree," for the first *Transactions* of the Illinois State Agricultural Society, 1853–54, and J. B. Turner (1859), a professor of Latin and Greek, presented a paper, "Microscopic Insects," at the first meeting of the Illinois Natural History Society in 1858. It is interesting to note that at this time two men, Le Baron (1855) and Thomas (1859*a*), each one later appointed to the office of State Entomologist, were presenting papers on Illinois birds and other topics in the field of natural history.

In the light of these pleasant surprises, one is amazed to realize that the combined knowledge of all the experts was almost nil when it came to questions of practical control measures that could be employed to eliminate these pests or even to reduce materially the annual losses attributable to them. It is possible that the paucity of practical information can best be understood if we recall that for many years it was believed well-nigh sacrilegious for a scientist to consider the practical application of his accumulated knowledge; as the distinguished Professor Louis Agassiz (1863:24) once said, "the man of science who follows his studies into their practical application is false to his calling."

Local and national repudiation of this philosophy contributed to the industrial and agrarian crusades that resulted in creation of state entomologists' offices and land grant colleges. Touching upon the new philosophy of science and education in addressing the founders of the Illinois Natural History Society at their first meeting in 1858, Turner (1859: 647) said:

> In respect, also, to those grosser forms of vegetable and animal life, it seems to me that our research should in future aim more directly at practical utility than in the past.
>
> We are quite too content with mere description of forms and names, sometimes, without pushing our inquiries into the causes, relations and uses, and evils of things. . . .
>
> We need not simply to christen all these things—not simply to name the beasts, but also to rule over them, as did our great father Adam; and, also, all other forms of matter. And we cannot do this till we know minutely their history, habits and relations to other things and beings.
>
> The grand end to be aimed at, in reference to most forms of fungi and parasites of all sorts, is their prevention or destruction. But a vast amount of minute antecedent knowledge is needed before we can hope to say, "thus far and no farther," even to one single race or tribe, much more to the vast myriad of races and tribes.

Benjamin Walsh, the first State Entomologist of Illinois, was in full accord with the views of Turner. In addressing

a meeting at Cobden, Illinois, in November, 1867, he said:

> I do not regret to say that I belong to the modern school of science, and think it no degradation, so far as my specialty is concerned, to bring science to the aid of practical men in the related departments of human industry. And I need not tell you, for you know, that insects pick your pockets, and that to fight them successfully it is necessary to know their habits and how to distinguish friends from foes (Walsh 1868*a*:143).

Cyrus Thomas subscribed to the new philosophy several years before he became State Entomologist.

> And the study of natural history is a useful study, having many direct practical advantages. Agriculture is the pedestal on which the stately fortunes of bankers and merchant kings are reared, and as the pedestal contracts or expands, so rises or falls the lofty column (Thomas 1859*a*:667).
>
> Therefore, we say, that natural history should be studied for the practical use made of the knowledge obtained. And, if it be a study so desirable and so useful, the question arises, *Should not the study be generally introduced into our schools and colleges?*
>
> I answer, most emphatically, yes! There is no other branch of physics, nor any branch of metaphysics so important and so necessary to be studied in the school room as natural history. And I am glad to see that quite a number of institutions have ventured to cross the Rubicon; yet others are halting at the brink, fearful of the result (Thomas 1859*a*:668).

Thus, the first and third State Entomologists publicly expressed their views. They took office dedicated to the task of assisting the residents of the state of Illinois to find practical solutions for their numerous and complex entomological problems. Their successors followed the same course.

PRACTICAL PROBLEMS AND PROGRESS

Change is eternal in the insect world; thus, it appears that the need for continued study of insects will never end. This situation may be confusing to laymen, but entomologists and others who have closely studied nature realize that insects are dynamic creatures subject to constant change in characteristics. Because of their great mutability, insects have survived in an ever-changing world for millions of years and are still capable of making the necessary adjustments to many of the important changes in their environment. Most of the important ecological changes in an area or community are accompanied by changes in the insect fauna; some species drop out and others move in.

Every agricultural practice adopted or discarded by man induces a significant environmental change or modification which will favorably or unfavorably affect insects and, for that matter, all other living organisms in the area involved. Changes in crop rotations, fertilization practices, pruning, or drainage will prove favorable for some species and unfavorable for others.

At the time the Office of State Entomologist was established in Illinois, fruit and vegetable crops could not be economically produced and marketed in the state without reasonably effective insect control. Since the high per acre value of such crops seemed to warrant expenditures for insect control, Illinois producers of these crops demanded and received a large share of the Entomologist's time. As the nature and magnitude of insect losses in other agricultural and nonagricultural areas became more apparent and better understood, pressures from a multitude of other sources necessitated a realignment and much greater diversification of entomological research.

Space will not permit enumeration and full discussion of all the insect problems that have arisen to plague Illinois farmers in the past century and it will not allow a detailed review of the thousands of printed pages that have been used to record the findings of research conducted during this period. Therefore, in the brief resumé that follows we confine our attention to a few specific examples.

Fruit Insects

In 1868 an editor of *The American Entomologist*, probably Walsh, summarized the fruit insect situation as follows:

> It is notorious among fruit growers, that the Curculio has now almost entirely vetoed the cultivation of the plum; and of late years this pernicious little Snout-beetle has extended its ravages to the peach, and even to the apple and pear, to say nothing of those rarer and

choicer fruits, the nectarine and the apricot. The strawberry and the grape vine are infested by a host of insects, some of them known for many years back to science, others described and illustrated for the first time by the editors of this paper in various publications; while there are still others the natural history of which has never yet been published to the world, and which will be figured and described by the editors in the progress of this work. What with the Bark-louse in the North, the Apple-root Plant-louse in the South and the Apple-worm everywhere, the apple crop in North America is gradually becoming almost as uncertain and precarious as the plum crop (Walsh & Riley 1868*a*:1).

To show that the testimony of an entomologist was not biased and that the conditions described above were more or less general, we may note a comment made by the eminent journalist Horace Greeley (1870:301):

If I were to estimate the average loss per annum of the farmers of this country from insects at $100,000,000, I should doubtless be far below the mark. The loss of fruit alone by the devastations of insects, within a radius of fifty miles from this city, must amount in value to millions. . . . We must fight our paltry adversaries more efficiently, or allow them to drive us wholly from the field.

The first white settlers in Illinois observed that the native fruits—plums, grapes, haws, and berries—were subject to attack by a variety of insects. More than three-fourths of the species recognized as fruit pests today were recognized and mentioned in agricultural or horticultural reports and farm journals prior to 1870. The plum curculio, for example, was to be found in every plum thicket and, when improved varieties of plums were introduced, the curculio took to them like ducks to water. In discussing plum culture at a fruit growers' meeting in 1852, a Mr. Brewster reported that for 4 years the curculio had destroyed his plum crop. Then followed a general discussion of proposed control measures, such as jarring, banding, paving, and using lime, soap suds, and chamber lye. The following year a similar report provoked a repetition of the members' favorite control measures, but by then two gentlemen had the answer: Just fence the plum orchard and turn in chickens (J. A. Kennicott 1855:296, 314–5).

The idea of using chickens for control of curculio paralleled a suggestion made by a Mr. Harkness at a horticultural meeting in 1853:

Some twelve years since, a neighbor of his enclosed a wild plum thicket, as a yard for swine; trees bore full crops every year; never troubled by curculio, whilst other thickets about had fruit nearly all destroyed by them. Four years since the hogs were turned out, and the ground appropriated to other uses; the first year after, the fruit was mostly destroyed by curculio (J. A. Kennicott 1855:314).

Gradually certain members of the curculio tribe developed a liking for related stone fruits and even apples. In his first and only report as State Entomologist, Walsh (1868*b*:64) noted:

Although the Curculio now infests the cultivated species of Plum (*Prunus domestica,* Linnaeus,) to fully as great an extent as our common wild species (*Prunus americana,*) yet it is only at a comparatively recent date that it attacked our cultivated Plums, and since that epoch it has been growing every year worse and worse, and making onslaughts upon other fruits, such as the Peach, the Cherry, and even the Apple.

For 20 to 30 years the use of Hull's curculio catcher or similar devices to jar curculios out of infested trees, so that the insects could be destroyed, and the use of hogs and chickens confined to the orchards to consume infested fruits as they fell were the two principal, and perhaps the only meritorious, control measures. One should note, however, that farm journals carried glowing advertisements for numerous concoctions, which were almost worthless or which did more harm than good.

The successful use of insecticides for the control of the plum curculio on peach and other stone fruits did not materialize until lead arsenate came into the picture in the late 1890's, because the more soluble arsenic compounds—white arsenic, Paris green, and London purple—then available proved too phytotoxic for use on such delicate foliage as that of peach, plum, and cherry. With the aid of improved insecticide formulations, spray schedules, and equipment developed through years of continued research, Illinois orchardists were able to hold their own with the curculio until a crisis developed during World War II. Then as labor and other overhead costs increased and lead arsenate became less effective,

many peach growers, after a few years in the red, pulled up their trees and abandoned production. A hope that DDT would control plum curculio faded quickly, but BHC became available just in time to save the peach-growing industry. BHC was short-lived as an insecticide for plum curculio control; it was replaced by more effective and less objectionable materials such as chlordane, dieldrin, and parathion. However, it was BHC that saved the day for a number of orchardists. Orchards that could have been bought for a song, and a poor one at that, in the fall of 1946 and spring of 1947 were not for sale in 1948.

After a century of research by the Natural History Survey and its parent organizations, we find the plum curculio is, for the moment at least, very well under control. Surveys conducted in 32 commercial peach orchards for the past 5 years showed that at harvest time less than 1 per cent of the fruit was infested or damaged by this weevil.

Other insects of the peach that have required research attention include the oriental fruit moth, a group of sucking insects responsible for an injury known as catfacing, the peach tree borers, and at least three species of scale insects. Fortunately these, too, are successfully controlled by currently available measures. Even so, peach growers insist that the entomologist will have to find more economical control measures, or the high cost of producing peaches will put the growers out of business.

The codling moth (mentioned by Walsh as the "Apple-worm"), unquestionably the No. 1 apple insect in Illinois, apparently arrived in eastern United States from Europe about 1800 and made its first appearance in Illinois about 1850. In 1869, while checking his theory that this insect had been a hitch-hiker in apple barrels, Walsh reportedly found about 200 cocoons in a single barrel. The codling moth wasted no time in becoming adapted to its new environment. In the early transactions of the horticultural and agricultural societies and in pioneer farm journals, there are numerous references to the ravages of this insect. For example, in the first issue of *The American Entomologist* in September, 1868, we read:

> Jotham Bradbury, residing near Quincy, Ill., has an old apple orchard, which many years ago used invariably to produce nothing but wormy and gnarly fruit. A few years ago he plowed up this orchard and seeded it to clover, by way of hog pasture. As soon as the clover had got a sufficient start, he turned in a gang of hogs, and has allowed them the range of his orchard ever since. Two years after the land was plowed the apple trees produced a good crop of fair, smooth fruit, and have continued to bear well ever since (Walsh & Riley 1868*b*:4–5).

In the same article, further extolling the value of hogs, we read:

> But the plum curculio and its allies are not the only insects that we can successfully attack through the instrumentality of the hog; neither is stone fruit the only crop that can be protected in this manner. For the last fifteen years or so, pip fruit, namely, apples, pears, and quinces, have been annually more or less deteriorated by the apple worm or larva of the codling moth boring into their cores, and filling their flesh with its loathsome excrement (Walsh & Riley 1868*b*:3).

In addressing the Southern Illinois Fruit Growers Association in 1867, President Parker Earle (1868:137) said:

> The curculio and the tree borers have been discussed at length in our former meetings, but the codling moth—which threatens us even greater damage than the curculio—has received little attention. There is some hope that great promptness and energy may save us from the terrible devastation which this moth has wrought in all the older States, and in the older fruit-growing neighborhoods of Illinois. Its damage to the apple crop of the country each passing year should be reckoned at millions of dollars. From all sections we have the same sad story of "the apples dropping prematurely"—"the apples mostly wormy"—"the apple crop used up," by the codling worm.
>
> In many districts of the East where apples were once abundant they now entirely fail, because of the worms, and they not only threaten the destruction of the apple crop of the country, the whole country, but pears seem equally exposed. In many sections of the West nine-tenths of the pears are reported spoiled by the codling moth.

The comments of Earle and other early horticultural leaders clearly establish the codling moth as the outstanding pest of apples in Illinois in the third quarter of the nineteenth century. From 1850 to 1870 the pasturing of hogs in the orchards and the use of straw or cloth bands around the tree trunks to trap larvae for later destruction were about the only control measures of established merit. Even

these measures were only partially effective, and a large percentage of the apples harvested showed insect damage. In fact, the situation was so bad that the fruit judges at county fairs protested the admission of fruit damaged by codling moth, and eventually a rule was passed that the unmistakable evidence of codling moth damage or the presence of San Jose scale disqualified a fruit for competition. Insecticides did not come into the picture until after the value of Paris green had been established for the control of the Colorado potato beetle and a number of other pests.

In his third report as State Entomologist, Le Baron (1873:172) recommended only cultural practices for control of the codling moth:

> PRACTICAL TREATMENT.
>
> This may be reduced to the four following heads:
>
> 1st. Destroying the insects in their winter quarters.
>
> 2d. Picking the wormy apples from the trees.
>
> 3d. Gathering the wormy apples from the ground, or letting swine and sheep have the range of the orchard.
>
> 4th. Entrapping the worms in bands and other contrivances.
>
> To which may be added the help to be derived from their natural enemies.

In his previous report, Le Baron (1872:116) had mentioned the use of Paris green to control cankerworms on apple, and this may in part have led to the subsequent work by Forbes and others for control of codling moth on apple.

We find but few references to trials with Paris green on crops in 1867 and the following decade. In 1880, however, with repeated warnings that suitable precautions must be observed, large-scale testing of Paris green and its companion, London purple, got under way. After 2 years (1885–1886) of experimentation, Forbes (1889:15) concluded:

> The experiments above described seem to me to prove that at least seventy per cent of the loss commonly suffered by the fruit grower from the ravages of the codling moth or apple worm may be prevented at a nominal expense, or, practically, in the long run, at no expense at all, by thoroughly applying Paris green in a spray with water, once or twice in early spring, as soon as the fruit is fairly set, and not so late as the time when the growing apple turns downward on the stem.

He presented data showing that, in 1885, 68 per cent of the unsprayed apples were wormy, whereas only 21 per cent of the sprayed apples were wormy, and, in 1886, 40 per cent of the unsprayed apples were wormy and 12 per cent of the sprayed fruit. When lead arsenate became available about 1895, entomologists began experimenting with it, and for the next 30 to 40 years practically all codling moth research centered around attempts to improve formulations and spray schedules involving the use of this chemical. Between 1915 and 1918, in seven separate studies, Illinois entomologists found that in unsprayed blocks fruit ranged from 9 to 84 per cent wormy and averaged 45 per cent wormy, whereas in the blocks sprayed with improved lead arsenate formulations the fruit ranged from 1 to 20 per cent wormy and averaged 4.4 per cent wormy.

With what appeared to be a satisfactory control measure working reasonably well year after year, entomologists and fruit growers alike became more or less complacent, only to be shocked by a double-barrelled attack. The codling moth began to show evidences of resistance to arsenical sprays, and, as dosage rates and numbers of applications were increased, the United States Food and Drug Administration began to bear down on lead and arsenic tolerances. The next three decades might be characterized as a period of mad scramble for cover. Attempts were made to find (1) ways to remove spray residues, (2) suitable substitute materials, (3) ways to synergize insecticidal action without increasing residues, and (4) better sanitation and other nonchemical procedures. Research did well to hold its own, during this critical period, until DDT came into the picture at the close of World War II. The success of DDT in controlling the codling moth was spectacular, and within 2 years the growers' clamor for more work on codling moth control faded.

A review of research data and the results of harvest surveys made the past 3 years show that now 33 to 94 per cent of the fruit in unsprayed apple orchards is wormy, approximately the same percentages as in the 1860's, 1880's, and the second decade of the present century. In

contrast, we find that in sprayed orchards 0.03 to 7.6 per cent, or an average of 2.2 per cent, of the fruit is wormy. Thus, we find that, in spite of adversities and reverses, continued research has developed control measures that have enabled apple growers to reduce the percentage of worm-damaged apples from possibly 60 to 100 per cent in 1867 to 21 per cent in 1885, 4.4 per cent in 1915, and 2.2 per cent in 1957.

Spraying equipment designed and used about 1897 by the State Entomologist and his assistants for experiments on control of San Jose scale. "The principal apparatus used is a large and complicated machine sprayer consisting of a one-horse power gasoline engine, a three-cylinder force pump, and a large double galvanized-iron tank with a powerful gasoline heater beneath for making the solution of whale-oil soap" Forbes 1900:14 . The sprayer was mounted on a two-horse baggage wagon.

If it appears that entomologists have devoted too much attention to this one insect, let us recall that codling moth research has been the traditional guinea pig for the study of many insect control procedures, and that the measures developed for the control of the codling moth for the most part have given satisfactory control of a considerable number of other pests of apples.

A list of the insects attacking fruit crops in Illinois would no doubt include 100 or more species. There are at least a dozen important scale insects alone. One scale insect of great importance is the San Jose scale, which was introduced into California from China about 1880 and into Illinois about 1895. For a time this scale threatened to wipe out the Illinois commercial fruit industry. Parasites, predators, and diseases have played an important role in holding this insect at bay, but for over 50 years orchardists have found it necessary to apply a dormant spray or some other special treatment to bring this insect under control. As late as 1950, Illinois apple growers seemed to agree that if the use of sprays was to be forbidden San Jose scale would eliminate commercial orchards within 5 years. This insect, perhaps more than any other, has been responsible for the development of a strong plant inspection and quarantine system in Illinois, and, for that matter, in other states as well. Here we have an insect that can barely survive on wild or neglected trees but that thrives on young,

vigorously growing orchard trees—an excellent example of how man creates, or at least aggravates, his own insect problems. The more man prunes and fertilizes, the more certain he is to develop a serious San Jose scale problem.

Truck Crop Pests

An article, probably by Walsh, published in 1869 makes it clear that at an early date a host of insects were recognized as important pests of a wide variety of vegetable crops:

> There is scarcely a vegetable raised in our gardens that is not preyed upon by one or more grubs, caterpillars, or maggots, so that, when we eat it, we have positively no security that we are not mingling animal with vegetable food. Two distinct kinds of maggots, producing two distinct species of two-winged Fly, burrow in the bulb of the onion. Scabby potatoes are inhabited by a more elongated maggot, producing a very different kind of two-winged Fly, and also by several minute species of Mites. Turnips, beets, carrots and parsnips are each attacked by peculiar larvae. And as to the multifarious varieties of the cabbage, not only are they often grievously infested by the Cabbage Plant-louse—a species which has been introduced from Europe into this country—but also by an imported caterpillar producing a small moth, and by several indigenous caterpillars producing much larger moths, some of which caterpillars, when full-grown, are over one inch long (Walsh & Riley 1869:114).

Why the article failed to include the corn earworm, the squash vine borer, the cucumber beetles, and the melon louse is hard to say, for they were numbered among the best known pests at the time. One is amazed that the Colorado potato beetle was not mentioned, because this species was the most spectacular insect pest of vegetable crops in Illinois in the latter half of the 1860's. Presumably, prior to 1850 the Colorado potato beetle was unknown except as an interesting species found only in the foothills of the Rocky Mountains, where it fed on a wild potato somewhat resembling the common horse nettle. When the pioneers planted Irish potato and egg plant in Nebraska and Colorado, the beetle found these closely related plants to its liking, increased its numbers many fold, and took off for the East, flying from one settler's potato patch to another's. Here again we have an example of how man may create his own insect control problems. The introduction of a crop highly attractive to a native insect invites this insect to transfer its affections to the newly introduced crop. The potato beetle transferred its affections from its native host to the introduced potato. It seems quite probable that the potato beetle's many natural enemies did not travel eastward but continued searching for it in its old haunts. With an abundance of lush, nutritious potato vines and a temporary release from its natural control agencies, the Colorado potato beetle, in the vernacular of today, "went to town" until a new system of checks and balances could be established.

The eastward movement of the potato beetle was first noted in eastern Colorado in 1859. It did not appear in Illinois until 1864. Damaging populations of this beetle were reported in several Illinois counties in 1865. Some of the tales of wholesale potato destruction related in the local press and the *Prairie Farmer* were downright pathetic:

> "Let every man and woman in the country or in town, who has a potato patch, try experiments for the destruction of these pests and report progress. Something must be done to stop the destruction of the vines by these insatiate creatures or we may as well quit trying to raise potatoes" (*Cedar Valley, Iowa, Times,* quoted by Riley 1866:432).
>
> I know of several cases near Rock Island, Illinois, where the owners of potato-patches, after persevering in a course of hand-picking for fully a month, finally gave up in despair, because as fast as they killed off their own bugs, a fresh supply from their neighbors' potato-patches kept flying in upon them (Walsh 1866:14).
>
> All accounts seem to agree that neither lime, nor ashes, nor any available external application is of the least use in checking the depredations of this insect. The *Prairie Farmer* says that "Mr. Jones found, after many experiments, that neither hot lime, lime-water, brine, tobacco-water, wine (?) nor sulphur had any effect on them; that turpentine, benzine and kerosene would kill them when copiously applied, *but also killed the potatoes,*" and that "coal-oil mixed with water is ineffectual." . . . Although there is some contradictory evidence, yet the general result of all the testimony is, that neither domestic fowls, nor ducks, nor turkeys will eat them, at all events to any very extensive amount (Walsh 1866:14).

Hand picking, or the manual collection and destruction of the beetles, their larvae, and their eggs, was about the only really effective control measure. During

the next several decades, it was said of many a farm boy who had risen to a prominent position, "He made his first dime collecting potato bugs on his grandfather's farm"—not his father's farm, for there, in accord with the tradition of the day, he performed the task without compensation as a member of the family.

Many potato growers experimented with Paris green applied in several ways, and by 1870 dusting plants with a mixture of Paris green and flour or lime was quite generally accepted as the most effective remedy available. However, there were many growers who were fearful of the poisonous properties of the arsenical compounds and they continued to place their trust in hand picking. Some growers went so far as to design rather elaborate mechanical devices which they mounted on skids and dragged up and down the rows to beat the beetles from the plants and collect them in pans, trays, or boxes, where the beetles could be destroyed.

The value of predators and parasites was not overlooked, and at times different kinds of poultry, particularly turkeys, were noted as effective control agents. Hellebore, London purple, and calcium arsenate were later added to the list of insecticides recommended for control of the Colorado potato beetle. As the potato leafhopper, aphids, blight, and other pests attracted increased attention, a variety of insecticide and fungicide combinations came into common use. Research produced minor improvements in formulations and methods of application that enhanced the effectiveness or economy of control measures, but there was no substantial or basic change in control procedures or practices until the advent of DDT in 1946. While potato growers and entomologists alike had been inclined to feel that the control measures in use in the early 1940's left little to be desired, they apparently overlooked or grossly underestimated the damage inflicted by the insects, for within 2 years after

Spraying equipment developed in recent years by entomologists of the Illinois Natural History Survey for the control of the corn earworm and the European corn borer on sweet corn and field corn.

DDT came into general use the per-acre potato yields practically doubled.

Numerous early reports indicate that the pioneer cabbage grower had to contend with about the same insects that plague the cabbage grower of today, but the pioneer had no arsenal of effective insecticides. Lime, lye, and ash mixtures advocated by some growers were of little use except in those cases where the plants were so heavily coated with one of the mixtures that physical contact between the insect and the plant was practically impossible. The scalding water drench proposed by some persons was at times of value, but was very apt to damage the plants. The arsenicals were used sparingly and on small plants only; they could not be safely employed on more mature cabbages. Thus, for many years the sound, unblemished head of cabbage was a rarity, and there was always danger of consuming protein with the slaw. In fact, it is very doubtful if any kraut made in those days could have passed present day Food and Drug Administration inspections for insect fragments. There are those who contend that the prevalence of scurvy in the armies of the North and the South during the Civil War was in no small measure due to the fact that farmers could not produce adequate quantities of cabbage and related cole crops.

Although some nicotine and pyrethrin products had been known for many years, they did not come into practical use until about 1910. Derris, cubé, and other rotenone preparations made their appearance in the 1920's. When properly applied, these insecticides were quite effective, but they possessed very limited residual properties and were relatively expensive. Their acceptance by cabbage growers was not enthusiastic, and entomologists were under constant pressure to improve formulations by the use of synergists or stabilizing agents. Then came DDT and the organic phosphate insecticides, and it looked for a time as if the cabbage growers' insect problems were effectively solved. But the insects once again demonstrated their mutability, and soon cabbage worms were resistant to DDT. Today the entomologist is worse off than he was in the early 1940's, because the cabbage growers, having once experienced the fine performance and economy of DDT in the early 1950's, are unwilling to settle for anything less efficient. The currently recommended spray schedule, which calls for using endrin until cabbage heads begin to form and finishing with occasional applications of phosdrin or parathion, is a highly effective treatment, but the growers remember equally satisfactory results with the less complicated use of DDT.

Sweet corn growers in Illinois, like the cabbage growers, must cope with an insect problem that requires both a thorough knowledge of the seasonal activities of the pest and a rather meticulous control treatment. The corn earworm is a native American pest that has long contested man's right to the sweet corn produced in Illinois. Unlike the cabbage worm, this insect has continued to defy man's best efforts to control it. Several reasonably effective control measures have been developed, but none has been fully accepted by Illinois sweet corn growers. The corn earworm control measure currently recommended involves precise but not unreasonable methods of application and accurate timing of treatments. Some Illinois sweet corn growers have been unable or unwilling to apply the requisite control measures. When infestations of the corn earworm are light, mediocre control practices prove adequate, but, when infestations are heavy, more meticulous practices are essential. In parts of Florida and Texas, where sweet corn growers cannot afford to gamble on having light infestations, many growers produce 97 to 99 per cent clean ears of corn by carefully following the control measures recommended by entomologists.

Cereal and Forage Crop Pests

Insect depredations were by no means confined to the fruit and vegetable crops produced by the early settlers in Illinois. Wheat, corn, and even the native prairie grasses were subject to attacks that at times amounted to almost total crop destruction. In an article in the first issue of *The American Entomologist*, a writer, presumably Walsh, observed:

> Few persons are aware of the enormous amount of wealth annually abstracted from the pockets of the cultivators of the soil by those

insignificant little creatures, which in popular parlance are called "bugs," but which the scientific world chooses to denominate "insects." Scarcely a year elapses in which the wheat crop of several States of the Union is not more or less completely ruined by the Chinch-bug, the Hessian Fly, the Wheat Midge, or the Joint Worm. . . . The White Grub attacks indiscriminately the timothy in the meadows, the corn in the plowed field, the young fruit trees in the nursery, and the strawberry beds in the garden; always lurking insidiously under ground, and only making its presence known to the impoverished agriculturist by the losses which it has already inflicted upon him. . . . at periodic intervals the Army-worm marches over their fields like a destroying pestilence; while in Kansas, Nebraska, and Minnesota, and the more westerly parts of Missouri and Iowa, the Hateful Grasshopper, in particular seasons, swoops down with the western breeze in devouring swarms from the Rocky Mountains, and, like its close ally, the Locust of Scripture and of Modern Europe, devours every green thing from off the face of the earth (Walsh & Riley 1868*a*:1).

Certainly Walsh was in a position to know the armyworm problem, because in 1861, 6 years before the creation of the State Entomologist's Office, the Rock Island and Chicago and the Illinois Central railroads granted him, as a member of the Illinois Natural History Society, passes that permitted him to spend several weeks studying a major armyworm outbreak that developed in central and southern Illinois. That fall, in typical Walsh style, he wrote:

. . . I always hate to give *nothing* for *something*, and having been obliged by the railroad companies, I endeavored, to the extent of my poor abilities, to return the obligation, by seeking a remedy for a little pest, that has this year destroyed one-fourth part of the tame hay grown within the limits of the State (Walsh 1861:350).

This was the introduction to an extremely interesting and informative 15-page report on the ecology of the armyworm and its natural enemies which he appended to an essay prepared for delivery at the annual meeting of the Illinois Agricultural Society. Walsh reported:

When they [armyworms] leave the meadows in which they originate, they travel on—sometimes as far as half a mile—until they meet with wheat, rye, oats, corn, sorghum, or Hungarian grass (Walsh 1861:351).

Many instances are on record of the great difficulty with which they have been kept out of houses which happened to lie in their path (Walsh 1861:352).

From the *Prairie Farmer* of July 4, 1861, Walsh (1861:351) quoted the words of "an accurate observer" who described an infestation of armyworms: "As to their number, they have been seen moving from one field to another, THREE TIERS DEEP. A ditch has been filled with them to the depth of THREE INCHES IN HALF AN HOUR."

Walsh was fortunate in being able to acquire, through contacts with a number of pioneer settlers, valuable notes on historic armyworm outbreaks of the past. Some of these notes seem worthy of repetition as an example of the fund of unpublished entomological history and knowledge that has passed from one generation to another:

As we might expect from the laws governing the development of insect life, the armyworms make their appearance in noticeable numbers in different years in different parts of the State. I have no doubt that they exist in small numbers in every part of the State from year to year; for although they have never appeared till 1861 in the neighborhood of Rock Island, in such numbers as to attract attention, yet I myself captured a single specimen of the army-worm moth in Rock Island county, in each of three years, '58, '59 and '60. At Okaw they are recorded to have appeared in 1850; in the south part of Vermilion county, in 1835; and Mr. Joseph Bragshaw, of Perry county, says that they visited that county in '25, '26, '34, '39, '41 and '42. Colonel Dougherty, of Jonesboro, in Union county, one of the oldest and most respected citizens of Southern Illinois, informed me that about 1818 or '20 they were far more numerous there than in 1861, and that in 1861 there would not be a single cock of hay put up in his neighborhood save one meadow which was part clover and part timothy, and which I can myself testify was badly "patchy," there not being more than an eighth part of it which would turn out a good swarth of clover, the timothy being "nil" throughout. In 1838 again, according to the Colonel, there were but few of them. In 1842 they were about as in 1861; and in 1856 they occurred only in small numbers (Walsh 1861: 353).

It certainly is an encouraging sign of the progress of entomological discovery in this State, that a noxious insect of primary importance should have been, for the first time, traced through all its transformations in the year 1861 by no less than four citizens of Illinois to my certain knowledge—I refer to Mr. Cyrus Thomas of Murphysboro, Mr. Emery of the Prairie Farmer, Col. Dougherty of Jonesboro, and last and least myself (Walsh 1861: 356).

While many of the observations made by Walsh and the other gentlemen mentioned were sound and are still valid, one observation was in error and resulted in a recommendation which, although it had the desired effect, was based upon a false premise. Walsh (1861:349) advised, *"Burn your tame grass meadows over annually, in the dead of the year, and get your neighbors to do the same, and you will never more be troubled with the army worm."* Walsh thought that the armyworm passes the winter in the egg stage, but such is not the case, and therefore burning, as he recommended, did not destroy the eggs. We now know that when the moths appear in the early spring they fly at night; in the daytime, they hide in rank grass, preferably a dense mat of old, dead grass in a vigorous meadow. There, in April and May, they lay their eggs. Thus, while winter burning did not destroy eggs, it had a profound effect on the number of worms developing in burned-over fields and often, if not usually, prevented serious infestations from developing.

The recommendation for burning persisted for several years, and by 1880 it was supplemented by a recommendation for the use of dusty trench barriers to trap worms on the march. Spraying strips with Paris green was proposed by some, but was generally considered both dangerous and impractical.

The use of poison bait (a mixture of bran and Paris green) for the control of armyworms, cutworms, and grasshoppers came into use about 1885, and with minor modifications remained the principal and most practical control measure available until the advent of the modern chlorinated hydrocarbon insecticides. Since 1951, growers have been generally successful in controlling armyworms by spraying with such materials as toxaphene, dieldrin, and endrin. Furthermore, with the insect outlook and warning service bulletins available weekly during crop seasons from the Natural History Survey, Illinois farmers are now able to control armyworms effectively when the worms are one-fourth to one-half grown. Applied control measures save the small grain and the meadow grasses as well as protect adjacent crops from migrations.

The chinch bug, another infamous pest, has been well known to Illinois farmers since 1820. This species, like the armyworm and many others, is not a serious pest every year, but tends to be sporadic, perhaps somewhat cyclic, in its appearance. Weather, of course, is a factor that influences the chinch bug population.

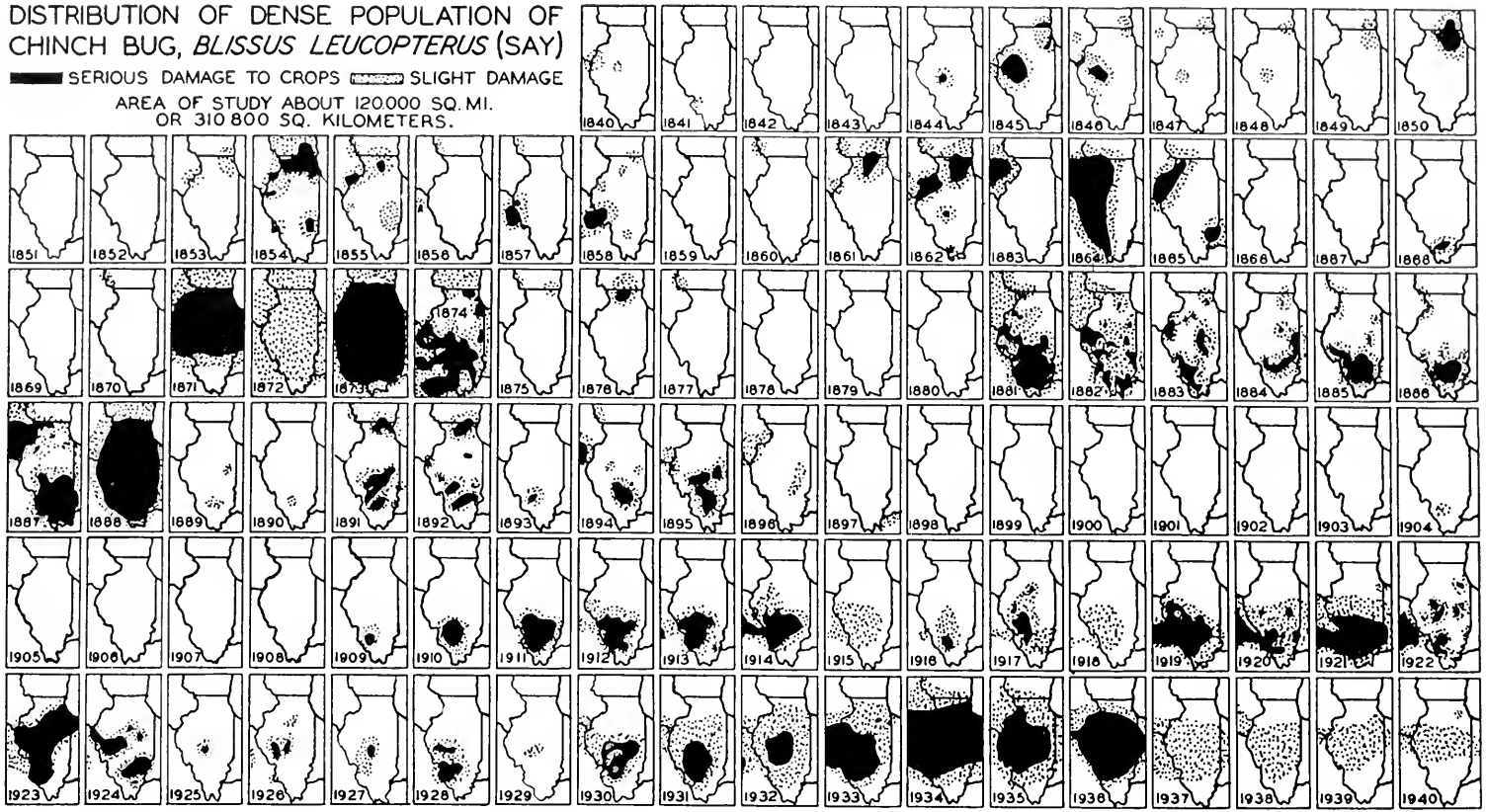
One is indeed surprised to learn that the farmers of 1860 were just about as much aware of this pest as are the farmers of 1958. In 1861 Thomas (1865: 466–7) observed:

> Although we cannot predict with certainty one season the action of insect enemies for the next, yet we often can from the character of the season itself, know that certain species are likely to be upon us in increased numbers.
>
> This was the case the present season in regard to the appearance of the "Army-worm." The cold, cloudy spring hanging so long before opening into summer weather, caused the exclamation from several of our older citizens, "I wouldn't be surprised if we had the Army-worm this season." Although this was rather guessing, yet there evidently pervaded the minds of the elder settlers a semi-conscious feeling of dread in regard to this insect, which most assuredly originated from the similarity in this spring to the previous seasons when it had appeared. And when the long dry weather we sometimes have in June and July has parched the vegetation, we may expect the grass-hoppers to multiply rapidly, and by their attacks on the plants already struggling for life, to soon effect a far greater injury than the same attack made on vigorous plants would have done.

Later, Thomas (1880:242) observed, "The high temperature of 1854, '71 and '74, together with the diminished rainfall, furnish the key to the cause of the great development of the Chinch-bug during these years."

One could cite hundreds of quotations, from the *Prairie Farmer* and other early farm papers, concerning damage by the chinch bug and other field crop pests that would put the potato beetle reports to shame. But let the words of Walsh and of Thomas suffice. Walsh wrote as follows:

> It is only two years since the entire wheat crop of the State was so damaged by the chinch bug that a great deal of it was not cut at all, and a great deal that was cut barely paid for the harvesting. Scarcely a year elapses but what more or less damage is done to it by this insect, and by the Hessian fly and the wheat midge. A large breadth of winter wheat, which is commonly supposed to be "winter-



Maps of Illinois and parts of adjoining states on which are shown areas of serious damage, slight damage, and no damage by chinch bugs in 101 years, 1840–1940. Records kept by the Illinois Natural History Survey and its parent organizations make possible the study of population trends in such groups as insects, fishes, birds, and mammals.

killed," is in reality killed by the Hessian fly; and there may be, and probably are, many other insects which depredate upon this crop, but whose habits have not yet fallen under the notice of entomologists (Walsh 1861:335).

Taking the average of years, we may safely assume that a fifth part of the wheat crop—or, which is the same thing, a quantity equal to one-fourth of what we actually do harvest—is destroyed by insects. Even at the low price, therefore, of 75 cents per bushel, we have *over four and a half million dollars' worth* of wheat annually destroyed by "little vermin which it is not worth our while to notice." But this is not all. Other crops are damaged by other insects, though not generally to so ruinous an extent; so that we cannot put the whole annual damage done by insects to the State of Illinois at less than TWENTY MILLION DOLLARS (Walsh 1861:336).

And Thomas (1865:457) wrote: "So much has already been written in the papers of this State concerning the Chinch-bug (*Macropus leucopterus,* Fitch,) that I shall pass it by in this paper without further notice."

Shelford & Flint (1943) made a thorough study of the history of the chinch bug in Illinois. The figure on page 116 is presented to illustrate the type of historic records that have been made and preserved by the Natural History Survey. The data on which the figure is based cover the century beginning in 1840. Records for subsequent years have, of course, been kept. Similar data have been collected for several other important pests.

In the 1860's and '70's, many measures were proposed for control of the chinch bug: abandon wheat and barley or corn; burn fencerows and all wild grass areas to destroy hibernating bugs; plant border crops to retard migrations; fertilize crops to get dense stands unattractive to the insects; and construct barrier lines of lime, salt, and carbolic acid solutions. The measure most widely used was the dusty furrow. Each year saw some new version of the furrow proposed, such as pouring tar oil, road oil, or creosote into the furrow to form a barrier; covering the furrow with straw and setting it afire to destroy the bugs; digging post-hole traps in the furrow and later spraying the trapped bugs with kerosene and burning them. There was no great change until the paper fence barrier, proposed in 1934, was widely adopted, but even this barrier was not without precedent; over 50 years earlier the use of tar-covered boards set on edge and placed end to end had been proposed. The later control measures, like the early ones, were scheduled to be used around harvest time. About 1945, the paper fence barrier was practically replaced by the dinitro dust barrier, and in another 10 years this was replaced by dieldrin, sprayed on strips of ground along the margins of small grain fields where these fields adjoined fields of corn or later maturing grain. The more aggressive followers of research progress were spraying entire fields of heavily infested wheat as soon as chinch bug eggs began to hatch so as to protect the wheat crop itself from serious damage and to eliminate the necessity of establishing a barrier of any type 2 or 3 weeks later.

In the past century, progress has been made in controlling many other insect pests that attack cereal and forage crops. Among the most important of these pests are the grasshoppers, the cutworms, the white grubs, and the hessian fly. Instead of attempting to summarize in detail, we note here some of the general trends in this area of insect control.

Before extensive agricultural development of the state, a large part of Illinois consisted of broad expanses of prairie grass, much of which was replaced by timothy and other tame grass or cereal crops planted by farmers. Insects preferring these crops became notorious pests, but as the acreage of grasses was reduced as a result of increased legume production, certain insects began to decline in importance. These included the white grubs, the billbugs, the armyworms, the sod webworms, and the corn root aphid. The burrowing webworm and the cutworm *Luperina stipata* have all but disappeared; not a single specimen of either has been received by us for identification in the last 20 years. As the rail fence was replaced by the wire fence, and roadsides and ditch banks were graded or otherwise cleaned up, the amount of giant ragweed and elderberry available to insects was greatly reduced, so that the common stalk borer became less important and the old spindleworm was practically exterminated. Likewise, as the pot holes and low spots were drained, wireworm damage in

those areas declined steadily. Conversely, in certain dry, sandy areas which were brought under irrigation wireworm damage increased.

As legume production increased, the insect pests of legumes tended to increase. Notable examples are the clover leaf weevil, clover root borer, pea aphid, bean leaf beetle, sweet clover weevil, green cloverworm, and spotted alfalfa aphid.

Two attempts to initiate and promote the commercial production of sunflowers in Illinois were doomed to failure largely because of the overwhelming insect problems encountered when many species from the native sunflowers swarmed onto the cultivated varieties. In contrast, we find that in extreme southern Illinois cotton production survives in a rather unfavorable climate, and under other adverse conditions, largely because important cotton insects are absent and planters are spared the cost of extensive insect control measures.

Pests of Forest and Shade Trees and Ornamental Plants

Effective control measures are now available for most of the insect pests of trees and ornamental plants; yet man seems to have little success in combating these insects. It is not that these insects are new or relatively unknown, for the majority of these pests were recognized and well known prior to 1850. The bark lice (scale insects), round-headed borers, flat-headed borers, bark beetles, bagworm, walnut caterpillars, cankerworms, and the 17-year locusts are frequently mentioned in the Illinois entomological writings of a century or more ago. Chemical control measures were not available at that time, but some of the proposed measures were partially effective and more or less practical. Mechanical barriers and sticky bands were used to control the cankerworms, sometimes successfully and sometimes not. It now appears that improper timing and failure to recognize the difference between the spring and the fall cankerworms accounted for most of the variation in control. Hand picking was often mentioned and, according to reports, if done diligently it was effective in controlling the bagworm, the walnut caterpillars, and the tent caterpillars. Hand grubbing, with a wire or knife, was considered an effective means of controlling several species of borers. Several types of soapy washes were proposed for the control of aphids and scale insects, but perhaps the most positive, wisest, and most ingenious of all recommendations was that proposed by Dr. Mygatt (1855: 516) in his essay on the bark louse: "Whether you choose a seedling or graft, by all means TRANSPLANT A CLEAN TREE, if you have to occupy hours and even days in examining and clearing your trees from *every scale.*"

As insecticides and means of applying them were being developed for use on various agricultural crops, it was natural that most of them would be tested to determine their potential usefulness in controlling insects attacking trees. The value of Paris green in controlling the cankerworms was established at a very early date. By 1910 lead arsenate, first developed in 1891 for use against the gypsy moth, was being recommended for a variety of leaf-eating insects, and by 1925 high-powered sprayers, dusters, and even airplanes had been developed and were quite generally available for use in treating both shade and forest trees. Nevertheless, progress was slow; apparently the weather and tree protection have something in common—everybody talks about them, but nobody does anything about them.

The average citizen who professes an interest in and a love for trees is sometimes like the kibitzer who, at an active poker table, talks a good game, but, for reasons best known to himself, fails to put his money on the line. In the past 2 years in many Illinois communities, beautiful landscape plantings, such as juniper, valued at hundreds of dollars were rendered unsightly and in many cases were killed outright by the bagworm; a dollar's worth of malathion, or the old faithful, lead arsenate, and 30 minutes' time could have prevented any damage. In some communities there has been a wholesale loss of elm, oak, and birch trees of inestimable value and irreplaceable in less than 3 decades; little evidence was available that control measures were even considered.

This seeming indifference in some communities is partially offset by the genuine

interest of a number of ardent tree lovers and conservationists in other communities. Some of these tree lovers, however, clamor for more research without making full use of the control measures already available. Scientists have spent many years in developing fairly efficient and practical control measures for 90 per cent of the insect pests affecting shade trees and ornamental plants, yet we find that these measures either are ignored or are employed in less than 1 per cent of the cases in which they might be useful. It seems doubtful whether administrators will feel justified in diverting any considerable portion of their funds to similar projects until there is evidence that the control measures already recommended are being put to better use. A recently published circular (English 1958) will bring interested people up to date on control of insects attacking ornamentals and shade plants.

Insects Attacking Man and Animals

Entomology has made its most profound and spectacular advances of the past 100 years in combating those insects that are pests to man and animals. There seem to be two good reasons why this is so. In the first place, we have learned considerably more of the habits and relative importance of these pests than was known in 1858, and, in the second place, as the medical implications of these pests became apparent, state and federal public health agencies, men in many branches of science, and the general public gave wholehearted support to large research and action programs.

Early Illinois entomologists had collected and identified many species of ticks, mites, mosquitoes, and flies, and it did not require the services of a scientist to advise farmers that large numbers of these species were sources of annoyance to their livestock, their families, and themselves. A couple of very casual comments adequately attest to the ferociousness of these pests: "There are prairies in Central Illinois, as I am credibly informed by numerous witnesses, across which it is impossible to ride or drive a horse in the heat of a summer's day on account of the *Tabanus*" (Walsh quoted in Cresson *et al.* 1865:18). The genus *Simulium* includes "the Buffalo-fly of Illinois and the West, which I have observed killing poultry in great numbers, and which is known to torment horses and other animals to death, when very numerous" (Barnard 1880:191).

While these reports may sound farfetched and exaggerated, the latter is supported by a more recent experience. In 10 days of April, 1945, black flies killed 125 head of horses and mules and untold numbers of poultry in Franklin and Williamson counties, Illinois.

Possible relationships between these insects and several of the most dreaded diseases known to occur in the state were unknown in 1858 and for the most part were unsuspected. For example, no one thought of connecting the common house fly with the spread of cholera that took the lives of one-tenth of the population of several western Illinois communities in the 1830's or with the outbreaks of typhoid fever and dysentery that were so common during and immediately after the Civil War.

It seems ironic that B. D. Walsh, the first State Entomologist, was driven from his farm near Cambridge by a malaria epidemic and that he never suspected the mosquitoes that increased with the damming of the river as being responsible for the epidemic. All we know of this incident is contained in two sentences of Walsh's obituary by C. V. Riley (1869–70:67).

> Finally, a colony of Swedes settled in his neighborhood, and, by damming up the water at Bishop Hill, produced so much miasma in the vicinity, that very much sickness prevailed there. His own health in time became impaired, and at the suggestion of M. B. Osborn, of Rock Island, he removed to that city in 1851, and entered into the lumber business.

Indeed, there is every reason to believe that neither Walsh nor any of his contemporaries even suspected the relationship between mosquitoes and malaria. In his zeal to protect all beneficial insects and to maintain the balance of nature, Walsh was inclined to regard house flies, horse flies, and mosquitoes as possibly more beneficial than destructive. In 1865 he was quoted as saying:

> The scheme of the Creation is perfect and Nature is never at fault. It is only when Nature's

system is but half understood, that we heedlessly complain of its imperfections. We blame the house-flies for annoying us, and fail to see that in the larva state they have cleared away impurities around our dwellings, which might otherwise have bred cholera and typhus fever. We execrate the blood-thirsty mosquito, and forget that in the larva state she has purified the water, which would otherwise, by its malarial effluvia, have generated agues and fevers. In all probability, when we rail at the *Tabanus* that torment our horses in the summer, we are railing at insects which, in the larva state, have added millions of dollars to the national wealth, by preying upon those most [insidious] and unmanageable of all the insect-foes of the farmer—subterraneous, root-feeding larvae (Walsh quoted in Cresson *et al.* 1865: 18).

An editor of *The Practical Entomologist,* in commenting on Walsh's paper, cautioned his readers:

Before you undertake to kill off the larvae of the Horse-flies and the Mosquitoes, you had best make yourself quite sure that they are really your enemies, and not, as Mr. Walsh maintains, some of your very best friends (Cresson *et al.* 1865:18).

Flies and mosquitoes passed practically unmentioned until about 1880 when, because of the insects' annoyance and nuisance characteristics, a few workers began to investigate suppressive measures. Window screens and the use of smoke came into the picture first, followed by oil sprays, crude repellents, and several fly traps. If we exclude the modern insecticides developed since 1940, most of the control measures that are recommended today for the control of flies and mosquitoes had been developed by 1900. By the combined use of drainage, good sanitation practices, screening, and the known insecticides such as lime, borax, oils, arsenicals, and pyrethrins, public health agencies made remarkable progress in reducing the incidence of insect-borne diseases, but it was not until DDT and the more recent synthetic organic insecticides became available that it was possible to reduce fly and mosquito numbers to the near vanishing point and to eradicate almost all insect-borne diseases of man.

Shortly before the outbreak of World War I, the country embarked on an all-out "Swat-the-Fly" campaign that carried over into the dairy industry. This campaign stimulated interest in the development of sprays for use on livestock, as well as space sprays for use in and around buildings.

Unfortunately, many of the formulations used prior to the late 1930's were only partially effective in controlling flies, and in many cases the injury they inflicted on cows exceeded the benefits derived. It was difficult, if not impossible, to establish clearly the fact that flies did affect milk production and that good fly control would pay dividends in the form of higher milk production. In the last 10 years, with the new insecticides such as DDT, methoxychlor, and several effective organo-phosphates, and with some repellents far more effective and much more persistent than anything available prior to 1940, it has been possible to demonstrate that good control of flies, whether they be tabanids, stable flies, or horn flies, will result in an increase of milk production of as much as 10 to 25 per cent. The exact gains depend upon the intensity of the fly population, the species involved, and the duration of the attack. Significant findings in this field have been reported in a number of scientific articles (Bruce & Decker 1951, 1957, 1958; Bruce 1952, 1953).

BIOLOGICAL CONTROL

Man discovered at a very early date that not all insects are bad, that some are definitely his allies, some are indifferent or neutral, and some are in the category of Dr. Jekyll–Mr. Hyde—half good and half bad. Walsh, Le Baron, Thomas, and other early entomologists in their writings repeatedly referred to the necessity of distinguishing between man's foes and friends in the insect world, and emphasized, as did their successors, the importance and potentialities of parasites and predators in the natural control of insects.

In December, 1854, William Le Baron, who 16 years later became the second State Entomologist of Illinois, wrote:

Birds benefit the agriculturist by destroying countless myriads of noxious insects, whilst they injure him by consuming a part of those products which he would fain reserve for his own exclusive benefit. But it is the universal testimony of those who have investigated the matter, that the evil compared with the good which they accomplish is extremely trivial. Probably every reader of ornithology will call

to mind, in this connection, the computation of Mr. Wilson the ornithologist, the result of which was, that the single species of Red-winged Blackbird, which is usually considered one of the greatest pests of the farmer, consumes in one season, in the United States, sixteen thousand and two hundred million of noxious insects (Le Baron 1855:559–60).

In an essay on insects, prepared in 1861 at the invitation of the Illinois Agricultural Society, Cyrus Thomas (1865:462, 464) made several pertinent comments on insect control measures, the balance of nature, and the biological control of insects:

When we have obtained a complete knowledge of the laws of nature, and shall have attained to perfection in agricultural pursuits, then most assuredly our reliance for a check upon these insect enemies will be upon the parasites a kind Providence has provided for our benefit. And the reason for so doing will be that then we will work in accordance with the laws of nature which are adapted to our best method of living and acting. Then if this theory be true, the nearer we can approach such a condition, individually or collectively, the better it will be for us.

. . . . . .

Let the birds go unmolested, or even go so far as to entice them to abide near you. Learn to distinguish insect enemies from insect friends, and when you find the hiding places of the latter, as far as possible, protect them from injury. When you find a swarm of "Lady-bugs" huddling around the root of a tree in the winter, throw a few dry leaves over them that the birds may not see them. When you see the eggs of the Syrphus fly lying singly among those of the Aphis, do not molest it, for the young larvae will surely destroy that nest. And when the bright banded flies hover like bees around you, during the hot days of summer, while resting beneath the shade, brush them lightly away, and remember they are your friends. And when you see the eggs of the Lace-winged fly (*Hemerobius*) mounted on their long stalks on the leaves of your plants, let them alone, the voracious larvae they produce will soon destroy the most numerous colony of plant lice.

Benjamin Walsh (1861:339–40, 341) likewise had something to say about the balance of nature and the value of parasites and predators:

Now it is universally the case, that whenever man, by his artificial arrangements, violates great natural laws, unless by some artificial means he can restore the overturned balance, he pays the penalty affixed to his offense. The voluptuary may overload his stomach, but, unless he has recourse to his dinner pill, he pays the penalty of an indigestion. So with the farmer and the horticulturist. Until they can restore the natural equilibrium which has been disarranged by their artificial processes, they pay the penalty in the damage inflicted on them by plant-feeding insects. They must assist nature, whenever, for necessary purposes, they have thwarted and controlled her, if they wish to appease her wrath.

If these views be correct, it would seem to follow, as a necessary consequence, that one of the most effectual means of controlling noxious insects is to be found in the artificial propagation of such cannibal species as are naturally designed to prey on them.

. . . . . .

Although, so far as I am aware, cannibal insects have never yet been bred for utilitarian purposes, yet it is by no means an uncommon practice to collect such as are found at large in the woods and fields, and apply them to subdue some particular insect that is annoying us.

The foregoing quotations portray not only the profound interest in biological control that these early entomologists possessed but also the breadth and depth of the general knowledge of the day.

Forbes, who followed Thomas as State Entomologist, was likewise interested in parasites and predators. The fact is impressive that, in studying the biology and ecology of insect pests, these men invariably made extensive notes on the parasites and predators encountered. While others before him had made notes of entomophagous fungi and other evidences of disease, Forbes was the first to examine the possibilities of control of insects by their diseases. In fact, he is regarded by many as the father of insect pathology in the United States. His work on the chinch bug fungus and the work by Dr. F. H. Snow of Kansas are outstanding classics of early research in this field.

Forbes did not limit his interest and research in insect pathology to chinch bug diseases. He noted, and in many cases studied in great detail, the diseases found in numerous lepidopterous larvae, aphids, white grubs, grasshoppers, and several other insects. In the late 1880's he was strongly advocating more thorough studies on the possible advantageous uses of contagious insect diseases, and his Eighth Report (Nineteenth Illinois Report), published in 1895, contained a monograph of nearly 150 pages on chinch bug diseases. In general, the success of attempts to propagate insect diseases and to disseminate them as a means of controlling noxious insects in Illinois has not been as

spectacular as sponsors and interested observers had hoped. These projects have been greatly underestimated by the public; control of insects by their diseases has a value that should not be ignored.

If nothing more, these studies demonstrate the important role that insect diseases play in the natural control of many important pest species. They also shed light on the epizootiology of these diseases, which may prove to have even further value. Unfortunately, in practically all cases these projects were initiated on the premise that an epidemic would be initiated that could and would completely eliminate the pest species in a matter of days or weeks. When extermination of the offending pest was not immediately forthcoming, public sentiment turned from hope to disgust and ridicule, and researchers were forced to abandon their studies for lack of financial support. It is doubtful whether there is a single case in which an honest appraisal of the long-range or even the immediate value of disease inoculation or dissemination, or a combination of both, has been made. In recent years we have belatedly come to realize that insect pathogens have not been adequately explored nor their potential value determined. We and others are renewing our efforts in this basic field of research.

The performance of a protozoan disease of the European corn borer, a disease which, like the parasites of the hessian fly, apparently accompanied the host when it migrated to North America, seems worthy of mention. In Illinois the disease was first observed in the north central part of the state in 1945, 6 or 7 years after the borer made its first appearance in Kankakee County. The disease was artificially introduced into all sections of the state by colonizing disease-infected borers in many widely scattered counties. It is now prevalent in all parts of the state and has for several years been an important, if not the most important, factor in holding corn borer populations to relatively low levels, where they can be successfully controlled by other means at a greatly reduced cost.

In a co-operative effort, the Illinois Natural History Survey, United States Department of Agriculture, and Illinois Conservation Department introduced a virus disease obtained from Canada to combat a serious outbreak of a pine sawfly, *Neodiprion sertifer,* that in 1952 was raging out of control in the Henderson State Forest. The virus took hold in a spectacular fashion, and sawflies died by the thousands. Whether the virus can be given full credit or not remains to be determined. In any case, the sawfly has not been reported as doing serious damage in that area since 1953.

The value of parasites imported from abroad to help control accidentally introduced species has also been underestimated. Here, as in an effort to control an insect pest by disease, the public seems to expect the immediate annihilation of the pest species or it regards the effort as a complete failure. To demonstrate that a species need not be annihilated to be prevented from causing appreciable damage, let us look at the record. The hessian fly and the wheat midge were both introduced in colonial days as immigrants from Europe. Fortunately, several of their European parasites came along with them in the same lots of straw, but, as usually happens, each pest reproduced and spread faster than its parasites. In due time the parasites overtook their hosts, and, for over a century, they have been important factors in preventing these pests from eliminating wheat production from the list of agricultural enterprises in Illinois.

When the oriental fruit moth appeared in Illinois in 1927, the Illinois Natural History Survey, in co-operation with the United States Department of Agriculture, obtained, for release in Illinois, oriental fruit moth parasites (principally *Macrocentrus ancylivorus*) reared in New Jersey. These were colonized at several points in the infested southern Illinois counties. At first the results of the experiment did not appear promising, but consistent recoveries were made in 1934, and eight surveys made since then have shown that parasitism by this species ranged from 17.3 to 53.2 per cent and averaged 36.5 per cent. While the parasite has not eliminated its host, it has held the population to a level where peaches can be adequately protected with a minimum use of insecticides. The average

percentage of the fruit infested since the establishment of the parasite is less than one-tenth what it was before colonization of the parasite was initiated.

Shortly after the European corn borer made its appearance in the Midwest, attempts to introduce several of its parasites into the infested area (1926–1930) were relatively, if not wholly, unsuccessful. Later attempts, in which the Illinois Natural History Survey and the United States Department of Agriculture co-operated (1944–1950), were more successful, and a Tachinid fly, *Lydella stabulans grisescens,* became firmly established in all sections of the state. Surveys made annually for the past 10 years have shown that, for the state as a whole, 15 to 40 per cent of the overwintering corn borers are parasitized and destroyed by this fly. In many instances parasitism in some of the northern Illinois counties has run as high as 80 to 85 per cent. While this parasitic fly has not eliminated the corn borer, it plays a very important role in holding this pest in check.

VALUE OF INSECT CONTROL

Man's progress in applied entomology is partly obscured by the ever-changing circumstances and conditions of insect control. Quantitative data on the exact magnitude of insect damage are generally unavailable, and only the more or less catastrophic insect outbreaks are adequately recorded in the literature. There are few specific points of reference with which we can compare the present with the past. Our memories are often faulty. We recall that Grandfather had a home orchard and how much we enjoyed the fruit; only after prolonged meditation do we also recall that only 1 apple in 10 was fit for storage in the fall, and that even in preparing a pie from the stored apples Grandmother had to cut out numerous areas damaged by codling moth.

Despite the paucity of precise quantitative data, entomologists have developed practical control measures for a long list of once serious pests. Orchardists are now able to produce fruit crops 90 to 99 per cent free of insect damage instead of crops only 10 to 50 per cent free of insect damage, as they were 100 years ago or as they are now in abandoned or unsprayed orchards. The Colorado potato beetle, which came close to eliminating Irish potato production just about 100 years ago, is no longer regarded as a serious pest. The grasshoppers, the armyworms, and the chinch bug, which less than a century ago caused many Midwestern pioneers to give up in despair and to abandon their farms, can now be controlled with comparative ease. The principal insect vectors of important human diseases have been brought under control to such a degree that the once dreaded diseases—malaria, typhoid fever, dysentery, cholera, and bubonic plague—are little more than an unhappy memory. Reasonably effective measures for the control of important household pests such as the bedbug, cockroaches, stored-grain pests, clothes moths, and carpet beetles have brought peace of mind to the housewife and have contributed much to increase the comfort of the home. Measures developed for the control of insects attacking livestock—ticks, tabanids, stable flies, lice, and screwworms—have contributed much to the livestock industry. The successes mentioned above were attained despite the drastic rise in level of acceptance imposed by the public, the United States Food and Drug Administration, and market grades and standards. Under present regulations, the diseased and damaged condition of fruits, vegetables, grain, and other agricultural products that were accepted at the turn of the century would eliminate them from moving in interstate

Table 1.—Number of acres treated with insecticides and estimated profit from treatment for a few important insect pests of cereal and forage crops in Illinois, 1953-1957.

YEAR	NUMBER OF PEST SPECIES CONSIDERED*	NUMBER OF ACRES TREATED	ESTIMATED PROFIT FROM TREATMENT
1953	10	770,625	$ 8,596,995
1954	7	1,095,165	7,130,258
1955	9	1,532,859	13,983,855
1956	10	1,405,624	7,097,630
1957	11	934,224	2,696,960
Average	*9*	*1,147,699*	*$ 7,901,140*

*Insects considered in these surveys: spittlebug, leafhopper, spotted alfalfa aphid, sweet clover weevil, pea aphid, soil insects, chinch bug, cutworms, grasshoppers, European corn borer, and fall armyworm.

commerce or even from being sold on the local market.

Though it is not possible to establish monetary values for each of the accomplishments just mentioned, the almost $8,000,000 average annual profit, table 1, resulting from the use of insecticides on cereal and forage crops in Illinois illustrates the benefits of entomological research.

There are those who will say that agriculture cannot afford the cost of insect control or that the farmer dare not add such charges to his overhead cost. Such assertions are economically unsound. The overhead charges associated with the planting, cultivating, and harvesting of each acre of crops are fixed. If a farmer can increase yields sufficiently to provide a cash return of two, four, eight, or more times the cost of insecticide treatment, the extra harvest is produced much more cheaply than the rest of the crop and thereby increases net profits and effects a reduction of operating costs.

Insect control—or the lack thereof—may have an indirect bearing on economic and sociological considerations in addition to those related to crop savings or crop losses. By increasing per-acre yields, maximum utilization of insect control measures might enable upwards of a million acres of Illinois farm land to be retired from cultivation and put to new uses. Some reactionaries will argue that increased yields would mean overproduction and lower prices; this argument has been applied to almost every new technological development.

For years we have been attaining production goals by mining the soil—by wringing from it the fertility that must be replaced if future generations are to have their share. Economically and morally, we are obligated to produce maximum yields as efficiently as possible on a minimum number of acres. The surplus land should be removed from annual cultivation and its fertility maintained or improved with soil building practices employed until such time as an expanding population requires further production. Even if Illinois could afford to squander its land resources and its manpower, the support of research for effective insect control would still be a foresighted investment. When men of wisdom, interested in the nation's future, combine forces in building a sound agricultural program, insect control will rank high in the list of technological musts.

EMPHASIS FOR THE FUTURE

Throughout the past century in Illinois, the extent and variety of insect control problems, which were often of an emergency nature, dictated that entomology be strictly applied and be aimed at immediate, practical goals. Perhaps the pressure for immediate, practical results reached its peak in the mid-1940's, when a number of new and apparently highly effective insecticides became available for study and use. Everyone wanted to know at once what these insecticides were good for, how they should be used, and what hazards might be involved in their use. Now this pressure is subsiding; the Illinois farmer is in possession of reasonably practical control measures for most of his important insect pests. Economic entomology in Illinois is now in a position to seek information on the basic problems of insect control.

This statement does not mean that all the insect problems of Illinois are solved; we should not be surprised that new problems will arise as new insect species are introduced and as species already here modify their habits or adjust their responses and behavior to an ever-changing environment. However, we have apparently reached a turning point that will require a revision of our responsibilities and will materially alter our objectives and procedures.

With reasonably effective control methods available for most pests, and with the majority of our basic crops in surplus production, emphasis on the temporary solution of immediate problems and on increased production must logically be shifted to the development of more basic studies ultimately leading to new methods of insect control. A review of the history of chinch bug, armyworm, codling moth, and potato beetle control makes it apparent that progress came in steps spaced 10 or 20 or more years apart. In entomology, as in other branches of science, real progress is made through the

development of some new fact, some biological or chemical law or principle referred to as a "break-through," discovered by scientists pursuing basic research.

Practically all entomologists agree that Nature is more efficient than man in controlling insects; there is an urgent need for a return to the basic study of insect biology and ecology and for expanded work in the promising field of biological control. With a more thorough knowledge of the environmental factors that favor insect reproduction and survival and of those factors detrimental to these processes, man might conceivably control some pests by diminishing the favorable factors, enhancing the unfavorable factors, or pursuing both courses. This type of basic research is expensive, and progress comes slowly, but successful projects based on the accumulated results of such research pay handsome dividends.

While more intensive studies in insect genetics, ecology, and biology may play increasingly important roles in the development of new insect control procedures, man will for many years find it necessary to rely on chemical weapons—insecticides—to fight many of his insect pests. As more and more toxic insecticides are developed, it becomes increasingly important that they be thoroughly tested for safety before they are placed in general use. The evaluation of insecticide residues, their degradation products, and possible adverse effects on man and other animals, is currently time consuming and expensive. We must undertake considerable basic research to discover and to develop basic principles or natural laws that will simplify insecticide evaluation and reduce the cost of pursuing such routine studies.

Come what may, man must never become complacent with his temporary successes nor assume that the insects have given up or will give up their struggle for supremacy. We must be ever mindful of the theses of L. O. Howard (1933) that insects are better equipped to occupy the earth than are humans; insects have been on earth for 40,000,000 years, while the human race is only 400,000 years old. As Forbes (1915:2) soberly asserted:

> The struggle between man and insects began long before the dawn of civilization, has continued without cessation to the present time, and will continue, no doubt, as long as the human race endures. It is due to the fact that both men and certain insect species constantly want the same things at the same time. Its intensity is owing to the vital importance to both of the things they struggle for, and its long continuance is due to the fact that the contestants are so equally matched. We commonly think of ourselves as the lords and conquerors of nature, but insects had thoroughly mastered the world and taken full possession of it long before man began the attempt. They had, consequently, all the advantage of a possession of the field when the contest began, and they have disputed every step of our invasion of their original domain so persistently and so successfully that we can even yet scarcely flatter ourselves that we have gained any very important advantage over them.

There seems to be little question that insects will continue to demand tribute of enormous proportions which will have to be paid in terms of damage, pain, and suffering caused by the insects, or in expenditures for insect control. Man may, through judicious expenditures for research and practical insect control measures, reduce or minimize the tribute to be paid, but he can never eliminate it entirely. In this connection, it should again be noted that entomology is not static. Insects, as highly versatile living organisms, are constantly changing to meet each change in the environment, whether it be biological, physical, or chemical. If we are to hold our own in this continuing battle, research must be carried on undiminished, and, if we are to make progress, research must be expanded.

At the moment, entomology and related biological sciences appear to be losing ground. State and federal appropriations have not kept pace with rising costs. Basic research is currently financed largely by grants from the principal endowed foundations. If it were not for funds made available by chemical and other large industrial companies, applied research in entomology would have been greatly handicapped and curtailed in the last decade.

Today, faced with the fact that another nation was the first to launch a man-made earth satellite, America is subjecting her own research facilities and educational system to critical review. At the moment, the physical sciences are in the limelight and apparently stand to profit from increased emphasis. That the

natural sciences can safely be relegated to a secondary or back-seat position is open to question. Almost 100 years ago, B. D. Walsh, deploring American neglect of the natural sciences, observed: "They manage these things better in Europe. In Russia and other continental states, Entomology in its rudiments is made a portion of common school education" (Anon. 1860:12).

There is every reason to believe that current entomological research in other countries is in no way inferior to our own. If the biological sciences, including entomology, are neglected in a revitalized educational program, America may find herself again out-distanced by other countries—by men who are trained in a science-oriented system that is balanced to include all areas of scientific endeavor. If one step forward in the physical sciences causes us to slide two steps backward in the biological sciences, all our efforts spent to initiate a sound program for the advancement of science—all science—will have proved useless.

Faunistic Surveys

HERBERT H. ROSS

IN their beginnings and early development, investigations of the fauna of the Midwest differed in several respects from similar endeavors in other parts of the world. The Midwest was explored and collected intensively considerably later than the eastern American seaboard, so that the advances in the knowledge of the North American fauna made in the eastern United States were available as an aid to moderately rapid advances when faunal studies were begun in the Midwest. In the eastern United States and also in Europe, systematic investigations were begun in response to man's inherent curiosity concerning the kinds of life in his surroundings and were developed to a considerable state of advancement chiefly under this stimulus. In the Midwest, the first serious systematic efforts were undoubtedly begun in answer to pure curiosity, but almost immediately after their inception, especially in Illinois, these studies were picked up and swept along by the tremendous demand for identification caused by the agricultural and scientific developments of the latter half of the nineteenth century.

EARLY BACKGROUND

The sudden formation of natural history societies in the Midwest during the 1850's — at Louisville in 1851, Grand Rapids in 1854, Milwaukee in 1855, and Chicago in 1856—gives an impression in retrospect that before that decade there were no naturalists in the area. This was far from the case, for a few enthusiastic naturalists were active in various localities through the Midwestern region even before these dates.

Among the Midwestern naturalists were the famous zoologists Thomas Say, C. A. Le Sueur, and G. Troost, living and working on the banks of the Wabash River at New Harmony, Indiana, in the 1820's and 1830's, and C. S. Rafinesque at Louisville, Kentucky, in the 1810's and 1820's. Many other persons collected material for these men or sent specimens for identification to taxonomists in the eastern United States or Europe.

The early faunistic workers of the 1840's and the 1850's in Illinois included such men as Cyrus Thomas, John A. and Robert Kennicott, J. B. Turner, and Benjamin D. Walsh, all of them self-taught naturalists. These and other enthusiasts made accurate observations on the fauna, built up collections of various animal groups, and kept in touch with their confreres in the eastern states. The Illinois entomologists published articles, some of them in the *Prairie Farmer,* and absorbed the ideas of such great early entomologists as T. W. Harris of Massachusetts and Asa Fitch of New York.

In Illinois the State Agricultural Society, formed in 1853, was an important agent in bringing together Illinois zoologists, entomologists, and botanists into an organized natural history society. The progressive officers of the Agricultural Society were conscious from the first of the destructive nature of insects and were sufficiently versed in biological concepts to realize that applied biology requires a full knowledge of all forms of natural life. To encourage acquisition of this knowledge, the Agricultural Society offered prizes at its state fairs for collections in natural history fields. In 1854 Wm. J. Shaw of Tazewell County won first prize for the "Best suite of the animal kingdom, including insects and animals injurious to the farmer" (J. A. Kennicott 1855:122). In 1855 Robert Kennicott won two prizes, one for the "Greatest and best collection of named insects," the other for a zoological collection; in 1856 he won seven firsts—for a collection in each of the following classes: shells, named insects, zoology, botany, stuffed birds, reptiles, and fishes (J. A. Kennicott 1857:90, 142).

In the State Agricultural Society's first *Transactions*, three lists of animals for Illinois were published, one on southern

Illinois birds by Henry Pratten (1855), one on the Mollusca of southern Illinois by H. A. Ulffers (1855), and another (solicited by the Society's secretary) on the animals of Cook County by Robert Kennicott (1855). It is interesting that in this last article Kennicott recorded "buffalo" and elk for Cook County and noted that the "wild pigeon" (passenger pigeon) was "very abundant" and the magpie "not uncommon in winter."

For a few years after the first corporate form of the Illinois Natural History Survey had come into being as the Illinois Natural History Society, the Agricultural Society published the proceedings of the infant organization.

In Illinois the faunistic worker of 1858 had few of the work aids which we enjoy today. The only Midwestern institutional reference collection was that at Northwestern University, built up by Robert Kennicott and considered outstanding in its day, although small and limited in group representation compared with collections now available.

Most zoologists accumulated their own private collections, identifying their specimens with the aid of the few books available and through consultation with other naturalists. Few libraries existed in the area. The reference shelves of the best zoologists contained comprehensive treatments covering the eastern North American fauna for most of the vertebrates and the Mollusca. For the insects Say's volumes were available, but for many orders his treatment was fragmentary. For most insect groups and many other invertebrates, extremely helpful world synopses had just been written by European authors, and some of them contained separate keys for the North American species. Aside from these basic references, there existed a number of journals carrying short papers, some of them published by the scientific societies of the Atlantic seaboard states, where such societies had been organized a century before their Midwestern counterparts.

This period, the 1850's, was a stirring one scientifically. Europe had just witnessed the successive development of comparative anatomy and physiology, the cell theory, embryology, histology, and the theory of evolution. These basic concepts did not immediately influence faunistic work in North America but they did so later to a greater and greater degree. In North America prior to the 1850's, the great bulk of the invertebrate material, including insects, had been sent to European specialists for description. Following the pioneer examples of Frederick Melsheimer and Thomas Say with insects and mollusks, American zoologists were beginning to describe more and more species of the native American fauna. In the invertebrate groups they had virtually a virgin field, for in 1858 great numbers of species were still unknown, and workable synopses were available for only a small proportion of the native American fauna.

CHANGING HABITATS

Originally Illinois was chiefly a combination of forested hilly country and flat mesic prairies of a marshy nature. Interspersed with these main types were sand areas, bogs, river and stream habitats, and other local areas of diverse kinds. The rapid rise in the population of Illinois in the mid-nineteenth century initiated in the native vegetation drastic changes which have progressed steadily to the present time; these changes have had a marked effect on the distribution and composition of the animal life of the state.

By 1858, towns or farms or logged-over areas had broken up large tracts of forest. Plowing had made great inroads into the prairies. Large area drainage operations in the marsh country had started about 1850, had gained great momentum by 1880, and by 1900 had turned the great bulk of the marshland into farms. The resultant changing ecology is a background feature important to keep in mind when viewing the faunistic developments outlined in this chapter.

PERIODS OF FAUNISTIC ACTIVITIES

The faunistic activities of the Illinois Natural History Survey and its predecessors may be divided into three fairly distinct periods, the initial, chiefly voluntary, period of roughly 1858–1869, the

expansion period of roughly 1871–1922, and the specialized faunistic survey period of roughly 1923 to date.

Initial Period, 1858–1869

The Illinois Natural History Society, when formed in 1858, had as its primary objectives the exploration of the biota of Illinois and the establishment of a scientific library. Encouragement of animal studies was patently aimed at systematics; yet even in the inaugural presidential address by J. B. Turner there is more than an overtone of putting systematics to work. In the words of Turner (1859: 647),

> A true philosophy, as it seems to me, would never let us rest content till we had truly and fully learned not the bare name and form, but the final cause and use, the good and evil, the full relation of each thing, object and being, to all other beings, and especially to man—to all his interests, enterprises, arts, uses and developments, physical, mental and moral.

At the anniversary meeting in 1860 at Bloomington, certain objectives of the Society were expressed differently but in equally broad terms (Anon. 1860:3):

> It is the aim of the Society . . . to establish a Museum of Natural History, at the State Normal University, comprising every species of plants, birds, shells, fishes, insects, quadrupeds, minerals and fossils, found in Illinois, together with such collections from various parts of the world as will assist our youth in gaining a knowledge of the general studies of nature.

The Natural History Society did in fact found a museum at Normal, Illinois, which served as a rallying point for zoologists of the area. The Society's papers and proceedings continued to be published by the Agricultural Society, which further continued its active encouragement of faunistic work by awarding prizes for exhibited collections at the state fair.

At about this time several Illinois naturalists began publishing accounts of the zoology of the state. C. D. Wilber (1861*b*) described a fossil mastodon, Thomas (1861*a*, 1861*b*) wrote lists of mammals and of some insects, R. H. Holder (1861*a*, 1861*b*) wrote about birds, and Walsh (1861–1868) published a remarkably fine series of papers before his death in 1869. Although a skeleton network of railroads crisscrossed the state, most of the collecting was local, because it had to be done as a hobby appended to the naturalist's business or other occupation; hence, the papers were based chiefly on material from a few localities.

Collections exhibited at the state fairs give another informative light on faunistic activities of that time. At the 1859 fair three entries were exhibited, one a red deer, another a collection of stuffed birds, and the third a collection of insects. In 1860 seven entries (Reynolds 1861:190–1) and in 1861 eight entries (Reynolds 1865:137) were exhibited in zoology. There were no more exhibits in zoology until 1864; in that year the winners were chiefly the Illinois Natural History Society and Illinois Wesleyan University at Bloomington (Reynolds 1865:310). Apparently these two groups enjoyed some rivalry at that time in the development of natural history.

An idea of the high merit of these exhibits can be gained from the 1861 Awarding Committee's remarks (Reynolds 1865:149) on the insect exhibits:

> In Entomology, a collection exhibited by T. G. Floyd, of Macomb, entitled the exhibitor to the "commendation" of the Society. In this department, Dr. Charles A. Helmuth, of Chicago, made a fine exhibition. His collection of Beetles is very valuable and attracted much attention. He has over 1100 species collected in Illinois, besides many fine species from other States and foreign countries. We think him entitled to "very high commendation," especially for specimens exhibited belonging to the order of Coleoptera. But by far the best collection exhibited was presented by B. D. Walsh, Esq., of Rock Island. It is hardly possible to speak in too high terms of this extensive collection of the insects of Illinois. So far as Illinois insects are concerned, it outnumbers in the order of Coleoptera, the collection of Dr. Helmuth, and is very full in all the other orders. It could only have been collected and arranged by an exercise of industry, [perseverance] and skill, and by an application of scientific knowledge, reflecting great honor upon the collector and entitling him to high rank among the Naturalists of the State and of the country. The Committee do not hesitate to pronounce his the "best collection illustrating the Entomology of Illinois," and unanimously award to him the premium of the Society.

In spite of the achievements in faunistic activities shown by both publications

and exhibits, the Natural History Society itself faltered because it could not make ends meet on private subscriptions alone and by the end of the 1860's was a mere shell of an organization.

Expansion Period, 1871–1922

The establishment of the State Entomologist's Office in 1867 and the incorporation of the Illinois Natural History Society into the State Board of Education in 1871 brought together as official state organizations two agencies investigating natural science and marked the beginning of continuing state support for faunistic programs.

The appointment of Walsh as first State Entomologist had little effect on this movement because Walsh confined his official writings almost entirely to nontaxonomic subjects. His successor, William Le Baron, introduced serious taxonomic contributions into the reports of the State Entomologist in 1871.

In his first report as State Entomologist, Le Baron described a new species of moth attacking apple, in his second described four more new species of insects of economic importance, and in his third gave an outline of and key to the orders of Illinois insects (Le Baron 1871: 20–3; 1872:117–24, 138–9, 140, 157–8; 1873:25). Here he called particular attention to the great need for identification aids in the pursuit of economic entomology. Le Baron's was the first of much faunistic work which continued as an integral part of the development of economic entomology in Illinois. At almost the same time (1871), the educators and scientists of the state, alarmed at the continued decline of their Natural History Society, induced the legislature to take over and assign the Society's museum and library to the State Board of Education in exchange for state appropriations (Illinois General Assembly 1872: 151–2) for the Society's continued growth. Thus, the need for state aid in the development of faunistics arose from two different directions.

Both Le Baron and Thomas as State Entomologists published many fine taxonomic insect studies in their reports. Under the auspices of the Illinois Museum of Natural History, naturalists in the state published faunistic papers on a wide range of Illinois groups, including Crustacea, fish, birds, reptiles, and insects.

The period 1858–1878 witnessed the first concerted awakening of American naturalists to the taxonomic opportunities in the invertebrates, especially in the insects. Specialists in many states published comprehensive treatises on orders or families of insects of North America. For these animals, this was truly the age of North American discovery.

In 1877 the Museum of the Natural History Society, by that time known as the Illinois Museum of Natural History, was separated into two institutions: the Natural History Museum, designed as a public exhibition museum, in Springfield, and the State Laboratory of Natural History, at Normal (Illinois General Assembly 1877:14–6). The duties of the State Laboratory, presumably as set forth by Stephen A. Forbes, its Director, stressed ecological approaches to the animal life of the state and in this policy reflected thoughts expressed by Turner 20 years before. The primary intent of the systematic program described was "to monograph those groups which have not been thoroughly studied elsewhere" (Forbes 1882*a*:9).

In 1882 Forbes became State Entomologist, as well as Director of the State Laboratory. Following the establishment of both of these offices at Urbana in 1885, the faunistic program received great impetus. Reading between the lines of the original reports of the Director, it seems safe to surmise that by this time the ecological studies already attempted had highlighted the pressing need for the accurate identification of the animal species encountered in these studies. In the revised list of duties of the State Laboratory we find the directive, "he [the Director] shall present for publication, from time to time, a series of systematic reports covering the entire field of the zoölogy . . . of Illinois" (Illinois General Assembly 1885:23). In its *Bulletin*, the Laboratory had previously published many papers by nonstaff members, but from this time on a larger and larger proportion of these papers was the product of staff members of the State Laboratory or of the State Entomologist's Office.

The main faunistic activities of these staff members concerned aquatic organisms and insects associated with the development of ecology and economic entomology. Forbes repeatedly mentions that the most important tools of the biologist are a reference collection for the identification of specimens and a scientific library. All staff members collected specimens as part of their duties, and every effort was made to obtain material from different parts of the state and from areas of interest in adjacent states. By 1894 the collections were of sufficient magnitude to be placed under the charge of a curator, C. A. Hart. In 1903 Hart became Systematic Entomologist and Curator of the insect collections, and R. E. Richardson was brought in to take charge of the fish collections. In 1915 J. R. Malloch was appointed to assist Hart with the insects.

Field party of the Illinois State Laboratory of Natural History at one of several collecting stations near Havana, 1894. This station was on the east shore of Thompson's Lake, which has since been drained. In the picture are, left to right, Frank Smith and Henry E. Summers, zoologists, Charles A. Hart, entomologist, and Miles Newberry, fisherman and boatman.

Collecting conditions from 1870 to well into the 1900's were greatly different from those of today. A few railroads traversed the state and these were the only means of rapid travel. Collecting was done intensively around a few headquarters, especially Urbana, Carbondale, and Havana. On the Illinois River and other waterways, boats were available for travel up and down the rivers. Local travel was done by horse-drawn vehicles. As late as 1900 Forbes (1901:3, 5–6) wrote of the Laboratory:

> Its field operations have been conducted mainly from the Illinois Biological Station [at Havana and Meredosia] as a center, . . .
>
> . . . . . .
>
> Besides this local work on the fishes of the State, two extensive wagon trips have been provided for, one made in the fall of 1899, and the other in progress at this date [September, 1900]. . . .
>
> A considerable number of collections have also been made by high school principals and science teachers and sent to the Laboratory in aid of this survey.

Hart and his assistants traveled to various points by train and in each town set up headquarters in a local hotel or rooming house, hired a buggy, and made

day trips into the surrounding territory. In this way, over the years a remarkably fine collection of insects was built up from almost every part of the state. The establishment of the field laboratory at Havana formed a basis for many seasons of intensive insect collecting in the rich waters of that area and on the extremely interesting sand areas which line the east bank of the Illinois River through several counties.

At the present time such restrictions on movement might seem a terrible handicap, but one must remember that in those days the land was not so intensively cultivated as it is at present. Within a very short distance of almost any town, tracts of virgin forest, prairie, marsh, or other undisturbed habitats could be reached with little effort. Many of the old virgin landscapes which were the type localities of Illinois species are now either flooded by artificial lakes, under cultivation, or covered by urban developments. Most of the marshes, which were once commonplace, have been drained. Because of the abundance and accessibility of varied habitats, the early collections were both large and diversified. The very nature of the substation headquarters method encouraged the collection of all species of insects in a given locality, rather than specialization on any one group. Human labor was relatively cheap; hence, preparators and collectors could be hired and trained at a nominal cost.

As a result, the State Laboratory insect collections (which constituted also the insect collections servicing the State Entomologist's Office) became the finest which had ever been assembled for any one state, and early in the twentieth century the collections of fishes and certain other groups were equally fine. This faunistic program reached a peak about 1910 and continued into the next decade.

In 1917, when the State Entomologist's Office and the State Laboratory were combined to form the present Illinois State Natural History Survey, the reorganization did not effect any changes in the internal structure of the faunistic staff. Immediately afterward, however, the faunistic program began to dwindle. Many of the well-trained personnel accepted positions in universities and other scientific centers which were growing rapidly. World War I drew away much of the younger help. Richardson concentrated on ecology. Hart, the work horse of the entomological collections, died in 1918, and in 1919 C. P. Alexander was appointed Systematic Entomologist. Alexander and Malloch worked chiefly on stream surveys. The studies of Alexander resulted in a report on the Vermilion River (Alexander 1925). After the resignations of Malloch, in 1921, and Alexander, in 1922, there were no faunistic taxonomists left on the Natural History Survey staff. No comprehensive faunistic projects had been in operation for several years, and these resignations left the Survey without even curators.

Specialization Period, 1923 to Present

The appointment of Theodore H. Frison as Systematic Entomologist in 1923 marked the beginning of a resurgence in the faunistic activities of the Natural History Survey. Until several years later this move was felt primarily in the insects, but eventually it spread to the other animal groups. Frison's first endeavors were to collate the insect collections, but his chief thoughts were aimed at methods for revitalizing the old charge to publish a series of systematic reports covering the entire field of the zoology of Illinois (Illinois General Assembly 1885:23). Forbes was as anxious as Frison to see this program begin. By this time several factors had changed the faunistic outlook considerably from that of the beginning of the century. Good roads reached almost every hamlet in the state, and the automobile had supplanted the train and buggy as a ready means of travel. The ease of reaching all points of the state made up in large measure for the increasing destruction of large tracts of native habitats and the necessity of seeking primeval collecting spots in remote and widely separated localities.

Taxonomically the picture had changed to an equal extent, at least for insects. In 1900 it was generally considered that except in groups like aphids and ectoparasites, species could be readily identified by external characters through use of, at most, a hand lens. Variation had

been little recognized as a factor in and a difficulty of identification. A reference series of a few specimens was considered thoroughly adequate for each species. Although the value of series of specimens was becoming recognized at the beginning of the twentieth century, the true necessity for larger population samples was not fully recognized in insect groups until about the 1920's. By this time, in group after group of insects and indeed of other invertebrates, many of the older species units were each being divided into several species separated only by microscopic characters, which were often minute in character and difficult to see. So detailed was the knowledge required to identify many of these groups that it was no longer possible for one person to cover reliably the tremendous number of groups which Hart had done so successfully according to the standards of his day.

Influenced by these changes, a faunistic program was evolved centering around intensive studies of individual groups. The program called for each staff member to study some special group, collect material throughout the state at different seasons and in different habitats, identify the material, and write up a report of the group for Illinois. It was hoped that the services of specialists at other institutions could be obtained during the summer months to work with Natural History Survey personnel on Illinois reports. In the original plan, the thought was that these reports could be restricted quite closely to Illinois material and to Illinois species. This plan did in fact prove satisfactory for the aphids and Orthoptera, which were relatively well known for the country as a whole. When, however, projects were started for groups which were poorly known for the continent, it was found essential to extend the scope of the reports to cover roughly the mid-central states, as Forbes had implied as a general policy as early as 1900.

It was recognized early in this program that many insect groups of little importance economically were nevertheless of great importance ecologically. An attempt was therefore made to develop a program which would alternate the treatment of groups having principally economic importance with those having principally ecological importance.

Within the bounds of a primarily systematic treatment, it was hoped that basic information could be obtained on *the place of the species in nature*. Collecting programs therefore stressed discovering the microhabitats, hosts, seasonal appearance, or other ecological attributes of the different species.

An aim of great importance which developed for these reports concerned their usability from the viewpoint of the beginning student. Many keys made by specialists contained language too technical to be readily understood by nonspecialists. Frison was acutely aware of this fact and insisted that all keys in the faunistic bulletins be couched in language as simple as possible and that, wherever helpful to an understanding of characters or specialized terms, illustrations should accompany the keys.

Frison's plan for faunistic reports was not put into operation until 1928, when F. C. Hottes was employed during the summer as a special appointee to work on the aphids of Illinois. The appointment of Hottes was the first of several of its kind. In 1931, when Frison became Chief, Herbert H. Ross became Systematic Entomologist. In 1935 the insect systematic program became the Insect Survey Section of the Natural History Survey.

The identification of economic insects, always a duty of the Systematic Entomologist, became an important feature of the Section. The Section was called on also for the identification of certain other invertebrates important in agriculture or public health, especially mites, ticks, aquatic Crustacea, and earthworms. In these activities, changing taxonomic concepts and the introduction of economic insects and mites new to the state continually increased the difficulties of accurate identification and the need for obtaining additional specialists for the staff.

In 1947 the faunistic program was expanded to cover all animal groups, with the idea of extending to groups other than the insects the faunal survey aims which had been developed for insects. The Insect Survey Section was renamed the Section of Faunistic Surveys and Insect Identification, and it became the

custodian of all the Survey's taxonomic collections of animal groups.

Over the years several artists have contributed greatly to the utility and appearance of the Survey's faunistic publications—Lydia M. Hart, H. K. Knab, C. O. Mohr, Kathryn M. Sommerman, and Elizabeth Maxwell. Miss Hart and Dr. Mohr, especially, have graced Natural History Survey publications with a multitude of remarkably fine total views of insects.

RESEARCH COLLECTIONS

The great value of research and reference collections to programs in natural history was stressed in the founding articles of the Illinois Natural History Society and has been evident ever since in all phases of applied ecology. The Natural History Survey has therefore stressed the assembling and maintenance of adequate research collections of animal groups as a corollary to its faunistic activities.

The general aims in augmenting the collections have varied over the years, but in recent decades have approached closely the policy expressed at the 1860 anniversary meeting of the Natural History Society and have emphasized first the species found in Illinois and then species or additional material from other regions which contribute to analyzing or interpreting the Illinois fauna.

Taxonomists in other institutions have aided the Illinois Natural History Survey greatly by identifying Survey material in their respective specialties. This aid has not only resulted in keeping the Survey collection up-to-date but has afforded needed reference material in many genera or families.

Vertebrates

During the early periods of Survey history, Forbes and his assistants built up and maintained a large collection of Illinois fishes, but kept only a small reference collection of other groups. Much of the fish collection is intact at present, but the older material of other vertebrate groups has become dissipated. In recent decades emphasis has been placed on building up collections of amphibians and reptiles, especially variational series from Illinois and surrounding states; on starting reference collections of birds and mammals; and, more recently, on assembling fish collections designed to be a basis for a re-study of Illinois fishes.

Invertebrates Other Than Insects

In early records of the Survey, there is no indication of the extent of invertebrate collections other than that given by incidental mention in a few small published papers. The largest of these collections comprised the molluscs; the aquatic species were obtained chiefly from river surveys and the extensive series of land species from the collecting of Frank C. Baker and Thural Dale Foster. Early collections of other groups were made, at least of phalangids, crustaceans, and certain protozoans, but only scattered vials or slides of these materials are extant at the present. Since 1930, special Illinois collecting has been initiated for a few groups, and in the pseudoscorpions and ticks excellent Illinois series have been assembled.

Insects

From the late 1870's to the present, the insect collections grew steadily. The first official collection was Walsh's private collection purchased by the State for Le Baron in 1870. Le Baron picked out duplicates for a reference collection in his office and then sent the main Walsh collection to the Chicago Academy of Sciences for safekeeping. There it was destroyed in the Chicago fire of 1871. Ironically, some of the material Le Baron selected from the Walsh collection may have persisted and be represented in the present Natural History Survey collection. Since the extant Le Baron specimens lack locality data, however, it is impossible to determine their original source. A collection of aphids made by Thomas was preserved, also.

The insect collection which Forbes began in the State Laboratory was quite small while he was at Normal. As soon as he became established in Urbana in 1885, he started to place great emphasis on building it up. About 5 years later Forbes (1890:3) gave the following account of the collection:

The entomological collection has been greatly enlarged, especially in Diptera, and a large number of determinations in all orders have been made. The named collection is now contained in 160 double boxes, and numbers about 5,000 species, each being represented, as a rule, by four selected specimens. The pinned and determined duplicate insects on hand—largely in process of distribution to public schools—amount to 42,600 specimens. The alcoholic insects, including large numbers of larvae, are contained in about 10,200 bottles and vials.

Although we have no later estimates of the size of this insect collection, it is obvious from material now in the collection that by 1910 Hart was keeping much larger series of each species.

In addition to material gathered by the staff, in the Natural History Survey collection are several collections of note that have been given to or acquired by the Survey. Notable items include the W. A. Nason collection (insects of Algonquin, Illinois), the C. W. Stromberg collection (insects of northwestern Illinois), the Andreas Bolter collection (all orders of insects), the Emil Beer Lepidoptera collection, the Charles Robertson collection (insects on flowers), the L. J. Milne caddisfly collection, the C. L. Metcalf flower fly collection, the W. P. Hayes weevil collection, the A. D. MacGillivray sawfly collection, the P. N. Musgrave water beetle collection, and the K. F. Auden beetle collection. Amateur entomologists, such as Murray O. Glenn of Henry and Alex K. Wyatt of Chicago, have made numerous valuable additions to the collection.

Because of special taxonomic interests on the part of staff members, the collection is unusually comprehensive in certain groups of insects. To this category belong the stoneflies, mayflies, and caddisflies; the aphids, mirids, and leafhoppers; the leaf beetles, rove beetles, and June beetles; the sawflies and bees; the thrips and psocids; the springtails; and a few groups of the true flies. In many orders the collection contains a great deal of material of the immature stages, which have been emphasized in our reports. The large collections of rove beetles, sawflies, and ectoparasitic groups are associated with plans for future projects.

Since 1925 primary types at the Natural History Survey have been segregated for reference and protection. In 1927 these represented about 1,000 species; the number now stands at about 2,500 species. At present the total insect collection contains roughly 2,000,000 specimens, including over 50,000 slide mounts, representing about 40,000 species and housed in 2,700 insect drawers and 100,000 vials.

FAUNISTIC REPORTS

The preparation and publication of reports on the animals of Illinois, a responsibility repeated several times in mandates to the Natural History Survey and its predecessors, was begun with the first publications of the Illinois Natural History Society and has been continued to the present. Many of the first reports were mere lists, often local in nature, and have needed revision or complete retreatment.

In addition to the chiefly systematic accounts outlined below, ecological and economic studies over the years have contained a wealth of records and descriptions of a large number of species. This is true especially of surveys of the sand areas, prairie and forest areas, and extensive bottom fauna and shore studies of the large rivers.

Vertebrates

Faunistic reports have been published on all the vertebrate groups occurring in Illinois. Certain of the older reports are now out-of-date because of our greatly increased knowledge of the fauna.

Fishes.—The work on Illinois fishes may truly be considered the first sustained faunistic project carried on by personnel of the Natural History Survey or its parent organizations. The project was begun with Forbes' first connection with the Illinois Natural History Society and continued as a cohesive systematic study until 1909.

At the time of birth of the Illinois Natural History Society, approximately three-quarters of the Illinois fishes had been described and named by such distinguished early ichthyologists as Rafinesque, Le Sueur, Girard, Agassiz, Mitchell, and Kirtland. Half a dozen of these species were first discovered in Illinois waters. During the next three or four decades,

when Illinois waters were being studied intensively by Forbes and his colleagues, most of the remaining Illinois fishes were described by such famous zoologists as Jordan, Cope, Gilbert, Nelson, and Forbes himself.

A regional list treating the fishes of the Chicago area was prepared by Robert Kennicott (1855), and comprehensive catalogs of the fishes of the entire state appeared in the first volume of the *Bulletin* (Nelson 1876; Jordan 1878). Several years later Forbes (1884) prepared a third catalog of Illinois fishes, and early in the present century Thomas Large (1903) published a fourth list.

Some time in the 1870's Forbes seems to have developed the idea of producing a well-illustrated and detailed account of the Illinois fishes which would be useful for all the Mississippi River states. Year after year, wagon parties were sent to explore and collect in different streams of the state until finally records were available for virtually every river and rill in Illinois. Along the Illinois River large collections were made year after year. Some extensive collecting parties visited localities in neighboring states. The amount of human endeavor that went into this project is monumental and represents the steadfast patience and toil of 30 years. The final report, *The Fishes of Illinois* and its *Atlas*, by Forbes & Richardson (1908), summarized all this information and featured a remarkable set of color plates prepared by Lydia Hart.

Since the appearance of the Forbes & Richardson report, two other contributions have been made by the Natural History Survey to Illinois fish taxonomy. D. H. Thompson & F. D. Hunt (1930) published a report on the fishes of Champaign County, and D. J. O'Donnell (1935) published an annotated list of Illinois fishes.

Birds.—Before 1858 there was an abundance of illustrative and synoptic references to North American birds by Wilson, Nuttall, Audubon, and others, and there were local lists of Illinois birds by Robert Kennicott (1855) and H. Pratten (1855). Later, R. H. Holder (1861*a*) published a list of Illinois birds and a short taxidermy manual in the *Transactions* of the Illinois Natural History Society. In 1881 Robert Ridgway published a revised catalog and, a few years later, two large reports, the two volumes of *The Ornithology of Illinois* (Ridgway 1881, 1889, 1895). The first volume was destroyed by fire in the state printer's office and had to be completely reprinted before it was issued. These two volumes were among the pioneers in the use of structural characters in keying the birds of an area. Ridgway, a native of Illinois, was not an employee of the state but wrote these volumes because of his intense interest in Illinois birds.

In later years Forbes, A. O. Gross, and Frank Smith made many observations on Illinois birds, but these studies were primarily of an ecological nature.

Amphibians and Reptiles.—Survey studies concerned with these animals did not start until the 1880's. In the first volume of the *Bulletin,* N. S. Davis, Jr., & F. L. Rice (1883) published a catalog of amphibians and reptiles found east of the Mississippi River. H. Garman (1890) also studied these groups. No synoptic collections were kept of the early material. In the 1930's Francis Lueth and Willard Stanley accumulated records and assembled several hundred specimens. In the early 1940's the Natural History Survey focused attention on these groups through the co-operation of H. K. Gloyd of the Chicago Academy of Sciences, C. H. Pope of the Chicago Natural History Museum, and H. M. Smith of the University of Illinois. In 1947 P. W. Smith initiated an intensive study of these animals, making collections in all parts of the state and plotting the variation and distribution of each species. In 1957 this project culminated in a comprehensive report on the amphibians and reptiles of Illinois; the report is now awaiting publication.

Mammals.—The Natural History Survey and its parent agencies have published only a small number of reports on Illinois mammals. The first, by Cyrus Thomas (1861*b*), was published by the Natural History Society. Early in the present century, F. E. Wood (1910*a*) published on the mammals of Champaign County. In the 1930's C. O. Mohr became interested in the mammal fauna of Illinois and gathered a great deal of in-

formation on distribution and habits. After Mohr left the Natural History Survey in 1947, the work on mammals was taken up by D. F. Hoffmeister of the University of Illinois, and the resulting fieldbook appeared shortly after Mohr had rejoined the Survey staff (Hoffmeister & Mohr 1957).

Invertebrates Other Than Insects

Most of the invertebrate studies made during the early history of the Survey concerned chiefly aquatic organisms which were important in limnological investigations. The first paper by Forbes (1876) in the *Bulletin* was a list of the Illinois Crustacea; this was followed by a paper on Crustacea by L. M. Underwood (1886). A. Hempel (1896, 1899) described a few rotifers and protozoans from the Illinois River, and C. A. Kofoid (1898, 1899) described a few plankton organisms of Illinois. R. W. Sharpe (1897), F. W. Schacht (1897, 1898), and Ernest Forbes (1897) made additional contributions to a knowledge of the Crustacea. C. M. Weed (1890) did considerable work on the phalangids of Illinois and published a partial catalog of the group.

Several other invertebrate studies published in the *Bulletin* were almost entirely the work of nonstaff members, some of whom worked actively in co-operation with the Survey. J. P. Moore (1901) treated the Illinois leeches; Frank Smith (1895–1928) published many papers on earthworms; H. J. Van Cleave (1919) studied Illinois River Acanthocephala; Henry E. Ewing (1909) studied the orobatid mites; and F. C. Baker (1906) published a catalog of the Illinois Mollusca.

Ecological work on the rivers amassed collections of the various plankton groups, but only those portions noted above were ever analyzed taxonomically. Much of the material was discarded after being recorded, and much was lost by desiccation. Except for the collections of Mollusca, by 1947 only a small amount of the early invertebrate collections remained.

About 1930 a survey of the land snails of Illinois was organized under the leadership of F. C. Baker. The field work was done primarily by T. D. Foster. Foster used a motorcycle on collecting trips and shared with S. C. Chandler the distinction of being one of the few members of the Survey's motorcycle brigade. For 2 years he conducted a whirlwind search over the entire state for land snails and brought together a remarkable number of records. The material was identified by Baker, who prepared a report that appeared as a fieldbook of the Illinois land snails (Baker 1939). The book was beautifully illustrated by C. O. Mohr.

Berlese collecting, instituted about 1933 primarily for exploring the insects in duff, netted not only insects but large numbers of terrestrial invertebrates, mainly arachnoids. About 1940 C. C. Hoff of the University of New Mexico became interested in co-operating in a study of pseudoscorpions of Illinois. He found that many species collected in these Berlese samples were new and represented a Midwestern faunal element which had remained unseen because other pseudoscorpion specialists lived in either the East or the West. Hoff's report on the Illinois fauna was published by the Natural History Survey (Hoff 1949).

Insects

Considering not only the economic importance of insects but also the exceedingly large number of species expected in the state (approximately 20,000), it is not surprising that the Natural History Survey's most extensive faunistic contributions have been made in this group. Many of the studies have resulted in descriptions of new species, life history notes, and distribution records contained in short papers; many others have resulted in comprehensive accounts of various groups found in Illinois.

Orthoptera.—Thomas was early a keen student of the Orthoptera and in the first of the *Transactions* of the Natural History Society published a list of this order for Illinois (Thomas 1859*b*). His interest continued and he published a second, enlarged list in the first volume of the *Bulletin* (Thomas 1876). In the early 1900's, Hart and A. G. Vestal made large and extremely interesting collections of this order in the Illinois sand areas, in which an appreciable number of western

species occur. In 1932 Morgan Hebard of the Academy of Natural Sciences of Philadelphia offered to prepare an account of the Dermaptera and Orthoptera of Illinois. For this project staff members made additional collections in areas of the state not previously covered for the group. The report appeared 2 years later (Hebard 1934).

Aphids.—This group was one of the first emphasized in studies by the Natural History Survey's parent organizations. Thomas, one of the leading early investigators in the taxonomy of this group, published a synopsis of one of the tribes and described many new forms from Illinois (Thomas 1878). About the same time Nettie Middleton (1878) described another species, and several years later C. M. Weed (1891) published the results of his studies on the life histories of a number of species. Little more was done with this group until J. J. Davis started further taxonomic investigation of the aphids about 1908. In the *Bulletin,* Davis (1913) published a commentary on the Cyrus Thomas collection and in addition 20 papers on aphid taxonomy in various entomological journals. Most of this work he did while an assistant in the State Entomologist's Office.

In 1928 Frison and F. C. Hottes, the latter now at Grand Junction, Colorado, took up a study of Illinois aphids. This was the first study to be based on a combination of intensive collecting for one group and opportunities for rapid travel to all parts of the state. Field investigations were made during the summers of 1928–1930. Each year collecting parties started in the southern part of Illinois and worked north and then reversed the pattern so that each locality was collected at different seasons. A complete set of slide mounting equipment was taken into the field, and temporary headquarters were

An Illinois Natural History Survey entomologist making field notes relating to insects he has collected. The association of insects with their host plants is an important phase of the work of Survey entomologists.

set up in hotels at various towns. Each party consisted of three persons. Usually all three collected during the first half-day spent in each locality; after that one person stayed in the headquarters hotel and mounted aphids while the other two continued collecting. Lists of potential hosts, with especially interesting ones indicated, were used as a tick sheet in each locality. About a hundred species, 36 of them new to science, were added to the state list. The report on this project was published in the *Bulletin* (Hottes & Frison 1931).

Odonata.—Nymphs of this order were frequently encountered in limnological work, and H. Garman and Hart reared many of them during the 1880's and 1890's. This work set the stage for the first report on Illinois dragonflies, an article by J. G. Needham & Hart (1903). Later Philip Garman did much work on the group and wrote an excellent account of the damselfly suborder Zygoptera in Illinois (P. Garman 1917).

Pentatomoidea.—This group includes the stink bugs, a group of sucking insects for which Hart had a special interest. He assembled a remarkably fine collection of the Illinois species and had virtually completed an account of the state fauna at the time of his death. The manuscript was completed by J. R. Malloch and was published in the *Bulletin* (Hart 1919). This report was especially useful because it included not only keys to the Illinois species but also keys to the Nearctic genera.

Diptera.—The first serious work on the flies done for the Natural History Survey or a parent organization was by J. R. Malloch. Although interested in Diptera in general, Malloch specialized in the Chironomidae or midges, of great importance in the economy of Illinois waters. He reared a large number of these insects and was one of the first workers to delve into the minute characters of the male genitalia and the larval mouthparts as an aid in species discrimination and identification. His rearings were done chiefly in the vicinity of Havana and Urbana, with a great deal of help from Hart, who also collected adult material from various parts of Illinois and surrounding states. The report by Malloch (1915) on the midges was outstanding among faunistic works. Not only did it give equal emphasis to the adults and larvae, a most unusual feature for the time, but it benefited from two remarkable faculties of Malloch's. One was Malloch's ability to spot new characters (dipterists agree that Malloch was a genius at this not only in the midges but in every group in which he worked). The other was his ability to prepare unusually clear keys, which made his publications quite out of the ordinary in their usefulness to other workers.

The breadth of Malloch's interest in Diptera was expressed when he published in the *Bulletin* a classification of the order based primarily on larval and pupal characters (Malloch 1917). This study was one of the first in which recognition was given to the value of characters of the immature stages in determining the relationships of families within a large insect order. Certainly it is a classic and contains cogent ideas of fly classification which even at this date have not been fully incorporated into accepted classifications of the order.

The next intensive Natural History Survey work on Diptera was a study commenced by H. H. Ross about 1938 on the Illinois mosquitoes. Because of restrictions on travel and lack of availability of personnel during World War II, field work and rearing progressed at a relatively slow rate. The report on these insects was published in the *Bulletin* (Ross 1947).

Plecoptera.—Although the Plecoptera or stoneflies are an abundant component of many aquatic communities, no state-wide taxonomic work on the Illinois species was done until Frison became interested in them in 1927. Previously Walsh (1863, 1864*a*) had observed and recorded many of the species occurring in the vicinity of Rock Island. Frison and another entomologist, R. D. Glasgow, loved to hike and picnic, especially in the hilly country along the Salt Fork River south of Oakwood, Illinois. On fall excursions to this locality they noticed that, in some of the very small streams, the smallest of the stonefly nymphs kept increasing in size as winter approached. This observation excited Frison's curiosity and from it arose an abiding interest

in and love of stoneflies which continued through the rest of his life. Frison followed the development of these little stoneflies, which proved to be the small group called winter stoneflies. He discovered that little was known concerning the fauna of the Midwest and began a study of the group for Illinois. The first report on stoneflies treated a few small families comprising the winter stoneflies (Frison 1929).

The collecting and rearing of species of the other families in the order were begun. Rearing these insects proved to be difficult because the laboratory water available at Urbana did not sustain the stoneflies. Copper cages on a raft placed in a stream were eventually devised to overcome this difficulty, but the losses of these expensive cages by vandalism finally proved so great that the practice was discontinued. A considerable number of species were reared from emerging nymphs caught at the water's edge. By one means or another, all the Illinois species were finally reared. Six years after publication of the winter stonefly report, a report covering all the Illinois Plecoptera appeared (Frison 1935).

Frison found sets of nymphal characters which appeared to have great promise for indicating natural groupings of the species and genera, indications such as Malloch had previously found when exploring characters of the larvae and pupae of Diptera. The studies of stonefly nymphs set the stage for what might be called the modern classification of the order and stimulated emphasis on the study of immature stages in subsequent Survey projects on several other orders of insects.

These insects proved so fascinating that Frison's studies did not long stop at the boundaries of Illinois. Through material obtained on vacation trips and at other opportunities, the stonefly collection was enlarged to cover all of North America. With large series available from diverse areas of the continent, it became apparent that many of the old species were in reality species complexes, and as a result many of the Illinois populations had to be described as new. The results of these latter developments in the stoneflies were published in the *Bulletin* (Frison 1937, 1942*a*) and as shorter papers in various entomological journals.

Megaloptera.—These, the alderflies and dobsonflies, were collected during the aquatic work on stoneflies and caddisflies; some specimens were received from fishermen who had encountered them along streams and had sent them in for identification. Attempts to identify these Megaloptera by means of then current literature proved unsatisfactory. In the alderfly genus *Sialis,* characters noticed in the male genitalia seemed to provide an excellent means for positive determination of the species and an analysis of these characters led to a re-evaluation of the species in the genus, many of which proved to be new. About half a dozen species were found in the material from Illinois and surrounding states. As part of an effort to learn something of the entire distribution pattern of the Illinois species, the study was extended to cover the fauna of the whole continent. The report on this study was published in the Natural History Survey *Bulletin* (Ross 1937).

Miridae.—As the aphid project was coming to a close, H. H. Knight of Iowa State College agreed to work summers with the Illinois Natural History Survey and prepare a report on the Miridae or plant bugs of Illinois. Knight was on the Survey payroll for three summers. Previously Hart had assembled and identified an excellent collection of this group for the state, but since Hart's time Knight had shown that characters of the genitalia indicated a much larger fauna than earlier workers had suspected on the basis of the external characters they used.

The mirid field trip pattern followed that of the aphids, with the trips around the state scattered through the different seasons. Again host collecting was emphasized, and field headquarters were set up locally in hotels. The general plan was to collect until about 3 o'clock in the afternoon, and then pin up the day's catch. With the Miridae, this was thought desirable because of the fragile nature of certain diagnostic characters, especially pubescence, which might be brushed off if the specimens were relaxed and pinned later. Many thousands of specimens were collected each year, and

again a large number of species, including about 20 new ones, were added to the state list. Members of the staff served as "guinea pigs" to try out the keys, to point out spots difficult for the uninitiated, and to suggest improvements. Mohr did his usual excellent job in providing many total views of various species. The report resulting from this project was published in the *Bulletin* (Knight 1941).

Ephemeroptera.—The mayflies were early recognized as being one of the most important components of the fresh-water biota of Illinois, but, except for early local studies by Walsh (1863, 1864*b*), little was done concerning their systematics in this state until about 1925. At that time collections were sent to J. W. McDunnough at Ottawa, Canada, who identified a considerable amount of material. Collecting and rearing of species in the order were only sporadic until about 1937, when B. D. Burks, assigned to the project, began an intensive field program.

Certain genera of the mayflies proved difficult to rear because the subimagoes seldom survived in cages, and in some species the nymphs did not molt to the subimaginal stage in still water. For these genera Burks worked out a neat contrivance. He placed fully mature nymphs (which emerge at night) in a pan of water containing a large stone, placed the pan on the floor of a car at nightfall, and had the car driven over a gravel road. The wave action produced in the pan by the rough ride broke the surface film enough so that the nymphs could emerge. As the driver guided the car along the road, Burks sat in the back seat and periodically examined the pan with a flashlight; he captured each subimago as it emerged, put it in a vial for emergence to imago, and associated the cast skin with it.

The extremely short period of adult emergence of many species frequently necessitated camping out along a stream and keeping an around-the-clock vigil for emergence. During one summer a rearing station was established at a fish hatchery along Nippersink Creek, in the extreme northeastern part of the state, which is especially rich in mayfly species. A flash flood inundated the rearing rooms and nearly swept away the summer's material. The material was rescued as the vials were beginning to float out of the window in the shoulder-deep water.

At first, Burks had difficulty obtaining good series of imagoes, although the subimagoes could be collected in quantity at lights. Burks found that he could catch great quantities of these subimagoes in paper bags, turn them loose in his hotel room, and have them emerge in fine shape, so that any desired number of imagoes could be secured.

When Burks left the Natural History Survey in 1949, he had completed the mayfly report, which was published in the *Bulletin* (Burks 1953).

Cicadellidae.—About 70 years ago, C. W. Woodworth (1887) published a short treatment of this family, comprising the leafhoppers, and later Hart and Malloch made extensive collections of these insects, some of which were identified and recorded by W. L. McAtee of the United States Biological Survey (McAtee 1924, 1926). Malloch himself (1921) wrote a short paper on the group.

In 1934 D. M. DeLong of Ohio State University agreed to tackle the job of working up a more extensive treatment of the leafhoppers of Illinois. A few years prior to 1934, DeLong had begun an investigation of the male genitalia in the leafhoppers and found that, as in a number of other groups, many of the species previously identified on the basis of external characters were in reality clusters of species which could be separated primarily on the basis of genitalic structures. Both in North America and elsewhere the discovery of these characters had set off a tremendous burst of activity by leafhopper workers to explore these structures. It was in the midst of this burst of effort that the Illinois project was launched. DeLong and other staff members spent almost all of the next three summers crisscrossing Illinois and collecting leafhoppers in the various habitats of the state. During rainy weeks and also during the winter back in Columbus, Ohio, DeLong identified these collections and continued his revisional studies. Various members of the staff made special collections as indicated by new taxonomic discoveries.

By 1945 it was apparent that a report embracing all the leafhoppers under one cover was impractical, and DeLong prepared the manuscript for about half of the fauna, which included all the subfamilies except the Cicadellinae. This report was published in the *Bulletin* (DeLong 1948).

At this time, R. H. Beamer of the University of Kansas had drawn attention to the tremendous number of Midwestern species contained in the genus *Erythroneura,* the largest genus of the untreated subfamily Cicadellinae. Mrs. D. J. Knull had identified a large part of the Natural History Survey material in this genus. Most of the several hundred species were known only from hibernation collections, and it was felt that, before proceeding with the manuscript on this subfamily, the host relationships and other ecological information should be ascertained for these species. As a result the project was realigned and a new host-collecting program for the entire subfamily was delegated to the faunistic staff of the Survey. The large number of host associations already established have proved of interest in contributing ideas concerning evolutionary problems in insects having moderately rigid host associations.

Trichoptera.—A study of the caddisflies was prompted by the importance of this group in the economy of Illinois freshwater habitats. The project was planned originally as a joint one with Dean Cornelius Betten of Cornell University, who had in manuscript at the time the first comprehensive and useful New World faunistic study of the group; his study dealt with the fauna of New York. Betten in America and A. B. Martinov in Russia had pioneered in the technique of clearing the male genitalia of Trichoptera in KOH in order to get a more exact knowledge of these diagnostic structures. Betten spent 6 weeks on the Illinois Natural History Survey staff in the summer of 1931, his time being spent partly on collecting trips around the state and partly in identifying the caddisfly material in the Survey collection. In 1932 press of other duties caused Dean Betten to retire from the project, which was then assigned to Ross.

Much of the caddisfly collecting was done as an adjunct to stonefly, mayfly, mirid, and leafhopper collecting, but special trips were made to springs and certain rivers, such as the Kankakee, which supported unusual species. As the taxonomic analysis of the material progressed, it became evident that the Illinois fauna differed in remarkable fashion from that of the only other state for which it was well known, New York. As a result, it was necessary to practically revise the entire North American fauna before the Illinois groups could be satisfactorily segregated to species. This was true especially in the family Hydropsychidae and the so-called microcaddisflies, the Hydroptilidae. As with the other aquatic groups, an effort was made to rear the species and associate larvae and pupae. Some of this work was done with rearing cages, but the greater part was accomplished by associating mature pupae with their corresponding larval parts in the cocoon or case. The report of the Illinois fauna of this order, including keys to the adults and immature stages, was published by the Natural History Survey (Ross 1944).

After this report appeared, some activity relating to the Trichoptera was continued, primarily centered around attempts to reconstruct the origin of groups and the dispersal patterns which led to the formation of the present Illinois fauna. As genera and families from other parts of the world were studied, it was possible to get a better understanding of the classification and evolution of the order. It is reminiscent of Malloch's and Frison's work in the Diptera and Plecoptera that the immature stages were found to hold the principal key to deducing the evolution of the group. These studies made possible the publication of the book *Evolution and Classification of the Mountain Caddisflies* (Ross 1956).

Coleoptera. — The beetles have frequently been the subject of intensive study by the Natural History Survey staff. Early in the history of the organization, extensive rearing was done, and volumes of important information on this work are scattered through the State Entomologist's reports. The first extensive Illinois publication on the order was by Le Baron (1874) who, in his fourth report as

State Entomologist, published an outline of the Coleoptera of Illinois, with keys to genera and notes on many species.

The next serious study of the order concerned the genus *Phyllophaga*, the June beetles. The larvae of these beetles were extremely serious pests, and before 1890 Forbes and his assistants set about making systematic collections of the genus throughout the state. Forbes (1891) published a survey of the Illinois June beetles; the publication included keys to the species written by Hart. R. D. Glasgow (1916) reviewed this material and published a synopsis of the synonymy and the description of a new species. Shortly after, J. J. Davis made a detailed study of the ecology of *Phyllophaga* and also became interested in their taxonomy. The study resulted in one fine paper on the natural enemies of June beetles and in another describing new forms. These two papers appeared in the *Bulletin* (Davis 1919, 1920). Glasgow continued his interest in the genus, but subsequently published only one or two small papers on the subject.

In 1944 another beetle project was inaugurated, this one on the leaf-feeding beetles, or Chrysomelidae, with M. W. Sanderson as the investigator. The beginning of the leaf beetle investigation was based on a need for supplying correct names for various species of economic importance to Illinois crops. Early attempts at identification disclosed that much of the older literature on the family was unreliable, and diagnosis of species often was uncertain. Not only were there deficiencies in the literature; few attempts had been made in North America to relate larval and adult morphology for generic or species diagnosis. The project for Illinois was organized along the lines of earlier faunistic studies. Collections were made throughout the state, with special emphasis on securing host-adult-larval associations. At present a report embracing two-thirds of the subfamilies and including about a half of the Illinois species is nearing completion, and a large proportion of the field work for other subfamilies is in an advanced stage.

Thysanoptera. — Survey activity relating to this order of little insects, the thrips, had its beginning about 50 years ago; J. D. Hood (1908) published a paper describing a group of species from Illinois. Late in the 1930's, when Berlese sampling was started in the Survey, interest in this group was again aroused because of the large number of specimens and variety of species which appeared in the collections from moss and leaf mold.

In 1947 L. J. Stannard planned a comprehensive faunistic study of the order for Illinois. Many difficulties were encountered, including the inaccessibility of critical types, difficulties in finding satisfactory mounting media, and difficulties in interpreting existing keys and descriptions. The genera were especially poorly defined and inconsistently used, and before satisfactory names could be established for the Illinois species it was necessary to embark on major studies in the general classification of the group. The results of one of these studies, investigating the generic categories in the suborder Tubulifera, were published by the University of Illinois (Stannard 1957). As a consequence of all these factors the Illinois study of this group has come close to a treatment of the thrips for half the continent. Intensive collecting in all conceivable situations and at different seasons has brought to light large numbers of new state records. A report on these insects for Illinois is in an advanced state of preparation.

Lepidoptera.—As mentioned earlier, in his first report Le Baron (1871) described a new species of moth. Since that time a great deal has been written, especially in the State Entomologist's reports, on the moths of Illinois. Most of this material, however, is in the form of small contributions on the descriptions of species, their larvae, or their habits. However, Thomas (1881), with the assistance of Nettie Middleton and John Marten, published a synopsis of lepidopterous larvae for Illinois. This report included a similar synopsis by D. W. Coquillett (1881). Later, Forbes and his assistants prepared keys to certain economic species, and W. P. Flint & Malloch (1920) published in the Natural History Survey *Bulletin* a paper on the European corn borer and related species.

In 1955 R. B. Selander began a faunistic project designed to cover many of

the families of small moths or microlepidoptera, which were poorly known in Illinois. The Blastobasidae were chosen as the first family for study because the genitalic structures of the Nearctic species had never been investigated. Selander, now with the University of Illinois, assembled large quantities of Illinois material and unearthed a diagnostic set of characters in the genitalia. Work on this project is continuing.

Hymenoptera.—Aside from rearing and describing a few parasites and sawflies, the Natural History Survey staff has done only one serious piece of work on the Illinois Hymenoptera fauna. This was a study by Malloch (1918) on the genus *Tiphia*.

Collembola.—Although among the most abundant insects numerically, the Collembola or springtails were not stressed until 1928, when large collections were made in various parts of the state and sent to J. W. Folsom, U. S. Department of Agriculture, for identification. When Folsom died, the project reverted to simply a collecting program. Subsequently, Berlese sampling added large quantities of these insects to our series. The project was revitalized when H. B. Mills joined the Natural History Survey in 1947; since that time steady progress has been made on a study of this group for Illinois.

RETROSPECT AND PROSPECT

In following the objectives set forth in the original organization of the Illinois Natural History Survey, the faunistic program performs three principal functions pertaining to the animals of Illinois —assembling and maintaining research and reference collections, preparing reports on the various animal groups, and identifying economic species. At times the program has emphasized one function more than another, but over the years steady progress has been made in all three departments.

Today the taxonomic methods by which these functions are achieved are far more complex and time-consuming than they were when the program was started. If transplanted to today, the faunistic worker of 1858 would doubtless be astonished at changes in the species concept, in taxonomic techniques, in microscopic and other equipment, and at the great increase in recognized invertebrate species and genera.

As these complications have developed, it has become clear that there is no easy short cut in making an adequate survey of an animal group for Illinois. Each report represents a great deal of collecting and study over a period of years.

Members of other sections of the Natural History Survey have aided the faunistic program immeasurably by rearing and collecting material, identifying host or indicator plants, editing reports, and assisting with library problems. Taxonomists in other institutions have been of great aid not only by publishing papers of inestimable use in studies of Illinois species, but also by assisting in many other ways with specific problems.

It is a tribute to the founding fathers of the Illinois Natural History Society that certain of their general principles were and still are remarkably good guides for a faunistic program. The importance of combining systematics and ecology and of having a broad geographic scope for reference collections becomes more apparent as new discoveries help unravel the complex faunal relationships of Illinois species.

Applied Botany and Plant Pathology

J. CEDRIC CARTER

WHEN the Illinois Natural History Society was organized in 1858 to promote the advancement of science in the state, botany was a major field of interest of several of its founders.

The earliest reported botanical research in Illinois was the study of flora in southern Illinois by André Michaux (Sargent 1889), a distinguished botanist of France. In 1795 Michaux traveled from the Ohio River up the Wabash River to Vincennes, Indiana. He crossed Illinois to Kaskaskia, August 23–30, to Prairie du Rocher, September 5–6, and returned to Kaskaskia, September 8–9. On October 2, he started toward the Ohio River and arrived at Fort Massac on October 8. Later he returned to Kaskaskia, Fort Chartres, and Prairie du Rocher and started on his return from southern Illinois on December 14.

Following Michaux and during the first half of the nineteenth century, many physicians and amateur botanists studied and reported on the flora of Illinois. Dr. Lewis C. Beck (1826*a*, 1826*b*, 1828), in publishing his contributions to the botany of both Illinois and Missouri, listed 65 plants in the prairies near St. Louis and 14 in barrens. Also, he reported on his studies of plants along the Illinois River bluffs near St. Louis. A catalog of plants collected in Illinois by Charles A. Geyer was published with critical remarks by Dr. George Engelmann (1843) of St. Louis, Missouri. Dr. C. W. Short (1845) of Louisville, Kentucky, reported on his observations and collections of the flora of prairies of Illinois as a result of his extensive travels in several sections of the state. Dr. S. B. Mead (1846) prepared a catalog of plants growing in Illinois, most of them growing near Augusta in Hancock County; this work was published in the *Prairie Farmer*. Dr. Mead mentioned the habitats of the plants he included in his catalog. Also, he listed the uses of the plants, including those used by dyers and coopers, those used for hedges, chair bottoms, hay, ornamentals, edible fruits, common tea, and medicine, those known to be poisonous, and those known to be troublesome weeds. The year before the Illinois Natural History Society was founded, I. A. Lapham (1857*a*) published a catalog of the plants of Illinois; his catalog included lists contributed by Mead and Engelmann. In preparing the catalog, Lapham examined the extensive collections of plants made by Robert Kennicott, Emile Claussen, and others.

Mead's list, as mentioned above, comprised plants principally in the vicinity of Augusta in Hancock County. Engelmann's list comprised plants in southern Illinois, especially in the vicinity across the Mississippi River from St. Louis, Missouri. Dr. Mead, Lapham (1857*a*:494) wrote, "has probably devoted more time and labor to the examination of Illinois plants than any other botanist, and his collections now form part of most of the principal herbaria of the world."

Lapham emphasized that catalogs of plants were useful to farmers, physicians, horticulturists, botanists, cabinet makers, wheelwrights, and other workers in wood because these catalogs listed plants of interest to each group; his catalog listed 1,104 species representing 111 orders of plants. From a geographical point of view, Lapham divided Illinois into three districts: (1) the heavily timbered tracts, mainly in the southern portion of the state, and the "groves" or detached bodies of timber surrounded by prairies, in the middle and northern portions of the state; (2) the open prairie tracts of 1 to 20 miles in diameter and destitute of trees; (3) the tracts of "barrens," intermediate between the prairie tracts and the timbered tracts. The barrens appeared to be in transition from open prairies to densely timbered tracts. They were sparsely covered with several species of oak trees and with dense undergrowth of shrubs and annuals.

Treatises on plant material, published in the Illinois State Agricultural Society

Transactions for 1856–1857, indicated the rapidly increasing interest in applied botany. These treatises, presented by O. Ordway (1857) of Lawn Ridge, H. L. Brush (1857) of Ottawa, Samuel Edwards (1857) of La Moille, J. P. Eames (1857), Dr. Frederick Brendel (1857) of Peoria, and I. A. Lapham (1857*b*) of Milwaukee, Wisconsin, dealt with several phases of research, including culture and cultivation. The types of plants studied were evergreens, flowers, grasses, grain fruits, and vines.

At La Moille, Edwards started planting evergreens in 1845 and, by 1857, had planted more than 125,000 plants obtained from forests of Minnesota, Wisconsin, Michigan, Indiana, Ohio, New York, and upper Canada and also some obtained from eastern and European nurseries—in all, more than 25 species of evergreen plants. He was most favorably impressed with the growth of Norway and black spruces, Austrian, Scotch, and white pines, and balsam fir. Siberian and American arbor vitaes and red cedar, he found, were excellent for screening. Other species he mentioned that succeeded well in this climate and soil were Irish, Swedish, and savin junipers, red spruce, and a variety of pine from Tennessee. Hemlock was subject to winter injury; Douglas spruce, cedar of Lebanon, deodar cedar, silver fir, English and Irish yews, Himalayan and Araucarian pines, and Chinese arbor vitae did not survive the winters. In 1857 Dr. Cyrus Thomas, with the help of S. Burtley, started studying the flora of the Murphysboro region of southern Illinois (Thomas 1857).

EARLY ACTIVITIES

Among the persons interested in botany who were active in organizing the Illinois Natural History Society were M. S. Bebb, Dr. Frederick Brendel, E. Hall, Robert Kennicott, Dr. S. B. Mead, Dr. Cyrus Thomas, and Dr. George Vasey. Much of the information obtained by them on the flora of Illinois was published in the Illinois Natural History Society *Transactions*. When the original purpose in organizing the Natural History Society was set forth as the advancement of science, botany was mentioned along with entomology and geology. In succeeding years special interests developed in the field of botany, as indicated by the published works of Brendel, Bebb, Vasey, Thomas, Edwards, G. W. Minier, Henry W. Bannister, and H. H. Babcock from 1859 to 1887, most or all of whom were members of the Natural History Society. Brendel was a prolific worker and was the author of numerous articles published over a period of nearly 30 years (Brendel 1859*a*, 1859*b*, 1859*c*, 1859*d*, 1860, 1861, 1870, 1876, 1887). These articles included information on the flora of Peoria and other areas of the state. Brendel was interested in shrubs and forest trees, especially the oaks. Also, he wrote on rare plants in the state and on a peculiar growth of the water lily. It is significant that an article by him, "The Tree in Winter," was one of the first articles published in the *Bulletin* of the Illinois State Museum of Natural History.

Bebb (1859) published a list of 44 species of plants occurring in the northern counties of the state; his list was an addition to the catalog by Lapham (1857*a*). Vasey's interest in different phases of botany is indicated by his papers (Vasey 1859, 1861, 1870*a*, 1870*b*). Among these papers were studies on flora, including mosses of the state and maritime plants of the Great Lakes and interior regions; also, descriptions of two plants new to Illinois.

When Thomas (1861*c*) proposed a plan for a natural history survey of Illinois, he suggested that this survey include a systematic cataloging of the flora and fauna of the state and that the data be published so that the same work would not need to be repeated by others. Bannister (1868) described prairie and forest plants of Cook County, and Babcock (1872) described the flora of the Chicago area. John Wolf and Elihu Hall prepared a list of mosses, liverworts, and lichens of the state. This list, which was published in the *Bulletin* of the Illinois State Laboratory of Natural History, contained 115 genera and 386 species (Wolf & Hall 1878). Wolf was on the staff of the State Laboratory of Natural History in 1880.

By 1865 concern was voiced that trees of the state were being used so rapidly for lumber that cultivation and planting of trees should be promoted. Minier (1865, 1868) published two articles on the cultivation of forest trees. In his second article Minier (1868:279) stated: "Tree planting in Illinois is no longer for ornament merely. It has become a necessity. . . . If, then, the *coming* generations are to be supplied with timber, the *present* must plant it for them." Edwards (1868) recommended planting trees but pointed out that black locust trees that had been planted 25 years earlier had been seriously damaged by borers.

Specific interest in some specialized groups of plant life in Illinois became evident shortly after 1870, as indicated by the works of Thomas J. Burrill on plant diseases caused by fungi and bacteria. Burrill, on the staff of the Illinois Industrial University, the University of Illinois, and the Illinois State Laboratory of Natural History, was a close associate of Stephen A. Forbes for 27 years. He reported on fungus diseases in the 1870's, especially on fungi which cause diseases of vegetable and fruit crops (Burrill 1874, 1876, 1877). Later he reported that the widespread blight of pear trees was caused by a bacterium (Burrill 1881). This, the first report that bacteria cause plant diseases, opened up a new field of research. Burrill continued to publish articles on fungi and bacteria that cause plant diseases and in 1885 he published a 115-page article, in the *Bulletin* of the Illinois State Laboratory of Natural History, on the parasitic fungi of Illinois (Burrill 1885).

Following 1885 botanical research expanded in scope to include all types of native and naturalized plants in the state. The work of Burrill while on the staff of the Illinois State Laboratory of Natural History from 1885 to 1892 indicates the expanding development of botanical interest in forest trees and diseases of crop plants. Burrill prepared papers not only on fungal and bacterial diseases of crop plants but also on forest, roadside, and street trees, biology of silage, and extermination of the Canada thistle (Burrill 1886, 1887*b*, 1887*c*, 1888, 1889*a*, 1889*b*, 1890). Among others employed as botanists on the staff of the State Laboratory of Natural History were Rachel M. Fell, Arthur B. Seymour, Benjamin M. Duggar, and Arthur G. Vestal.

A well-illustrated, 142-page article on edible and poisonous mushrooms in Illinois, prepared by Walter B. McDougall (1917), was published in the *Bulletin* of the Illinois State Laboratory of Natural History. This article contains many plates illustrating the mushrooms described and is exceedingly useful in differentiating between poisonous and edible mushrooms.

Studies on plankton were carried on by C. A. Kofoid from 1895 to 1900 and by Samuel Eddy from 1925 to 1929. Kofoid's extensive work on the plankton of the Illinois River was published in the *Bulletin* of the Illinois State Laboratory of Natural History (Kofoid 1903, 1908). Eddy's work dealt with plankton of Lake Michigan, the Sangamon River, and some sinkhole ponds in southern Illinois; this work was reported in the *Bulletin* of the Illinois Natural History Survey (Eddy 1927, 1931, 1932).

Interest in the ecology of vegetation and plant associations of sand prairies in Illinois is indicated by the papers of C. A. Hart and H. A. Gleason (Hart & Gleason 1907; Gleason 1910), F. C. Gates (1912), and Vestal (1913) published in the *Bulletin*. Information was obtained not only on the general plant associations but also on the physical environment, the blow-out formations, the blow-sand complex, the blackjack oak associations, and some adaptations of the plants to the environment.

Although Minier (1865, 1868) and Edwards (1868) were concerned about the rapid destruction of trees in the 1860's, it was not until 1911 that a policy on forest management was recommended by R. C. Hall and O. D. Ingall. In an article on forest conditions in Illinois, published in the *Bulletin* (Hall & Ingall 1911), they recommended (1) adoption of an adequate state fire-protection system, (2) inauguration of an education campaign for scientific and practical forest management, and (3) further investigation of the forest problems involved and development and extension of wood lots

in the state. Also, they proposed a forest law for the state. Later, Forbes and Robert B. Miller (Forbes 1919*a*, 1919*b*; Forbes & Miller 1920) pointed out that the forests of Illinois were being rapidly destroyed and that only very few of the remaining forests were being properly handled. Miller (1923) made the first extensive report on a survey of the forests of Illinois; the report was published in the *Bulletin* of the Illinois Natural History Survey. The survey covered land classification; history and types of forests and important trees in the forests; uses of forest trees in milling and logging operations, wood-using industries and veneer industries; production of charcoal, ties, and mine timbers; and adverse effects of fires, erosion, and grazing on forested areas.

The second extensive report on a forest survey of Illinois was made by Herman H. Chapman and Miller and published in the *Bulletin* (Chapman & Miller 1924). In this report the economic value of the forests and the forests as a crop were emphasized. The uses made of forest trees were discussed, and a policy of proper management of the forests to prevent the continued decimation of timber was outlined.

C. J. Telford (1923), a Natural History Survey forester, reported on height and growth studies on certain bottomland tree species in southern Illinois. He found that naturally stocked plantings of sycamore, cottonwood, pin oak, and maple produced better growth than did plantings of most other species in the bottomlands.

Telford (1926) reported on the third forest survey of Illinois. In this report, which included descriptions of the forests in the state and data on growth of individual trees and yields of different types of trees, he reviewed the proposed forest policies given in the two previous forest surveys of the state and urgently recommended setting up an educational program to promote the development of farm wood lots, the protection of the then present forests, and the reforestation of much of the waste land, estimated to total 1,577,663 acres.

These reports on forests of Illinois stimulated interest in the preservation and expansion of the forest resources of the state. A forestry program was carried on and expanded by the extension foresters who succeeded Telford and who were employed jointly by the Natural History Survey and the Department of Forestry of the University of Illinois. They were L. E. Sawyer, J. E. Davis, and L. B. Culver. Since 1954 the Natural History Survey has not participated in this forestry program.

By 1900 special emphasis was being directed toward control of plant diseases in Illinois. This trend was emphasized by some of Burrill's papers, such as that on spraying for the control of bitter rot (Burrill 1903). As interest in this field continued to increase, it became evident that a systematic study of plants and plant diseases in Illinois should be inaugurated. In 1921 a botanical section was established within the framework of the Natural History Survey by the appointment of Leo R. Tehon as the first botanist.

Under the direction of Tehon as botanist in charge of the Section of Botany from 1921 to 1935 and as botanist and head of the Section of Applied Botany and Plant Pathology from 1935 until his untimely death in 1954, botanical research expanded to include work not only in the field of general botany but especially in the fields of mycology, plant pathology, and taxonomy. The number of technically trained scientists on the staff was increased from 1 in 1921 to 10 in 1954.

Tehon's broad background and training and his mastery of the various fields of research carried on in the botanical section are indicated, in part, by his many and varied publications. Tehon described many new genera and species of fungi, most of them in a series of six articles under the title "Notes on the Parasitic Fungi of Illinois" (Tehon 1924, 1933, 1937*b*; Tehon & Daniels 1925, 1927; Tehon & Stout 1929). Also he wrote "A Monographic Rearrangement of *Lophodermium*" and "New Species and Taxonomic Changes in the Hypodermataceae" (Tehon 1935, 1939*d*). He described diseases affecting economic crops, including those of fruits, vegetables, grain and forage crops, and diseases of ornamen-

tal plants, especially trees (Tehon 1925, 1939*b*, 1939*c*, 1943; Tehon & Stout 1928; Tehon & Jacks 1933; Tehon & Boewe 1939; Tehon & Harris 1941). He was especially interested in developing methods and principles for interpreting the phenology of crop pests (Tehon 1928).

Tehon's botanical interests are indicated by such publications as *The Native and Naturalized Trees of Illinois* (with Robert B. Miller), *Rout the Weeds, Pleasure With Plants, Fieldbook of Native Illinois Shrubs, The Drug Plants of Illinois*, and (with collaborators) *Illinois Plants Poisonous to Livestock* (Miller & Tehon 1929; Tehon 1937*a*, 1939*a*, 1942, 1951*a*; Tehon, Morrill, & Graham 1946). He was a linguist and translated Giovanni Targioni Tozzetti's *Alimurgia*, part V, 1767, an Italian article of 156 pages on diseases of wheat and other cereals; the translation was published in English as Phytopathological Classics No. 9 (Tehon 1952*a*).

RECENT ACTIVITIES

The early work in the Section of Botany consisted not only of a survey of the plant diseases in the state but the development and co-ordination of research in botany, with special emphasis on plant diseases and the establishment of a herbarium, which included a plant disease collection and a native plant collection. In an annual report Forbes (1923:386) described the work of the botanical section as follows:

> Beginning in July, 1921, active work has been done throughout the State on the fungus parasites of the crop plants, many of which are highly destructive and difficult to control. It was the principal first object of this inquiry to make accessible existing knowledge of the plant diseases of the State and of their distribution in Illinois and their destructiveness, and to ascertain whether known methods of protection against them are generally used, this to be followed by measures intended to make crop growers acquainted with the most important preventable diseases and the losses due to them and with established means for their prevention and control.

To aid in the work of the Section of Botany the co-operation of 135 unpaid field observers was obtained to watch for plant diseases and to report any unusual outbreaks of diseases occurring at any time. The information obtained included the crops attacked by each disease, the stage of growth of the crop when attacked, the damage caused, the first date of appearance of disease, the amount of damage to the crop, the control measures used, and the prevalence and destructiveness of each disease.

As the work of the Section of Botany continued to expand, greater emphasis was placed on the application of research information for the control of plant diseases, and in 1935 the name of the section was changed to Section of Applied Botany and Plant Pathology. At this time the activities of the section were divided into four main groups, namely, (1) Plant Disease Survey, (2) Botanical Survey, (3) Shade and Forest Tree Pathology, and (4) Floricultural Pathology. The first full-time staff member to conduct research on floricultural pathology was not appointed until 1939.

Plant Disease Survey

The plant disease survey, started by Tehon in 1921, included a survey of the diseases of all crop plants of Illinois, with special emphasis on field crops and fruit crops. Among the persons who have assisted in the plant disease survey since its beginning are Charles O. Peake, Charles L. Porter, O. A. Plunkett, Harry W. Anderson, Paul A. Young, Gilbert L. Stout, and G. H. Boewe. Constantine J. Alexopoulos and Leo Campbell collected numerous plants around peach orchards in southern Illinois counties as part of a study of possible hosts of the peach yellows virus.

Field Crop Diseases. — After the establishment of the Section of Botany in July of 1921, flag smut of wheat was the first major disease studied. This disease, discovered in Illinois in 1919, was causing serious losses of wheat in the East St. Louis area. The limits of the disease in the state were determined, and effective control measures, including a quarantine, were enforced. By following rigid quarantine regulations, which required burning all straw and treating all grain sold for seed, and by introducing varieties of wheat resistant to the disease, it was possible to eliminate flag smut. The effectiveness of this control program

prevented the disease from spreading over the whole soft wheat area.

Other activities of the Section during the 1920's included warning cotton growers in southern Illinois of the diseases to be encountered, discovering and destroying the only known instance of alfalfa infestation by the stem nematode, and collecting data on the prevalence and destructiveness of stinking smut of wheat. By 1923 it had been determined that 165 diseases affecting 44 different crops were present in the state. In that year the estimated reduction in yield of Illinois wheat caused by five diseases (leaf rust, stem rust, stinking smut, loose smut, and scab) was 7,712,800 bushels, valued at $11,837,000.

In most years of the past decade the estimated annual losses from diseases of Illinois wheat have been 5,500,000 to 7,150,000 bushels. The greatest loss in a single year, 7,150,000 bushels, valued at $15,158,000, occurred in 1950. In 1953, a year of minimum loss, the estimated reduction in yield was only 368,800 bushels, valued at $586,400.

The estimated annual losses resulting from diseases of corn usually are greater than the losses resulting from diseases of wheat. In the past decade the lowest estimated reduction in corn yield, 54,250,000 bushels, valued at $82,450,000, occurred in 1952 and the highest estimated reduction in yield, 168,100,000 bushels, valued at $198,358,000, occurred in 1949. The average annual estimated reduction in yield of corn in Illinois during the past decade was 90,626,100 bushels, valued at $112,139,072.

Homemade mixer used about 25 years ago by plant pathologists of the Illinois Natural History Survey to demonstrate effectiveness of chemical treatments in control of seed-borne diseases of small grains.

The plant disease survey not only indicates the annual losses caused by plant diseases but reveals diseases new in the state and the sudden and widespread damage caused by any disease that has caused only minor damage in preceding years. Downy mildew of alfalfa appeared generally in the state and was abundant in the extreme north in 1924. This disease had not been seen in Illinois previous to that year. A new leaf spot of cowpea was discovered in Clinton County in 1927. In an article by Stout (1930), 16 new fungi found on corn in Illinois were described. Downy mildew of soybean, first reported in Illinois in 1929, caused considerable damage in 1935, when it was found in 12 counties. Brown stem rot of soybean, first recognized in the state in 1944, suddenly became widespread and destructive in 1948. This outbreak of the disease followed a fortnight of low temperatures, which ended on August 10. Septoria leaf spot of broom corn was discovered in Illinois in 1949 and was very destructive in several fields west of Galton in Douglas County.

Diseases recorded for the first time in Illinois in recent years include ergot on timothy, bacterial blister spot on apple, charcoal rot on pepper, and downy mildew on wheat in 1952; basal glume rot on barley, anthracnose on sweet clover, and rosette on cherry in 1954; Ascochyta leaf spot on rhubarb and bacterial leaf spot on mulberry in 1955; powdery mildew on apple, ergot on oats, Helminthosporium leaf spot on red top, and Gloeosporium leaf spot on currant in 1956; and Phytophthora root rot on alfalfa, Phytophthora stem rot on lily, Cercospora leaf spot on Deutzia, Abelia, ornamental gooseberry, and wafer ash, downy mildew on cucumber, squash, and watermelon, rust on apricot, anthracnose on iris, powdery mildew on pecan and fragrant sumac, Badhamia slime mold on timothy, Herptobasidium scorch on bush honeysuckle, and Phyllachora tar spot on lespedeza in 1957.

In the plant disease survey, not only are the various kinds of crops examined but many plants in many fields of the same crop are examined each summer. For instance, in 1949, data on prevalence and severity of wheat diseases were obtained by examination of plants in 42 wheat fields that totaled 1,033 acres and that were located in 38 widely scattered counties of the state.

Another phase of the plant disease survey is that of forecasting the anticipated occurrence and seriousness of plant diseases. This forecasting has been notably effective for Stewart's disease of corn. The bacterium that causes Stewart's disease overwinters chiefly in the body of the adult corn flea beetle (*Chaetocnema pulicaria*). The mortality rate of the flea beetle is affected by weather conditions during hibernation.

Although forecasting the early season or wilt stage of Stewart's disease had previously been worked out by others, forecasting the late season or the leaf blight stage was worked out by G. H. Boewe. Making use of data accumulated in the 5-year period 1944–1948, Boewe found that a winter temperature index rather accurately forecast the late season development of Stewart's disease. The index for any growing season was based on the sum of the mean temperatures of the previous winter months of December, January, and February. While early season epidemics do not develop unless the index is 90 or above, light to moderate late season epidemics develop when the indexes are between 80 and 85, and moderate to heavy late season epidemics when the indexes are above 85. No disease or only a trace of disease develops when the indexes are below 80. Forecasting of the severity of disease each year has been quite accurate.

The appearance and spread of new diseases on crops in Illinois often are recorded first as a result of the annual survey made for plant diseases. Aid to farmers in combating these diseases is made through warnings and through publications such as *Diseases of Small Grain Crops in Illinois* (Boewe 1939).

Fruit Diseases.—Of the many diseases that affected fruit trees in the state each year during the early years of the plant disease survey, the most common and destructive were scab, shothole, brown rot, and leaf curl of peach; fireblight, frogeye, and blotch of apple; fireblight, leaf blight, and leaf spot of pear; and shothole and leaf spot of cherry.

In early August of 1927 Professor M. J. Dorsey of the University of Illinois found, in a large orchard near Centralia, the first authentic case of peach yellows in Illinois. By 1929 the disease had spread to 37 trees scattered in 11 orchards located in Jefferson, Marion, Pike, and Pulaski counties. In recent years peach yellows has not been observed in Illinois. Diseases which are destructive to the peach crop and which have appeared annually in recent years are scab, brown rot, shothole, and peach leaf curl.

During the early years of the plant disease survey, nailhead canker was a serious disease of apple trees. However, this disease disappeared from the orchards of the state when growers eliminated those varieties susceptible to the disease. The major destructive diseases of apples which have continued to appear annually are scab, fireblight, frogeye, and blotch. Mildew has increased in destructiveness in recent years because the sulfur fungicides which controlled the disease in the early years have been replaced by new types of fungicides; these new materials more effectively control the other diseases of apples. Cedar apple rust, which was prevalent and destructive for many years, is controlled satisfactorily at present by some of the recently developed fungicides, ferbam plus sulfur on the deciduous hosts, Elgetol and acti-dione on the evergreen hosts.

Many pear orchards in the state have been severely damaged or destroyed by fireblight. At present there is hope that this disease can be effectively controlled by some of the new antibiotic sprays. Other diseases destructive annually to pear trees are leaf blight and leaf spot.

The disease most destructive to cherry trees in the state is shothole. Yellowing, necrosis, and premature leaf drop, caused by this disease, gradually reduce the vigor of affected trees and, eventually, the quality and quantity of cherries produced.

Diseases that may appear annually on other fruit crops are bacterial spot and black knot of plum; black rot, downy mildew, and powdery mildew of grape; crown gall and rust of blackberry; angular leaf spot of currant; leaf spot, leaf scorch, and yellows of strawberry; anthracnose of raspberry, currant, and gooseberry; and Septoria leaf spot of blackberry and raspberry. Although many of these diseases are not destructive each year, they cause serious losses in some years.

Vegetable Diseases.—Although vegetable crops are affected by many diseases, only a few of the diseases cause serious losses annually. The most common and destructive diseases in Illinois are bacterial blight, halo blight, and mosaic of bean; yellows of cabbage; Ascochyta leaf spot, Fusarium wilt, and powdery mildew of pea; Fusarium wilt, mosaic, and bacterial leaf spot of pepper; early blight, Fusarium wilt, black leg, and scab of potato; and early blight, Fusarium wilt, and Verticillium wilt of tomato.

Botanical Collections

The first of the present botanical collections of the Natural History Survey was started in a small way in 1921. At that time the collection of plant disease fungi of the Natural History Survey was separated from the collection of the University of Illinois. The vascular plants collected with State Laboratory funds and with Natural History Survey funds previous to 1921 were left in the herbarium of the University of Illinois.

Plant Disease Collection.—The earliest reported specimens in the plant disease collection of the Natural History Survey are several hundred specimens collected, 1918–1921, by H. W. Anderson of the University of Illinois. Collection, identification, and preservation of such specimens were expanded rapidly during the four summers of 1921 through 1924, when special emphasis was placed on obtaining information on the plant disease situation of the state. To conduct this plant disease survey, one to four men were employed full-time each summer to collect specimens of diseased plants in each county of the state. This activity resulted in adding over 18,000 plant disease specimens to the collection. Among these specimens were five plant diseases new to the state and 18 species of plant parasites new to science.

In 1924 this collection contained type specimens which represented three genera and 73 species of plant-inhabiting fungi

first known for their occurrence in Illinois. Although some specimens have been added to the plant disease survey collection by all botany staff members since 1924, most of the specimens have been added by Boewe, the plant pathologist now responsible for the plant disease survey. Specimens of special interest sent to the laboratory for diagnosis of disease are added to the collection.

Gilbert L. Stout was the first plant pathologist to devote full time to plant disease survey work. He was succeeded by Boewe in 1930. In this work diseased plant material is carefully examined to determine the specific disease involved. Many specimens are collected not only as characteristic examples of the disease but for further study in the laboratory to determine the organism causing the disease. Specimens of diseases new to the United States, Illinois, or a county of the state are preserved in the plant disease collection.

As of April, 1958, the plant disease collection contained 32,624 specimens. Although this collection contains mostly fungi that cause plant diseases, it also contains specimens affected by disease-causing bacteria, viruses, and noninfectious agents. Information on new diseases has been published in *Mycologia, Phytopathology*, and the *Plant Disease Reporter*.

Vascular Plant Collection.—The collection of vascular plants in Illinois by Natural History Survey staff members was begun in 1927 with the establishment of a project on the accumulation of plants of the state. By 1931 three additional projects had been added: maintenance of a herbarium containing representative plants of Illinois, maintenance of a bibliography of Illinois plant records, and maintenance of a card record of the occurrence of plants in Illinois.

The first systematic collection of Illinois vascular plants for the Natural History Survey was made by James Schopf, who collected 1,676 specimens during the summer of 1931. In September of 1931 Dr. Herman S. Pepoon joined the Survey staff. Pepoon, with the assistance of E. G. Barrett, collected 1,300 specimens. After Pepoon left the Survey in 1933 the accumulation of Illinois plants was added to the duties of the plant pathologists. Much of the collecting was done by Boewe in conjunction with his work on the plant disease survey. In October of 1946 R. A. Evers joined the staff and was assigned the botanical survey work. His work is devoted almost exclusively to a study of the flora and vegetation of the state. Since 1946 he has collected plant specimens annually in each of the 102 counties of the state.

Previous to 1947 the number of specimens in the vascular plant collection was increased by gifts of specimens from R. A. Dobbs of Geneseo, R. A. Evers then of Quincy, and G. D. Fuller of the Illinois State Museum. Also, the herbarium of Charles Robertson of Carlinville was acquired. Since 1947, plant specimens, as gifts or exchanges, have been received from Franklin Buser (graduate student), James Long of Amboy, Dr. V. H. Chase of Peoria, Dr. Sidney Glassman of the University of Illinois staff at Navy Pier, Chicago, Dr. John Voigt of Southern Illinois University, Dr. John Thieret of the Chicago Museum of Natural History, and others.

Thirteen species of plants have been added to the known flora of Illinois by Natural History Survey staff members since 1947. They are *Daucus pusillus, Medicago arabica, Setaria faberii, Specularia biflora, Rudbeckia missouriensis, Heliotropium tenellum, Eriochloa villosa, Dicliptera brachiata, Cyperus lancastriensis, Haplopappus ciliatus, Verbascum virgatum, Helianthus angustifolius,* and *Jussiaea leptocarpa.*

Publications resulting from the collection of vascular plants of Illinois include a 339-page bulletin on native and naturalized trees of the state (Miller & Tehon 1929), two fieldbooks, one on wild flowers (Anon. 1936) and one on native shrubs (Tehon 1942), and articles on genera and species of Illinois plants, including several new to the state (Evers 1949, 1950, 1951, 1956; Evers & Thieret 1957).

Identification and preservation of vascular plants in the Natural History Survey herbarium were under way to a limited extent by 1927. In succeeding years students have been employed to mount specimens for the herbarium. In 1936 Richard A. Schneider was em-

ployed to identify the accumulated collection of plant specimens. Although collection, identification, and preservation of vascular plant specimens were curtailed during World War II, the herbarium contained 13,749 specimens in May of 1943 and 17,339 specimens in October of 1946. The abundant collection of plant material in succeeding years has increased the number of vascular plant specimens in the herbarium to 70,600, and approximately 8,000 additional specimens are on hand to be added to the herbarium. Under present conditions three student assistants are employed to prepare the plant material for placing in the herbarium. A card index is maintained of all plant specimens.

The bibliography of Illinois plants, started previous to 1931, is not up-to-date because of lack of funds and lack of assistants to examine the literature.

In co-operation with L. E. Yeager, R. E. Yeatter, A. S. Hawkins, and D. H. Thompson, fellow staff members doing wildlife or fisheries research, botanists made a census of waterfowl food plants of the Chautauqua Drainage District, carried on a survey of Illinois plants useful to wildlife as food or cover, and conducted experiments on propagation of plants useful to wildlife as food or cover. A collection of 848 samples of seeds was developed for identification of seeds ingested by waterfowl.

Activities pertaining to the botany of Illinois include preparation of manuscripts designed for publications, mainly of an educational or popular type. These publications are on such subjects as noxious weeds, directions for the study and identification of plants, drug plants (Tehon 1937*a*, 1939*a*, 1951*a*), plants poisonous to livestock (Tehon, Morrill, & Graham 1946), and vegetation of hill prairies in the state (Evers 1955).

The publication on the vegetation of hill prairies is a report on an extensive ecological study of 61 prairies on the brow slopes of bluffs of the Mississippi River from East Dubuque to southern Illinois, the Illinois River from the big bend near Hennepin to Grafton, and the Rock and Sangamon rivers. This type of publication by the Natural History Survey is a continuation of those published earlier by the State Laboratory of Natural History.

Shade and Forest Tree Pathology

The earliest reported conspicuous dying of trees in Illinois was among the elms in Normal-Bloomington and Champaign in the period 1883–1886 (Forbes 1912*a*). The next reported conspicuous dying among elms occurred from 1907 through 1911, when many trees succumbed in southern Illinois. During this period conspicuous losses of elms were reported in Cairo, Carbondale, Centralia, Clayton, Du Quoin, Edwardsville, Fairfield, Galatia, McLeansboro, Mount Vernon, Quincy, Robinson, Sumner, and Vandalia. These 14 towns are located in 13 counties of western and southern Illinois. Although the cause of the dying of elms during these two periods was not determined, it was suggested that some disease might be involved. Dying of feeder roots, wilting of foliage, and dying of terminal twigs was followed by death of the trees. Many of the affected elms in southern and western Illinois were heavily infested with the elm borer, *Saperda tridentata,* and the red elm bark weevil, *Magdalis armicollis,* called by Forbes the reddish elm snout-beetle.

Elm Diseases. — A few years after the establishment of the Section of Botany in 1921, reports and inquiries were received about a widespread wilting of elms growing in commercial nurseries and in decorative plantings, most of them in northern Illinois. Some special examinations made of these trees by Dr. Christine Buisman of Holland, an expert on elm diseases, revealed that the malady was not Dutch elm disease. Research on the cause and control of this wilting was started in 1930. Until May, 1934, the work was carried on by graduate students — H. A. Harris, Leo Campbell, J. A. Trumbower, and A. S. Peirce. In May of 1934 J. C. Carter joined the staff as a full-time plant pathologist to study diseases of trees. Although intensive study of the elm wilt problem was continued for several years, other elm diseases and diseases of other species of trees were studied as they became evident. From 1934 to 1950 research on tree diseases was carried on by Carter. With the expan-

sion of the tree disease research program in 1950, additional plant pathologists were added to the staff. The recent research program has been carried on by four plant pathologists, Richard J. Campana, Walter Hartstirn, Eugene B. Himelick, and Dan Neely.

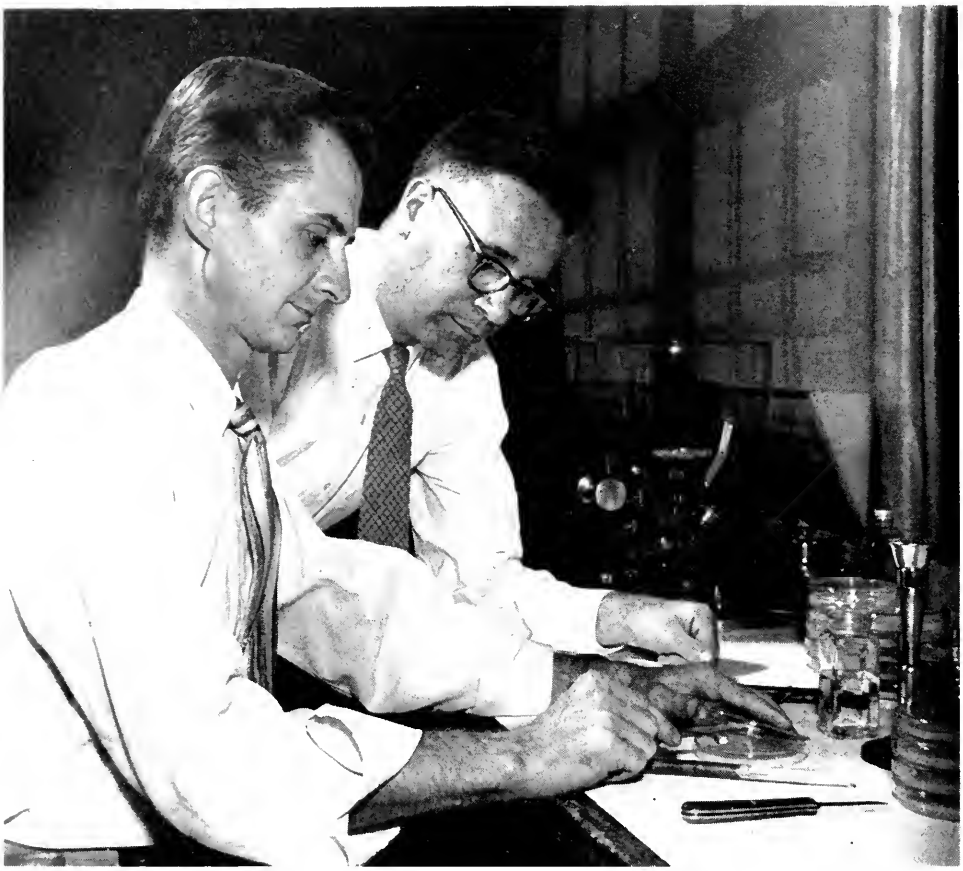
In the studies on the cause and control of the wilting of elms, it was found that several fungi were involved. Although the first report on this work (Harris 1932) indicated that several fungi were capable of causing the wilting, later studies showed that most wilting was caused by the Dothiorella wilt fungus and it was most serious in plantings of trees that were weakened by overcrowding and by repeated annual defoliations from heavy infestations of the spring cankerworm. Spraying with copper and sulfur fungicides was not effective in noticeably reducing or preventing wilting. This spraying included dormant and foliar applications, in some years as many as one dormant and seven foliar sprays. Although research failed to find a control for this type of wilting of elms, it showed that applications of either sulfur or copper fungicide in June and early July gave excellent control of the black leaf spot disease (Trumbower 1934). Control of this disease in commercial nursery plantings of elms increased the annual growth; sprayed trees made as much growth in 4 years as unsprayed trees made in 5 years (Carter 1939).

A conspicuous and widespread dying of elms which became evident in Danville and Peoria in the late 1930's appeared in other areas in succeeding years. It now is widespread and destructive throughout the southern two-thirds of the state. North of Peoria, Bloomington, Champaign, Urbana, and Danville, it occurs in only a few isolated places. The northernmost isolated infection is in Rockford. This disease, called phloem necrosis and described as a virus disease in 1942 (Swingle 1942), has killed thousands of elms in Illinois and is one of the two major diseases that continues to kill thousands of elms annually. In Champaign and Urbana phloem necrosis killed 2,460 trees in a period of 14 years; this number represents over 16 per cent of the total elm population in the two cities. Mount Pulaski, with an elm population of approximately 600 trees in 1940, had all but 19 elms killed by the disease by September of 1948.

During the late 1930's and early 1940's, in investigations of the wilting and dying of elms, several fungi capable of producing cankers were studied. Canker diseases usually were confined to a few trees in a planting of elms but were found in plantings in widely scattered locations in the state. The cankers caused by species of Cytosporina, Phoma, and Coniothyrium were prevalent only on American elm. The canker caused by *Tubercularia ulmi* affected the Asiatic species of elm, *Ulmus pumila* and *U. parvifolia*.

A serious and widespread wilting of elms in Hinsdale was brought to the attention of the Natural History Survey by Village Forester W. E. Rose in 1939. Intensive research on these elms resulted in the discovery of a bacterial disease called wetwood (Carter 1945). Wetwood is a chronic disease that affects most elms but usually does not result in the death of affected trees. *Ulmus pumila* is especially susceptible to wetwood. Research on this disease is described in a 42-page article under the title "Wetwood of Elms" (Carter 1945). The National Arborist Association awarded a citation to the author in "recognition of his excellent work" reported in the article. This work the Association "considered the outstanding research during 1945 on shade tree preservation."

Dutch elm disease is the most destructive disease of elms in Illinois. Although this disease was first discovered in the United States at Cleveland and Cincinnati, Ohio, in 1930, it was not until 1950 that the first diseased elm was found in Illinois. Only one tree affected with Dutch elm disease was found in 1950, 11 were found in 1951, 24 in 1952, and over 500 in 1953. The numbers of counties in which the disease has been found each year were 1 in 1950, 4 in 1951, 9 in 1952, 15 in 1953, 55 in 1954, 74 in 1955, 86 in 1956, 94 in 1957, and 99 in 1958. The rapid destruction of elms by the disease is illustrated by the numbers of trees affected each year in Champaign and Urbana. Only one affected tree was found in



Plant pathologists of the Illinois Natural History Survey culturing sample of American elm suspected of being affected by the Dutch elm disease. Modern laboratory equipment enables the plant pathologists to substantiate field diagnoses.

Urbana in 1951. The numbers of affected trees in succeeding years in Champaign and Urbana were 11 in 1952, 164 in 1953, 694 in 1954, 1,805 in 1955, 1,836 in 1956, and 2,116 in 1957. These 6,627 diseased elms represent over 44 per cent of the elm population of Champaign and Urbana when the disease was first found there.

The Natural History Survey has had one full-time plant pathologist conducting research on elm diseases, including Dutch elm disease, since July, 1951: Ralph W. Ames in 1951 and 1952 and Richard J. Campana in 1952 and later.

Oak Diseases.—Numerous inquiries about diseases of oak during the 1930's led to a special investigation which culminated in the publishing of a preliminary report (Carter 1941). Although a dozen fungi were associated with the development of canker and dieback diseases of oak in the field, only one fungus, *Dothiorella quercina,* caused canker and dieback under controlled experimental conditions. The other organisms appeared to produce canker and dieback only on trees previously weakened by adverse growing conditions.

Oak wilt, the most destructive and widespread disease of oak trees in the United States, was not found in Illinois until 1942, when a few affected trees were discovered in Ingersoll Park at Rockford in Winnebago County. In following years the disease was found in other counties; by 1958 it was killing trees in 70 of the 102 counties of the state.

Extensive research on the disease was started in 1950 with a grant of money

from the Forest Preserve District of Cook County, Illinois. A graduate student at the University of Illinois, E. A. Curl, was employed on a half-time basis. A second grant of money was received from the Forest Preserve District in 1951. Also in 1951, funds were obtained from the National Oak Wilt Research Committee of Memphis, Tennessee, composed of 10 hardwood industries, and from state appropriations for research on the diseases of trees. These funds made it possible to add three plant pathologists in 1951 to conduct full-time research on the oak wilt disease. The men employed were Bert M. Zuckerman, George J. Stessel, and Paul F. Hoffman. Additional funds were obtained from the National Oak Wilt Research Committee in 1952, 1953, and 1954. Funds appropriated by the state have continued to be a part of the Natural History Survey's regular budget. These funds have made it possible to employ additional plant pathologists to do research on oak wilt and other tree diseases. In 1953 four men full-time and two men half-time were conducting research on oak wilt. At present, with only state funds to support the research on oak wilt, three full-time regular staff members are continuing research on this disease. The men who have helped to carry on this program include E. A. Curl (1950–1954), Bert M. Zuckerman, George J. Stessel (1951–1952), Paul F. Hoffman, Eugene B. Himelick (1952–1954), Richard D. Schein (1952–1953), Norman C. Schenck (1952–1953), Irving R. Schneider, Harry Krueger (1954–1955), Arthur W. Engelhard, James D. Bilbruck (1955–1958), John M. Ferris, R. Dan Neely, and Walter Hartstirn. Persons whose names are followed by dates were employed on research funds granted to the Natural History Survey by the Forest Preserve District of Cook County, Illinois, or by the National Oak Wilt Research Committee. The dates indicate the periods of employment. Himelick was employed on research funds granted by the National Oak Wilt Research Committee (1952–1954) before he was employed by the Survey.

As a result of this extensive research program on oak wilt, many papers were published. The phases of research covered in these papers include laboratory studies on the morphology and physiology of the fungus (Zuckerman & Curl 1953) and isolation of the fungus from species of oak on which it had not been previously reported (Carter & Wysong 1951); greenhouse studies on host range (Hoffman 1953) and experimental transmission of the fungus by insects, mites, and squirrels (Himelick, Curl, & Zuckerman 1954; Himelick & Curl 1955, 1958); greenhouse studies on infection by and spread of C^{14}-labeled fungus in inoculated oaks (Zuckerman & Hoffman 1953; Hoffman & Zuckerman 1954); and field studies on distribution and spread of oak wilt in Illinois (Carter 1952), availability of oak wilt inoculum in the state (Curl 1953, 1955*a*, 1955*b*; Himelick, Schein, & Curl 1953), characteristic growth of the fungus under natural conditions (Curl, Stessel, & Zuckerman 1952), discovery of the perfect stage of the fungus in nature (Curl, Stessel, & Zuckerman 1953; Stessel & Zuckerman 1953), and effect of the fungus on oak fence posts (Walters, Zuckerman, & Meek 1955).

Other Diseases of Trees.—Although oak wilt, elm phloem necrosis, and Dutch elm disease are the most destructive tree diseases in the state, other diseases of trees and of shrubs have been sufficiently destructive to require the attention of plant pathologists of the Natural History Survey. A wilt disease that affects many species of trees in Illinois is Verticillium wilt. It is known to affect 27 species of plants, including 7 varieties of woody ornamentals representing 19 genera. Of the 27 species of woody hosts of this disease, 12 were first reported in Illinois: black locust, catalpa, Chinese, English, and slippery elms, goldenrain tree, linden, magnolia, multiflora rose, tupelo, wayfaring tree, and yellow-wood. Maple, elm, and catalpa are frequently affected by this disease.

Canker diseases found in Illinois affect different species of trees, including crab apple, hawthorn, juniper, maple, mountain ash, pine, poplar, redbud, spruce, sycamore, and willow. Rust diseases are widespread and destructive in some years. They include cedar apple rust, cedar-hawthorn rust, cedar-quince rust, pine needle rust, and poplar leaf rust.

Foliage diseases which cause especial damage during cool, moist springs affect many species of trees. The most destructive foliage diseases are anthracnose of ash, maple, oak, and sycamore; blotch of buckeye and horsechestnut; and leaf spot of elm, hawthorn, maple, oak, and walnut.

Some trees decline and die each year because of unfavorable growing conditions that include physiological disorders, adverse weather conditions, and mechanical injuries. These conditions, as well as disease organisms, have received the attention of Natural History Survey plant pathologists.

Research on the control of foliage diseases includes testing of numerous fungicides each year. In some years as many as 18 species of trees have been treated with fungicides and as many as 12 different fungicides have been tested on one or more species. An example of an effective control measure resulting from these tests is the use of organic mercury fungicides to control anthracnose of sycamore.

Chemotherapy.—One phase of Natural History Survey research on the control of tree diseases relates to the effectiveness of various chemicals in preventing fungi from infecting trees or from causing disease symptoms after they have infected the trees. The early studies were confined mainly to oak wilt; the present studies include diseases of several species of trees and especially oak wilt, Dutch elm disease, and Verticillium wilt of elm, maple, and other trees. Of the hundreds of chemical compounds tested, a few systemic fungicides and antibiotic materials appear to be effective in preventing disease development. To obtain more information on what happens when these materials are introduced into trees, plant pathologists are studying the physiology of trees as well as the physiology of the fungi. The staff members who have carried on this program are Paul F. Hoffman, Eugene B. Himelick, Irving R. Schneider, John M. Ferris, and Walter Hartstirn.

Floricultural Pathology

Little research by the Natural History Survey was done in floricultural pathology before 1939. In response to numerous requests for help in dealing with disease problems in floricultural crops, a program of research was initiated, and Don B. Creager was appointed to the staff in September of 1939. This program, carried on by Creager for 5 years and continued by J. L. Forsberg, included work on diseases of greenhouse crops and field- and garden-grown floricultural plants. Much attention was given to bulbous ornamental plants, which were being propagated extensively in Illinois for shipment to other states.

The early work was concerned with (1) obtaining as much information as possible about diseases important to Illinois growers, (2) conducting research on diseases for which vital information on cause and control was lacking, and (3) rendering every possible aid to growers in the recognition and control of diseases in their crops. As the work progressed more attention was given to developing disease control measures that would be more effective than those that were being used.

Crops which have received attention during the course of this work are amaryllis, aster, azalea, begonia, calla, carnation, chrysanthemum, gardenia, geranium, gerbera, gladiolus, hollyhock, hydrangea, iris, ivy, lily, orchid, peony, peperomia, periwinkle, petunia, poinsettia, rose, African violet, snapdragon, stevia, stock, sweet pea, tuberose, tulip, violet, and zinnia. Of these crops, gladiolus, rose, and carnation are grown in greatest quantity, and, since all three crops are subject to a number of destructive diseases, more work has been done on them than on the other crops.

Because of the serious losses due to diseases of gladiolus in the large commercial gladiolus growing area in Kankakee County, much research work has been directed toward developing effective control measures for these diseases. Prior to 1940, gladiolus corms generally were not treated for disease control, but in recent years nearly all commercial gladiolus planting stocks in all parts of the United States have been treated with a fungicide before being planted. This practice has developed largely as a result of the success of experimental treatments by Illinois Natural History Survey pathologists. If these or other equally effective treat-

ments had not been worked out, the gladiolus industry in Illinois would have succumbed.

Among other noteworthy accomplishments achieved by Natural History Survey pathologists in the field of floricultural pathology are the following: control of peony measles with an Elgetol ground spray (Creager 1941*c*, 1943*a*); control of black mold of rose grafts by chemical treatments (Creager 1941*b*); control of calla rots by chemical treatments (Creager 1943*b*); establishment of viruses as the causes of peperomia ringspot (Creager 1941*a*), carnation mosaic and streak (Creager 1943*c*, 1944, Forsberg 1947), and coleus mosaic (Creager 1945); clarification of the Fusarium disease complex in gladiolus (Forsberg 1955*a*); discovery of the vascular phase of the Curvularia disease of gladiolus (Forsberg 1957); discovery of scab on violets in Illinois (Forsberg & Boewe 1945); control of Thielavia root rot of sweet peas (Creager 1942); control of bacterial scab of gladiolus by use of soil insecticides (Forsberg 1955*b*).

The value of an insecticide in the control of bacterial scab of gladiolus became apparent in 1953 when gladiolus corms were treated with a seed protectant which contained an insecticide in addition to a fungicide. This treatment resulted in the production of corms free of bacterial scab and free of injury caused by white grubs. Results of this treatment supported observations that white grubs are instrumental in spreading bacterial scab. Succeeding tests showed that 25 per cent aldrin granules applied to the soil at the rate of 4 or 8 grams per 10 feet of row prevented white grub injury and bacterial scab.

Identification and Extension

During each growing season the Section of Applied Botany and Plant Pathology receives for examination and diagnosis several thousand samples of trees, shrubs, and other plants suspected by Illinois residents of being diseased. Diagnosis results and treatment recommendations are sent as soon as possible to the persons sending the samples.

Most of the samples received are from elms suspected of being affected with Dutch elm disease. To handle the laboratory diagnoses requires the full-time help during the summer months of four additional persons: one mycologist, two laboratory technicians, and one stenographer. It is anticipated that the demand occasioned by Dutch elm disease for service from Natural History Survey personnel will continue indefinitely.

To supply the demand from hundreds of communities and individuals throughout the state for information on identification, control, and other aspects of Dutch elm disease has occupied a major portion of the time of one plant pathologist. Educational material on Dutch elm disease has been prepared for distribution; this has included mimeographed leaflets on control and other phases of the disease, a series of news releases, kodachrome transparencies, black and white photographs, specimens, exhibits, maps, tables, and graphs. Technical advice and information were furnished the Illinois State Chamber of Commerce for two state-wide conferences on Dutch elm disease, one in 1955 and one in 1956. These conferences provided specific and detailed information on the nature and control of the disease. Outstanding authorities on Dutch elm disease in the United States were on the programs. Additional activities have included aid in field identification of the disease, aid in local surveys, training and instruction in collecting specimens, setting up laboratories for final diagnosis of the disease, and making laboratory diagnosis of each of several thousand specimens received each year.

Each year, activities of an educational or extension nature by staff members of the Section of Applied Botany and Plant Pathology include talks on plants and vegetation of Illinois, and on diseases of trees, shrubs, and floricultural crops. Examinations are made of numerous plantings of ornamental and economic crops in various parts of the state. Numerous pasture lands are examined in co-operation with members of the University of Illinois College of Veterinary Medicine for plants poisonous to livestock. Many plants examined in the field or received through the mail are identified for farmers, homeowners, and other interested persons.

PAST AND PRESENT

Early botanical research in Illinois was concerned mainly with field surveys of plants native to the state and with the distribution of these plants in the state. Although botanical research in the state is still concerned with native plants, it is concerned also with the cause and control of diseases affecting ornamental plants—trees, shrubs, and floricultural crops—and losses caused by diseases of economic crops, including cereal, fruit, forage, pasture, and vegetable crops.

Much of the early work with plants was done by amateur botanists who had very little formal training in botany. Some of these men were physicians who were interested in plants that had medicinal values. These early botanists were individuals, engaged in various professions or businesses, who were keenly interested in nature, especially in the plant life around them. They usually studied plants in local areas, as their modes of travel were by foot, by horseback, or by carriage. Their equipment and reference works were meager. Their efforts were directed mainly toward the collection and identification of plants.

Many of these early botanists were members of the Natural History Society. Some of them became professional botanists and were employed by the State Laboratory of Natural History.

Inheritors of some of the traditions of these early botanists are the present members of the Section of Applied Botany and Plant Pathology of the Natural History Survey. Unlike the early botanists, these men have received specialized botanical training in leading colleges and universities of the United States. Their fields of specialization include botany, taxonomy, plant pathology, plant physiology, mycology, and biochemistry.

They are provided with specialized equipment including high-powered compound and phase microscopes, high-speed centrifuges, pH meters, fluorescent lamps, spectrophotometer, and Geiger counter, and with excellent library facilities including numerous books on specialized subjects in botany and related fields. They are able to study plants in all parts of the state, as they can rapidly travel great distances by automobile, train, airplane, or helicopter. They study the taxonomy of plants, as the early botanists did, and in addition the pathology, physiology, mycology, and biochemistry of plants, including fungi, and especially the fungi that cause diseases of plants.

UNSOLVED PROBLEMS

The partially solved problems receiving major attention of the Section of Applied Botany and Plant Pathology at the present include the control of gladiolus corm rots, oak wilt, elm phloem necrosis, and Dutch elm disease. Although these diseases have been investigated for several years, continued research is needed to develop more effective treatments for their control. Other unsolved problems include the abnormal growth, wilt, decline, or death of trees, floricultural crops, and shrubs used for ornamental, shade, or forest purposes. Some specific unsolved problems are a virus disease complex of gladiolus, a general decline of ash, elm, and oak in localized areas of the state; a rapid decline and death of red pine in localized plantings in northern Illinois; wilt, occasionally followed by death, of ash, catalpa, fragrant sumac, Japanese quince, and hard maple; a needle blighting of white pine; diseases of hackberry, Norway spruce, and white pine, with symptoms suggesting virus diseases; and wetwood of elm.

Although a research program on the control of diseases of fruit, grain, and vegetable crops is conducted by the Agricultural Experiment Station at the University of Illinois, some of the unsolved or partially solved problems are mentioned here. Because of the continued appearance of new physiologic races of rust on small grains, it is essential to develop new varieties of grains resistant to these races. Also needed are varieties of small grains resistant to scab and loose smut. Another disease of small grains that needs further study is the virus disease known as yellow dwarf.

Corn is affected by stalkrots caused by several fungi; varieties of corn are needed that are resistant to the stalkrot caused by each fungus. Other problems include more effective control for bacterial spot

of pepper and for diseases caused by soil-borne microorganisms including bacteria, fungi, and nematodes.

If the future can be measured in terms of experience in the past, new diseases and other types of new plant disorders will appear each year to require additional attention of the research personnel of the Section of Applied Botany and Plant Pathology.

FUTURE POSSIBILITIES

Future possibilities in the botanical survey include further collections of native and naturalized vascular plants to increase the knowledge of the habitats and the range of these species in the state. As plants migrate, slowly under natural conditions but swiftly with the help of man, it is necessary to be on the alert for new additions to the state flora and to give warning if any introductions are of an obnoxious character. The final aim of a floristic study is to produce a manual of the flora of Illinois which will give not only good descriptions of the species but also a discussion of the variations of the species within the state and a discussion of their distribution in Illinois.

Collections of the nonvascular plants —algae, fungi, and bryophytes—should be expanded. Although a small collection of bryophytes—mosses and liverworts—is housed in the herbarium, much collecting remains to be done before the present bryophyte flora and its distribution in the state can be known. A nucleus of a phycological collection has been made and should be increased. Only a few of the nonpathogenic fungi are represented in the Natural History Survey collections. Collections of slime molds, lichens, and fleshy fungi—mushrooms and bracket fungi—should be started, as these plants are a part of the flora of Illinois and thus a part of the natural resources of the state.

Vegetational studies should be continued. Although many of the original prairie types of Illinois have been destroyed and only remnants remain, these remnants should be described so that future citizens of Illinois will have some botanical knowledge of the prairie types. Hill prairie studies should be continued to solve some of the problems of succession in this type of prairie and to learn how such prairie recovers from heavy grazing. Additional study should be made of the vegetation of the sand areas of the state. An ecological study of the forests in Illinois should be made. The ultimate aim of these studies is to produce a manual of the plant geography of Illinois.

Not only should the various vegetations of Illinois be described; remnants of them should be preserved. This is true especially of the prairie types. As we do not know what lies in the future for land use in the locations of the present hill prairies, now one of the least disturbed prairie types in Illinois, several of these beautiful grasslands should be set aside as natural areas by the state or federal government and should be so administered that picnic parties, hunters, or others cannot disturb them but that interested persons may view and study them. Although only very small remnants of the flatland and bottomland types of prairie remain, several such remnants should be set aside and allowed to expand so that future generations may have a general idea of the nature of these types of prairie which gave the name "the prairie state" to Illinois. Examples of sand prairies should be preserved. Some of these prairies which come under state control should be left as prairies instead of being converted into pine plantations. Abandoned railroad trackways in sand prairie regions should be permitted to develop as a type of the sand prairie. Other vegetations also should be preserved. The bogs in northeastern Illinois, in Lake County, are valuable from the botanist's point of view. The few remaining, sizable tamarack bogs could be easily set aside for the study of bog plants and animals and of succession in the bogs.

Future research on plant diseases will continue the advancement of present research, and new fields of research will open up. Some of the types of research that appear promising in the control of plant diseases include the use of chemotherapeutants, antibiotics, and soil fungicides. Further research is needed on insecticides and their indirect role in the control of plant diseases. One instance of this is illustrated in the control of bac-

terial scab of gladiolus by use of aldrin to prevent white grub injury to the corms. Chemical compounds obtained from mineral deposits in the state hold promise for the control of some plant diseases (Schenck & Carter 1954). Research on these compounds through the co-operation of the Geochemical and Coal sections of the Illinois Geological Survey and the Wright Air Development Center of the United States Air Force has been fruitful in the development of fluorine compounds with fungicidal properties against certain disease-producing fungi. Research along these lines resulted in publication of six articles on the fungistatic capacities of aromatic fluorine compounds in relation to cloth-rotting fungi (Tehon 1951*b*, 1952*b*, 1954; Tehon & Wolcyrz 1952*a*, 1952*b*; Finger, Reed, & Tehon 1955).

Research on the physiology of plants and on organisms that produce plant diseases will aid materially in the development of more effective controls for these diseases. One objective of this research is to develop a more realistic approach to the control of diseases through obtaining information on the movement of raw materials, elaborated foods, and chemical compounds introduced into woody plants. The addition of a plant physiologist to our staff would materially increase research in this field.

In our study of several thousand specimens of diseased ornamental plants each year, many unknown fungi are obtained. These fungi need to be identified and those that are found affecting new hosts or that have not been found previously in the state should be added to our mycological collection. To adequately handle this work, to make monographic studies of economically important fungi, and to attack new mycological problems as they appear, a mycologist with special interest in economic fungi would greatly facilitate our research.

As we contemplate the future possibilities for research by the Section of Applied Botany and Plant Pathology, it is evident that there are unlimited opportunities not only to continue the research now in progress but to expand into new fields of research. This statement applies to the botanical survey, the study of vegetation, the study of diseases of ornamental plants, and the study of the various kinds of fungi that occur in the state.

Aquatic Biology

GEORGE W. BENNETT

THE research in aquatic biology that was so much a part of the endeavors of the staff of the Illinois State Laboratory of Natural History and later the Illinois Natural History Survey was initiated by Stephen A. Forbes. From the very beginning of his active period in Illinois, Forbes showed great interest in fishes and he began collecting specimens for species records, distributional records, and food habits studies. He wrote articles on Illinois Crustacea and food of Illinois fishes for the first volume of the *Bulletin* of the Illinois State Laboratory of Natural History (Forbes 1876, 1878*a*, 1880*b*, 1880*c*, 1883*b*, 1883*c*). In the period 1876–1888 he collected 1,221 fish of 87 species, 63 genera, and 25 families; these he used to study their diagnostic characteristics, their distribution in the state, and their food habits. Forbes' interest in aquatic biology was broad, and he himself worked on or arranged for others to work on crustaceans, leeches, protozoans, rotifers, and aquatic insects, as well as fishes native to Illinois.

BEGINNING OF AQUATIC ECOLOGY

Many of the early publications of the Illinois State Laboratory of Natural History dealt with the taxonomy and distribution of aquatic animals new to science, or additions to the known distribution of named animals. Forbes was familiar with these subjects and also with the ecology of aquatic organisms at least as early as 1887. In that year his "The Lake as a Microcosm" was first published in the *Bulletin* of the Peoria Scientific Association; later it was republished in volume 15 of the *Bulletin* of the Illinois State Laboratory. In this short but epoch-marking paper, Forbes (1925) described a lake or pond as an environment in which the animals and plants were largely isolated from the surrounding terrestrial animals and plants but were very much interrelated and interdependent among themselves; each organism was producing more new individuals than the environment could support, so that many of them served as food for other types of animals, and competition was very keen. Forbes had observed the biological phenomena associated with fluctuating water levels—with floods following excessive precipitation and low waters following droughts—and described them as follows:

> Whenever the waters of the river remain for a long time far beyond their banks, the breeding grounds of fishes and other animals are immensely extended, and their food supplies increased to a corresponding degree (Forbes 1925:538).
>
> As the waters retire, the lakes are again defined; the teeming life which they contain is restricted within daily narrower bounds, and a fearful slaughter follows; the lower and more defenceless animals are penned up more and more closely with their predaceous enemies, and these thrive for a time to an extraordinary degree (Forbes 1925:539).

Forbes recognized that periods of biological expansion and contraction were normal and, without the introduction of abnormal forces, would tend to hold "each species within the limits of a uniform average number, year after year." Every organism had its enemies that seemed to be balanced against its reproductive potential and, although every species had to "fight its way inch by inch from the egg to maturity," yet no species was exterminated.

Apparently the Illinois State Fish Commissioners, assigned the duties of protecting the fisheries resources of the state during this period, either had not read Forbes' "The Lake as a Microcosm" or did not understand it, because their main activity for the 20 years following 1890 was the rescuing of fishes from the land-locked, drying backwaters of the Illinois and Mississippi rivers and the returning of these fishes to the open waters.

Perhaps the Commissioners should not be condemned severely, because their beliefs and activities were in no way dif-

ferent from those of similar bodies in other states throughout the country. They were in tune with the times. In the report of the Commissioners to the Governor of Illinois for the period October 1, 1890, to September 30, 1892 (Bartlett 1893:3), is to be found the following statement:

> The number of fish left to die in the shallow waters has been beyond computation, and has seemed to be greater than ever before, from the fact that the attention of the people generally has been called to them and the terrible waste ensuing. . . .
>
> . . . . . .
>
> We have been severely criticised because so many fish are allowed to perish, but when the fact is considered that the Mississippi river has a meandering frontage of 450 miles in this State, with bottoms varying in width from a few hundred yards to several miles, and the Illinois and other rivers adding perhaps as much more, it can readily be seen that, if the work were carried on to a successful completion, it would require hundreds of men and thousands of dollars of expense; in other words, it would be simply impracticable.

Fish rescue operations were done with seines dragged through shallow waters by crews of men. The fish were separated from the mud and vegetation and carried by boat to open water, or in tubs to tanks on wagons when overland transportation was necessary. The operations were carried on in summer and early fall when both the water and the air were very warm. Today fisheries biologists are well aware of the fact that, even if the fish had been released "alive" in open water, their chance of survival was very low. Few fishes are able to survive even a short exposure to a lukewarm, mud-and-water suspension, such as is created when a seine is dragged through shallow backwaters in August. This statement applies particularly to the game and fine fishes.

We now suspect that the phenomenon of fluctuating water levels, which created a fish rescue problem along the Illinois and Mississippi rivers for the Illinois State Fish Commissioners, may have been highly favorable to the well-being of the population of fishes, particularly largemouth bass, northern pike, walleyes, crappies, and other pan fishes. A combination of natural predation (largely by fish-eating birds) and water level fluctuations prevented excessive competition among the coexisting species and allowed for excellent survival of game fish. The report of the Fish Commissioners (Bartlett 1893:4) for the 2-year period ending September 30, 1892, contains the following statement:

> In the Quincy Bay [of the Mississippi River], this season, the number of black bass has been unprecedented, and a fair estimate of the number taken with hook and line would place it in the hundreds of thousands. Most of them were too small to use on the table, yet were as voracious as larger ones and fell an easy prey to the angler, whether he of the rod and reel or the small boy with a willow switch and a tow line, all caught bass. One man, who called himself a sportsman, boasted of having caught 800 of them in one day with hook and line, all too small to eat, but he carried them away and threw them on the ash heap. From my office window I saw 225 taken by two little boys in one day, all of them wasted.

The production of a dominant brood of bass (undoubtedly largemouth) such as this might be expected to follow a period of very low water in the late summer and fall and a period of moderately high water during the bass spawning season the following June.

The theory of the benefits of fluctuating water levels is further substantiated by a published record of the catch of four commercial fishing firms operating in the Illinois River near Havana between July 1 and December 1 (5 months) in 1895 (Roe & Schmidt 1897). Their catch was 358,843 pounds, mostly of carp and buffalo, which made up 85.7 per cent of the total. An unusual part of the catch was the proportion of "bass" (undoubtedly largemouth), 7,852 pounds, and walleye and "pike" (northern), each 200 pounds. The last two species are seldom taken in the Illinois River today. The catch of bass (7,852 pounds) was larger than the catch of crappies (7,405 pounds). Crappies are easily caught in hoop and fyke nets or seines; bass do not enter hoop and fyke nets readily and when surrounded with a seine they show considerable aptitude for jumping over. Inasmuch as more pounds of bass than of crappies were caught, probably many more pounds of bass were available.

Today, with water levels of bottomland lakes in the Havana region much more stabilized, it would be an impossi-

ble task to catch 7,000 pounds of bass with commercial fishing gear. This important game species is very much less abundant now than it was when the river was free to spread over its wide flood plain.

FIRST FIELD LABORATORY

Forbes was much interested in the Illinois River and in 1894 he established a biological station on its shores (Forbes 1895*a*:39) "for the continuous investigation of the aquatic life of the Illinois river and its dependent waters, near Havana."

That Forbes (1895*a*:46–7) had great breadth of vision in biological research is shown by his description of the objectives of the laboratory:

> The general objects of our Station are to provide additional facilities and resources for the natural history survey of the State, now being carried on, under legislative authorization, by the State Laboratory of Natural History; to contribute largely to a thoroughgoing scientific knowledge of the whole system of life existing in the waters of this State, with a view to economic as well as educational applications, and especially with reference to the improvement of fish culture and to the prevention of a progressive pollution of our streams and lakes; to occupy a rich and promising field of original biological investigation hitherto largely overlooked or neglected, not only in America, but throughout the world; and to increase the resources of the zoölogical and botanical departments of the University by providing means and facilities for special lines of both graduate and undergraduate work and study for those taking major courses in these departments.
>
> The Station differs from most of the small number of similar stations thus far established in this country from the fact that its main object is investigation instead of instruction, the latter being a secondary, and at present an incidental object only. It has for its field the entire system of life in the Illinois river and connected lakes and other adjacent waters, and it is my intention to extend the work as rapidly as possible to the Mississippi river system, thus making a beginning on a comprehensive and very thoroughgoing work in the general field of the aquatic life of the Mississippi Valley, in all its relations, scientific and economic.
>
> The special subject which I have fixed upon as the point of direction towards which all our studies shall tend is the effect on the aquatic plant and animal life of a region produced by the periodical overflow and gradual recession of the waters of great rivers, phenomena of which the Illinois and Mississippi rivers afford excellent and strongly marked examples.

Forbes (1895*a*:47) believed that the natural sciences should be studied out of doors and that colleges and universities of his day were not doing well by their students in botany and zoology when they confined them to laboratory studies:

> Not many years ago, biological instruction in American colleges was mostly derived from books. Of late, it has been largely obtained from laboratories instead, but several years' experience of the output of the zoölogical college laboratory has convinced me that the mere book-worm is hardly narrower and more mechanical than the mere laboratory grub. Both have suffered, and almost equally, from a lack of opportunity to study nature alive. One knows about as much as the other of the real aspect of living nature and of the ways in which living things limit and determine each others' activities and characters, or in which all are determined by the inorganic environment.

It is possible that Forbes' feeling on this point of training may have influenced the University of Illinois to require field courses at a biological station before granting a graduate degree in zoology.

Havana was selected as the location for the Illinois Biological Station because of its several advantages: Forbes liked the bluffs along the eastern shore of the Illinois River because at their bases they furnished a clean, hard sand beach suitable to work from and ideal for camping. Moreover, along these bluffs was an abundance of pure, cold spring water.

The laboratory consisted of "three well-placed rooms" in the town itself and a "cabin boat" on the Illinois River.

> The office and laboratory rooms were supplied with running water and electric light, and liberally provided with the usual equipment of a biological laboratory, consisting of compound and dissecting microscopes (Reichert and Zeiss), microtomes, biological reagents to the number of one hundred bottles, water and [paraffin] baths, laboratory glassware, tanks for alcohol, a coal stove, a kerosene stove, laboratory tables for five assistants, and a working library of about one hundred and twenty volumes (Forbes 1895*a*:48).

The cabin boat was stationed on Quiver Lake north of Havana, about 2.5 miles from town. The boat contained a well-furnished kitchen and sleeping quarters for four men. Most of the rest of the space was taken up by equipment, including limnological apparatus, seines, collecting nets, microscopes, and a small library.

The original staff of the station, in 1894, consisted of Frank Smith, who was directly in charge and whose principal interest was aquatic worms; Charles A. Hart, entomologist and curator of collections for the State Laboratory; Adolph Hempel, who worked on protozoans and rotifers; and Mrs. Dora Smith, who served as microtechnician and was in charge of the rooms in Havana. Miles Newberry, who lived in Havana, had charge of the cabin boat and acted as a general field assistant. Others who were present at some time during the first year of operation were Ernest Forbes, for 6 weeks of general collecting, Professor Thomas J. Burrill, a Mr. Clinton, a Mr. Yeakel, and a Miss Ayers, all of the University of Illinois Botany Department, who were collecting aquatic plants; a Professor Palmer, who was making chemical analyses of the water; Assistant Professor Henry E. Summers of the University Physiology Department, who photographed the region; and the staff artist, Miss Lydia M. Hart. Professor Forbes exercised general supervision over the station work, planning and following its operation.

FISHES AND PLANKTON

Within a year or so aquatic investigations were stepped up through increased use of the laboratory and cabin boat at Havana. At the beginning of this century Frank Smith (1901:567) stated in *Science* that the ichthyological survey of Illinois had received much attention during the previous 2 years and that a comprehensive report was soon to be published. He also stated that Dr. C. A. Kofoid had been studying the plankton of the Illinois River for the previous 5 years. This short statement in *Science* announced the progress being made on two of the important contemporary contributions to aquatic biology, namely Forbes & Richardson's *The Fishes of Illinois* (1908) and Kofoid's studies on the plankton of the Illinois River.

Shortly after, in an essay dealing with "statistical ecology," Forbes (1907*a*) presented a method for showing relationships between individual species of fishes and preferences of certain kinds of fishes with respect to features of the physical environment. The validity of this method depended upon the numbers of collections that were available for study. Where sufficiently large numbers of collections could be mustered, Forbes compared observed relationships with expected relationships and obtained a *coefficient of association* by dividing the former by the latter. A hypothetical example is given below:

Given species *A* and species *B* inhabiting waters in the same general land area: In 1,000 collections, species *A* occurred 159 times and species *B* 85 times. Thus, the probability that they would occur together in any single collection was 159/1,000 × 85/1,000 or 13,515 times in a million or 13.5 times in 1,000, and the probable number of these double occurrences in the 1,000 collections was 13.5/1,000 × 1,000/1 or 13.5 times. However, in the 1,000 collections, species *A* and species *B* were found together in 40; thus, the coefficient of association for species *A* and *B* was 40/13.5 or 2.96: they were found together about three times as often as was to be expected.

This same type of reasoning was applied to show relationships between individual species and the physical environment: stream, lake, pond, marsh; size of water area and water movement; bottom of mud, sand, gravel, or rock. These coefficients of association are found frequently in Forbes & Richardson's *The Fishes of Illinois*. Unfortunately about half the collections referred to in this publication were made without notes on water current and bottom materials, so that this method of showing association could be applied only to stream, lake, pond, or marsh, or to sectional distribution in the state. Thus, when Forbes & Richardson (1908:195) stated that the frequency ratios for a fish were "3.19 for the smaller rivers, 2.06 for creeks, and .58 for the largest streams," they meant that these fish exceeded expectancy in "smaller rivers" and "creeks" by about 3 and 2 times, respectively, and were considerably below expectancy in "the largest streams." A coefficient of association of 1 indicated correspondence with expectancy; a coefficient below 1 indicated a negative relationship.

This method of showing ecological relationships between species and ranges, species and local habitats, or between species themselves, allowed the use of numbers to show the degree of the relationship or lack of it. Its shortcoming was that it made no distinction between collections containing one fish of a species under consideration and those containing several hundreds or thousands.

THE FISHES OF ILLINOIS

The first edition of *The Fishes of Illinois* was published by the State of Illinois in 1908; a second edition was published in 1920. Collections and observations for this work had been started in 1876 by Forbes and had been expanded through the help of many assistants working at rather irregular intervals until 1903. Field work on fishes became nearly continuous for a few years after establishment of the Illinois Biological Station at Havana in 1894. Special recognition was given to Wallace Craig, who collected during the winter and spring seasons of 1898 and 1899, to H. A. Surface, who collected during 1899, and to Thomas Large, who made extensive wagon trips, the most important of them in 1899, to collect fishes from streams in many parts of the state. Recognition was given also to unnamed high school teachers who collected fishes under specific instructions.

Collections of fishes studied by Forbes and Richardson were taken from many sources: catches made by collecting parties with seines of various size and mesh (including minnow seines and bag seines), trammel nets, set nets (both fyke and hoop); catches made by commercial fishermen; and selections from fishes on display in fish markets. More than 200,000 specimens representing 150 species were collected from more than 450 locations in the state.

The Fishes of Illinois was published in two parts, one of which was an atlas. The larger or first part contained a section on "The Topography and Hydrography of Illinois" written by Professor Charles W. Rolfe, at that time head of the Geology Department of the University, a section entitled "On the General and Interior Distribution of Illinois Fishes," a section on "The Fisheries of Illinois," and one on the individual species of fishes found in the state. This last section made up by far the largest number of pages and included keys for the identification of fishes and a glossary of technical terms. For each species of fish were given the scientific name, common name or names, synonomy of scientific names (where such existed), and a detailed description of the fish. The description was followed by a statement of the fish's distribution within and without the state, a statement on average and maximum lengths and weights, and information on habitat preferences, food preferences, and other phases of biology. For most species, information was given on how the fish might be caught and its value (if any) as food. Many species were illustrated by black and white photographs or by colored plates painted by Mrs. Lydia M. (Hart) Green and Miss Charlotte M. Pinkerton. These colored plates were so fine that for nearly a half century none published elsewhere was their equal.

The second part, the atlas, contained maps of the 10 stream systems of the state. These maps showed the glacial geology of Illinois, localities from which collections were made, and interior distribution of 98 of the most important fishes.

As a state publication on fresh-water fishes, *The Fishes of Illinois* remained unique for a period of more than 40 years.

ILLINOIS RIVER PLANKTON

Kofoid's studies of the plankton of the Illinois River appeared as five articles in volumes 5, 6, and 8 of the *Bulletin* of the State Laboratory of Natural History. Altogether Kofoid published nearly 1,000 printed pages on the plankton of the Illinois River.

From 1895 to 1900 Kofoid was superintendent of the biological station at Havana. In 1900 he went to the University of California at Berkeley. At the time he left Illinois for California and a new position, he had published only three short papers on plankton, one dealing with methods and apparatus, one with a

Two members of the staff of the Illinois State Laboratory of Natural History making observations on the breeding habits of fish near Havana, 1910 or 1911. The box at the stern of the boat was used by observers in watching the movements of fish and in searching for fish nests and fry.

new species, and one with a new genus of plankton (Kofoid 1897, 1898, 1899). Two longer papers on plankton (Kofoid 1903, 1908), one on quantitative investigations and the other on constituent organisms and their seasonal distribution, he wrote in California. Kofoid remained on the staff at Berkeley until his retirement in 1936.

BOTTOM FAUNA

R. E. Richardson's classic studies of the bottom fauna of the Illinois River covered a period that coincided with severe changes in the biology of the river (Forbes & Richardson 1913, 1919; Richardson 1921, 1925*a*, 1925*b*, 1928). Before 1900 the Illinois was a reasonably clean river receiving very limited organic pollution from a small number of towns along its banks. By 1900 Chicago had become an important trading center and was growing rapidly. In order to get rid of the sewage and the organic waste from a number of meat packing plants of Chicago, a diversion channel was opened between Lake Michigan and the Des Plaines River, one of the headwater streams which united with the Kankakee to form the Illinois. Forbes and Richardson had collected bottom fauna in the Illinois prior to 1900, and Richardson had continued to do so after the diversion of Lake Michigan water had begun. At first the organic pollutants created a nuisance only in the upper part of the river, at Morris, Marseilles, and Starved Rock. Richardson studied the bottom fauna throughout the length of the upper part of the river in 1909, 1910, and 1911 and found that the river was nearly normal at Chillicothe and Hennepin. Above these towns it became progressively more polluted.

During the period 1900–1908 the organic pollutants acted as fertilizer, and the annual fish yield of the lower part of the Illinois increased from 11.5 million to 24 million pounds. Gradually, after

1908, organic waste from Chicago increased until the volume approached the capacity of the river to oxidize it. Diversion was increased, and the fish yield dropped; a peak diversion occurred in 1927 with a flow of 10,245 cubic feet per second (Mulvihill & Cornish 1930:57). The period of maximum pollution occurred between 1915 and 1920. From his studies of bottom fauna during this time, Richardson calculated a reduction in the total weight of bottom organisms in the reach from Chillicothe to La Grange of 34.5 million pounds, representing a potential loss of 7 million pounds of fish. By 1921 the fish yield of the river had hit an all-time low of 4 million pounds, partly from pollution and partly from extensive bottomland lake drainage. After 1922 there was some reduction of the raw sewage going into the Illinois River, and from 1924 to 1930 the yield of commercial fish varied around 10 million pounds per year.

Between 1913 and 1928, Richardson (with some assistance from Forbes on two of the early papers) published six articles in the *Bulletin* series. Because of the opportune timing of his studies in relation to the pollution of the Illinois, Richardson was able to set up a classification of seven degrees of pollution based on the presence of certain groups of aquatic organisms. These groups were often better indicators of the degree of pollution than were oxygen analyses, because the animal associations were sensitive to small increases in pollution, or to fluctuations in pollution that might be missed unless oxygen analyses were made continuously.

NEW LINES OF RESEARCH

During the second decade of the twentieth century, biologists became interested in measuring the effects of physical and chemical changes in the aquatic environment upon fish, and in the responses of the fish to these changes. From 1914 to 1925, members of the staff working in aquatic biology published papers on the suitability of bodies of water for fishes; the poisoning of fishes by illuminating gas wastes; the reaction of fishes to carbon dioxide and carbon monoxide; a collecting bottle for quantitative determination of dissolved gases; methods of measuring the dangers of pollution to fisheries; and observations on the oxygen requirements of fishes in the Illinois River. These publications were the work of Victor E. Shelford (1917, 1918*a*, 1918*b*), Morris M. Wells (1918), Edwin B. Powers (1918), and David H. Thompson (1925). They represent a new approach to fisheries studies, e.g., the use of laboratory studies to explain and expand the knowledge of the relationships of fishes and other aquatic organisms to their environments.

In the early 1920's aquatic investigations were continued on the Illinois River, where the Natural History Survey maintained a houseboat laboratory and attending boats and equipment. At this time studies were begun on the lakes of northeastern Illinois, studies that included the taking of quantitative plankton and bottom samples and collections of fishes and higher aquatic plants. In 1923, an investigation was begun also on the Rock River (Forbes 1928).

Surveys on the Illinois River, made in co-operation with the Illinois Water Survey in 1923 and 1924, showed that the normal life of the river had been destroyed by pollution as far down as Peoria Lake.

By 1927 the staff had published in the *Bulletin* 20 articles, comprising 1,856 printed pages, on Illinois River biology. These articles apparently had had a profound effect on aquatic biologists in many parts of the United States; other states were engaged in making their own lake and stream surveys, for the most part not so comprehensive as those of the Illinois River, but adequate to give some information on physical and chemical conditions and rough measurements of the fish food resources, plus inventories of the kinds and relative abundance of fishes present.

At this time (1927) the Natural History Survey had expanded its own stream survey program to include, besides the Rock River, the Hennepin Canal, the Sangamon and Kaskaskia rivers, and the streams of Champaign County (Forbes 1928). The Rock River investigation was operated from 1923 to 1927 with David H. Thompson in charge of field collecting and R. E. Richardson in charge

of the analysis of data at Urbana. Thompson and three or four other men, working steadily each year through spring, summer, and fall, collected and shipped to Urbana about 90,000 fishes of 90 species, 2,400 fish stomachs, 15,000 river mussels belonging to 40 species, 820 collections of small invertebrates, and 500 collections of plankton and algae.

Samuel Eddy (1927, 1931, 1932) worked on the plankton of Lake Michigan and the Sangamon River and on plankton collections from some sinkhole ponds in southern Illinois.

EARLY MANAGEMENT ATTEMPTS

Many of the early activities in the management of aquatic resources of the United States were based on premises which later research proved to be inaccurate or erroneous. These included such measures as stocking and the protection of fish from human exploitation through restrictions in the form of fishing seasons, length limits, and creel limits. Toward the end of the last century, James Nevin (1898:18), speaking before the American Fisheries Society, made the following statement:

> Personally I have been on the various spawning grounds of the whole chain of Great Lakes from the Gulf of St. Lawrence to Lake Superior during the spawning seasons; and I have many times watched the salmon trout, white fish and wall-eyed pike spawn in their natural way; and I am convinced that only a very small percentage of the eggs so deposited are fertilized.

This statement represented the attitude of the hatchery supervisors and most administrative personnel connected with federal and state agencies dealing with fisheries resources. As the spawning grounds of most fishes of the Great Lakes remain relatively unexplored even today, it is doubtful if Nevin was very familiar with them.

Ideas having no scientific basis often become widely accepted. For example, almost everyone has heard that one should wet his hands before handling a fish if he wants it to remain alive after release. Apparently this idea originated with G. H. Thomson, Superintendent of the Estes Park Fish Hatchery, Colorado. Thomson had cards printed with the title, "A Plea for the Fish." The cards stated:

> When removing an undersized trout from your hook, always moisten your hands before grasping the fish; otherwise the dry hand will remove the slime from the back of the trout, when it is only a question of time until fungus sets in and the fish will die.

Thomson distributed these cards to residents of all states and of many foreign countries. In 1912 he reported that at the September 21–24, 1908, meeting of the American Fisheries Society in Washington, D. C., the Society "recommended that the various state commissions educate the people by every means in their power to follow the directions given about wetting the hands" (Thomson 1913:171). He reported also that his program was endorsed by 28 fish and game commissioners throughout the United States. His idea was so widely disseminated that almost everyone has heard of it; yet there is no evidence that any attempt was made to test it through scientific experimentation.

In spite of continued emphasis on artificial propagation, new techniques were gradually discovered and put into use by researchers in the fisheries field, and these laid the foundation for modern thought in management. Borodin (1924) and Barney (1924) called attention to the value of using growth rings on scales and otoliths for determining the age of fishes; Wiebe (1929) proposed the use of fertilizers to increase plankton production; Surber (1931) discussed the use of sodium arsenite in the control of aquatic vegetation; Burr (1931) used electrical equipment to stun fish; Markus (1932) investigated the relationship between water temperatures and food digestion in largemouth bass; through tagging and recovery, Thompson (1933*a*) studied migrations of stream fishes. These and other findings laid the groundwork for modern attack on the problems of fish management.

MODERN MANAGEMENT

The modern concept and use of the term "fish management" first appeared about 30 years ago. It was suggested

(if not named) by E. A. Birge in writing about fish and their food. Birge (1929:194) stated:

> Good fishing for sport calls for the continued presence in a lake of a relatively few large individuals of the desired species, which are to be caught singly. They must be larger than the average adult. They are not caught primarily for food but for sport and as a basis for stories. A dozen half-pound bass are by no means an equivalent to one three-pounder from this point of view. But these large individuals are few in number: they are old and have come to full size very slowly. It is easy to catch them and very hard to replace them in the presence of the vigorous competition for food that goes on in a lake. *And as yet little thought and less study have been given to the needs of this specific form of conservation of fish resources.* (Italics mine.)

This statement implies a concept of management for sport fishing.

When Carl L. Hubbs described the organization of the Institute for Fisheries Research (Hubbs 1930), fisheries researchers in Michigan were working on a state-wide creel census, lake and stream surveys, stream improvement, nursery waters, fish migration, predators of fish, fish diseases, and fish growth.

At about the same time, fisheries research at the Illinois Natural History Survey (Wickliff 1933) included studies of fish migration through tagging of fish, ages and growth rates of important fishes, general quantitative determinations of plankton and bottom organisms, a comparison of fish population densities by means of standardized fishing methods, and the determination of the fish population of a lake by capture, fin marking, and recapture of adult fish.

The point at which fish management emerged as a more or less discrete discipline is not easily established. If fish management is assumed to be the art of producing sustained annual crops of wild fish for recreational use (modified from Leopold 1933), agreement as to the time management began is difficult to reach.

Modern management could hardly have made a beginning until biologists had discovered enough basic information about fishes to be able to discredit the unfounded but strongly held theories relative to the values of stocking, closed seasons, length limits, and creel limits. This basic information came from many sources and was available before 1940. In Ohio, Langlois (1937) was convinced that the closed season was worthless for increasing the numbers of bass. In Michigan, Eschmeyer (1938) had poisoned the entire fish populations of several small lakes in which the fishing was poor and had discovered an "overabundance of fish" instead of a scarcity. Also in Michigan, Carbine (1939) had investigated the spawning and hatching of nest-building centrarchids in Deep Lake and had discovered that many more young were produced than the lake could support. In Illinois, David H. Thompson had followed dominant broods of crappies in Lake Senachwine for 4 years (1933–1936) and had come to the conclusion that, while sizes and numbers of fish varied, the total weight of the population remained fairly constant. Also in Illinois, Thompson & Bennett (1939*c*) had demonstrated relationships between length of food chains and poundages of fish supported by ponds. In Alabama, Swingle & Smith (1939) had demonstrated the capacity of fish populations to expand or contract in relation to the capacity of the habitat to support them.

These researches on the dynamics of fish populations formed the bases for modern fish management. Yet old ideas were difficult to uproot. Clarence R. Lucas (1939) of the U. S. Bureau of Fisheries published a paper titled "Game Fish Management," in which he listed what he termed the "operative" techniques of fish management: (1) regulation—closed seasons, bag limits; (2) fish culture—rearing of game fishes for stocking; (3) distribution—transportation and liberation of hatchery-reared fish; (4) stream and lake improvement; and (5) predator control—the removal of predatory fishes or of fishes that otherwise interfere with the production of the game fish crop. This paper reflected exactly the old conception of operation, but under a new name.

Thompson's ideas on fish management were summarized in his contribution to *A Symposium on Hydrobiology*. In a section titled "The Fish Production of Inland Streams and Lakes" Thompson (1941) stated that production and yield were synonymous—both represented the

crop that was harvested. The total amount of fish in a lake or stream at any given time was the standing crop; when the standing crop reached "saturation" it represented the carrying capacity of the lake or stream. Thompson believed that the food resources and the carrying capacity of a body of water remained fairly constant but that the number of fish could vary widely. He reasoned that, if the weight of fish remained constant, then the removal of some fish would furnish more food per individual for those remaining, and the growth rate would increase; if more fish were planted, less food would be available per individual, and the growth rate would decrease. To further this thesis, he was able to demonstrate from his own laboratory experiments that at a water temperature of 70 degrees F. a 10-inch bass required as food an amount of minnows equal to three-fourths of 1 per cent of its body weight per day in order to maintain a constant weight; and that, at an optimum feeding rate, 2.5 pounds of minnows were required to produce 1 pound of bass.

Complete censuses of nine Illinois lakes subject to floods and indiscriminate stocking showed that, although 46 different species were present, only 10 species of fish comprised more than 1 per cent each of the total weight of all fish. The rough fish listed were redmouth buffalo, mongrel buffalo, and carp; forage fish were gizzard shad and golden shiner; catfish included only the black bullhead; the pan or fine fish were bluegill, white crappie, and black crappie; and the only game fish was the largemouth bass. These species must be considered as showing superior adjustment to the pond habitat in Illinois.

Thompson had observed cycles in fish that were the result of interspecific and intraspecific competition. The "fine" fish in Lake Senachwine (Illinois) amounted to about 50 to 55 pounds per acre, regardless of the number of fish or the area of the lake. In some years there were 10 times as many fish as in other years, and the individual fish averaged one-tenth the weight of the individual fish of other years. Large broods of crappies were produced at intervals of about 4 years, and during interim seasons they controlled the survival of their own young and the young of other species.

Thompson attempted to construct a theoretical maximum cropping rate for any water area as a percentage of its carrying capacity. He believed that the cropping rate was related to latitude (length of growing season). He estimated annual cropping rates for Vilas County and Madison, Wisconsin; Urbana and Cairo, Illinois; Memphis, Tennessee; Jackson, Mississippi; and New Orleans, Louisiana. He assumed that in northern Wisconsin about 21 per cent of the carrying capacity could be replaced each year; in New Orleans the replacement could be as much as 118 per cent; other locations fell between these extremes.

Thompson also presented the idea that fish predators were probably beneficial, although he gave no data to back this assumption.

THE LAST TWENTY YEARS

With the death of Robert E. Richardson in 1935, the aquatic biology staff of the Illinois Natural History Survey was reduced to Thompson and one full-time field assistant; however, several graduate students were working under Thompson's direction. At that time, Thompson was interested in beginning some pond management investigations. As a result of a policy of expansion for the Section of Aquatic Biology, I was employed on January 1, 1938, to work with Thompson on ponds. To gather experience in a new censusing technique that involved poisoning fish with rotenone, a technique developed by R. W. Eschmeyer in Michigan, Thompson and I made a trip to Ann Arbor, where Eschmeyer was censusing several small Michigan lakes. We helped in one of the censusing operations and were served some of the poisoned fish at the home of Dr. Carl L. Hubbs.

Returning to Illinois, we (with the help of Donald F. Hansen) began censusing ponds, one of the first of which was Homewood Lake, a 2.8-acre pond on the property of the Homewood Fishing Club on the outskirts of Decatur, Illinois. From the standpoint of public relations, the operation was a huge success. The pond contained mostly carp, buffalo, giz-

zard shad, and stunted bluegills; all day, local sportsmen slipped through the underbrush to spy on the "fish killers," but, seeing few, or no, dead useful hook-and-line fish, they stayed to help us collect the outsized carp and buffalo.

Through the able assistance of Sam A. Parr, at that time Investigator for the Department of Conservation for Macon County, we were able to census 22 artificial lakes and ponds in central and southern Illinois. One of these ponds was Fork Lake, owned by Paul S. Smith (formerly Chief Inspector with the Department of Conservation), who gave us carte blanche use of the pond. These censuses, and the studies of the fish populations that replaced those poisoned in these ponds, led to the publication of three reports on lake management (Thompson & Bennett 1939*a*, 1939*b*, and Bennett, Thompson, & Parr 1940) and two articles of the *Bulletin*, "Management of Small Artificial Lakes" (Bennett 1943) and "The Bass-Bluegill Combination in a Small Artificial Lake" (Bennett 1948).

Censuses of the ponds, most of which were poor fishing waters, brought out the fact that overpopulation and stunting and/or large numbers of fish of undesirable species, rather than a lack of fish, were the causes of poor fishing. In fact, one of the poorest ponds for fishing was found to contain 1,145 pounds of fish per acre. At Fork Lake ("The Bass-Bluegill Combination in a Small Artificial Lake"), we attempted to crop heavily the largemouth bass and bluegills in this 1.4-acre pond; we used six fyke nets of 1-inch-mesh, set with leads to completely block off the pond into sections. When these nets were fished for 10 days each month from March to November of each year for 3 years, we discovered that we could not crop the bass because they refused to enter the nets, and the constant cropping of bluegills contributed to the well-being of both species. This discovery led to the belief that anglers had nothing to fear from commercial fishing operations.

In July of 1938 Hansen was given charge of the scale collections for studying age and growth of fishes and the task of investigating the fish populations of water supply reservoirs where fishing was an important secondary function to water supply. At that time he was operating fyke nets at Lake Decatur and in other waters in order to gather material for a life history study of the white crappie (Hansen 1951).

In the late 1930's and the early 1940's federal agencies were engaged in construction projects under various work programs. The Natural History Survey was to benefit from these programs through the construction of a laboratory located on the Chautauqua National Wildlife Refuge, near Havana, and a laboratory and artificial lake in Fox Ridge State Park, near Charleston. The Havana laboratory, completed in early 1940, became the headquarters for waterfowl and fishery research on the Illinois and Mississippi rivers. The laboratory and lake in Fox Ridge State Park were completed in 1941 and became a center for studies on largemouth bass management.

About the same time the U. S. Forest Service constructed two lakes in the Shawnee National Forest in the southern part of Illinois. These were Pounds Hollow Lake, near Gibsonia, and Lake Glendale, near Dixon Springs; the latter has been used by the Natural History Survey as a study area since it was first stocked in 1940. Lake Glendale is located in a region of low soil fertility and is fairly typical of impoundments in forested lands. Hansen has found that the lake produces excessive populations of both bass and bluegills, and that fishing may be improved at intervals by the removal of part of the population of both of these species.

In 1942 Thompson and Hansen made a fish survey of the Illinois River from Channahon to the river mouth at Grafton. About 34,000 fish were studied, most of which were caught in hoop or fyke nets. Many of the carp in the upper part of the river (particularly at all stations above Henry) showed the knothead abnormality which was an indication of gross pollution. At Channahon 94.8 per cent of the catch was composed of "rough" fish, most of them carp or goldfish. In contrast, at the Creve Coeur station below Peoria, 88.4 per cent of the fish taken were "fine" fish (most of them white crappies or black crappies) and only 6.0 per cent were "rough" fish.

In December, 1943, conservation representatives from the states of Illinois, Iowa, Missouri, Minnesota, and Wisconsin, from the United States Fish and Wildlife Service, and from other interested agencies met at Dubuque, Iowa, and formed the Upper Mississippi River Conservation Committee (Smith 1949). This group was organized for the purpose of sponsoring studies of the fishery and wildlife resources of the Mississippi River from Caruthersville, Missouri, to Hastings, Minnesota. The studies were designed to serve as a basis for making scientifically sound recommendations for the management of these resources (Barnickol & Starrett 1951:267).

Field operations in the Missouri-Illinois section were begun in March, 1944, with the Conservation Commission of Missouri, the Illinois Department of Conservation, and the Illinois Natural History Survey participating. A crew consisting of four men, working from the Natural History Survey's laboratory boat *Anax*, operated test nets and other types of fishing gear at 19 stations between Caruthersville, Missouri, and Warsaw, Illinois. Two years later, in 1946, field operations were resumed in the Iowa-Illinois part of the river with the Iowa Conservation Commission and the two Illinois agencies co-operating. The survey in 1944 was begun with Thompson in charge of the laboratory boat and Paul G. Barnickol as the chief fisheries investigator for Missouri. Thompson resigned from the Natural History Survey to go with the Forest Preserve District of Cook County, and in May, 1945, Barnickol was employed to replace him. Barnickol was in charge of the crew that covered the upper part of the river from Burlington to Dubuque in 1946. In May, 1948, Barnickol was recalled to Missouri to become Head of Fisheries Research for the Conservation Commission. At that time data from 2 years of field work on the Mississippi River were only partly analyzed.

On July 1, 1948, William C. Starrett began employment by the Natural History Survey for the difficult task of working over Mississippi River fishery data collected by others. In this he had the co-operation of Barnickol; their combined efforts resulted in publication of two articles of the Natural History Survey *Bulletin*: "Commercial and Sport Fishes of the Mississippi River Between Caruthersville, Missouri, and Dubuque, Iowa" (Barnickol & Starrett 1951) and "Efficiency and Selectivity of Commercial Fishing Devices Used on the Mississippi River" (Starrett & Barnickol 1955). The first of these articles listed the fishes caught in the Mississippi River, their distribution, size range, growth rates, and other information on their biology. A total of 26,037 fish weighing 28,294 pounds were taken in 1944 and 1946. The second article presented a statistical study of the efficiency and selectivity of various types of gear used in the Mississippi River survey. The study was made for the purpose of furnishing information to those assigned the task of managing the river's commercial fishery. It included a consideration of seines, trammel nets, basket traps, wing nets, hoop nets, trap nets, and trot lines, the kinds of fish most commonly captured or trapped, the sizes of fish taken with various mesh sizes, and the comparative efficiency of several types of gear.

One of the interesting findings to come out of the Mississippi River survey was the collection of post-larval paddlefish, *Polyodon spathula* (Wal.), by Thompson and Barnickol. While minnow seining off a sand bar in the Mississippi near Cape Girardeau, Missouri, on May 29, 1944, the Thompson and Barnickol party took four paddlefish ranging in length from 17 to 26 mm. Other than the collection of seven paddlefish larvae (17–20 mm.) taken by Thompson in 1933 (Thompson 1933*b*), these are the only young paddlefish of less than 35 mm. in length known to have been collected.

These post-larval paddlefish and other paddlefish material were studied by R. Weldon Larimore (1949, 1950), who described the changes in the cranial nerves of the paddlefish accompanying development of the rostrum and gametogenesis of *Polyodon* and its relationship to practical regulation of the paddlefish fishery.

In 1948 Larimore was made a permanent member of the Aquatic Biology staff. He had already nearly completed a study on the life history and ecology of the warmouth, *Chaenobryttus gulosus* (Cuvier), a fish that was being considered as a possible companion species for largemouth bass in ponds. This study of

the warmouth was later published as an article of the Natural History Survey *Bulletin* (Larimore 1957).

During the summer of 1950 Larimore, with the help of Leonard Durham and others, began an intensive investigation of the fishes in Jordan Creek, a small spring-fed, upland stream in Vermilion County. This project marked the beginning of upland stream investigations as a continuous program of the Section of Aquatic Biology. Through the use of the electric seine and other special equipment developed for stream work, it has been possible to make both intensive and extensive studies on the ecology of stream fishes in the central Illinois region (Larimore, Pickering, & Durham 1952). The smallmouth bass, *Micropterus dolomieui* Lacépède, was found to be the most important anglers' fish in these streams. The fry of this bass were particularly vulnerable to floods on streams when the floods were accompanied by sudden changes in water temperatures. The adult bass showed well-developed homing instincts as did some other species (Larimore 1952). Tests of the value of planting 6– to 8–inch smallmouths in a stream already containing a population of smallmouth bass demonstrated that it was possible to build up numbers of these fish only temporarily. Minnows removed from a stream with an electric seine were replaced by other minnows through migration and reproduction within a period of a few months (Larimore 1955). Apparently streams are quickly repopulated even when fish are killed by drought conditions, heavy winter ice, or temporary severe pollution.

In studies of ponds and lakes, by 1945 evidence had accumulated to substantiate the idea that a lack of fish predators was an important problem to be faced in the management of these waters. Obviously, fishing was no substitute for natural predation, and much of the task of the fish manager was that of functioning as a predator of small fishes (Bennett 1947).

Fisheries technicians of the Illinois Natural History Survey using fish shocker for sampling the population of a stream. The shocker is a recent development that has been used successfully in both streams and lakes.

Studies on the effects of fish predators were begun with the placing of six short-nosed gars in a 1-acre pond containing bass and bluegills; in this pond, bluegills were constantly in a state of overpopulation. Because the short-nosed gars were unable to reproduce in the pond, their numbers were easily controlled. From this experiment, Durham (1955) expanded the investigations of fish predation to include about a dozen additional ponds containing populations of stunted fish. Using gars and cormorants as predators, he was able to show improvement in growth and size of fish and an improvement in the survival rate of naturally produced bass.

Ten years of recording catches of fishermen at Ridge Lake (Bennett 1954*a*) gave a yield figure of more than 11,000 largemouth bass following an original stocking of 435; the fact that, in the last 6 years of the 10, 155,000 bluegills had been removed following an original stocking of 129 of these fish indicated that the bluegills were not only more prolific but showed a higher survival rate than the bass. The annual hook-and-line yield of bass varied between 10.9 and 30 pounds per acre, although the lake was not considered a highly fertile one. During this time the standing crop of bass varied between 30 and 50 pounds per acre. The success of a bass spawn (and survival) was negatively correlated with the numbers of yearling fish present in the lake, particularly yearling bluegills. Young bass surviving to post schooling fry stage had about 1 chance in 35 of living to reach a size of 7 to 10 inches; natural mortality remained relatively high until the fish reached an average weight of 0.75 pound; then it dropped to less than 5 per cent per year until fish reached ages of 7 to 8 years, when the natural death rate again became high. With the system followed at Ridge Lake of culling the fish population at intervals of 2 years, the average length of bass at the end of the first growing season was 7.5 inches, at the end of the second growing season 10.8 inches, and at the end of the third 13.0 inches. The single most important finding at Ridge Lake was that a large new year class of bass could be produced at any spawning season by reducing the numbers of small bluegills in the lake prior to the spawning period. This reduction could come about through artificial culling of the fish population, or, as was later discovered, through concentrating the fish during the fall months preceding the bass spawning season by releasing a large proportion of the water from the lake and then allowing the lake to refill over winter. Studies of the effects of these water releases, or drawdowns, were begun in 1951 (Bennett 1954*b*) and they are still in progress.

Swingle & Smith (1942), working on fishes in Alabama ponds, built their management practices around a program of pond fertilization; they recommended fertilization for ponds in other parts of the country. In order to test the usefulness of fertilization as a pond management technique in Illinois, Donald F. Hansen began a testing program in ponds located on the University of Illinois Experimental Farm near Dixon Springs in southern Illinois, where soils are as poor as any within the state. After 7 years of fertilizing three ponds at various rates with complete fertilizers and using three other similar but unfertilized ponds for controls, Hansen concluded that the improvement in fishing did not justify the cost of the fertilizer, if fish were cropped by hook-and-line. The unfertilized or control ponds furnished better bass fishing than the fertilized ponds. Bluegills could be caught at a more rapid rate in the fertilized ponds, and the fish averaged larger in size. In terms of extra fish flesh produced by the fertilizer, the improved fishing cost about $1.00 per pound of fish.

Tests on various combinations of fishes in ponds have been going on for many years (Bennett 1952). The combinations used include largemouth bass–bluegill; largemouth bass–bluegill–warmouth–black bullhead; largemouth bass–bluegill–warmouth–channel catfish; largemouth bass–golden shiner; largemouth bass–redear; largemouth bass–warmouth; largemouth bass–short-nosed gar; largemouth bass–bluegill–short-nosed gar; smallmouth bass alone; and largemouth bass alone. No combination appeared to be ideal, although several combinations proved to be as productive of good fishing as the highly ad-

vertised largemouth bass–bluegill combination.

Redear sunfish, *Lepomis microlophus* (Gunther), were not reported from Illinois prior to 1945. In that year Dr. C. L. Schloemer, then located at Denton, Texas, sent a small number of adult redears to the Natural History Survey at Urbana. These fish were placed in several ponds near Urbana, but none apparently survived the winter of 1945–46. In the spring of 1946 Dr. William E. Ricker, then located at Bloomington, Indiana, furnished 30 large adult redears from central Indiana. These fish were planted in several locations; 12 were placed in a stripmine pond, near Danville, that contained largemouth bass. The redears in the stripmine pond multiplied very successfully and were the source for introductions into many lakes and ponds scattered through central and southern Illinois. Redears are now present in tributaries of the Illinois River (particularly the Sangamon) and in the Wabash drainage along the eastern border of the state, as well as in the Big Muddy system of southern Illinois. As far as is known, all of these fish originated from the 12 fish released in the pond near Danville.

In 1949 Starrett was placed in charge of the Natural History Survey laboratory at Havana, where he began a study of Lake Chautauqua, a shallow flood plain lake of some 3,000 acres belonging to the U. S. Fish and Wildlife Service and used principally as a waterfowl refuge. This lake was fairly typical of other areas in the Illinois valley that had been leveed to keep out the river, pumped dry so that they could be used for farming, and later flooded. We wondered about comparative over-all values of these areas for recreation (duck hunting and sport fishing), fish production (commercial fishes), fur production (native furbearers), and timber production (wood pulp), as contrasted with values of these areas for corn production that required government help in the construction and maintenance of levees, pumping costs and equipment, and support of corn prices. In spite of the fact that recreational values are often intangible, it soon became evident that the value of this area for fishing and recreational activities by people in the nearby industrial towns of Pekin and Peoria were much greater than the value of the corn the lake bottom would produce if the lake were drained (Starrett & McNeil 1952). In addition to studies in recreational values, Starrett has made intensive studies of the fish and bottom fauna of Chautauqua and similar lakes, and the physical, chemical, and biological factors which influence them. Through the assistance of biologists from the Illinois Department of Conservation he has collected annual commercial fishing statistics on all of the large Illinois rivers and information on native lamprey distribution.

In many of our operations during the past 20 years we have had the co-operation of the Illinois Department of Conservation: in pond management studies, stream investigations, surveys of the fishes of large rivers, and statistical studies on yields of commercial fishes. Sometimes this assistance has been in the form of funds for construction works or for physical equipment, sometimes for half-time or full-time assistants; occasionally personnel of the Department have participated in operations requiring many men for a short period of time. This co-operation has not been based on written agreement; rather, it has come about through an understanding of mutual needs and interests by certain personnel of the Department, particularly Sam A. Parr, formerly Investigator, Inspector, and Superintendent of Fisheries, now Administrative Assistant to the Director of Conservation; and William J. Harth, recently made Superintendent of Fisheries. We are grateful for this assistance and co-operation.

DIRECTION OF FUTURE STUDIES

In looking toward the future we find that some lines of research are taking shape now and others are still in the planning stages.

One program that was begun in the spring of 1958 centers on a study of such basic concepts of fish management as carrying capacity and standing crop, as well as the effects of cropping and

stocking on populations of fishes. This work is centered at the Fin 'n' Feather Club near Dundee.

At the Eighteenth North American Wildlife Conference held in Washington, D. C., in 1953, Max McGraw, President of the North American Wildlife Foundation, suggested the development of a fisheries research unit at the Fin 'n' Feather Club. It was agreed that the McGraw Foundation (with the assistance of the Illinois Department of Conservation) would develop a research unit of at least 15 1-acre ponds and provide space for laboratory and offices in the Fin 'n' Feather Lodge. When this would be accomplished, the laboratory and pond unit would be assigned to the North American Wildlife Foundation, which in turn would assign the use of the facility to the Illinois Natural History Survey and the Illinois Department of Conservation for fisheries research. Some progress had been made in physical plant construction by 1956, and on February 1 of that year David Homer Buck was employed by the Natural History Survey to give immediate supervision to the project. Soon after, Maurice A. Whitacre, biologist with the Department of Conservation, was assigned to this program to work with Dr. Buck. At the beginning of the 1958 season 11 ponds were ready for use. Eight other ponds are in various stages of construction, and as these are completed they will be stocked and added to the units in operation.

A second program, already begun, has to do with studies of the biochemistry of fishes. A chemical laboratory was developed in conjunction with the aquarium laboratories in the Natural Resources Building at Urbana, and Robert C. Hiltibran was employed on May 1, 1957, to begin biochemical investigations. Hiltibran was forced to pioneer in this field because little research had been done on fish biochemistry. He has begun by studying the "normal" enzyme systems of the bluegill, *Lepomis macrochirus* Rafinesque. Once the "normal" enzyme systems are known, Hiltibran will measure the action of various chemicals on these systems: waste products from commercial chemical processes and substances applied to aquatic areas for the control of noxious animals and plants. From these studies he may be able to suggest methods of reducing the toxicity of these chemicals to fishes and other aquatic organisms.

Prior to 1934 Wilbur M. Luce (now Professor of Zoology, University of Illinois) and David H. Thompson developed a method for stripping and fertilizing sunfish eggs, which they used to produce hybrids between species of these centrarchids. Luce raised many of these sunfish to maturity, and Thompson recognized that two of the hybrids were similar to fish pictured by Forbes & Richardson (1908) as being valid species. Recently we have revived the technique of artificial insemination of sunfish eggs in order to explore the possibility of developing hybrids for use in fish management. In 1957 William F. Childers produced viable fry from all possible combinations of crosses of bluegills, redears, green sunfish, and warmouths. Some of these combinations appear to be superior to parent types.

It is probable that within the next few decades great advances will be made in the management of fish populations for sport and commercial uses. Research basic to this management may lead to the discovery of ecological factors which control the expansion of populations of important sport species, such factors as have already been found for the largemouth and smallmouth basses. Adjustments of these factors may be, to some extent, applicable to most natural waters, but they probably will be more practical in artificial waters and in controllable natural waters. It seems reasonable to assume that progress will be made in environment control until waters can be made to produce crops of selected plants and animals much as terrestrial habitats can be made to produce wheat, rice, swine, and cattle. The development of water management may not only give ways to control the kinds and numbers of fishes but also to control the individual steps in the food chains of fishes.

Wildlife Research

THOMAS G. SCOTT

WILDLIFE was high on the scale of human values during the period of discovery and initial settlement in Illinois. When the Illinois Natural History Society was founded in 1858, most Illinoisans were self-reliant farmers who measured values in terms of the length of fences constructed, the acreage of cleared forest land, the acreage of land under cultivation, and the extent of drainage programs, roadways, and railroads. The Illinois Central Railroad line from Chicago to the junction of the Ohio and Mississippi rivers had been completed only 2 years earlier. Representative of the period are the reflections of Benjamin F. Johnson, chairman of a committee for the examination of farms and nurseries for the Illinois State Agricultural Society. In reporting on improvements in "northern Illinois" following inspections in 1859 by the committee, Johnson (1861:84) undoubtedly impressed members of the Society when he stated that

> the progress of improvement in this portion of Illinois is little less than wonderful. Ten years ago much of the country was wild, open prairie; now there is scarcely a rood of uninclosed land, except portions of the timber along the rivers and streams.

Today one cannot help but ponder why there weren't a few rebels hardy enough to stand against the surge of progress and insist that Illinois, the settlers' "prairie state," set aside a prairie park or primitive forest for future generations.

The loss of primitive areas and much of what went with them was accepted as inevitable. Even Dr. Stephen A. Forbes (1912*b*:40), a giant among the naturalists of the time, pointed out that the reduction and elimination of wildlife through settlement of Illinois by white man

> has evidently been a perfectly natural and inevitable one—as much so as the flow of the tide in the wake of the revolving moon—and immensely advantageous, also, from every point of view except that of the inadequate, incompetent and ill-adapted population which it [settlement] has reduced or suppressed.

Dr. Theodore H. Frison (1938:19), who knew and understood Forbes as well as anyone, quoted the above statement as representative of the philosophy of 1912.

DEVELOPMENT

Wildlife research, as it is recognized today, first became evident in the annals of the Natural History Survey in the late 1870's when Forbes initiated his investigation of the food of birds. O. B. Galusha (1881:238) provided insight into the conception of this research when, following Forbes' presentation of a paper on the food of meadowlarks at the January, 1881, meeting of the Horticultural Society of Northern Illinois, he observed

> that when a few of us, six years ago, met in the Normal University, as a committee of the State Horticultural Society, to inaugurate the enterprise, I had serious fears that the work was too great for accomplishment.

These studies accompanied and probably assisted in the accomplishment of the reorganization which converted the Illinois Museum of Natural History into a State Laboratory of Natural History on July 1, 1877. The reorganization was accompanied by a new conception of purpose, relieving the members of the staff of the preparation of museum displays and allowing them to concentrate on research. Although I have been unable to uncover direct evidence of it, I feel certain that the change was manipulated by Forbes and members of the Illinois State Horticultural Society. Of legislative action approved May 29, 1879, to become effective July 1, 1879, Forbes (1880*f*:1) generously reported:

> We were also directed to investigate the large and intricate subject of the food of birds, in the interests of agriculture and horticulture, $200 per annum being voted for the expenses of this work.

Forbes' research on the food of birds was to become one of the outstanding contributions to avian biology. This research

provides us with further insight into the motivations of the man who guided the program of the Natural History Survey and its parent organizations for many years (1872–1930). I have come to believe that wildlife research made such an auspicious start in the Survey program not only because of Forbes' professional qualifications but also because of his intense desire to contribute to knowledge relating to human economy and welfare. W. L. McAtee (1917:249) believed that F. E. L. Beal and Forbes were "the founders of the scientific method of studying the economic value of birds." *Birds in Their Relations to Man* (Weed & Dearborn 1903) is inscribed "To Stephen Alfred Forbes . . . whose classic studies of the economic relations of birds will long remain the model for later students."

In an early report Forbes (1882*a*:1) advised:

> The work of the State Laboratory of Natural History . . . is essentially that of a zoölogical and botanical survey of the State, conducted with principal reference to economic questions, and to the interests of public education.

Although economic consideration constituted a principal responsibility, such a responsibility is adequately met only when men are willing to meet it and are capable of meeting it. If the desire had not been there, it seems likely that Forbes and his associates would have been content to occupy themselves with the systematics and descriptive records of the native flora and fauna, and wildlife research would have had to find its beginning at a much later date. I marvel at the courage of Forbes' convictions when I consider the statement of Robert Ridgway (1901:1), a close associate of Forbes, on a prevailing attitude of the day:

> There are two essentially different kinds of ornithology: *systematic* or *scientific*, and *popular*. The former deals with the structure and classification of birds, their synonymies and technical descriptions. The latter treats of their habits, songs, nesting, and other facts pertaining to their life-histories. . . . Popular ornithology is the more entertaining, with its savor of the wildwood, green fields, the riverside and seashore, bird songs, and the many fascinating things connected with out-of-door Nature. But systematic ornithology, being a component part of biology—the science of life—is the more instructive and therefore more important.

It is unfortunate that Forbes' responsibilities were such that he could not have devoted more time to wildlife research, for he seems to have possessed an understanding of wildlife biology which was much in advance of his time. In a single early paper (Forbes 1880*a*), a number of observations were made which, by their earliness, seem prophetic of views which are credited to relatively recent times. Current beliefs on predation may be seen in *"the annihilation of all the established 'enemies' of a species would, as a rule, have no effect to increase its final average numbers"* (Forbes 1880*a*:11).

Forbes (1880*a*:8) recognized a need for an understanding of animal populations long before they received serious study. Of this he wrote:

> Our problem is, therefore, to determine how these innumerable small oscillations, due to imperfect adjustment, are usually kept within bounds—to discover the forces and laws which tend to prevent either inordinate increase or decrease of any species, and also those by which widely oscillating species are brought into subjection and reduced to a condition of prosperous uniformity.

It is apparent that this view implies population management in the modern sense. Further implications of management may be seen in the following statement by Forbes (1880*a*:4):

> It is also plain that if man understands clearly the disorders which arise in the system of Nature as a result of the rapid progressive changes in his own condition and activities, and understands also the processes of Nature which tend to lessen and remove these disorders, he may, by his own intelligent interference, often avoid or greatly mitigate the evils of his situation, as well as hasten their remedy and removal.

Forbes (1880*a*:9) seems to have been well on the way toward an understanding of density dependent factors as used by today's students of animal populations, as well as modern views on predation, when he wrote: "The fact of survival is therefore usually sufficient evidence of a fairly complete adjustment of the rate of reproduction to the drains upon the species." That his understanding of the effect of density dependent factors on animal populations was astonishingly well advanced is evident in his (Forbes 1882*b*:122) reasoning that excessive populations are, "in one way or another, self-

limiting." Earlier he (Forbes 1880*a*:5) had written that "as a general rule, the rate of reproduction is in inverse ratio to the grade of individual development and activity; . . ." The "grade of individual development and activity" refers to the degree of evolutionary progress from a primitive form. Forbes (1880*a*:11) seems to have been grasping at the role of density independent factors in population control when he observed that the "real and final limits of a species are the *inorganic* features of its environment,—soil, climate, seasonal peculiarities, and the like."

What is today recognized as wildlife research continued to develop under Forbes' guidance in the form of bird censuses. The results of these censuses are classics in American ornithology. They constituted the first extensive, quantitative investigations of bird numbers, or of any wildlife population for that matter, and introduced a census technique.

Despite Forbes' modern views, there is little evidence that he promoted wildlife management to any great extent. The thinking of Forbes (1912*b*:40) with respect to game management, despite earlier, more promising views, seems to have been limited to the encouragement of restrictive laws, as evidenced by the following: "Our resident game birds would all have been gone long ago if it had not been for the restraints of law put upon the activities of the hunter . . . " Forbes (1912*b*:46) made a plea for the Illinois Academy of Science to support by resolution the "Anthony bill" (Migratory Bird Act of 1913), then under consideration in the House of Representatives. It should be remembered that legal protection was virtually the only management concept of the times.

ORGANIZATION

Game research in the modern sense began to receive recognition in the Natural History Survey's program in the early 1930's. Probably stimulation was received from the federal government's emphasis on conservation of natural resources, an emphasis that accompanied the search for work during that period of national economic emergency, and from the influence of Herbert L. Stoddard (1931) and Aldo Leopold (1931, 1933). By that time, progressive leaders in the field realized that restrictive regulations and game farms were not meeting wildlife management needs. Also, it had become apparent that game populations could be managed wisely only when management practices were based on a fund of pertinent and precise knowledge. Frison, who became Acting Chief of the Illinois Natural History Survey upon Forbes' death on March 13, 1930, and then Chief on July 1, 1931, was among these leaders. An enthusiastic hunter, Frison had a consuming interest in game management. Wildlife research was recognized in the organizational structure of the Natural History Survey for the first time when Frison (1938:31) established a Section of Game Research and Management on July 1, 1934. Dr. Ralph E. Yeatter, one of the nation's first game specialists, was employed in this section.

Frison initiated formation of the now well-established Midwest Wildlife Conference, and the first meeting was held in Urbana on December 5, 6, and 7, 1935. This meeting, known as the North Central States Fish and Game Conference, was the first regional conference of wildlife technicians in the United States. Frison (1938:27) described the conference as

> essentially a fish and game clinic at which scientists from all the north-central states, without being dominated by administrators or the political type of conservationists, freely discussed wildlife management practices in an effort to winnow out the chaff from the wheat, to coordinate such researches and to orientate scientific studies of wildlife resources in such a way that demonstrable sound management practices would result.

By 1936 Frison (1938:31) had concluded that experimental wildlife areas were needed for the purpose of testing management theories under practical conditions, a need which has still not been adequately met. A Section of Wildlife Experimental Areas was listed on the staff page of the *Bulletin* from March, 1938, to September, 1945. On June 1, 1938, a special program dealing with forest problems in game management was undertaken by Dr. Lee E. Yeager, who had joined the staff in the Section of Forestry.

Following passage of the Federal Aid in Wildlife Restoration Act in 1937, Frison undertook to arrange a co-operative wildlife research program with the Illinois Department of Conservation and the United States Bureau of Biological Survey (now the U. S. Bureau of Sport Fisheries and Wildlife). The first co-operative project, "Illinois Fur Animal Resources Survey," with Louis G. Brown as leader, was approved on May 23, 1939 (Frison 1940:8–9). In 1940 a Cooperative Wildlife Restoration Program, embracing interagency co-operation in Federal Aid, was listed on the staff page on the section level. Of this program Frison (1940:8) recorded: "General program planning and supervision of projects dealing with wildlife research have been assigned to the Chief and various other members of the scientific staff of the Illinois Natural History Survey." In evidence of its success this co-operative arrangement has survived through the years, and in 1956 the Conservation Advisory Board (Mann 1956:6) included, in a statement of policies, provisions for the development of an adequate game research program "through cooperation with and support of the Illinois Natural History Survey Division."

Thus, by 1940 Frison had stimulated and obtained support for a wildlife research program which involved the primary activity of four sections within the Natural History Survey's organizational structure. This compartition of the work was believed by those who knew Frison to have grown out of his extreme interest in wildlife resources and his desire to give each facet of study his personal direction.

There was little change in the wildlife research program while Dr. Leo R. Tehon served as Acting Chief, December 10, 1945, through February 28, 1947, following Frison's death on December 9, 1945.

Dr. Harlow B. Mills, who became Chief on March 1, 1947, proved to have the same consuming interest in wildlife research which had marked Frison's leadership. In August, 1947, the Cooperative Wildlife Restoration Program was more properly designated Cooperative Wildlife Research, and a Section of Migratory Waterfowl was added to the organization. The latter section had been discontinued by June, 1948.

Dr. Thomas G. Scott was appointed the Head of the Section of Game Research and Management on January 1, 1950. He was the first person to bear this title. Soon after that date, arrangements were made for formal co-operation in wildlife research between the Natural History Survey and Southern Illinois University, where Dr. Willard D. Klimstra was guiding the program in wildlife research and education. That part of the Survey's organizational structure, Co-operative Wildlife Research, which embraced the Federal Aid research, was dropped, and the personnel and administrative responsibilities of this program were transferred to the Section of Game Research and Management in March, 1950. On September 1, 1954, the Section of Forestry was abolished, and all of its wildlife activities and personnel transferred to the Section of Game Research and Management. Thus, by 1954 all wildlife research had been assigned to one section. The name of the section was more appropriately designated the Section of Wildlife Research on May 1, 1956. The area of research assigned to the section was similar to that of its predecessors: the biology of warm-blooded vertebrates except that associated with taxonomy and classification. In 1956 the extensive activities of the section were divided and were assigned to branches to provide for more effective supervision. The new branches were Nongame Birds, Upland Game Birds, Migratory Game Birds, Mammals, Co-operative Wildlife Research, and Environmental Research.

As the first century of the Illinois Natural History Survey ends, interest in wildlife resources of Illinois and other parts of the United States is greater than ever before. The number of people engaged in the wildlife management profession is at an all-time high and promises to go higher. Frison's North Central States Fish and Game Conference has so grown in attendance and extent of interest that its facilities no longer seem to meet the needs seen at the outset. As a consequence, there is a tendency for specialists to draw apart in committees or "councils." Some of those who look

into the future to a greatly increased human population and a more intensive land-use program seem to be returning to Forbes' "let's face the inevitable" philosophy of 1912. They seem willing to stand by while part of our wildlife heritage, the prairie chicken, for example, goes down the drain. Foreign game birds are being feverishly investigated and released with the hope of finding species which will supplement populations of native game birds being reduced by a changing habitat. In anticipation of the time when shootable wild game populations will no longer meet the demand, there are the programs for pen-rearing game birds to be released under the gun. The rooting out of osage orange hedges throughout the state is symbolic of the cancerous-like growth in activities designed to bring increasing amounts of land into agricultural, residential, or industrial use. Public realization of the vital importance of habitat in the management of a wildlife resource is showing growth; however, the area of desirable wildlife habitat, especially that for upland species, is continuing to shrink. Thus, the most perplexing problem of the wildlife manager in Illinois today is that of developing and protecting suitable habitat.

RESEARCH CONTRIBUTIONS

A review of outstanding contributions made to wildlife biology and conservation by employees of the Illinois Natural History Survey and its parent organizations will aid understanding of work in these fields during the first 100 years. A few publications by non-Survey personnel are cited to provide perspective or to recognize Survey publications by workers who were not employed by the Survey.

Birds

Contributions on the biology and conservation of birds may be conveniently grouped into three classes: those for nongame, those for upland game, and those for migratory game birds.

Nongame Birds.—Of the meadowlark, Forbes (1881*b*:234–5) wrote:

> He is first cousin to the Indian, the prairie-wolf and the badger, but with a better knack than they at adapting himself to the new life of civilization. He is a perfect reflection of his most constant surroundings — with a bosom of prairie butter-cups, a back like the dead grass of autumn, and a song that harmonizes well with the whistling of prairie winds.

This colorful description reveals something of Forbes' deep feeling for birds. Sentiment, however, is not evident in his systematic and painstakingly conservative evaluations of the place of birds in an economic scheme of things.

Forbes' research on the food of birds constituted a milestone in ornithological history. "No part of the recent work of the Laboratory has excited a wider interest than that relating to the food of birds" (Forbes 1880*f*:7). This work established Forbes among contemporary ornithologists as the ranking authority on the insect food of birds. Dr. Elliott Coues (1883:105) believed him to be "Our best authority upon the insect food of birds . . . " Drs. Clarence M. Weed and Ned Dearborn (1903:19–20) considered Forbes' publications on the food of birds to be "classic papers" and "the basis for the modern development of economic ornithology."

The findings of Forbes' studies of the food of birds appeared in a number of papers. The most substantial contributions, however, were brought together in two papers (Forbes 1880*d*, 1883*a*). The first dealt with the food of certain birds in the families Mimidae and Turdidae. The second reported observations on the regulative action of birds feeding on an excessively high population of canker-worms and vine leaf chafers. The latter paper, "The Regulative Action of Birds Upon Insect Oscillations," was approved by Indiana University in fulfillment of Forbes' thesis requirements for the Ph.D. degree granted in 188+ (letter of May 2, 1952, from E. Lingle Craig, Reference Librarian, Indiana University, to Marguerite Simmons, Librarian, Illinois Natural History Survey). Of lesser importance were notes on the food of the meadowlark (Forbes 1881*b*), the English sparrow (Forbes 1881*c*), and the kinglets (Forbes 1883*d*).

The scope of these investigations may be seen in the following report (Forbes 1882*a*:5–6):

> The collection designed to illustrate the food of birds has been more than doubled in the last two years, and now numbers over six thousand stomachs, representing about two hundred species. Eight hundred and eighty of these have now been exhaustively studied, . . .

Unfortunately, the analyses were apparently discontinued at this point, for there were no more publications on the food of birds, and the annual reports of the State Laboratory of Natural History indicate that nothing further on this subject was done.

Forbes' evaluations of his findings on the food of birds indicated awareness of the need for giving special consideration to the high mobility of birds, food preferences, density effects, ability to diversify diet, and the importance of seasons, geographic location, and specific ecological circumstances. Forbes (1880*c*:122–3) described what appears to have been a new method of evaluating proportions of food in the stomachs and crops of birds, a technique which is used yet today. He (Forbes 1881*a*:107) also showed himself to be aware of the importance of sample size and made crude tests for significance by comparing the results of analyses of small samples with those of larger samples to determine whether there were important departures in the pattern of the diet.

Because Forbes believed that the numbers and kinds of birds in specific habitat categories needed to be known before their economic importance could be evaluated, he encouraged studies based on systematic censuses, which were carried out in 1906, 1907, 1908, and 1909. These studies are classics in American ornithology and introduce a new censusing technique for birds. I believe them to be the first extensive statistical analyses of bird populations in this country. Although the results of these surveys are presented in six papers, two of them contain most of the data (Forbes & Gross 1922, 1923). Unfortunately, a final paper in which it was hoped to present all of the findings for each species was never published. Plans for this paper are described (Forbes & Gross 1923:397) as follows:

> It has been our general plan to work at first with broad strokes of the full brush, refining upon our neutral background by degrees and ending, as we hope to do in a paper following the present one, with the final details for each species taken up separately and followed all over the state and around the year.

Forbes' experience with plankton surveys guided him in the development of the census technique devised specifically for the bird surveys (Forbes & Gross 1921:1). Forbes believed that two men walking abreast could identify and count all of the birds flushed by them or crossing their track on a strip 150 feet wide in relatively open country but 60 feet wide in heavier cover, such as orchards, open woods, and patches of close shrubbery. This census technique was pictured (Forbes & Gross 1921:1) as a

> huge net a hundred and fifty feet wide, drawn in straight lines across every kind of crop or other surface vegetation, by which all the birds found there should be caught and held until they had been identified and counted.

Results were obtained by application of this census technique during the summers of 1907 and 1909 (Forbes & Gross 1922:189, 199): the census indicated an average of 852 birds per square mile for the state as a whole. The numbers of birds per square mile showed a striking increase of 54 per cent from the 1907 figure to that of 1909. Orchards were found to have the greatest numbers of birds per square mile, 3,943; yards and gardens were a close second with 3,418. The statewide number of birds per square mile in winter was estimated from data collected in 1906 and 1907 to have been 520 (Forbes & Gross 1923:398).

Dr. Frank Smith (1930) prepared a thorough and useful paper dealing with a chronology of the spring migration of 221 species of birds through Urbana from 1903 through 1922. The objective of the study was to determine whether there was a correlation between migration flights of spring migrants and certain kinds of weather. Smith (1930:112) concluded:

> A careful study of the weather maps during the time when records were being made revealed that the greatest migratory activity in spring occurred at times when the weather maps showed an area of low barometric pressure approaching from the west, with the south winds and rising temperatures which normally accompany such movements.

The monograph by Dr. Alfred O. Gross (1921) on the dickcissel must be

classified as one of the outstanding early studies of its kind. I was especially impressed by his statistical evaluation of the abundance of the bird in relationship to habitat categories. He found that hayfields constituted preferred habitat; within this classification, clover and alfalfa were preferred to other kinds of hayfields

Ornithologists in winter equipment ready to set out on a collecting expedition for the Illinois State Laboratory of Natural History, about 1906. At the right is Alfred O. Gross, and with him is Howard A. Ray.

available at the time. Perhaps it is also appropriate to mention the paper by W. E. Loucks (1894) on the prothonotary warbler. While the paper is unfortunately more subjective than objective, it constitutes a colorful record of the findings of a talented observer.

The participation of the Natural History Survey staff in the effort to obtain legal protection for all hawks and owls in Illinois merits attention. At the urging of Dr. David H. Thompson, Director Ralph Bradford of the Illinois Department of Conservation sought and obtained legislation, effective July 1, 1929, to protect all hawks and owls except the great horned owl, the goshawk, sharp-shinned hawk, Cooper's hawk, duck hawk, and pigeon hawk.

Members of the Natural History Survey staff continued to advocate protection of hawks and owls, and, effective July 1, 1941, protection was obtained for all but the great horned owl. This condition prevailed until July 1, 1947, when, for some unexplained reason, the Cooper's and sharp-shinned hawks were removed from the protected list. In 1956 and 1957 a new effort, spearheaded by Elton Fawks, representing the Illinois Audubon Society, was made to obtain protection for all hawks and owls. I presented a paper at the annual meeting of the Natural Resources Council of Illinois on October 20, 1956; this paper has been credited with having much to do with winning the support of the Council and member clubs for the needed legislation (Fawks 1957:1). I read a second paper at the annual meeting of the Illinois Audubon Society in Rockford on May 18, 1957, at the time the bill was before the legislature (Bayless 1957:3), and I made an appeal for further support in the official publication of the Illinois Federation of Sportsmen's Clubs (Scott 1957). Dr. Richard R. Graber assisted this effort by analyzing data on hawk and owl numbers reported in the Christmas counts of the Illinois Audubon Society for the past 50 years and by demonstrating that some species had declined in numbers and that there was no evidence of need for measures designed to reduce hawk and owl populations. The bill proposed for the protection of hawks and owls, House Bill No. 1063, included protection also for the crow, blue jay, cowbird, and grackle by the time it had passed the General Assembly, June 27, 1957, and was signed into law by Governor William G. Stratton, July 8, 1957 (Illinois General Assembly 1957:1937–8). The bill provided for amending Section 21 of the Game Code to define all hawks and owls as protected species but, as a consequence of an oversight, Section 36 of the Code was not amended to include the Cooper's hawk, the sharp-shinned hawk, and the great horned owl among the hawks and owls which were unlawful to have in possession at any time.

The Prairie Chicken.—If the Illinois farmer of the 1860's had taken time from his backbreaking work to sit down and figure out the cause of the enormous populations of prairie chickens which he alternately cursed and blessed, perhaps he would have seen that he had just completed a gigantic habitat development project for upland game birds. He had extended the range of the chicken by clearing the timberland, and he had provided thousands of food patches by establishing grainfields.

From these high populations, the prairie chickens declined in numbers with the gradual increase in grain farming and the accompanying reduction of grassland. The hunting season on prairie chickens was closed in 1903 and was not opened again until 1911. The relaxation of hunting regulations at this time undoubtedly followed an increase in the population, probably associated with "The Indiana 'Comeback' of 1912" (Leopold 1931: 172). Contemporary data for Illinois had apparently not been called to Leopold's attention because Forbes (1912*b*: 47–8), reported that

> prairie-hens—thanks to our protective laws—are now to be seen in at least seventy-four counties, so abundantly in some that farmers are beginning to protest against their further increase because of the amount of grain which they devour.

The records on which this statement is based remain in the files of the Illinois Natural History Survey. Re-examination of them brings out the conservativeness of Forbes, for they indicate that the reporting observers had found a few prairie

chickens in all of Illinois' 102 counties except 10 (Yeatter 1957:8). Despite an exaggerated confidence in protective regulations, Forbes (1912*b*:48) recognized the basic environmental factor which was limiting the prairie chicken population because he advised that:

> The very country in which it was formerly most numerous—that is, the open prairie—is now least favorable to it because of the agricultural operations, which disturb and destroy it during its breeding season.

When it again became evident that the prairie chicken population was endangered, Director Bradford of the Department of Conservation, at the urging of Dr. Thompson of the Natural History Survey, obtained legislation, effective July 1, 1933, to prohibit the taking of the prairie chicken at any time. No open season on this bird has been permitted since that date.

It seems fitting that, with the upsurge of interest in wildlife conservation in the 1930's, one of the first comprehensive studies of a game species to be undertaken in Illinois was concerned with the prairie chicken. The valuable monograph (Yeatter 1943) resulting from this study includes data on early distribution, range, life history, populations, mortality causes, food habits, and management. I believe that this publication was the first to direct attention to the importance of grass-seed farming in the management of prairie chickens. Yeatter (1943:409) advised that areas harboring a few prairie chickens

> might be converted into good chicken range by leasing, and converting to refuges for a term of years, 25 per cent of the total land in the form of 20-acre, 40-acre or larger tracts of the poorer farm soil throughout each township.

In a later publication Yeatter (1957:8) revised his recommendation on grassland refuges to a minimum of 40 acres in each square mile of farm land.

When unusually large numbers of young prairie chickens were found dead on a study area in Jasper County in 1935 and 1936, an investigation of parasites as a possible cause of these deaths was undertaken (Leigh 1940:186). Tapeworms were found in 10 of 14 partly grown birds and in not one of 14 adults which were collected in Jasper and Richland counties in the summers of 1936 and 1937.

> Because cestodes of a previously undescribed species of *Raillietina* occurred in 10 [actually 9] of 14 young birds and in 4 cases were so numerous or so large as to occlude the lumen of the greater part of the small intestine, they should not be overlooked as a factor in prairie chicken mortality (Leigh 1940:188–9).

Shelford & Yeatter (1955) interpreted year-to-year population fluctuations of male prairie chickens during a period of 18 years on the study area near Hunt in Jasper County, Illinois, in relation to weather and climate. Field observations indicated that the period of the late stages of development of the reproductive cells during April, the period of egg-hatching in June, and the period when young prairie chickens were 4 to 8 weeks old were critical times in the reproductive cycle of prairie chickens. Many trials in which various weather records were used showed that the population level tended to respond to only two weather combinations: (1) rainfall and sunshine in April and (2) rainfall and temperature in June. Reproduction was most successful in seasons when April rainfall averaged 2–5 inches and when 48–64 per cent of the possible hours of sunshine were experienced. As the amounts of rainfall and sunshine varied from these optimum limits, reproductive success became progressively lower.

Thus, the prairie chicken in Illinois has passed from the enormous populations of Civil War times to small, scattered colonies, in only 24 counties in 1957 (Yeatter 1957). It seems evident that the prairie chicken will soon become something of the past in Illinois unless a positive program of management such as that being proposed at the present time saves them.

The Bobwhite Quail.—To the upland bird hunter of Illinois, events which established the present boundaries of Illinois proved inadvertently provident, for they led to the inclusion of excellent quail range over the southern one-third of the state as well as what was to become fairly good pheasant range in the northern one-third.

Illinois has the distinction of being the locale of the first systematic and extensive

census of quail populations. These censuses were carried out during the period 1906–1909 by a strip-census technique (Forbes & Gross 1921, 1922, 1923). The increase in the density of quail populations from north to south in Illinois was just as clearly marked in the findings of Forbes and Gross as it is today. Censuses during the summers of 1907 and 1909 revealed quail populations of 21 birds on 7,966.5 acres or 1 bird per 379.4 acres in northern Illinois, 53 birds on 5,823.9 acres or 1 bird per 109.9 acres in central Illinois, and 241 birds on 5,527.2 acres or 1 bird per 22.9 acres in southern Illinois (Forbes & Gross 1922:191, 197).

A similar distribution of quail population densities was evident in the winter counts made during the period November 23, 1906, through February 21, 1907, when 180 quail were counted on 1,422.4 acres or 1 bird per 7.9 acres in southern Illinois and 54 on 4,956.0 acres or 1 bird per 91.8 acres in central and northern Illinois combined (Forbes & Gross 1923: 398, 400). The data for the counts made during the summers of 1907 and 1909 indicated an increase in quail populations for the state as a whole; 91 quail were counted on 7,693.6 acres, 1 bird per 84.5 acres, in 1907 and 224 birds on 11,624.1 acres, 1 bird per 51.9 acres, in 1909 (Forbes & Gross 1922:191).

The densities of quail populations were recorded by general habitat category. In a special study, August 19 to September 15, 1908, in which orchards in the vicinity of Centralia and Olney received special attention, 774.5 acres of orchard and 594.5 acres in other habitat categories were censused; 356 quail, 1 per 2.2 acres, were counted in the orchards and 32, 1 per 18.6 acres, outside the orchard area (Forbes & Gross 1921:5, 7). The importance of undisturbed grassland to the management of quail was suggested by Forbes & Gross (1921:3) in their consideration of reasons for the high densities of quail in orchards when they concluded: "Evidently it is not the trees that attract it, but the cover afforded by an undisturbed growth of grass and weeds between the rows."

Following these early censuses, there was a pause in the attention given quail by Natural History Survey researchers. The species did not become the subject of further study until the hunting season of 1936, when 141 quail were collected in an investigation of helminth parasites by Leigh (1940:186, 190), who concluded "that the quail of Illinois are not so heavily infested with the diversity of helminth parasites as are the quail of the southeastern states." In the summer of 1938 a brief investigation of quail productivity in Calhoun County was carried out by Bellrose (1940:10), who pointed out the importance of undisturbed grassland and concluded that the possibilities for providing suitable nesting sites were greatest in apple orchards.

In 1948 and 1949 the hatchability of the eggs of the bobwhite was compared with that of the eggs of pheasants after experimental exposure to temperatures of 62, 73, 78, 83, and 88 degrees F. for a period of 7 days to simulate preincubation exposure (Yeatter 1950:529). Yeatter (1950:530) concluded that "No significant reduction of hatchability of the bobwhite eggs by high temperatures was evident."

Bobwhite quail were investigated from 1948 to 1954 on the Crab Orchard National Wildlife Refuge, in Williamson County, to determine what types of cover importantly influenced the abundance of quail (W. R. Hanson & R. J. Miller unpublished MS). Quail abundance was significantly correlated with the amount of "edge" between cultivated fields and brushy pastures. Twenty-five linear miles of multiflora rose hedges, planted on an area of about 5.5 square miles, failed to increase the numbers of quail.

A most important step was made in the direction of a thoroughgoing investigation of the biology of the bobwhite quail in Illinois by the signing, on October 3, 1950, of a memorandum of understanding providing for co-operation between the Natural History Survey and Southern Illinois University. The observations and impressions (Scott & Klimstra 1954) obtained during a trip to quail management areas in southeastern United States for the purpose of co-ordinating this co-operative program of research in Illinois with work elsewhere are believed noteworthy and cover the following subjects: hunting, management of habitat, and populations.

The co-operative research has involved nearly all phases of quail biology and an experimental habitat management program. Among the important contributions are two studies, one on the diet of quail (E. J. Larimer unpublished MS) and the other on quail populations on an unmanaged area. The second study has emphasized once again the great importance of undisturbed grassland to quail productivity and provided evidence of the amount and distribution of undisturbed grassland required to insure high quail productivity. The quail investigations have received outside financial assistance from Max McGraw, A. E. Staley, the North American Wildlife Foundation, and the United Electric Coal Company; the coal company also has made available extensive landholdings for experiments with habitat management.

The Ring-Necked Pheasant.—Although the attempt to establish pheasants in Illinois had gotten under way in the 1890's, this state's biological researchers were apparently unimpressed with it as a subject for investigation. In a discussion of the animal resources of the state, Forbes (1912*b*:48) advised that he had not had time to appraise efforts to improve "the composition of our fauna by the introduction of exotic species." Little or no attention was given pheasants until Leigh (1940:190) made his limited survey of the parasites of pheasants collected during the hunting season in 1936. During the summer of 1938 Bellrose (1940) made nesting studies and population estimates of pheasants in the southern part of Calhoun County, which is outside the recognized range of pheasants in Illinois. His observations (Bellrose 1940:9) appeared to indicate that this population had been maintained by repeated releases.

Intensive investigations of the ring-necked pheasant did not get under way until April 1, 1946, when the Illinois Department of Conservation, the U. S. Fish and Wildlife Service (now the U. S. Bureau of Sport Fisheries and Wildlife), and the Illinois Natural History Survey entered into a co-operative project with Federal Aid funds. Dr. William B. Robertson (1958) described the results of this co-operative research from inception to December 31, 1951, together with an account of the early history of pheasants in Illinois and an analysis of the factors limiting the pheasant range.

His report constitutes the first comprehensive account of pheasant research in Illinois. It is a valuable historical record of early introductions of pheasants and the development of hunting regulations. Curves based on an annual average of over 300 dates of the hatching of eggs in nests were constructed and analyzed for effects of photoperiod, weather, and farming operations. Observations made on the breeding behavior of marked birds released in Kendall County are believed to be especially enlightening. Of particular note to students of populations and behavior was the observation that adult hens tended to become associated in the harems earlier than did juvenile hens. One of the earliest attempts to eliminate bias from evaluation of the worth of artificial stocking is reported upon in the paper. Robertson (1958: 129) concluded "that 35 to 50 per cent of the cock pheasants in summer releases in Illinois were bagged in the succeeding hunting season. The recovery rate for spring-released adult cocks, estimated by similar methods, was only 6.1 per cent." In Livingston County a release of 1,000 adult hens in September of 1948 resulted in a survival of about 50 per cent to May, 1949; released hens made up one-third of the hens on the area at the latter date. It was found that about 33 per cent of the broods seen the following summer were accompanied by released adult hens. In Kendall County the effect of a release of 500 adult hens in August and 1,000 juvenile hens in November and December of 1949 was evident when it was seen that 25 per cent of the broods in 1950 were accompanied by released hens.

There has been much speculation as to the reason pheasants have failed to become established in southern United States. During brood studies beginning in 1937, Yeatter (1950:529) observed that the hatchability of pheasant eggs frequently declined in late spring in east-central Illinois, which is on the southern edge of the pheasant range. This observation suggested that high environmental temperatures at the time of egg-laying constituted a critical limiting factor. In 1948

and 1949 Yeatter (1950:529) compared the effect of temperature on paired lots of pheasant and quail eggs during a 7-day preincubation period and stated "that the hatchability of pheasant eggs was reduced by heat exposures, the reduction increasing with the higher temperatures." It was concluded that this vulnerability of pheasant eggs to high air temperatures constituted an important barrier to the southern distribution of pheasants, and it was suggested that pheasants in the southern Pacific Coast and Rocky Mountain regions might be more tolerant of higher temperatures. Recent experiments by Yeatter lend strong support for this surmise (Yeatter unpublished MS).

At the present time, the Illinois Department of Conservation, the Illinois Natural History Survey, and the U. S. Bureau of Sport Fisheries and Wildlife are co-operating in a comprehensive and intensive investigation of the ring-necked pheasant. This research is being carried on by Dr. William R. Hanson, Dr. Frederick Greeley, Jack A. Ellis, and Ronald F. Labisky and involves study of range-limiting factors, the biology of pheasants within the established range, and experiments with the establishment of self-maintaining populations outside the existing range.

The Canada Goose.—Canada geese wintering on the islands and bars in the Mississippi River from Chester, Illinois, southward to Cairo must have found the fight for survival during the early part of the twentieth century severe indeed. The conservationists who, with the objective of providing for pole-and-line fishing, arranged for the purchase of Horseshoe Lake, an ancient oxbow of the Mississippi River in Alexander County, by the Illinois Department of Conservation in 1927 were unaware of the part they would play in protecting this goose population and setting the stage for its future growth. About 1,900 Canada geese wintered at Horseshoe Lake, now famous as the Horseshoe Lake Game Refuge, during the first year. During the winter of 1957–58, about 225,000 Canada geese wintered in southern Illinois; these geese constitute a resource which has been estimated to contribute about $1,500,000 annually to the economy of southern Illinois.

The refuge was soon surrounded by commercial shooting clubs, and a problem which attracted national interest was created. Leopold (1931:206) wrote: "The question of whether public refuges should be surrounded by public shooting grounds is frequently debated. Horseshoe Lake in Alexander County, Illinois, is a good place to study the question." Nevertheless, it was not until 1939, when about 40,000 (the same number estimated to have been killed in southern Illinois in 1957) geese were wintering at the refuge, that the annual kill and the need for knowledge on which to base intelligent control became alarming enough to attract researchers.

In 1940 Arthur S. Hawkins initiated the Illinois Natural History Survey's long-time research program on Canada geese (Hanson & Smith 1950:70), and in 1941 geese were banded in the area for the first time by Hawkins and John M. Anderson. The initial effort was necessarily directed toward the development of efficient trapping and handling methods (Hanson 1949*a*), and colored bands were tested on geese (Balham & Elder 1953) for the first time.

The massing of so large a portion of the Canada geese of the flyway at Horseshoe Lake created a unique opportunity for population research. Practical methods for aging geese were worked out for the first time (Elder 1946; Hanson 1949*b*, 1953*a*), and these methods, which were used for measuring the composition of the population, formed the basis for all subsequent investigations. Elder's (1946:94–8) analysis of the weight of Canada geese by sex and age constituted the first analysis of its kind for geese. Hanson (1949*b*) developed techniques for placing Canada geese in three age categories (juvenile, yearling, and adult), thus making possible a considerable advancement in the understanding of population mechanics in these birds.

A definitive investigation of the biology of the Canada goose constitutes the long-range objective of the research on this species. Early findings were reported in a 144-page article (Hanson & Smith 1950). In this article the four flyway populations of Canada geese breeding in the general area of Hudson Bay were

revealed for the first time. The breeding range, migration routes, wintering grounds, and populations were discussed for each flyway population. Later, the South Atlantic Flyway population was treated in greater detail (Hanson & Griffith 1952). Observations on the relation of hunting losses to the age structure of the population wintering at the Horseshoe Lake Game Refuge proved especially useful. The heavy kills of immature geese in the first half of the 1940's not only altered the age composition of the flock but reduced the average longevity of these geese as shown by life survival indices, the first constructed for a species of waterfowl (Hanson & Smith 1950: 172–88). A recent 3-year study of the kills of Canada geese by the natives of the Hudson-James Bay region has established the location and size of these hunting losses with exactness (Hanson & Currie 1957).

The Canada geese on the Horseshoe Lake Game Refuge provide a unique opportunity for study of behavior. The adult males of the largest families usually dominate males leading smaller families, and the social rank of the adult female is determined by that of her mate (Hanson 1953*b*). The conception "that the small goose flock is usually a family and that larger flocks are frequently multiples of families rather than mere aggregations of individuals . . ." also became apparent in observations made at the Horseshoe Lake Game Refuge (Elder & Elder 1949:139).

Diseases and parasites of Canada geese have been investigated in anticipation of epizootics among geese crowding into winter refuges. Blood protozoa (Levine & Hanson 1953) and microfilaria (Hanson, Levine, & Kantor 1956; Hanson 1956) have been surveyed. The prevalence of helminths in relation to age and the incidence of *Leucocytozoon* infection in immature geese are currently under study. Dr. Norman D. Levine (1953) made a valuable review of the literature on coccidia in the avian orders Galliformes, Anseriformes, and Charadriiformes. Coccidial infection was initially investigated in the flock at the Horseshoe Lake Game Refuge by Levine (1952), and the coccidia of North American wild geese and swans were subsequently considered by Hanson, Levine, & Ivens (1957). Host specificity of some species of coccidia was shown, and certain coccidia seemed restricted to one flyway population. Thus, coccidia appeared to offer promise as biological tracers for confirming the distribution of flyway populations indicated earlier by band recoveries (Hanson & Smith 1950:74–9).

Ducks.—The early settler found multitudes of ducks in Illinois, not only along major streams, but also on the prairie sloughs. The vast numbers of ducks migrating through the bottomlands of the Illinois River valley made this valley a famous shooting ground as far back as the 1880's. Indeed, in 1886, a group of businessmen from the Peoria area founded the Duck Island Preserve, probably the first hunting club in the state.

Prior to 1900 the Illinois River and its connecting waters were in a near pristine condition. Sloughs and lakes contained an abundance of aquatic vegetation (Kofoid 1903), which provided food for ducks; other food was furnished by pecan nuts and pin oak acorns which became available when high water flooded the low-lying, timbered bottoms. In January of 1900 the Chicago Sanitary and Ship Canal was opened, greatly increasing earlier diversion of water from Lake Michigan (Mulvihill & Cornish 1930:53). This increased diversion resulted in water levels which were high enough to destroy extensive tracts of bottomland timber, including most of the pecans and pin oaks, in the Illinois River valley.

During the early 1900's not only were the tracts of mast-producing trees, so important as sources of food for mallards, lost to the ducks, but drainage destroyed many other important feeding grounds. Between 1900 and 1922, almost 200,000 of 400,000 acres in the flood plain of the Illinois River valley were leveed and drained (Mulvihill & Cornish 1930). The number of ducks in the lower flood plain area and shooting success declined when the mast-producing trees were lost. Then the practice of feeding waterfowl was begun at some duck hunting clubs in the early 1900's, was prohibited by state

law from 1909 to 1911, became a widespread practice in the 1920's, and was prohibited by federal regulation in 1935 (Bellrose 1944:333).

Finally, in recognition of the importance of waterfowl problems in Illinois, the Natural History Survey employed Arthur S. Hawkins and Frank C. Bellrose to initiate a waterfowl research program in 1938. Up to that time, the study of waterfowl had received little attention in Illinois. In 1922, at duck hunting clubs near the mouth of the Sangamon River, Dr. Frederick C. Lincoln (1924) of the U. S. Bureau of Biological Survey (now the U. S. Bureau of Sport Fisheries and Wildlife) made the first large-scale bandings of ducks in North America. Francis M. Uhler of the same agency examined the food contents of duck gizzards collected at the Duck Island Preserve in 1933 (Uhler unpublished report). Also, Uhler investigated the effect of baiting and live decoys on waterfowl and "estimated that 6,000,000 bushels of corn were fed by Illinois clubs during the 1933 season" (Bellrose 1944: 365).

About 1938 initial attention was given to the wood duck, and in 1939 the first successful nesting box of rough-cut lumber was developed for this waterfowl species (Bellrose 1953*a*). By experimenta-

Wildlife technicians preparing to fluoroscope a mallard drake at the Illinois Natural History Survey field laboratory near Havana. The fluoroscope has facilitated studies involving crippling by hunters and lead poisoning.

tion, a nest box entrance with a 4-inch horizontal measurement and a 3-inch vertical one was evolved in 1942 for the purpose of excluding raccoons which were preying upon the hens and their eggs. In 1950, a cylindrical, galvanized metal house was developed to exclude fox squirrels, as well as raccoons, as predators on wood duck eggs.

Because diversion of Lake Michigan water, drainage, and sediment decreased the duck foods in the Illinois River valley, several of the early investigations

dealt with duck food plants. A study of the ecology of aquatic and marsh plants revealed the relationships of fluctuating water levels and turbidity to plant growth (Bellrose 1941). As a result of this study, two techniques for production of duck foods were recommended: (1) dewatering certain areas to encourage growth of moist-soil plants on exposed mud flats and (2) stabilizing water levels at depths of 2 to 3 feet to promote growth of aquatic plants.

A study of the relative value of various plants as duck foods (Bellrose & Anderson 1943:432–3) showed that moist-soil plants, such as rice cut-grass, millets, smartweeds, and nutgrasses, were much more valuable as duck foods than such aquatic and marsh plants as the pondweeds, coontail, duck potato, and bur-reed. This study is believed to be the first in which the food habits of waterfowl were related to food availability. Later, a study by Low & Bellrose (1944:21) revealed that, among 28 waterfowl food plants, 6 of the 7 heaviest seed producers were emergent or moist-soil plants. Harry G. Anderson (unpublished MS) made a little known but substantial contribution to knowledge of the diet of ducks in Illinois when he analyzed and reported upon the contents of 4,977 gizzards of ducks, representing 17 species, taken during the hunting seasons in 1938, 1939, and 1940.

In a sense, Illinois is at the bottleneck of the Mississippi Flyway, the flyway with the largest population of ducks in North America. The resulting constriction of duck populations streaming into Illinois has provided a remarkably fine opportunity for study of flyway populations. A comprehensive investigation of sex and age among ducks, covering 1939 through 1954, has been completed (Bellrose, Hawkins, Low, & Scott unpublished MS). From 1938 through 1958, periodic censuses have been taken of waterfowl populations in the Illinois River valley during fall, winter, and spring. In 1946 the census route was expanded to include the Mississippi River valley between Rock Island and Alton. These censuses have provided information on the effect of weather, water levels, food, and refuges upon waterfowl populations.

A 5-year investigation of duck populations and kill by hunters revealed that "altering the length of the season is one of the most expedient ways to regulate the duck kill" (Bellrose 1944:371). The most desirable dates for waterfowl hunting seasons of various lengths in Illinois were determined (Bellrose 1944:371):

> For a 30-day season, November 1–30; for a 45-day season, October 22–December 5; for a 60-day season, October 10–December 8; for a 70-day season, October 1–December 9; for an 80-day season, September 26–December 14; for a 100-day season, September 20–December 28.

A study of flyway refuges in Illinois (Bellrose 1954:169) led to the conclusion that they were of value both to waterfowl and to hunters. Flyway refuges permitted waterfowl to rest along the flyway during the hunting season and placed more food within their reach, thereby conserving food resources on the wintering grounds. Waterfowl concentrating on the refuges fed in fields and marshes within their daily cruising range. Thus, the refuges provided for holding local concentrations of ducks which could be shot when they flew out to feed.

One of the most impressive duck flights in a decade swept through Illinois on November 2, 1955 (Bellrose 1957). It was determined that most of the birds in the flight left Canada on November 1 and moved so rapidly that some reached the Gulf of Mexico by the morning of November 3. This mass migration of waterfowl was evaluated by Bellrose (1957:24) as follows:

> Low pressure areas in Canada resulted in a southward flow of a mass of Continental Arctic air. The low temperatures resulting from Continental Arctic air triggered the flight from the Great Plains of Canada and the United States.

Over 75,000 ducks, largely mallards, have been banded by Natural History Survey investigators at four widely separated localities in the state. Recoveries from some of the bandings were used in calculating the annual mortality of the mallard, black duck, and blue-winged teal (Bellrose & Chase 1950). Of the three species, the mallard proved to have the lowest mortality rate, and this "amounted to 55 out of 100 birds the

first year, or year of banding, 20 the second year, 11 the third year, and 6 the fourth year" (Bellrose & Chase 1950: 25). The banding data have also been used to delineate the migration routes of ducks passing through Illinois.

As part of an effort to evaluate losses from crippling by hunters, several thousand ducks were trapped and fluoroscoped for shot pellets and broken bones. Among apparently healthy mallards, 36.4 per cent of the adult drakes, 18.0 per cent of the juvenile drakes, and 21.4 per cent of the hens were carrying one or more shot pellets imbedded in flesh or internal organs (Bellrose 1953*b*:344). "Of the ducks . . . knocked down by hunters, as reported from various sections of the United States, 22.5 per cent were not retrieved" (Bellrose 1953*b*:357).

A spectacular die-off of mallard ducks near Grafton in January, 1947, prompted a joint investigation by the Natural History Survey and the United States Fish and Wildlife Service [now U. S. Bureau of Sport Fisheries and Wildlife]. A still greater die-off in the same area a year later attracted the attention of officials of the Western Cartridge Company of East Alton. As an outgrowth of the situation, a co-operative investigation of lead poisoning in waterfowl was begun in July, 1948, by the Illinois Natural History Survey, the Western Cartridge Company, which is a Division of the Olin Industries, Inc. [now Olin Mathieson Chemical Corporation], and the University of Illinois (Jordan & Bellrose 1951:3–4).

Although Lubaloy shot and several lead alloys were tested as substitutes for commercial lead shot, none showed promise in alleviating lead poisoning in waterfowl (Jordan & Bellrose 1950:167–8). It was estimated by Bellrose (1959) that each year approximately 4 per cent of the mallards of the Mississippi Flyway die from lead poisoning and that an additional 1 per cent are afflicted with lead poisoning but are bagged by hunters. Although several other species of ducks ingested larger numbers of shot per bird than did the mallard, the mallard suffered the highest rate of loss. Mortality from lead poisoning proved to be greater among ducks of the Mississippi Flyway than among those of other flyways. The use of iron shot as a substitute for lead shot was suggested as a possible means of contending with the lead poisoning problem in the event drastic measures should become necessary.

The means by which ducks find their way from their breeding to wintering grounds has been under investigation. Juvenile blue-winged teals were captured in migration in Illinois and held in captivity until all the other blue-winged teals had migrated south of the United States (Bellrose 1958*a*). They were then banded and released. From recoveries of bands it was found that these juveniles, though unfamiliar with the route, flew southward along lines of flight similar to those of adults. Experiments with wild mallards demonstrated an ability to orient by celestial means (Bellrose 1958*b*). The initial flight of mallards released in unfamiliar areas was northward on clear days or nights and in apparently random directions when skies were cloudy and sun and stars were obscured.

The Mourning Dove.—The mourning dove became the subject of an intensive research effort in the autumn of 1948 when it was seen that data were needed for an objective evaluation of claims that doves were being shot to extinction by hunters in Illinois. The kill of doves in 1946 and 1947 was estimated from hunter reports to have been 200,000 in each year and about 300,000 in 1949 (Hanson & Kossack 1950:31). It was later determined that the kill was fairly evenly distributed over the state (Marquardt & Scott 1952).

A program of dove banding, particularly of nestlings, was undertaken to determine points of origin of populations. Banding by amateur co-operators was encouraged (Kossack 1955), and a technique employing elastic adhesive tape to secure bands on small nestlings was developed (Kossack 1952). These aspects of the program were later adopted on a country-wide scale by the U. S. Bureau of Sport Fisheries and Wildlife.

A portable candler was constructed for aging dove eggs in the field (Hanson 1954). Photographic and descriptive guides for aging incubated eggs and nestlings were prepared (Hanson & Kossack 1957*a*). The predominance of unisexual broods in mourning doves was found in early studies (Kossack & Hanson 1953). This subject is being treated

in greater detail in a report, now in preparation, on sex ratios in doves.

The effort to appraise mortality among mourning doves included study of their parasites and diseases (Kossack & Hanson 1954; Levine 1954; Hanson, Levine, Kossack, Kantor, & Stannard 1957). The paper by Hanson *et al.* describes the ectoparasites of doves and the arthropod fauna of their nests and summarizes the results of a 7-year study of the incidence of blood parasites in relation to ages of the doves and to regions of the state.

The relation of age and the stages of wing molt to body weight, body fat, and migration habits was studied (Hanson & Kossack 1957*b*). In contrast to interpretations of fat deposition in passerines, the analysis of data on fat deposition in mourning doves showed no consistent relationship to migratory habits, but instead proved to be related to the energy demands of the molt, regional farming practices, soil fertility, and food habits. Doves that had fed almost exclusively on corn in good soil areas had formed relatively heavy amounts of fat; most of those taken on poor, sandy soil where they fed largely on seeds of wild plants had formed little or no fat.

After 10 years of study there is still no evidence that dove populations in Illinois are controlled by hunting. Population declines which have taken place are generally traceable to habitat destruction, disease, and adverse weather.

Mammals

To the wildlife historian the apparent lack of interest in mammals by early researchers of the Natural History Survey and its predecessors constitutes something of an enigma. Almost half a century slipped away before Forbes, upon receiving a letter from C. A. Rowe of Jacksonville in April of 1907 reporting the destruction of seed corn by moles and enclosing the stomach contents of a mole containing about 65 per cent corn, was stimulated to authorize research on a problem in economic mammalogy (West 1910:14). The resulting studies (Wood 1910*b*; West 1910) provided the first evidence that moles included corn, or any substantial amount of plant food, for that matter, in their diet.

Fur-Bearing Mammals.—Forbes (1912*b*) included fur-bearing mammals among the animal resources of Illinois, but a program of consequence did not get under way until the 1930's, when evaluations of fur resources were undertaken.

> Neither technical nor popular interest was great enough to focus further attention of the state's research agencies on furbearers until, in 1930, David H. Thompson, E. C. Driver, and D. I. Rasmussen of the Illinois Natural History Survey staff borrowed trappers' reports . . . from the Illinois State Department of Conservation, to which law provided that each licensed trapper report his catch monthly during the trapping season (Mohr 1943*a*:505).

Brown & Yeager (1943:437) stated that some of the figures derived by Driver and Rasmussen were published in the *Blue Book of the State of Illinois* (Frison 1931, 1933).

Following a limited survey of helminth parasites in fur-bearing animals collected during the hunting seasons of 1935–36 and 1936–37, Leigh (1940:191) stated that "A study of the literature offers little information on pathogenicity of the parasites found in the hosts studied." This shortcoming in our knowledge continues to prevail.

The desire to obtain a reasonably reliable evaluation of the fur resource in Illinois eventually resulted in two impressive reports (Brown & Yeager 1943; Mohr 1943*a*). Brown & Yeager (1943) based their evaluation on an intensive oral survey covering the 1938–39 and 1939–40 trapping seasons, and Mohr (1943*a*) made an analysis of fur-taker reports beginning with the 1929–30 trapping season and ending with that of 1939–40, excepting the 1931–32, 1932–33, and 1933–34 seasons. The results obtained by the two methods were relatively similar. The average value of the annual fur catch was estimated to have been a little over $1,000,000, about 80 per cent of which represented returns for muskrats and minks. To aid in investigation of fur-bearing animals, Yeager (1941*a*) assembled a bibliography of over 2,600 references on North American fur animals.

Some valuable contributions on the relationship of muskrat populations to

fluctuating water levels in bottomland lakes flanking the Illinois River have been made by Natural History Survey researchers. Bellrose & Brown (1941:207) observed that the numbers of muskrat houses

> were nearly six times as many in lakes with a stable, as in those with a semistable, water level and there were twice as many lodges per acre in lakes with a semistable, as in those with a fluctuating, water level.

Stable water levels favored the growth of those species of aquatic plants most desirable for muskrats. Later, following an investigation of the response of muskrat populations to flood and low water levels in these bottomland lakes, Bellrose & Low (1943:187) concluded:

> While muskrats may be harassed and decimated within a short time during flood conditions, those living under low water conditions may escape without serious loss in summer but may be seriously affected during cold, winter weather.

In 1940–41 and 1943–44 Bellrose 1950) developed a new technique for evaluating the food preferences of muskrats by comparing the proportions of plant foods taken from "feeding" lodges in midwinter with the proportions of plants known to have been within the feeding range of the muskrats. Cattail was rated the most preferred food. The capacity of vegetative types to support muskrat populations was determined by recording the density of muskrat lodges in each vegetation type. River bulrush and cattail had the greatest population values.

Advantage was taken of two unusually fine opportunities for measuring the response of raccoons to a food windfall of ducks (Yeager & Rennels 1943) and geese (Yeager & Elder 1945) made available as hunters' crippling losses at the Pere Marquette Wildlife Experimental Area immediately above the confluence of the Illinois and Mississippi rivers and at the Horseshoe Lake Game Refuge in Alexander County. At the Horseshoe Lake Game Refuge, where crippling losses were alarmingly high, bird remains, chiefly those of Canada geese, occurred in 20.7 per cent of the raccoon droppings collected a day after the hunting season opened and in 87.9 per cent of the droppings collected 3 weeks after the close of the season (Yeager & Elder 1945:49–51). In 1939 and 1940, on the Pere Marquette Wildlife Experimental Area, duck remains did not occur in raccoon droppings collected before the opening of the waterfowl season, but after opening of the season "remains of mallard, pintail, and wood duck were 89 per cent of the bird material in 1939, and 76 per cent in 1940" (Yeager & Rennels 1943:59). These findings indicate that crippled waterfowl may not constitute a complete loss, inasmuch as furbearers utilize them as food. The biology of the raccoon is currently under intensive study by Glen C. Sanderson.

A survey of the population and distribution of beavers in Illinois was conducted under a co-operative Federal Aid project from April 1, 1947, through June 30, 1951. It was found (Pietsch 1957: 193–6) that beavers were "last reported" in Illinois in 1912, were reintroduced in 1929, were estimated to number 3,565 in 45 counties in 1950, and were reported from 55 counties in 1954.

The red fox was made the subject of a thorough evaluation (Scott 1955) because the values of this colorful mammal were believed to have been regularly underrated. This evaluation was based on personal experience extending over 20 years and a number of intensive investigations (Scott 1943, 1947; Scott & Klimstra 1955) especially relating to the red fox as a predator. As a result of this evaluation, Scott (1955:14) recommended:

> 1. The encouragement of an increased use of red foxes for sport hunting, . . .
>
> 2. The education of those who hope for increased small game populations through fox extermination campaigns to the more concrete and lasting results that may be expected from habitat improvement programs. . . .
>
> 3. The elimination of bounty payments on red foxes.
>
> 4. The enactment and enforcement of more effective antirabies laws, especially as applied to the compulsory vaccination and quarantine of domestic dogs, and prompt reduction by organized trapping of red fox populations in which rabies epizootics occur.
>
> 5. The increased attention by game managers to the proper management of the red fox resource in general, including assistance with the cropping of surplus animals in areas where adequate cropping has not been accomplished by hunters.

Game Mammals.—The cottontail rabbit tops the list of game mammals in Illinois in a number of respects. In a survey of license-stub kill cards for the 1950–51 hunting season, Marquardt & Scott (1952:4) found that rabbits provided twice as many sportsmen with game in the bag as did any other game species and numbered more than twice as many as any other kind of game animal reported. Rabbits constitute the chief game animal of the state largely because they are widely distributed and because they possess the reproductive potential to maintain themselves despite high mortality, including that from severe hunting pressure.

Proving that there is some bad with the good, however, is the fact that tularemia, a disease which is transmissible to man, occurs in rabbits. "In the period 1926–1949, Illinois had more than 3,000 reported cases of human tularemia, about twice as many as any of the other states" (Yeatter & Thompson 1952:351). Yeatter & Thompson (1952:379) reported that "The human tularemia rate in any year in Illinois seems to be determined both by temperatures about the time of the opening of the rabbit season and by the abundance of rabbits." They concluded that the incidence of human tularemia in Illinois could be reduced by delaying the opening of the rabbit hunting season until about December 1. As a result of these findings, the opening of the hunting season in Illinois was postponed until November 26 in 1955. In recent years methods of treating tularemia in humans have been greatly simplified by the use of antibiotics. It seems certain, however, that most hunters will prefer not to depend upon antibiotics—that they will enjoy their rabbit hunting far more knowing that by hunting within a season which opens after the onset of sharp freezing weather they and their families are exposed to the hazard of tularemia only to a minimum extent.

Yeatter & Thompson (1952:378) recommended, as a refinement to their studies, further study of ticks, other tularemia vectors, and the biology of the rabbit. Ecke (1955:294–6) recorded a complete description of the courtship and mating of cottontails. Also, Ecke (1955: 305) found evidence which suggested "that some component of green vegetation, possibly Vitamin E, is responsible for stimulating the pituitary glands of rabbits into the secretion of somatic nutritives, and consequently, determining the breeding conditions of the animals."

Dr. Rexford D. Lord (1958:274) has recently constructed life tables which indicate that as many as 24 to 27 per cent of the rabbits available to hunters in autumn may be the young of rabbits born in the spring of the same year.

Ecke & Yeatter (1956:212–3) attributed the death of a rabbit, estimated to have been about 13 days of age, to coccidiosis and suggested further study of coccidiosis as a cause of mortality among rabbits. Detailed studies of ectoparasites of rabbits have been carried on since 1952 by Dr. Lewis J. Stannard, Lysle R. Pietsch, Dr. Carl O. Mohr, and Dr. Lord.

The realization that tradition for a summer hunting season on squirrels in Illinois was not biologically sound touched off a thorough investigation (Brown & Yeager 1945) of fox squirrels and gray squirrels in 1940. The chief objection to a summer hunting season was that it resulted in the killing of pregnant and lactating females. Brown & Yeager (1945: 526) estimated that summer hunting resulted in a wasteful loss of 31.8 unborn and suckling squirrels for each 100 squirrels bagged. Because the tradition for summer hunting was strong and because squirrel hunting was good in some parts of the state despite early hunting seasons in the past, Brown & Yeager (1945: 526–8) believed it unwise to enact a season beginning so late that it would prevent all losses resulting from the killing of pregnant and lactating females and they observed: "Such a season could hardly begin earlier than October 1, and it would certainly be opposed by a large number of hunters." A compromise season of September 15 to November 15 in central and northern Illinois and September 1 to October 31 in southern Illinois was recommended. This recommendation has not been accepted by Illinois hunters.

The report by Pietsch (1954) on deer populations in Illinois will be of especial value to the future wildlife historian.

Pietsch reported upon the early history of the deer in Illinois, recent populations, and management. Hunting was suggested as a means of control, and the deer season, after being closed for 56 years, was opened in 1957 for hunting with bows and shotguns.

Miscellaneous Contributions to Mammalogy.—Mohr (1943*b*, 1947*a*) appraised population data for small mammals in North America. He calculated the weight of specific populations within the area occupied and concluded that population densities within groups of mammals having similar feeding habits were limited by the size of the mammal concerned. Also, Mohr (1947*b*) recorded miscellaneous data on populations of certain mammals in Illinois for future reference.

On December 1, 1956, a grant-in-aid was made by the National Institutes of Health of the U. S. Public Health Service to initiate a 3-year study of epizootiology of rabies in wild mammals. This investigation is aimed at identification of the key hosts to rabies in Illinois and those factors that make them key hosts.

WILDLIFE MANAGEMENT

"Applied programs in the field of biological science are seldom, if ever, developed without the aid of years of patient, so-called unapplied, researches" (Frison 1942*b*:5). Frison believed that sufficient basic knowledge had been accumulated to support applied management programs of an exploratory nature, and, with characteristic vigor, he encouraged work of this kind in the late 1930's. Later, he insisted that these programs be evaluated for monetary return, wildlife yield, and other benefits.

Two of these early programs concerned management of upland wildlife in central and northern Illinois. One of the first attempts to develop wildlife habitat on intensively cultivated land took place on the Urbana Township Wildlife Area, which was believed "typical of the best Illinois cornbelt farmland" (Hesselschwerdt 1942:31). Habitat development was begun on this area in 1937, and in 1939 the project came under the Federal Aid program. Development features included fencerow plantings, installation of den boxes, block planting, and protection of strips along drainage ditches. Usage of the den boxes was evaluated. Fox squirrels appeared to extend their range and to increase in numbers as a result of the provision of den boxes (Hesselschwerdt 1942:33–4, 36). Usable den boxes are no longer present on the area, and resident fox squirrels are uncommon. As the fencerow plantings matured, cottontail rabbits and songbirds increased in numbers (Wandell 1948:262–3), but populations of pheasants and quail have shown no appreciable increase. Minks and muskrats trapped along an ungrazed section of a drainage ditch in 1944–45 provided an estimated per-acre income of $62.78, more than 10 times that produced by the same ditch where it was heavily grazed (Yeager 1945:85).

On October 1, 1939, a Federal Aid project to determine the availability of land for wildlife habitat on the intensively cultivated farm land of the Illinois dark prairie was initiated (Spooner & Yeager 1942). Land for refuges and cover development was found to be available, without purchase, in small scattered tracts, and obtainable through long-term easements. Spooner & Yeager (1942: 54) concluded that "Although the project shows promise of wide application on the Illinois prairie, there are yet many problems which must be further analyzed before its entire success is proved."

Natural History Survey staff members have participated in various other programs closely related to management of upland wildlife. The Survey sponsored the initial acquisition in 1940, by the Department of Conservation, of a tract of sand prairie and wet land in Lee County, the Green River Area, as a management area for prairie chickens, waterfowl, and other animals. It is believed that this tract of land has played an important part in maintaining the only sizable flock of prairie chickens surviving in northern Illinois. However, unless the area is managed with primary consideration for the original objectives, it may well go down in history as the place where native prairie chickens met their end in northern Illinois. Frank C. Bellrose proposed the purchase of the Rice

Lake Wildlife Area by the state in 1942, and the area, now the best duck area in the state, was purchased by the Illinois Department of Conservation in 1943.

In 1955 a Federal Aid research project was initiated by Southern Illinois University, the Illinois Department of Conservation, and the Illinois Natural History Survey to determine the economic values and benefit to wildlife of wide-row culture of corn in southern Illinois. Potential benefits, to the farmer, of wide-row culture and interplanting with cover crops included conservation of soil, increase of fertility, elimination of the low-paying oat crop in rotations, saving of labor, and yields of corn comparable to those from conventional cultural methods (Vohs 1957).

The extent of use of wide-row cornfields by wildlife varied with the attractiveness of the interseeding. However, comparable observations on the numbers of wildlife in wide-row fields and standard interval fields revealed ratios of 5 to 1 for bobwhite quail, 12 to 1 for mourning doves, and 6 to 1 for cottontail rabbits. Wide-row corn is considered to have great potential for wildlife management especially, because it provides for an increase in wildlife values in thousands of acres of corn.

Evaluations of wildlife populations and possibilities for their management were made on marginal lands. Analyses were made of possibilities for management of coal-stripped land for the benefit of upland game and furbearers (Yeager 1941*b*, 1942), management of agricultural drainage systems for production of furbearers (Yeager 1943), and yields of fur from animals produced on different types of land (Yeager 1945). Another project concerned the use of hunting dogs in sport and conservation (Yeatter 1948).

Levee and drainage districts have reduced the flood plain along the Illinois River by almost half, about 200,000 acres. In view of the resulting loss of recreational opportunities and the increased danger from floods, Bellrose (1945) made a survey of the relative values of drained and undrained bottomlands. Later, Bellrose & Rollings (1949) calculated the annual per-acre value, to the public and to owners, of bottomland lakes of the Illinois River valley. They concluded that bottomland lakes in the Illinois River valley had an annual per-acre value to the public, 1944–1947, of $26.35, made up as follows: duck hunting $12.18, angling $2.40, commercial fishing $9.65, and fur trapping $2.12; they estimated that privately owned lakes were capable of producing an average yearly gross return to owners of $18.57 per acre (Bellrose & Rollings 1949:23).

Following an investigation of the effects of flooding on mammals in and around a bottomland lake in the Illinois River valley, Yeager & Anderson (1944: 178) concluded that "The effect of flooding on mammals ranged from heavy mortality in the case of woodchucks to apparently little basic change in the behavior of minks." For various kinds of fur-bearing and game mammals, Yeager (1949) recorded the changes in abundance caused by permanent flooding of wooded bottomland over an 8-year period, 1939–1946. The site was a tract of 600 acres in the junction of the Mississippi and Illinois rivers; the area was flooded in 1938 by closing of the gates of the then new Alton dam.

THE FUTURE

Because the wildlife resource and the environment essential to its existence have economic and recreational values beyond general public appreciation and because knowledge on which to base intelligent management of this resource is in the best interest of the people of Illinois, I believe that we must plan for the future of wildlife research in Illinois as a part of our evaluation of the past.

Forbes (1907*c*:892) expressed this view when he wrote

> that we are . . . practically interested in what has come and gone only as it may help us to bring a new thing into being in a way to secure its permanent continuance and its normal growth.

In the past the wildlife research program of the Illinois Natural History Survey has been heavily weighted toward investigations of migratory game birds. These investigations have been extremely valuable and must be continued in the

future; however, increasing attention must be given to other wild species, including nongame species. Nongame species must be studied not only because they represent economic and esthetic values but also because some of them, such as mice, are especially useful in basic research. Responsibility for research on certain species cannot be side-stepped on the ground that effective study of these species is being carried on in other states, for Illinois has problems characteristic of its own land-use pattern and it bears a responsibility to other states inasmuch as enlightenment on particular problems is often best obtained through comparison of range-wide differences.

While it is true that great progress has been made in wildlife research, and the number of unknowns has been reduced, this increased knowledge has expanded our awareness of unknowns. Many research techniques have been developed, but, in most instances, the degree of their reliability has not been adequately determined, and refinement is desirable. Although the research has been increasingly objective, it must be admitted that there is need for improvement. The expanding field of wildlife research requires specialization, but it also requires integration and synthesis.

This post-mortem of wildlife research impresses me with the fact that the quality of a contribution is influenced not only by the capabilities of the individual researcher but also by the length of time devoted to concentrated effort on particular problems. If real progress is to be realized in the future, the sustained and concentrated effort of top-flight researchers must be insured. Illinois will stand among the leaders in wildlife research only so long as the means with which to attract and hold qualified personnel for extended periods is provided. Provisions must be made for long-range research, with monographic-type publication being an objective. And, finally, we must guard against becoming desk- and laboratory-bound theorists and interpreters. It is essential that contact be maintained with living organisms in their natural surroundings.

Much of our research effort has moved in the direction of life history, ecology, and populations. And much of it must continue to move in this direction. However, means for improvement must be constantly sought out. In life history studies, we must be increasingly objective. In ecology, we must be mindful of the need for land-use practices which are compatible with the best interests of both landowners and wildlife, especially in view of the increasing use of marginal land and agricultural chemicals. In the area of population mechanics, we must not only measure population trends and population composition; we must also seek and evaluate with greater refinement those factors which influence population trends and make-up.

In the future more attention must be given to fields of study only lightly touched upon in the past. Animal behavior, a vital and challenging field, must be explored particularly, for what an animal does is more important to the wildlife manager than what it is. Mobility, especially migration, must be examined more critically. Nutrition, qualitative as well as quantitative, must be investigated, and techniques for evaluating "condition" in wildlife must be explored. Anatomy, embryology, genetics, physiology, and biochemistry must, of necessity, play a larger part in the evaluations of the future.

We must guard against the neglect or shunning of certain research by avoiding a "that's been done before" philosophy. It may well have been done before, but we must be careful to evaluate the thoroughness with which it was done. We must examine it for weaknesses and for its value as a basis for new working hypotheses.

The wildlife research of the Natural History Survey has been instrumental in bringing about desirable changes in established policies and practices and in the establishment of new policies and practices which affect wildlife. We must provide adequate bases for the policy making of the future. To these ends we must move in the direction of prompt publication, and we must make certain that useful publicity is given especially to those findings which indicate that support of, or changes in, practices or administrative policies are desirable.

Our thinking must be projected far into the future in an effort to visualize those areas where knowledge will be most needed. Anticipating the future is admittedly fraught with pitfalls. It seems certain, however, that human populations will continue to increase in Illinois. This increase will be attended by more intensive use of land and water, more extensive transportation and communication systems, more extensive residential and industrial areas, more exhaustive use of fuels and metals, greater use of atomic energy, more automation, and more leisure time.

From the wildlife manager's point of view, this condition forewarns of an increasingly severe competition between wildlife and basic human needs. When it is considered that wildlife must be produced primarily on lands utilized for other purposes, the problems of the future for wildlife become obvious. The increasing demand for human food will make it essential that harvest methods be refined to reduce waste, that more heavily yielding crops be developed, that more marginal land be brought into use, and that more agricultural chemicals be applied. This promises not only to reduce wildlife populations but to force them below minimum survival levels, unless effective provisions, such as wide-row corn may prove to be, are constantly sought out by wildlife managers. The need for refuges to insure the survival of rare species will increase. The relative importance of those wild animals which compete with humans for food by eating or contaminating it will be magnified. Intensive use of water could create a pollution problem such as would virtually deny aquatic life outside protected areas, unless pollution control, including provision for disposal of radioactive waste, keeps pace with increased water utilization.

The provision of a means for satisfying the psychological needs of a human population with more leisure time and relatively less elbow room comprises a formidable challenge. If the human population is to maintain some semblance of sanity, services such as those offered by wildlife biology must be given equal recognition with those of the physical sciences. Perhaps the average family of the future will tend to satisfy more of its needs for pleasure in the out-of-doors and for escape from the pressures of civilization in its own backyard. Hence, the wildlife manager should contrive to know more about the management of the home landscape for wildlife. It seems certain that an increasing amount of hunting will take place on regulated shooting areas, that is, unless hunting proves to be good in outer space.

The wildlife manager's problems of the past, considerable as they have been, seem as child's play compared with those looming in the future. The wildlife manager is going to need determination, courage, ability, compensation, and means such as never before. Perhaps we can ease some of his problems by the effective planning of current research to provide a sound basis for the essential decisions of the future. Indeed, wildlife management as a profession may well depend on the soundness of today's plans for the future.

Publications and Public Relations

JAMES S. AYARS

MANY of the men whose names were written large in the early annals of the Illinois Natural History Survey had been educated in the classical tradition. Most of the physicians, educators, and others whose formal schooling included college had undergone the discipline of Latin and Greek studies.

Jonathan Baldwin Turner, elected first president of the Illinois Natural History Society in 1858 (Bateman 1858:238), was a graduate of Yale College and for many years Professor of Belles Lettres, Latin, and Greek at Illinois College, Jacksonville (Carriel 1911:11, 40).

Charles E. Hovey, first secretary of the Society (Bateman 1858:238) and first head of the Illinois State Normal University, was a graduate of Dartmouth College (Marshall 1956:28). Joseph Addison Sewall, early curator, had studied at both Yale and Harvard and was a graduate of Harvard Medical College (Marshall 1956:78).

Benjamin Dann Walsh, first State Entomologist, was a graduate of Trinity College of Cambridge University in England (Weiss 1936:23). William Le Baron, second State Entomologist, was, like Sewall, a graduate of Harvard Medical College (Bridges 1896:...).

Although Stephen Alfred Forbes, fourth State Entomologist, first and only Director of the State Laboratory of Natural History, and first Chief of the Natural History Survey, had comparatively little formal education as a youth, he had subjected himself to the discipline of language study. At home he had studied French and Spanish, and in Confederate prisons during the Civil War he had spent some of his abundant leisure in studying Greek from books he managed to get (Mills and Howard 19...: ...).

The early leaders of Illinois science, most of them classicists before they were scientists, had developed respect for the meaning and sound of words and had acquired a skill in word usage that carried over into their scientific writings.

Trained in the classics though most of these leaders were, many were nevertheless aware that classical education had limitations. They saw that in Illinois, in the middle of the nineteenth century, education must be brought out of ivied halls to the furrow and the work bench.

In the Illinois College classroom, Turner was a teacher of Latin and Greek. Out of the classroom, he was a leader in the movement for industrial education, the education of the farmer and the mechanic.

Turner asked (Carriel 1911:76):

> But where are the universities, the apparatus, the professors, and the literature specifically adapted to any one of the industrial classes? ... society has become, long since, wise enough to know that its *teachers* need to be educated; but it has not yet become wise enough to know that its *workers* need education just as much.

Socrates, Cincinnatus, Washington, Franklin, and other worthies, Turner argued, derived their education "from their connection with the practical pursuits of life" (Carriel 1911:77):

> What we want from schools is to teach men to derive their mental and moral strength from their own pursuits, whatever they are, and to gather from other studies as much more as they find time to achieve. We wish to teach them to read books only that they may the better read and understand the great volume of nature ever open before them.
>
> Can not ... schools and ... literature, suited to the peculiar wants of the industrial classes, be created by the application of science to their pursuits?

Walsh (1868:3) emphasized that his annual report as Acting State Entomologist was "intended chiefly for the use of common folks."

Writing as Editor of the only volume of *Transactions* published by the Natural History Society itself, C. D. Wilber (1861:3) epitomized the educational movement of the time, a movement that might be termed a revolt of the classicists against the classical tradition:

> It has been the aim of the Editor to present only such articles and papers as are immediately useful, and interesting to the citizens and

schools of Illinois, with a hope that a zeal for the pursuits and studies of Natural History may spring up among our people, like the seeds of the sower, in the parable, falling upon good soil, and yielding, "some sixty and some an hundred fold."

In order to render the greatest good to all, the subjects have generally been treated in a popular rather than a technical style. It has been said, that he who places a valuable truth or fact within the reach of the million, is doing more for humanity than he who discovers it. And, indeed, if scientific men, or libraries and museums, cannot contribute to the elevation of the masses who are less privileged, their usefulness is questionable.

The ideas reflected in Turner's questions and answers and in Wilber's comments culminated in the Morrill Act of 1862, in land grant colleges, and, specifically, in the Illinois Industrial University at Urbana. Both cause and effect of the movement for general education was the increasing thirst that Illinois people in the middle of the nineteenth century had for knowledge, the growing conviction that information should be widely disseminated. The movement led to the formation of, and was abetted by, the Illinois State Horticultural Society, the Illinois State Agricultural Society, and the Illinois Natural History Society.

The Natural History Society was not an accident nor an isolated segment of history. It was part of a contagious movement sweeping the prairies. As seen by Wilber (1861*d*:7):

> The demand for this movement seemed to proceed from a want of accurate knowledge in nearly all departments of Natural History in the State; and also, from a desire that all facts and discoveries in a field so vast as Illinois, should be made immediately subservient to the great ends of popular education.

EARLY PUBLICATIONS

The Illinois scientist in mid-nineteenth century looking for means of disseminating knowledge had few publication outlets. Among the small number of scientific journals published before 1860 were *The American Journal of Science*, founded in 1818, the *Entomologist of London*, in 1840, and the *Boston Journal of Natural History*, in 1834. The first *Transactions* of the Illinois State Agricultural Society were published in 1855; the first *Transactions* published by the Illinois State Horticultural Society itself were dated 1863. The first *Proceedings* of the Entomological Society of Philadelphia were published in 1861. The *American Naturalist* was not founded until 1867, the *Botanical Gazette* not until 1875.

The *Prairie Farmer* had been established at Chicago in 1841, and to this periodical, frankly slanted toward the interests of practical farmers, Illinois scientists of mid-century turned for publication of their technical papers. The publication by *Prairie Farmer* of many of these papers, some significant enough to attract the attention of eminent scientists in other parts of the country, is indication of the extent to which the classicists and the industrialists had become wedded.

That publication of scientific papers was an important aim of the founders of the Illinois Natural History Society is evident from written records of the organization. The object of the Society, as outlined by Cyrus Thomas in his letter read before Illinois teachers meeting in Decatur, December 29, 1857 (Bateman 1858*a*:12),

> shall be the investigation and study of the Flora, Fauna, Geology, and Mineralogy of Illinois, and the illustration of the same by gathering specimens, exchanging the same, and by publishing such meritorious works thereon as the authors may present. . . .

At the last session of its second meeting, held on June 20 and 21, 1859, at Bloomington, the Society (Francis 1859*b*:664) resolved that "the Executive Committee be required to procure the publication of the papers and proceedings of the Society in some paper generally circulated through the State." The Executive Committee in turn resolved that, "in accordance with the resolution of the Society, we select THE PRAIRIE FARMER as its medium for publishing the papers and proceedings of the Society."

Another outlet for papers written by members of the Natural History Society was provided by the Illinois State Agricultural Society. In its own published *Transactions* the Agricultural Society included the *Transactions* of the first three meetings of the Natural History Society and several papers contributed by members (Francis 1859*a*, 1859*b*, Wilber 1861*a*).

In 1861 the Natural History Society itself published what it termed the "Second Edition" of Volume I, Series I, of its *Transactions* (Wilber 1861*d*). Most of the material in this volume had been printed previously by the Agricultural Society in its *Transactions* for 1857–1858 (Wilber 1861*a*). Wilber's Preface to the volume published by the Natural History Society was dated October 30, 1861 (Wilber 1861*d*:4). The Civil War had begun 6 months before.

In 1867, after the War was over and men again had time to consider civilian science, the state legislature in a single session made an appropriation to the Illinois Natural History Society, provided for a State Entomologist, and authorized establishment of the Illinois Industrial University (Illinois General Assembly 1867).

The legislative act that provided for a State Entomologist required him to prepare "a report of his researches and discoveries in entomology for publication by the state, annually" (Illinois General Assembly 1867:36).

The act of 1867 in which state appropriations were first made to the Illinois Natural History Society and the act of 10 years later establishing the Illinois State Laboratory of Natural History made no mention of publications (Illinois General Assembly 1867:21–2; 1877: 14–6). In 1879, however, the state legislature appropriated to the State Laboratory for "publication of bulletins, the sum of two hundred and fifty dollars per annum" (Illinois General Assembly 1879:42).

An act approved June 27, 1885, a few months after Forbes had moved to Urbana, was specific about publication. It stipulated that the Director of the State Laboratory "shall present for publication, from time to time, a series of systematic reports covering the entire field of the zoölogy and the cryptogamic botany of Illinois." The act appropriated "for the publication of bulletins, the sum of three hundred dollars per annum, and for the preparation and publication of the second volume of the report upon the zoölogy of the State, the sum of fifteen hundred dollars per annum" (Illinois General Assembly 1885:23–4).

The following year, Forbes staged an intellectual sit-down strike over a proposed publication. Insufficient funds and conflicting legalities would not permit him to include what he considered suitable illustrations in the State Entomologist's report he had prepared for publication in 1886.

Forbes (1886*a*:3) explained the situation in the preface to a group of articles that he and members of his staff had written and that he had submitted to the State Board of Agriculture for publication in its *Transactions*:

> A recent opinion of the Attorney General makes it doubtful whether the State Entomologist of Illinois has the right, under the laws referring to that office (to some extent inconsistent and conflicting), to prepare any other than a biennial report; and a change in practice of the State Board of Contracts leaves no doubt whatever that a report published this year could not be illustrated. As an elaborate monograph of insects injurious to Indian corn was intended as the principal part of my entomological report for 1885, and as this article certainly should not be published without a large number of excellent figures, I have decided, under existing circumstances, not only to withhold this paper, but also to refrain from presenting any formal report for 1885, leaving it to the State Legislature to provide for the proper illustration of the reports hereafter, and to remove the present inconsistencies of the law. Unwilling, however, that the work of the office of the past year should be without representation in the Transactions of the State Board of Agriculture, with which the entomological report has been annually published for the last ten years, I have submitted to the Board, at the request of its Secretary, C. F. Mills, Esq., the following miscellaneous essays on economic entomology, summarizing the results of such part of our operations as may well be published without cuts.

At its next session the Illinois General Assembly (1887:72) appropriated to the State Laboratory of Natural History $300 for publication of Laboratory bulletins and $500 for "the illustration of the biennial report of the State Entomologist."

In these days of high cost of printing, engraving, and other services, such sums as $300 and $500 seem insignificant. In 1887, however, they bulked large enough to help confirm in the public mind the importance of publication and illustration in scientific research.

In a biennial report issued about 3 years after assuming his duties in Urbana,

Forbes (1888:7) described in detail the publications that were being issued under his direction:

> Our regular publications run in four series, two from the Laboratory and two from the Office of the State Entomologist,—the former comprising the State zoological report and the bulletins of the State Laboratory of Natural History, and the latter the biennial entomological report and the bulletins of the entomological office.
>
> During the past two years we have finished the printing of the first volume on the zoology of the State,—containing five hundred and twenty pages of text and forty-six plates,—devoted to the ornithology of Illinois as far as the water birds. This is a reprint of the volume, the first edition having been entirely destroyed in the burning of the office of the State Printer last February.

PUBLICATIONS SERIES

The words "Volume I, Series I," at the top of the title page of the only *Transactions* published by the Illinois Natural History Society under its own name are evidence that the members looked forward hopefully to continued publication. The date at the bottom of the page, 1861, and a glance at American history give testimony to the role the Civil War played in the Society's annals. In 1861 Charles Hovey, first secretary of the Society and head of Illinois State Normal University, marched off to war as Colonel of the Schoolmaster's Regiment, taking with him most of the men of the student body and some of the faculty (Marshall 1956:75–6). No one knows how many potential scientists died at Fort Donelson and in other engagements, or how much brain power from Illinois centers of learning was siphoned from the science of peace into the science of war.

Two years after the Civil War was over, biological science in Illinois resumed its march, but the Natural History Society limped badly. It never recovered from the effects of the conflict. However, in voting an appropriation to the Natural History Society and establishing the State Entomologist's Office and the Illinois Industrial University, the Illinois General Assembly (1867) gave substantial evidence that the people of the state wanted to continue the educational movement that founders of the Society had helped to start.

Walsh's first and only report as State Entomologist was followed by the reports of his successors: 4 by William Le Baron, 6 by Cyrus Thomas, and 18 by Forbes. Le Baron (1871) named *his* first report *the* first report of the State Entomologist. The reports were discontinued when the State Entomologist's Office was merged with the Illinois State Laboratory of Natural History in 1917.

In 1876, about 4 years after his appointment as Curator of the Illinois Museum of Natural History, Forbes issued the first number of a technical series that has come down through the years as the *Bulletin*. It has been known successively as the *Bulletin* of the Illinois Museum of Natural History, 1876; *Bulletin* of the State Laboratory of Natural History, 1877 to the end of June, 1917; *Bulletin* of the Illinois State Natural History Survey, July, 1917, to early 1932; and Illinois Natural History Survey *Bulletin*, late 1932 to the present. Throughout its existence the *Bulletin* has reported the results of mature, original research. Most of the articles have been slanted toward technical workers in the biological sciences.

Of wider interest are numbers of the circular series. The emphasis in this series is on "how-to-do"—for example, how to control diseases or insect pests of shade trees. Directions in the circulars are based on the best available information and usually only to a limited extent on original research by the writers. The language of the circular series is less technical than that of the *Bulletin*.

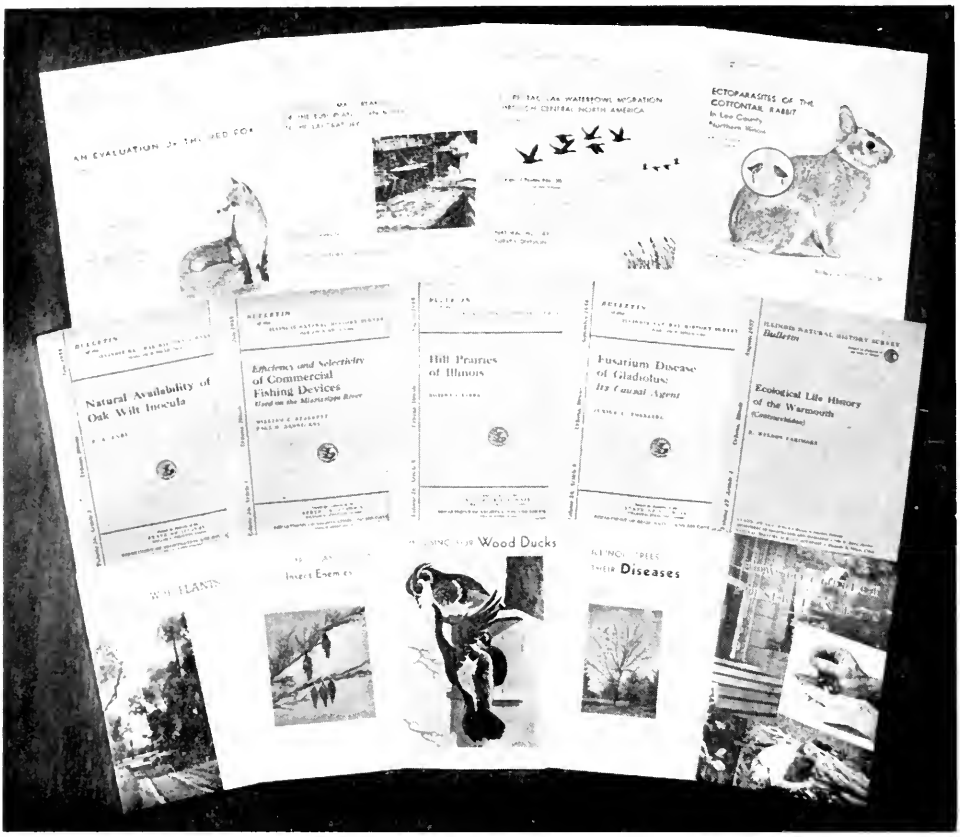
The complete history of the circulars is not known. "We have also issued several entomological circulars not of any series," Forbes (1888:7) wrote 70 years ago. The modern circular series dates from 1918 and a 6-page unnumbered publication titled "The More Important Insecticides and Repellents," by W. P. Flint. Between 1918 and 1930, 13 other circulars (3 unnumbered and 10 numbered) were issued by the economic entomologists, 4 by the foresters, and 1 by the botanist on the staff. Each circular was issued as a product of the section represented by its author. In 1934 the circular series was reorganized and the early circulars were numbered or renumbered.

The last circular published, *Illinois Trees and Shrubs: Their Insect Enemies,* is numbered 47. Some of the circulars have been reprinted more than once, one of them, that on insect collecting, five times.

Diverse in several ways are the articles published in the Biological Notes series, the first of which was issued in December, 1933, in mimeographed form. Some of the articles stand as progress reports of extensive projects, later to be subjects of articles in the *Bulletin.* Some are final reports covering small projects. Some are technical. Some emphasize "how-to-do" and in content and language are similar to the circulars. They are on various subjects and of various lengths. Early articles in this series were mimeographed and they contained no illustrations. Recent articles have contained illustrations and they have been planographed reproductions of typewritten copy. The most recent article of the Biological Notes is No. 39.

The fourth of the series of publications now issued by the Illinois Natural History Survey is the manual. Each number is concerned with a single group of the state flora or fauna, and each is designed for use by young as well as mature naturalists. The first of the manuals was *Fieldbook of Illinois Wild Flowers.* It was issued in 1936, is now out of print, and is being revised. Three other manuals have been published, one on land snails, one on native shrubs, and one on mammals.

Preceding the manual series in time, and somewhat similar in character, were the now discontinued final reports, two on birds and one on fishes (Ridgway 1889, 1895; Forbes & Richardson 1908).



A few of the circulars, articles of the *Bulletin,* and biological notes issued recently by the Illinois Natural History Survey.

Other discontinued series were the Executive Reports of the State Laboratory of Natural History, 1878–1916, and of the State Entomologist, 1900–1915. Most of these reports were published as pamphlets and were published also in University of Illinois reports or in *Transactions* of the State Horticultural Society.

Annual reports made by the Natural History Survey to the Illinois State Department of Registration and Education were begun in 1918 and have been continued to the present. These reports have been published by the Division or by other administrative units of the state government. Biennial reports have for many years been included in the Blue Book of the State of Illinois.

A considerable number of important contributions by Illinois Natural History Survey staff members have been published in the bulletin and circular series of the Illinois Agricultural Experiment Station.

Many staff-written articles covering results of research have been published in technical journals. In a biennial report published 70 years ago, Forbes (1888:8) listed about a dozen articles "written at the Laboratory, but published elsewhere." In each of the past few years, approximately 80 articles written by staff members of the Illinois Natural History Survey have appeared in publications other than those issued by the Survey.

EDITORIAL PERSONNEL

That some editing was done on the first papers published by the Illinois Natural History Society is evident from a sentence in the Secretary's Report published with the *Transactions* for 1860 (Wilber 1861*d*:8): "The following papers were prepared—most of them—for the last meeting of the Society, and have since been revised for publication in this report." The Preface indicates that Wilber (1861*d*:3–4) was the Editor.

For many years Forbes himself did considerable editing of the papers issued by the agencies he headed. Until 1926 his principal editorial assistants were Charles A. Hart and Miss Mary Jane Snyder. "Mr. C. A. Hart, my efficient secretary," Forbes (1882*a*:8) wrote in an early report, "is responsible for the correspondence, for the preparation of papers for the press, the correction of proofs, and other clerical service." To the "efficient secretary" was soon assigned the "labeling, determination, and arrangement of the insect collections" of the State Laboratory (Forbes 1887:2). By 1896 he was listed as Systematic Entomologist and Curator of Collections (Forbes 1896:2).

Miss Snyder joined the staff of the State Laboratory of Natural History in 1883 and retired from the staff of the Natural History Survey in 1925. She died in 1938 at the age of 93 years. She was listed successively as amanuensis, stenographer, secretary, and editor and proofreader. Apparently, as Hart's entomological activities increased, his editorial duties were taken over by Miss Snyder.

A scientist who knew Miss Snyder well characterized her recently as "an excellent editor." He added, "overcritical in a way." Good editors, like good scientists, are apt to be "overcritical in a way."

Tradition reports that Forbes was not easily satisfied either with his own or his assistants' papers, that he was meticulous about detail.

H. H. Chapman, Yale University staff member who worked on forestry problems for the Natural History Survey during the summers of 1922 and 1923, stated recently that Forbes was accustomed "to revising the reports of his subordinates, cutting them down to about one-fourth of their original bulk" (letter of July 10, 1958, from H. H. Chapman to C. W. Walters).

Successor to Miss Snyder in 1926 was H. Carl Oesterling, who for 2 years, before he was appointed full-time Editor of the Natural History Survey, was employed jointly by the Illinois Geological Survey, Illinois Water Survey, and Natural History Survey. Oesterling had previously taught at the University of Illinois.

After Oesterling went to the University of Illinois Press in 1931, Carroll B. Chouinard was appointed to replace him. Following Chouinard's appointment, the editorial office was called the Section of Publications. Chouinard resigned in 1937 to go to Pennsylvania State College, and James S. Ayars was appointed Editor. In 1947 the title of Editor was changed to

Technical Editor. In 1948 the Section of Publications was renamed the Section of Publications and Public Relations.

Until Mrs. Blanche Penrod Young was appointed Assistant Technical Editor in September, 1948, the editorial staff had consisted of the Editor and temporary or part-time assistants. In 1958 Mrs. Diana Root Braverman was appointed as a second Assistant Technical Editor.

For many years photographs for illustrating publications have been taken by members of the technical staff. More than 60 years ago, Forbes (1894:36) mentioned in a biennial report "a dark room for photography" among the rooms available to the State Laboratory of Natural History.

Robert E. Hesselschwerdt was the first person on the staff whose title included the word *photographer*. He was appointed Assistant Technical Photographer in 1946 and assigned to the Section of Publications. Upon his resignation in 1948, he was replaced by Charles L. Scott, who is now picture editor of the Milwaukee *Journal*.

William E. Clark, the present staff photographer, was appointed in April, 1951.

PUBLIC RELATIONS

Long before public relations in name were added to Illinois Natural History Survey activities, public relations in fact were being practiced with consummate skill. Forbes had a natural flair for public speaking and for writing. He was popular as a speaker before scientific, agricultural, and educational groups. His articles on insects and other subjects were welcomed by editors. In a biennial report Forbes (1888:8) mentioned "a considerable number of articles written for the agricultural papers in response to inquiries from their editors."

His well-organized, stimulating, even exciting reports of accomplishments by, or plans for, the agencies he represented were included as important parts of larger reports by university presidents or other administrators.

In recent years public relations media have included principally news releases (to press, radio, and television), educational motion pictures, photographs, and magazine feature articles. Many public contacts have been made each year by the Chief and members of the staff in addressing groups of persons interested in biological sciences and related subjects.

EDITORIAL POLICY

The scientific articles published by the founding fathers of the Illinois Natural History Survey and by Forbes and his contemporaries set standards of excellence that have served as a tradition and a challenge to subsequent members of the staff. Through the years, exactness of research and quality of the published reports based on research have been given precedence over quantity of research and speed of publication. Most of the organization's reports that stand as landmarks in biological literature were several years in the making. Extreme examples are some of the reports on the extensive bird studies made in 1905–1909; the last of the reports on these studies was not published until 1923 (Forbes 1907*b*, 1908, 1913; Forbes & Gross 1921, 1922, 1923).

Even 70 or more years ago, when printing and engraving processes were less efficient than now, Forbes laid great stress on adequate illustrations. His policy with respect to adequate illustrations has been continued, and with improvement in printing and engraving processes have come changes in illustration practices that have added to the convenience of readers. Instead of grouping illustrations at the end of an article, as Forbes was sometimes forced to do, recent editors have been able to place each illustration close to its principal text reference.

In the writing and editing of reports designed for publication is still felt the influence of the founding fathers, the classicists who sought to broaden the base of education. Respect for words is combined with respect for persons, the potential readers.

Editorial problems have not been so simple in the past half century as when Wilber (1861*d*:3) wrote that "the subjects have generally been treated in a popular rather than a technical style." The wide range of subject matter and the diversity of interests of the various reader

groups served by the Natural History Survey have made necessary a diversity of style and even of format. Each report to be published is written and edited for a particular reader group in the hope that to this group the report will be "immediately useful and interesting."

The joint aim of the writer, or writers, and the editorial staff is to make each published paper an orderly, logical presentation of the results of a particular segment of research; to include all pertinent data and to exclude all inconsequential or extraneous matter; to achieve accuracy in original data and in quoted and paraphrased material; to state only such conclusions as can be justified by data presented; to make all statements so clear that they can be easily understood and cannot readily be misunderstood.

Library

RUTH R. WARRICK

WHEN Cyrus Thomas proposed a Natural History Society of Illinois in 1857, his plan provided for the development of a library. In the letter outlining his plan, we find this statement: "That such works as can be collected by gift, which will be useful in the investigation of Natural History and relate thereto, be gathered by the members to form a library" (Bateman 1858*a*:12).

While the Natural History Society was in the process of organization, Dr. E. R. Roe of Bloomington reported for the Committee on Library (Wilber 1861*d*: 12): "That it shall contain all available works on the Natural Sciences, Home and Foreign Surveys, Manuals, Works of Reference in the several departments, Miscellaneous Works, not strictly scientific, Maps and Charts, etc."

THE LIBRARY AT NORMAL

When the Society received its charter from the state legislature in 1861, a library was provided for in Section 3 (Wilber 1861*d*:15):

> Said natural history society shall also provide for a library of scientific works, reports of home and foreign surveys, manuals, maps, charts, etc., etc., such as may be useful in determining the fauna and flora of Illinois, and said library shall be kept in the museum of said society at the State Normal University.

This library, while it was still at Illinois State Normal University, Normal, was transferred to the Illinois State Laboratory of Natural History when the Laboratory was created in 1877.

The library served not only the members of the Natural History Society and the State Laboratory; it was used by naturalists located in other parts of the state. In the report for 1879–1880 (Forbes 1880*f*:9–20), a classified list of more than 300 titles of the principal works added during that period was included. This list was for the "benefit of the students of natural science throughout the State" and included works on mammals, birds, reptiles, fishes, insects, plants, and miscellaneous biological subjects.

THE LIBRARY AT URBANA

In 1885, when Forbes accepted the position of Professor of Zoology and Entomology at Illinois Industrial University (soon to become the University of Illinois), he made the request that the property of the State Laboratory of Natural History be transferred to this University (Burrill 1887*a*:10–1). "The essentials of my original work and of the State natural history survey can be transferred from the Normal building to the basement of the University without detriment to any part of the work of the Normal School, . . ." The property transferred included the library (Burrill 1887*a*:101).

A special project of the State Laboratory of Natural History in 1893 was an exhibit of the zoology of Illinois at the Columbian Exposition, held in Chicago. This exhibit included a section of the library, "the books selected being mainly entomological, and including serial publications, periodicals, monographs, reference books, pamphlets, etc., to the number of about five hundred volumes" (Forbes 1894:7).

When the biological station was established near Havana in 1894, the libraries of the University and of the Laboratory supplied a working library of about 120 volumes (Forbes 1894:3, 19).

The floating laboratory, launched in April, 1896, had a cabin that at one end housed an office and library, 11 feet, 6 inches by 16 feet. A 24-page illustrated pamphlet describing the biological station contained the information that to summer students doing research "access will be given to the biological library of the Station. Books will also be loaned, as needed, from the library of the State Laboratory of Natural History and from that of the University of Illinois" (Forbes 1896:16, 26–7).

The library remained in the possession of the State Laboratory of Natural History and its successor, the State Natural History Survey, until 1928, when it was turned over to the University of Illinois Library (Cunningham 1928:275–6). This transfer was made with the following stipulations:

1. That each article now belonging to the library of the Natural History Survey or added to it hereafter shall bear a distinctive mark;
2. That such additions shall be made to it, from time to time, as are necessary to the work of the Natural History Survey as certified by the Chief thereof and approved by the President of the University; and
3. That the scientific staff of the Natural History Survey shall have at all times a prior right to the use of books, pamphlets, and papers of the aforesaid library, their use by members of the faculty and by the students of the University being second to this claim.

When the Natural History Building was completed, the library moved to the rooms assigned to it (Forbes 1894:35–6).

> Since my last report to you the State Laboratory has removed to the rooms assigned to it in the new Natural History Hall of the University of Illinois, five on the first floor and two in the basement. These rooms are a Director's office, 21 ft.x19 ft., a library room 22x32, . . .

Provision was again made for a separate library when the Natural Resources Building was planned. Plans for transferring the book collection from the Natural History Building to the Natural Resources Building were being considered as early as July, 1939. A letter dated July 26, 1939, from Dr. P. L. Windsor, Director of University Libraries, to Dr. T. H. Frison, Chief of the Natural History Survey, contained this statement:

> I am beginning to think of the preparations that will have to be made when the State Survey building is completed and you take over with you, such parts of the Natural History Library as you think are necessary for your current work.

After much planning and working out of policies, an agreement between the Natural History Survey and the University was reached. This agreement was outlined in a letter dated January 22, 1941, from Dr. Carl M. White, then Director of University Libraries, to Dr. Frison, as follows:

(1) The University is to catalog all books, journals, etc., including arrears and recataloging.

(2) The University is to provide in the regular library budget a fund for the purchase of books for the Natural History Survey (at present $400).

(3) The University is to manage the Natural History Survey Library the same as other departmental libraries, including provision of service to the Natural History Survey from other libraries on the campus. The professional staff of the Survey is to receive service from the various libraries on the campus on the same basis as the faculty of the University.

(4) The University is to allow the Natural History Survey "preferred use" of the material in the Natural History Survey Library as "preferred use" is defined in your letter to me of December 16.

(5) The University is to provide, besides general supervision, the sum of $700 in 1940–41 for staff in the Natural History Survey Library.

It is to provide $1500 for each year of the biennium 1941–43.

(6) The Natural History Survey is to provide housing for such books as need to be housed in the Natural Resources Building.

(7) The Survey is to relieve the University September 1, 1943, of the responsibility for providing staff for library service.

The Natural History Survey Library, opened as a separate unit in September, 1940 (Lill 1942:1), was located on the fourth floor of the Natural Resources Building, and remained in that location until the west wing of the Natural Resources Building was completed. In February, 1952 (Simmons 1952:1), the library was moved to its permanent location on the first floor at the south end of the west wing.

LIBRARY COLLECTIONS

In a paper, "Natural History in Schools," which was read before the Illinois State Teachers' Association in 1860, A. M. Gow of Dixon gave a brief history of the Illinois Natural History Society and stated that its library at that time contained 300 volumes (Gow 1861: 96).

Professor Forbes in his 1881–1882 report stated that additions to the library since his last report had been 360 volumes and 200 pamphlets, many of them "rare and costly works—the foundation stones of zoölogical and botanical literature" (Forbes 1882*a*:7). He wrote that

"particular attention has been paid to catalogning, and this has been kept fully abreast of the additions. A card catalogue of authors is now absolutely complete to date, and a subject catalogue is well under way."

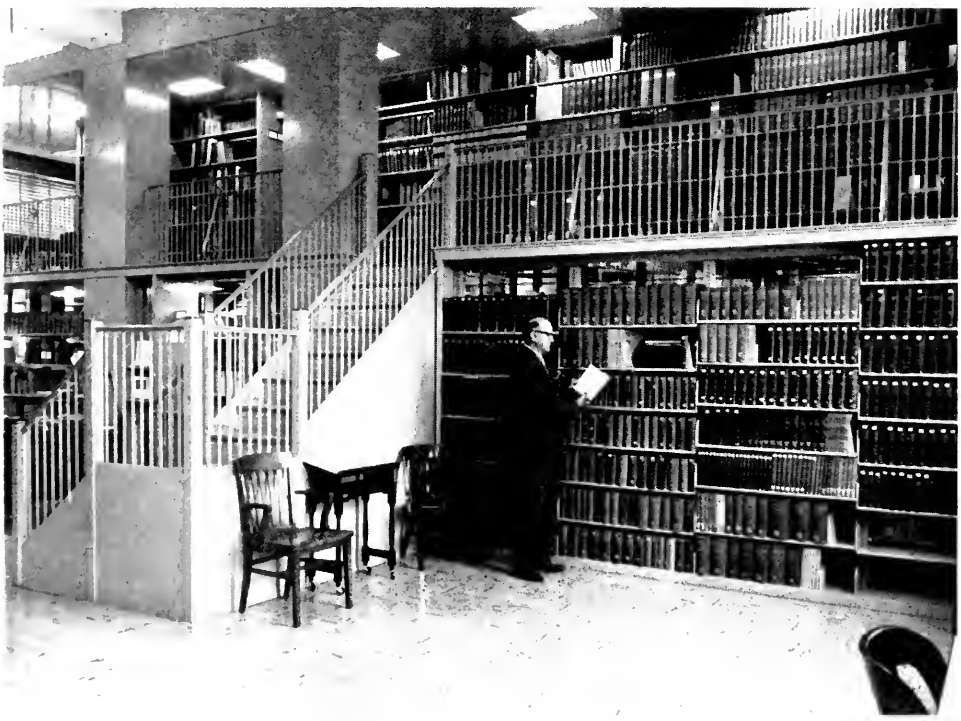
In 1885, when the State Laboratory of Natural History was transferred from Illinois State Normal University to the University of Illinois at Urbana, the library had a collection of 1,207 bound volumes and 3,856 pamphlets and periodicals (Burrill 1887*a*:101). The library additions in 1899–1900 were 648 volumes and 764 pamphlets (Forbes 1901:11). Professor Forbes in 1909 stated that the library then had nearly 7,000 books and something over 17,000 pamphlets (Forbes 1909:55–6).

The library at present contains over 19,000 volumes and approximately 5,000 pamphlets, the greater part being periodicals and other serials. The field of entomology is represented most strongly in the collection, but other subjects, such as zoology, botany, wildlife, and conservation, are emphasized.

For many years, the library has added to its collection by exchanging the publications of the State Laboratory of Natural History and the Natural History Survey with other institutions. The policy toward exchanges was expressed by Mr. Gow (1861:96) nearly 100 years ago: "The library of the Society will embrace everything that can be procured by gift, purchase or exchange, upon Natural History in particular, and Science in general."

As the number of publications of the State Laboratory increased, the library was able to establish a larger number of exchanges, especially with European societies and institutions (Forbes 1901:10).

We are now receiving in exchange for our State Laboratory Bulletin one hundred and eighty-one periodical scientific publications, of which fifty-nine are American, twenty-eight are British or British-colonial, twenty-six are German, sixteen French, twelve Italian, and the remaining forty are Russian, Swedish, Norwegian, Danish, Dutch, Hun-



Part of the Illinois Natural History Survey library in the Natural Resources Building. This library is noted especially for its large collection of bound volumes of periodicals in the biological sciences.

garian, Portugese, Egyptian, South American, and Japanese.

At the present time the library has an exchange arrangement with approximately 500 scientific institutions and societies, a large number of which are foreign.

LIBRARY PERSONNEL

Provision for the care of the library has been made from the beginning of the Natural History Society to the present time. The person in charge of the library has always had the title *librarian* and has been a member of the staff, first of the Natural History Society (Wilber 1861*d*:10) and later a member of the staff of each of the state agencies that followed, except for a period from 1928 (Cunningham 1928:275) to 1943 when the University of Illinois assumed full responsibility for the book collection.

The first librarian was Ira Moore, instructor in mathematics at Illinois State Normal University (Wilber 1861*d*:10; Hovey 1859:401). His duties were definitely stated in the Report of Committee on Library (Wilber 1861*d*:12):

> It shall be the duty of the Librarian to arrange the books of the Society, to make and keep a catalogue of the same, to keep a record of the books drawn from the library as directed by the Society, and report to the Society at its annual meeting.

In a report to the Regent of the University of Illinois in 1886, Professor Forbes mentioned a librarian among the personnel of the State Laboratory (Burrill 1887*a*:101). Henry Clinton Forbes served as Librarian and Business Agent of the Laboratory from 1892 to 1902 (Pillsbury 1892:284; 1894:135; 1896:[14]; 1898:[15]; 1901:XVII; 1902:XX).

The policy of appointing professional librarians was started in 1906 with the appointment of Miss Edna Lucy Goss, B.L.S. (Pillsbury 1906:XXII) and has continued to the present.

FINANCIAL SUPPORT

Financial support for the library has always been considered of great importance. It was considered important even before the Illinois Natural History Society became a chartered organization. In the Report of Committee on Library, the following provision for a library was made (Wilber 1861*d*:12): "That the Society devote all moneys obtained by donations and memberships to this important object [library], except so much as are necessary for expenses."

In an early report of the Director of the State Laboratory of Natural History, a plea was made for a public scientific library (Forbes 1878*b*:5–6):

> A most indispensable requisite for thorough work in any direction is an increase of the Library. Much of the time and money already invested in the Laboratory collections and belongings must lie idle until this improvement is made. There is not anywhere within reach of our naturalists a scientific library sufficient to assist them to reliable original work in any department of natural history. Nothing which the State could do for science would so stimulate a productive activity among them as a moderate appropriation for a public scientific library; and there is evidently no place where this library may be so properly built up as in connection with the State Laboratory of Natural History. I have therefore included the sum of $2,000 for this purpose in my estimates, and the further sum of $200 for the services of a Librarian, to catalogue and thoroughly organize the accessions on the plan already in use. This plan of organization place[s] the resources of the library at the ready command of the investigator, without requiring that complete previous acquaintance with the literature of his subject which he can gain only by long use of a large library. It is proposed to use the money which may be voted for library purposes, first of all to procure those books now actually needed by our Illinois naturalists for the successful prosecution of the original investigations upon which they are at present engaged, and to provide for the future only when these present pressing needs have been supplied.

The state legislature granted part of the appropriation requested by Professor Forbes. In a subsequent report he made a statement concerning the value of the library (Forbes 1880*f*:9):

> No expenditure made by the Laboratory during the last two years has been so immediately profitable, both to the work of the establishment and to the studies of other naturalists, as that made for new books. While the additions are very few compared with the literature needed, they have cleared the field of difficulties which have blocked the progress of our work for years, and have first made possible to the students of our local natural history, original work of a satisfactory character, in a few departments of zoölogy and botany.

The library received its support from appropriations made by the state legislature to the State Laboratory or Natural History Survey until the books were transferred to the University of Illinois, at which time the University assumed the responsibility for the book collection (Cunningham 1928:275–6).

After 100 years of library service to the staff and to the naturalists of the state, we hope that a statement made by Professor Forbes a half century ago is still true and that the library will always maintain the high standard set for it by its founders. "Apart from its collections, . . . the most useful possession of the Laboratory is its library, which is the product of many years of careful selection and purchase of the literature of the world . . ." (Forbes 1909:55).

Former Technical Employees

Illinois Natural History Society, Illinois State Entomologist's Office, Illinois State Museum of Natural History, Illinois State Laboratory of Natural History, Illinois Natural History Survey

BESSIE B. EAST

FOLLOWING is a partial list of former employees of the Illinois Natural History Society (1858–1871), Illinois State Entomologist's Office (1867–1917), Illinois State Museum of Natural History (1871–1877), Illinois State Laboratory of Natural History (1877–1917), and Illinois Natural History Survey (since 1917). The list is not complete because early records are fragmentary or do not exist, and because, for the sake of brevity, it seemed desirable to omit the names of many short-term or part-time employees. A number of collaborators who worked closely with regular staff members are not listed, although they made contributions to the official publications. Because of their important contributions to the work of the Natural History Society and the maintenance of its collections, the names of two early curators, C. D. Wilber (1858–1864) and Joseph A. Sewall (1864–1867), and of the first librarian, Ira Moore (1858–1863), have been included; all three were members of the staff of Illinois State Normal University.

The first official employee whose salary was paid from funds appropriated by the state legislature for that purpose was John Wesley Powell, appointed Curator in 1867. From this beginning, the staff has increased to its present total of 101. No present employees are included in the following list.

ADAMS, CHARLES CHRISTOPHER
Entomologist, 1896–1898

ADAMS, LEVERETT ALLEN
Zoologist, 1929

ALEXANDER, CHARLES PAUL
Entomologist, 1919–1922

ALEXOPOULOS, CONSTANTINE J.
Botanist, 1930–1931

AMES, RALPH WOLFLEY
Plant Pathologist, 1951–1952

ANDERSON, HARRY WARREN
Botanist, 1922

ANDERSON, JOHN M.
Biologist, 1939–1941

APPLE, JAMES WILBUR
Entomologist, 1943–1949

AUDEN, KENNETH FRANCIS
Entomologist, 1925–1927

BAKER, FRANK COLLINS
Zoologist, 1931–1932

BALDUF, WALTER VALENTINE
Entomologist, 1923

BARNICKOL, PAUL GEORGE
Aquatic Biologist, 1945–1948

BARRETT, E. G.
Botanist, 1931–1932

BEACH, ALICE MARIE
Entomologist, 1899–1900

BERGER, BERNARD GEORGE
Entomologist, 1941–1945

BETTEN, CORNELIUS
Entomologist, 1931

BROWN, FRANK ARTHUR
Zoologist, 1935

BURKS, BARNARD DE WITT
Entomologist, 1937–1949

BURRILL, THOMAS JONATHAN
Botanist, 1885–1892

BUTLER, CYRUS W.
Biologist, 1880–1882

CAMPANA, RICHARD JOHN
Plant Pathologist, 1952–1958

CAMPBELL, LEO
Botanist, 1930–1931

CHANDLER, STEWART CURTIS
Entomologist, 1917–1957

CHAPMAN, HERMAN HAUPT
Forester, 1922–1923

CHASE, ELIZABETH BROWN
Biologist, 1945–1948

CHOUINARD, CARROLL BENEDICT
Editor, 1931–1937

COMPTON, CHARLES CHALMER
Entomologist, 1921–1944

COQUILLETT, DANIEL WILLIAM
Entomologist, 1881

CRAIG, WALLACE
Aquatic Biologist, 1898–1899
CRAWLEY, HENRI DOUGLAS
Forester, 1950–1951
CREAGER, DON BAXTER
Plant Pathologist, 1939–1943
CULVER, LAWSON BLAINE
Forester, 1947–1954
DANIELS, EVE
Botanist, 1924–1926
DAVIS, JAMES ELWOOD
Forester, 1935–1947
DAVIS, JOHN JUNE
Entomologist, 1907–1911
DECOURSEY, JOHN D.
Entomologist, 1929–1932
DELONG, DWIGHT MOORE
Entomologist, 1934–1936, 1938, 1941, 1945
DOZIER, HERBERT LAWRENCE
Entomologist, 1932
DRIVER, ERNEST CHARLES
Zoologist, 1930
DUGGAR, BENJAMIN MINGE
Botanist, 1895–1896
DURHAM, LEONARD
Aquatic Biologist, 1947–1950
EARLE, FRANKLIN SUMNER
Mycologist, 1886
EDDY, SAMUEL
Botanist, 1925–1929
ELDER, WILLIAM HANNA
Game Specialist, 1941–1943
ENGELHARD, ARTHUR WILLIAM
Plant Pathologist, 1955–1956
FARRAR, MILTON DYER
Entomologist, 1931–1946
FELL, RACHEL M.
Botanist, 1881–1882
FERRIS, JOHN MASON
Plant Pathologist, 1957–1958
FISK, VERNON C.
Forester, 1921–1923
FLINT, WESLEY PILLSBURY
Entomologist, 1907–1943
FORBES, ERNEST BROWNING
Zoologist, 1894–1896, 1899–1901
FORBES, HENRY CLINTON
Librarian, 1894–1902
FORBES, STEPHEN ALFRED
Curator, State Museum of Natural History, 1872–1877; Director, State Laboratory of Natural History, 1877–1917; State Entomologist, 1882–1917; Chief, Natural History Survey, 1917–1930
FOSTER, T. DALE
Zoologist, 1931–1932
FRENCH, GEORGE HAZEN
Entomologist, 1877–1878
FRISON, THEODORE HENRY
Entomologist, 1923–1930; Chief, Natural History Survey, 1930–1945
GARMAN, PHILIP
Entomologist, 1914
GARMAN, W. HARRISON
Zoologist, 1877–1889
GIRAULT, ALEXANDRE ARSENE
Entomologist, 1908–1911
GLASGOW, ROBERT DOUGLASS
Entomologist, 1905–1909, 1912–1915, 1927
GLENN, PRESSLEY ADAMS
Entomologist, 1911–1917
GODING, FREDERICK WEBSTER
Entomologist, 1885
GOFF, CARLOS CLYDE
Entomologist, 1927–1930
GOSS, EDNA LUCY
Librarian, 1906–1908
GROSS, ALFRED OTTO
Ornithologist, 1906–1907, 1909, 1912
HANKINSON, THOMAS LEROY
Zoologist, 1911
HARRIS, HUBERT ANDREW
Botanist, 1930–1933
HART, CHARLES ARTHUR
Entomologist, 1880–1918
HART, LYDIA MOORE
Artist, 1891–1898
HAWKINS, ARTHUR STUART
Game Specialist, 1938–1945
HAYES, WILLIAM PATRICK
Entomologist, 1926, 1928–1934
HEMPEL, ADOLPH
Zoologist, 1894–1896
HESSELSCHWERDT, ROBERT EDWARD
Zoologist, 1936–1942; Photographer, 1946–1948
HOFFMAN, PAUL FREDRICK, JR.
Plant Pathologist, 1951–1954
HOOD, JOSEPH DOUGLAS
Entomologist, 1910–1912
HOTTES, FREDERICK CHARLES
Entomologist, 1928–1930
HUNT, FRANCIS D.
Aquatic Assistant, 1925–1937
HUNT, THOMAS FORSYTH
Entomologist, 1885–1886
HUTCHENS, LYNN HENRY
Aquatic Biologist, 1936–1938, 1946–1947

JANVRIN, CHARLES EDWIN
Librarian, 1912–1929
JOHNSON, WILLIS GRANT
Entomologist, 1894–1896
JORDAN, JAMES SCHUYLER
Game Specialist, 1948–1955
KAHL, HUGO
Entomologist, 1892–1894, 1901–1902
KELLEY, GRACE OSGOOD
Librarian, 1908–1912
KNAB, FREDERICK
Artist, 1903–1905
KNIGHT, HARRY HAZELTON
Entomologist, 1930, 1932–1933, 1937
KNIGHT, KENNETH LEE
Entomologist, 1938–1939
KOFOID, CHARLES ATWOOD
Aquatic Biologist, 1895–1900
KRUMHOLZ, LOUIS A.
Zoologist, 1938–1941
KUDO, RICHARD R.
Zoologist, 1930
LARGE, THOMAS
Aquatic Biologist, 1899–1902
LE BARON, WILLIAM
Entomologist, 1870–1875
LEIGH, WALTER HENRY
Game Specialist, 1935–1938
LOW, JESSOP BUDGE
Game Specialist, 1941–1943
LUCE, WILBUR MARSHALL
Zoologist, 1929–1930, 1932
LUETH, FRANCIS X.
Zoologist, 1939–1940
MCCAULEY, WILLIAM EDWARD
Entomologist, 1934–1941
MCCLURE, HOWE ELLIOTT
Entomologist, 1930–1933
MCCORMICK, A. K.
Aquatic Biologist, 1881–1882
MCDOUGALL, WALTER BYRON
Botanist, 1928
MALLOCH, JOHN RUSSELL
Entomologist, 1913–1921
MALLY, FREDERICK WILLIAM
Entomologist, 1889–1890
MALTBY, CORA M.
Librarian, 1885–1886
MARTEN, JOHN
Entomologist, 1888–1894
MIDDLETON, NETTIE
Entomologist, 1878–1880
MILLER, AUGUST EDWARD
Entomologist, 1926–1928
MILLER, ROSS JEWELL
Forester, 1947–1956
MILNER, ANGE V.
Librarian, 1880–1882
MOORE, IRA
Librarian, 1858–1863
MOORE, THOMAS EDWIN
Entomologist, 1948–1956
NYBERG, FLORENCE ANNA
Assistant to the Chief, 1922–1945
O'DONNELL, DONALD JOHN
Zoologist, 1931–1937
OESTERLING, H. CARL
Editor, 1926–1931
PEAKE, CHARLES O.
Botanist, 1921–1923
PEIRCE, ALAN STANLEY
Botanist, 1933–1934
PEPOON, HERMAN S.
Botanist, 1931–1933
PLUNKETT, ORDA ALLEN
Botanist, 1922
PORTER, CHARLES LYMAN
Botanist, 1921–1922
POWELL, JOHN WESLEY
Curator, 1867–1872
POWERS, EDWIN BOOTH
Entomologist, 1917
RASMUSSEN, DANIEL IRVIN
Biologist, 1931–1932
RICHARDS, WILLIAM ROBIN
Entomologist, 1950–1953
RICHARDSON, ROBERT EARL
Aquatic Biologist, 1903–1904, 1909–1933
RIEGEL, GARLAND TAVNER
Entomologist, 1938–1942
RIES, DONALD TIMMERMAN
Naturalist, 1938
ROBERTSON, WILLIAM BECKWITH, JR.
Game Specialist, 1952–1956
SAWYER, LESLIE EDWIN
Forester, 1929–1935
SCHNEIDER, IRVING ROBERT
Plant Pathologist, 1954–1956
SCHOPF, JAMES
Botanist, 1931
SCHREEDER, W. F.
Forester, 1921–1925
SCOTT, CHARLES L.
Photographer, 1948–1951
SELANDER, RICHARD B.
Entomologist, 1955–1958
SEWALL, JOSEPH A.
Curator, 1864–1867
SEYMOUR, ARTHUR BLISS
Botanist, 1881–1883, 1884, 1886

SHELFORD, VICTOR ERNEST
Ecologist, 1914–1927
SHOEMAKER, HURST
Zoologist, 1942, 1944
SHROPSHIRE, LESLIE HAROLD
Entomologist, 1931–1942
SIMMONS, LILLIAN MARGUERITE
Librarian, 1943–1952
SMITH, DORA
Biologist, 1894
SMITH, EMMA A.
Entomologist, 1877
SMITH, FRANK
Zoologist, 1894–1897, 1907–1910
SMITH, LINDLEY MALCOLM
Entomologist, 1907–1917
SNOW, FRANCIS HUNTINGTON
Entomologist, 1892
SNYDER, MARY JANE
Amanuensis and Editor, 1883–1925
SOMMERMAN, KATHRYN MARTHA
Entomologist, 1939–1946
SOWLS, LYLE K.
Game Specialist, 1940–1941
SPOONER, CHARLES S.
Entomologist, 1917–1920
SPOONER, CHARLES S., JR.
Biologist, 1939–1942
STANLEY, WILLARD FRANCIS
Zoologist, 1935
STOUT, GILBERT LEONIDAS
Botanist, 1926–1930
SUMMERS, HENRY ELIJA
Entomologist, 1892–1893
SURANY, PAUL
Entomologist, 1950–1955
SURFACE, HARVEY ADAM
Zoologist, 1899
TANQUARY, MAURICE COLE
Entomologist, 1910–1912
TAYLOR, ESTES PARK
Entomologist, 1903–1905
TEHON, LEO ROY
Botanist, 1921–1954; Acting Chief, Natural History Survey, 1945–1946
TELFORD, C. J.
Forester, 1921–1929
THOMAS, CYRUS
Entomologist, 1875–1882
THOMPSON, DAVID HIRAM
Zoologist, 1923–1944
TITUS, EDWARD SHARP GAIGE
Entomologist, 1902–1903
TOWNSEND, LEE HILL
Entomologist, 1932–1936
TRUMBOWER, JOHN ABBOTT
Botanist, 1932–1933
VAN CLEAVE, HARLEY JONES
Parasitologist, 1911–1912
VASEY, GEORGE W.
Acting Curator, 1871–1872
VESTAL, ARTHUR GIBSON
Botanist, 1909
VON LIMBACH, BRUNO
Zoologist, 1940–1945
WADLEY, FRANCIS MARION
Entomologist, 1920
WALSH, BENJAMIN D.
Entomologist, 1867–1869
WANDELL, WILLET NORBERT
Forester, 1945–1954
WEBSTER, FRANCIS MARION
Entomologist, 1881–1884, 1902–1904
WEED, CLARENCE MOORES
Entomologist, 1885–1888
WEINMAN, CARL JOHN
Entomologist, 1937–1952
WEST, JAMES ALEXANDER
Entomologist, 1905–1908
WILBER, C. D.
Curator, 1858–1864
WOLF, JOHN
Botanist, 1880
WOOD, FRANK ELMER
Aquatic Biologist, 1905–1909
WOODWORTH, C. W.
Entomologist, 1884–1886
WRIGHT, JOHN MCMASTER
Entomologist, 1943–1957
YEAGER, LEE EMMETT
Forester, 1938–1945
YOUNG, PAUL ALLEN
Botanist, 1922–1925
YUASA, HACH'RO
Entomologist, 1921–1922
ZETEK, JAMES
Entomologist, 1909–1911
ZUCKERMAN, BERT MERTON
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