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NATURAL HISTORY  
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STATE OF ILLINOIS  
DWIGHT H. GREEN, *Governor*  
DEPARTMENT OF REGISTRATION AND EDUCATION  
FRANK G. THOMPSON, *Director*

DIVISION OF THE  
NATURAL HISTORY SURVEY  
THEODORE H. FRISON, *CHIEF*

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Volume 21

BULLETIN

1936-1941

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# Contents and Index



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URBANA, ILLINOIS

September 1945



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# Illinois Natural History Survey BULLETIN

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#### EMENDATIONS

1. Page 65, Fig. 29. For *S. infumata* read *S. velata*.
2. Page 65, Fig. 30. For *S. velata* read *S. infumata*.
3. Page 65, Fig. 35. For *S. infumata* read *S. velata*.
4. Page 65, Fig. 36. For *S. velata* read *S. infumata*.
5. Page 67, Fig. 54. Read as follows: *S. velata* showing bursa copulatrix *in situ*.
6. Page 67, Fig. 60. For *S. velata* read *S. infumata*.
7. Page 73, line 3 under *Sialis infumata* Newman, Male. Read as follows: genitalia as follows: figs. 30 and 36: ninth
8. Page 73, line 3 under *Sialis infumata* Newman, Female. Read as follows: sternite, fig. 60. This is longer and rec-
9. Page 197, line 53. For *Spaeropsis* read *Sphaeropsis*.
10. Page 243, Table 1, line 20. For *Vallisneria spiralis* read *Vallisneria spiralis*.

# INDEX

The following index covers Articles 1, 2, 5, 6, 7 and 8 of Volume 21 of the ILLINOIS NATURAL HISTORY SURVEY BULLETIN. An index to Article 3, *Studies of Nearctic Aquatic Insects*, by H. H. Ross and T. H. Frison, will be found on page 98 of this volume, and an index to Article 4, *Descriptions of Nearctic Caddis Flies*, by Herbert H. Ross, will be found on page 180. An appendix to Article 8, *Duck Food Plants of the Illinois River Valley*, by Frank C. Bellrose, Jr., appears on page 280. It contains a list of all but the rarer plants occurring in the Illinois River valley that may be used as food by waterfowl. Only the names of plants referred to in the text of Article 8 are included in the following index.

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Volume 21

BULLETIN

Article 1

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# The Effect of Petroleum-oil Sprays on Insects and Plants

---

M. D. FARRAR



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URBANA, ILLINOIS  
November 1936



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## FOREWORD

IN 1919 the ILLINOIS NATURAL HISTORY SURVEY began an investigation of oil sprays for the control of insects. In 1925 the Crop Protection Institute established a research fellowship on oil sprays with the NATURAL HISTORY SURVEY. This fellowship was supported by funds from the Standard Oil Co. of Indiana. This paper brings together data from the eight years of investigation 1925-33, and includes the data that appear to illustrate progress in the knowledge of oil sprays.

### Types of materials and tests

The experiments have included tests on about 310 oil or oil-emulsion formulae, of which about 16 per cent were soluble oils and 84 per cent stock emulsions. In addition to these, various chemicals were included in many of the formulae. For purposes of discussion and comparison of the various emulsions the information is grouped under general headings referring to the specific insects and plants used in the experiments.

A very limited number of emulsion formulae were tested under field conditions for more than one season. The greater portion were tested under field conditions for only one year. Laboratory studies were made upon all of the formulae to determine their physical properties and toxicity to bear foliage. A limited number of tests were performed on insects to evaluate the insecticidal properties of each emulsion. Those formulae which looked promising as a result of information gained in the laboratory were tested under field conditions the following season.

### Present knowledge of oil sprays

As tangible results of the investigation, a miscible oil and a white-oil stock emulsion have been developed. In the investigation of these products and the study of their related formulae, a fund of constructive information has been compiled that has been of great assistance in the interpretation of results. This information has added greatly to our understanding of some of the factors affecting the reactions of petroleum oils on insects and plants.

Indicative of present knowledge concerning oil sprays are the following:

The use of oil emulsions for codling moth control in late-brood sprays, particularly when mixed with nicotine sulfate, is very promising.

Sprays of oil emulsions for late-brood codling moth larvae have given excellent results in the reduction of lead arsenate residues.

The larvicidal limits of oil emulsions are fairly well established.

The use of oil emulsions with lead arsenate sprays shows promise in the control of codling moth larvae.

The use of petroleum oil as a carrier for plant poisons is recognized.

Oil emulsions are giving a control of scale insects superior to all other sprays for scale.

### Acknowledgments

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#### Definition of Terms

*Concentration of emulsions* refers to measurements by volume.

*Lead arsenate* is acid lead arsenate, the powdered commercial product marketed for insecticidal purposes.

*Miscible or soluble oils* are clear oil-like emulsions containing very little water. In these a soap emulsifier is dissolved into the oil. Upon the addition of water the miscible oils disperse to form a milky white emulsion of very small oil-droplet size. The commercial oils *Dendrol* and *Sunoco* are examples.

*Paraffin oil or unsaturated oil* is not as highly refined as technical white oil (which see) and contains unsaturated hydrocarbons in varying amounts depending on the degree of refinement. The degree of saturation is expressed as unsulfonated residue and is determined by a standard procedure known as the Whiting method.

*Quick-breaking emulsions* are made in the spray tank with or without addition of some emulsifying agent. The emulsion depends upon the agitation to break up the oil into droplets. The oil droplets are very large and loosely emulsified, so that the oil phase may separate either on standing or soon after application. For certain insects such as leaf rollers and case-bearers, they are superior to the more stable emulsions.

*Stock emulsions* are oil emulsions of a pastelike consistency. They generally contain water as a separate phase. Boiled fish-oil soap emulsion is an example of this type.

*Technical white oil* is an oil from which the preponderance of unsaturated hydrocarbons has been removed, but it is not of medicinal grade. A technical white oil, or saturated oil, is practically inert chemically.

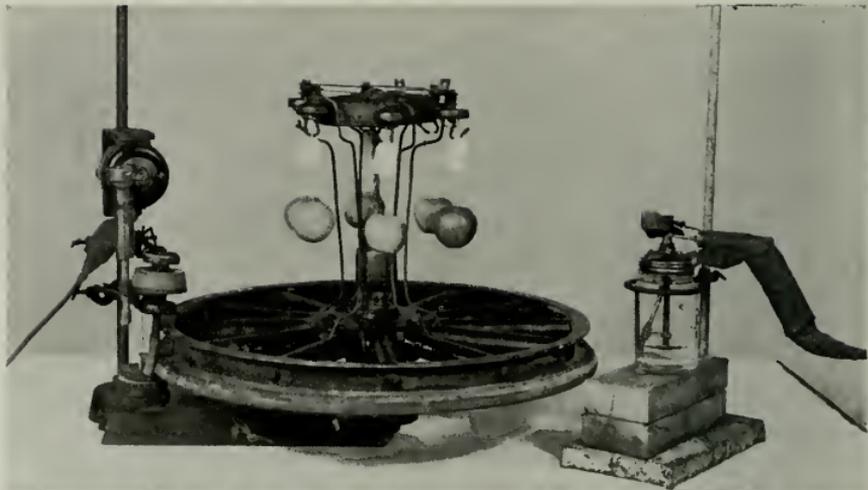
*Viscosity*, as measured by the Saybolt test, is the resistance to flow of a given volume of oil through a given orifice at 100° F, and is expressed in seconds.

Urbana  
January 1, 1936

M. D. F.

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TESTING CODLING MOTH SPRAYS.—*Top*, Apparatus devised by Farrar and McGovran to secure uniform deposit of spray on apples. At the left is shown a 110-volt, 60-cycle (1800 rpm) one-sixth horsepower stir motor with reduction gear. The stir rod buffers against a No. 13 rubber stopper supported between two roller-skate wheels as bearings. On the lower end of the shaft carrying the stopper is a heavy-walled rubber tube extension that buffers against the rim of an auto wheel covered with friction tape to reduce slipping. The wheel is part of a whirligig that rotates a group of six experimental apples while revolving each apple separately. Moving at 8 rpm, the wheel turns six skate wheels, supporting an apple apiece, at 27 rpm against a fixed 6-inch buffer wheel. At right is a sprayer constructed for use with compressed air, spraying with 25 pounds pressure. The spray mixture in the jar is stirred by an agitator driven by a compressed-air turbine. *Bottom*, Rack of test apples used in laboratory tests of codling moth sprays.

# The Effect of Petroleum-oil Sprays on Insects and Plants

M. D. FARRAR

## PROPERTIES OF OIL EMULSIONS

The ratio between saturated and unsaturated hydrocarbons in an oil determines to a large extent the use of that oil as an insecticide on either dormant or non-dormant plants. The viscosity, volatility and degree of dispersion are important properties which affect both plant tolerance and insecticidal efficiency. Spreading properties of unit volumes of spray are nearly identical as to coverage and time. Preparation of emulsions for these experiments was by the Whiting method.

**S**ATURATED, or the ratio between saturated and unsaturated hydrocarbons, has sharply divided the usage of oil sprays into two distinct fields. The works of Gray & deOng (1926), deOng, Knight & Chamberlin (1927), English (1928) and others show that the oils containing the larger quantities of unsaturated hydrocarbons are the more likely to cause plant injury under comparable conditions. Extensive experiments indicate that the less highly refined oils are safe to apply on dormant trees if they are properly emulsified. Because of the lower cost of this grade of oil its use in dormant sprays has become general.

### Plant Tolerance Limits Viscosity

The viscosity of oils used in tree sprays must be kept within the limits of plant tolerance. Oils of less than 40-50 seconds of viscosity are very difficult to combine into a stable emulsion. Although somewhat safer to use on plants, these light-viscosity oils disappear too rapidly to have a good insecticidal value. Knight, Chamberlin & Samuels (1929) feel that a 60-second viscosity oil represents about the upper limit of plant tolerance and that oils of higher

viscosities must be used with caution if serious ultimate injury is to be avoided. Most authors agree that the lighter oils are safer on plants and generally recommend the lightest oil that will give proper control of the insect involved. Temperature under which an oil is used in the field should determine the proper viscosity, according to deOng (1931), although Green (1927) did not find viscosity a factor for toxicity in dormant spraying. Oils of 60-125 seconds viscosity are now being used in the manufacture of the greater part of the commercial brands of oil emulsions.

### Less Stable Emulsions Most Toxic

Volatility is a property that some authors have considered important in petroleum oils for use in tree sprays. Although perhaps of some importance its significance has not been fully accepted by all workers. The property of volatility is by no means identical with that of viscosity, nevertheless it is closely associated with viscosity. According to the findings of Knight, Chamberlin & Samuels (1929), the effect of volatility "due to the enclosure of the oil in the intercellular spaces . . . is unquestionably negligible in comparison with translocation." In this paper the author has not considered volatility an independent property of the oils used in the emulsions tested.

The emulsifier plays a very important rôle in the performance of oil emulsions, as is shown by the work of deOng & Knight (1925), deOng (1926), deOng, Knight &

Chamberlin (1927) and others. Oil emulsions that incorporate excessive amounts of emulsifier are very easily emulsified but are not as efficient for the control of scale as are less stable emulsions. English (1928), working with aphids, San Jose scale and oyster-shell scale, clearly demonstrated that high mortality was associated with emulsions exhibiting the quicker breaking properties.

#### Spray Methods Regulate Coverage

The total volume of any spray material required to cover a certain block of fruit

applied. This fact is in accordance with the findings of Swingle & Snapp (1931), and it is brought out also in the records of commercial orchards which use large amounts of materials for each spray. In well-equipped orchards the variations can usually be accounted for by adverse weather conditions.

Additional proof that the volume of spray material necessary to cover a unit number of trees is relatively constant was given in a series of tests that made use of commercial oil 17<sup>1</sup> at 2 per cent concentra-

Table 1.—Properties of experimental oils.\*

TYPE OF OIL AND NUMBER	SPECIFIC GRAVITY AT 60° F	FLASH POINT	FIRE POINT	VISCOSITY seconds at 100° F	PERCENTAGE OF EVAPORATION 8 hours at 212° F	PERCENTAGE OF UNSULFONATED RESIDUE
	grams per cc	°F	°F			
Technical white oil 32	.801	174	206	32	35.1	100.
Technical white oil 83	.857	345	395	83		99.
Technical white oil 95		366	410	95-100	8.6	99.5
Technical white oil 190	1.878	375	430	190	.2	98.
Paraffin oil 32	.82	164	196	32	54.3	92.
Paraffin oil 83	.883	335	385	83	1.7	91.
Paraffin oil 104	.889	355	405	104	1.2	93.

\* Technical white oils of viscosities other than those listed correspond to technical white oil 83 in unsulfonated residue. Paraffin oils correspond to paraffin oils 83 and 104 in unsulfonated residues. The data given above were submitted from the laboratory of the Standard Oil Co. of

Indiana. Whiting. Unsulfonated residue (degree of saturation) values given in this paper were determined by the Whiting method. These values are higher than those given by some other methods.

trees has not been a settled question in the minds of many horticulturists. They have been led to believe that there are wide differences in the spreading and covering properties of certain spray materials. Salesmen of insecticides often claim that this or that material will give a greater spread, and so reduce the actual cost of a spray to cover an orchard.

There are certain factors involved in the practice of spraying that influence the amount of material required to cover a certain number of trees. Some of these factors are the type of equipment, number and size of nozzles, the pressure, visibility, wind direction, type of workmen doing the work, and the care with which the workmen attempt to wet the trees thoroughly. If the workmen are given a standard set of equipment and have uniform weather conditions, the amount of material that they will use will vary but slightly regardless of the physical properties of the spray material

tion, commercial oil 2<sup>4</sup> at 6.5 per cent, "Illinois formulae" boiled fish-oil soap emulsion<sup>2</sup> at 3 per cent, and liquid lime sulfur solution at 10 per cent. In four tests 200 gallons of each material covered between 13.6 and 14.8 trees and required between 13.6 and 14.8 minutes for application. The test indicates that the volume of spray material necessary to cover a unit number of trees is relatively constant, irrespective of the nature of the spray material applied.

#### Stability Determines Mortality

By combining the proper grades of oils and emulsifiers in certain proportions it is possible to produce an emulsion that is stable under ordinary conditions of storage and handling and that will give a high kill of insects when it has been properly diluted. Addition of various chemicals to either the

<sup>1</sup>Laboratory designations of various experimental oils. Many others follow.

oil, water or emulsifier phases of these emulsions often changed the degree of dispersion. The difficulty of classification made impractical the consideration of particle size in the experimental white-oil emulsions. It is generally recognized that the less dispersed oil emulsions separate faster and are more toxic to insects.

Most miscible oils and many of the stock emulsions were prepared by a standard technique worked out in the Standard Oil laboratories at Whiting, Ind. Stock emulsions incorporating inert emulsifiers were emulsified by colloid mills, capable of producing emulsions of uniform dispersion of oil droplets in the technical white-oil emulsions. (For analysis of oils used see Table 1.)<sup>2</sup>

#### EFFECT OF PETROLEUM OILS ON PLANTS

The physical properties of oil emulsions cannot be associated with some forms of plant injury that follow applications of oil sprays. Such plant disturbances are associated with general vigor, stage of growth, soil moisture and food relations.

Petroleum-oil emulsions formed with soap are generally toxic to foliage irrespective of the saturation or viscosity of the petroleum oil.

The amount of emulsifier present in an emulsion determines to some extent the physical nature of the emulsion and to a greater extent its insecticidal value. The emulsions which possess the larger oil droplets are the more toxic to insects and less toxic to plants.

The viscosity of a petroleum oil determines to a limited extent its safety to growing plants. The lighter oils, 50 seconds of viscosity or less, are less toxic to plants but are not efficient insecticides. Oils of greater than 100 seconds of viscosity tend to create physiological disturbances within the growing plant.

A laboratory study of the larvicidal efficiency of emulsions indicates only a limited possibility of increasing the mortality of codling moth larvae by changes in the physical properties of an emulsion.

The technical white-oil emulsions are relatively safe on foliage if they possess the proper degree of saturation, viscosity, oil-droplet size, and an inert emulsifier.

Previous to 1900 many cases of plant injury were reported<sup>3</sup> from the spraying of plants with petroleum oils. It is not surprising to find injury occurring early in the

development of oil sprays. About 1900 the use of petroleum oils became more general and information became available as to the more suitable oils and emulsion types that could be safely used on growing plants. During this same period there was rapid development in the machinery necessary for the proper preparation and application of emulsions.

#### Oils the Modern Insecticide

Entomologists now recognize that oil sprays serve as very important weapons for the control of many dangerous pests, such as scales, mites, aphids, leaf rollers, case-bearers, codling moth and oriental fruit moth. Petroleum-oil emulsions are now available that are adaptable for definite insecticidal purposes with a minimum of danger to the host plant.

Volck (1903) published the first comprehensive paper on the effect of petroleum oil when used on plants as an insecticide. In this paper he concluded, "by far the greatest cause of injury to vegetable tissue is brought about by the penetration of the oil applied, into the interior of the plant." He also found the lighter oils less injurious than heavy oils and that the degree of injury depended upon certain physical factors. Some of the factors listed by Volck are the condition of the plant, type of oil, amount of spray used, whether the spray is applied to the upper or lower leaf surface, and temperature and humidity at the time of spraying. He demonstrated a physical injury from oil that he attributed to "insulation" or sealing over of the parts of the plant; this insulation interfered with both respiration and transpiration of the plant. The chemical effects caused by the petroleum oils used by Volck can now be largely corrected by employing the highly refined white oils, which contain a minimum of unsaturated hydrocarbons.

<sup>2</sup>Manufacturers of commercial oils used in these tests: Sun Oil Co., B. G. Pratt & Co., Sherwin-Williams Co., California Spray-Chemical Co., Shell Oil Co., Schaeffer Bros. & Powell, and Standard Oil Co. of Indiana.

<sup>3</sup>According to Lode-man (1896), Goetze was the first to recommend the use of oils on plants. In 1763, J. A. E. Goetze wrote, "petroleum, turpentine and other oils are also recommended, but care must be taken in their use, since they act upon the plants, making them sick or even killing them." Lode-man also credits William Forsyth as the first (1800) to call attention to the use of train (whale) oil against coccus or scale insects on plants.

The first record of petroleum oil as an insecticide in America is a recommendation in 1865

to use kerosene undiluted. The oil was to be applied by means of a feather on citrus trees for the control of citrus scale. Kerosene was first employed as a spray in 1868 by Henry Bird, Newark, N. J. He used a mixture of kerosene, soap and water for the control of the currant worm. It was not generally used as an emulsion until recommended by A. J. Cook in 1878.

By 1882, H. O. Hubbard had developed a satisfactory formula for kerosene emulsion, using soap as an emulsifier. Kerosene and other light petroleum oils were used quite generally either as emulsions or as mechanical mixtures previous to 1900, followed by distillate-water mechanical mixtures in 1902 and by miscible oils in 1904, according to Mason (1928) and Essig (1931).

#### Tolerances Variable, Specific

Volck (1903) found that the important injuries to citrus leaves by oil are general and not local. This observation has been substantiated in more recent work by the determination of rather definite plant tolerances to oil sprays. No rules can be established relative to the tolerance of plant species to oils, but we do know within limits the amount of certain petroleum oils that can be applied with relative safety to the more important trees and plants. It is now well established that a dormant tree will withstand higher dosages of less refined oils than the growing tree. The type of oil that may be used with safety to the plant will depend to a great extent on the season of the year when it is applied.

The accumulative effect of oil sprays has been mentioned by Volck (1903), Yothers (1913) and others. It is pronounced during the active growth of the plant and becomes less evident as the plant approaches dormancy, at which time the effect apparently disappears.

Burroughs (1924) stated, "from theoretical considerations and from observations and experiments, it is quite certain that a covering of oil on the surface of the plant organ may affect the physiological processes of that organ. It is probable that under some conditions the effect of the oil may be infinitesimal."

#### Normal Metabolism Disturbed

Herbert (1924), working with prunes, found the greatest plant stimulation associated with the heavy types of miscible oils. He correlated the degree of stimulation with the moisture and food relations of the soil and the season of the year when the trees were sprayed with the oil. deOng (1926) also found a correlation between the season of spraying and the effect on French prunes. In his experiments, extending over two years, sprays applied in November before the trees were fully dormant slightly retarded development, December sprays had little effect, January and early February sprays stimulated, while sprays applied between February 15 and March 15 retarded development.

Knight, Chamberlin & Samuels (1929) determined histologically the distribution of the petroleum oil in the plant tissue following an oil spray. They found that the

saturated white oils were absorbed by the tissues and not volatilized, as considered by some authors. The translocation of the absorbed oil was traced from the leaf surface to its final deposition in the large storage cells of the pith and the old wood fiber of the xylem. During the period of oil penetration and initial translocation, transpiration was sharply decreased and respiration enormously increased. Knight and his co-workers attributed the metabolic disturbances to physical rather than chemical handicaps imposed by the intrusion of the saturated petroleum oils into the plant tissue. Ginsburg (1929) found that apple foliage sprayed four times between July 12 and August 24 increased in chlorophyll content from 28 to 47 per cent in the two apple varieties tested. This secondary effect of oil sprays, that of intensifying the green appearance of the oil-sprayed foliage, has been reported by numerous workers with oil emulsions. Working with excised twigs, Kelley (1930a) found that "Saturation of the heavier oils, comparable to those used in commercial spraying, was not important in either the dormant or delayed-dormant periods. It was relatively unimportant in foliage applications."

#### Measure of Injury Unsettled

The works of Volck (1903), Yothers (1913), deOng (1926, 1928b, 1931), English (1928), Knight, Chamberlin & Samuels (1929), Kelley (1926, 1930a, b), Ginsburg (1929, 1931a, b) and others demonstrate that oils applied to foliage produce certain physiological effects on the trees. As yet no one has advanced a good criterion for classifying these physiological effects as injury resulting from an oil spray. Woodworth (1930) proposes certain terms which may be useful in classifying these effects. It is true that certain oils will injure or burn more than other oils under a comparable set of conditions, but it has never been possible to show that a certain property of an oil, if present in an emulsion, will result in foliage injury. In this paper, injury is considered as visible changes in the normal leaf tissue following the application of an oil spray. This type of injury usually is evident on the margins or tips of the terminal and adjoining leaves.

A part of the difficulty in dealing with emulsions lies in the fact that every emul-

sion prepared is an individual colloidal system possessing properties distinctive from every other emulsion. Although this condition is literally true, the emulsions tested in this work were approximately the same since they were prepared in the same way and from very similar materials. It was found possible to duplicate quite closely formulae that had been used in previous tests.

#### Annual Dormant Sprays Safe

Consistent annual spraying of deciduous fruit trees in the dormant stage with good oil emulsions has produced no apparent injury to them, according to Yothers (1918), Burroughs (1924), Newcomer & Yothers (1927) and Swingle & Snapp (1931). This fact is well established even though many individual cases of injury

Table 2.—Relation between the properties of emulsions and their relative safety when applied on apple foliage at a concentration of 2 per cent.

ITEM	TYPE OF EMULSION	COMPOSITION				NO. FORMULAE TESTED	TOTAL NO. TESTS	CASES OF NO INJURY	CASES OF SLIGHT INJURY	CASES OF MODERATE INJURY	CASES OF SEVERE INJURY
		Oil	Percentage Unsulfonated Residue	Emulsifier	Additional Material						
1	Stock	Technical white oil	99.	Inert	None	7	75	69	3	2	1
2	Stock	Technical white oil	99.	Inert	Misc.*	8	19	19			
3	Stock	Technical white oil	99.	Inert	Nicotine	5	17	17			
4	Stock	Technical white oil	99.	Inert	Derris	3	9	9			
5	Stock	Technical white oil	99.	Inert	Pyrethrum	8	41	37		2	2
6	Stock	Technical white oil	99	Inert	Copper	7	17	9	6	1	1
7	Stock	Technical white oil	99.	Inert	Sulfur	10	43	12	12	9	10
8	Stock	Technical white oil	99.	Inert	Sodium fluosilicate	2	5	2	2		1
9	Stock	Technical white oil	99.	Soap	None	2	4	4			
10	Miscible	Technical white oil	99.	Soap	None	7	22	19	1		2
11	Commercial miscible	Paraffin	90. $\frac{1}{2}$	Soap	None	4	20	5	4	3	8
12	Experimental miscible	Paraffin	91.	Soap	None	8	53	9	16	19	9
13	Experimental stocks	Paraffin	91.	Soap	None	4	14	5	3	1	5
14				Soap	None	5	22	8	4	5	4
15	Water control					0	0	0	0	0	0

\* Petroleum compounds with nitrogen or oxygen, furfuramide, chinchona alkaloids.

In addition, wide variations in individual trees, localities, weather conditions, etc., exist in most orchard experiments. These variations have led to the publication of a vast amount of data covering experiments with the use of oil emulsions. In many of the experiments the results cannot be duplicated by the workers themselves. This has filled the literature with numerous discussions of individual experiments most of which prove little one way or the other relative to the toxicity of oils to plants.

have been reported during certain experiments, particularly with nondormant trees. Vigorous trees are very tolerant to oil sprays and are seldom injured by them if the emulsions are properly prepared and applied. Where oils or other spray materials are applied under abnormal conditions, numerous foliage reactions may set in, according to Overley & Spuler (1928) and Dutton (1932). The accumulative effect of petroleum oils applied to foliage has been observed by Yothers (1913) and

others. Overholser & Overley (1930) found that more than three applications of medium to heavy-viscosity oils applied to apple trees carrying a heavy crop resulted in a decrease in the size of fruit and a poor set of buds and fruit the following year. These effects usually follow the too-frequent application of emulsions to foliage early in the growth of new tissue. Delay of such sprays until growth has about stopped and the tissues hardened greatly reduces the abnormal physiological changes, such as destruction of tissue, yellowing, premature leaf-drop, and change in chlorophyll content.

#### Unsaturated Oils Highly Toxic

The lower-viscosity oils have from the first been considered less toxic to foliage than the heavier oils. The usual explanation is based on the fact that the heavier oils are less volatile and persist on the plant over a longer period than do the lighter oils. Detection by Gray and deOng in 1915, (Gray & deOng 1926), that the unsaturated hydrocarbons present in untreated oils are largely responsible for the injury to plants has contributed more toward the development of emulsions for use on growing plants than any other discovery.

Associated with plant injury are additional, less important factors: the use of inert emulsifiers, the limits of the size of the oil droplets, and the effect of oil-droplet size on quick breaking. All of these properties have a bearing on the emulsions and predetermine to a limited extent the physical properties of an emulsion suitable for tree-spray purposes.

The stage of growth in the plant, weather conditions at the time and following spray application, time and method of application, and a host of other factors so influence the results from application of an oil spray that an emulsion incorporating all the desirable properties of a summer oil will not insure uniform performance of an insecticide without injury to the host plant.

#### Saturated Oils Generally Safe

With these conditions in mind one is in position to attempt to judge foliage injury following the use of an oil spray. Table 2 presents data summarizing most of the results obtained from the use of oil sprays on foliage over a five-year period. Particu-

lar attention should be given to item 1, covering the work with a summer oil that possessed all the physical properties deemed necessary for safety to foliage. This oil emulsion in 75 field tests gave one case of severe injury, two of moderate, three of slight injury and 69 cases where no injury was observed. When given adverse conditions, this oil emulsion, although relatively safe, produced severe injury or burn to apple foliage. A very similar result was obtained with the emulsions under item 5. If given a sufficient number of trials under varying conditions, there is no doubt that the other emulsions listed in the table would have shown a similar number of cases where injury occurred.

Emulsions listed in items 3 and 4 are similar to those in item 1 with the exception that extracts of tobacco or derris have been added to the emulsions for the purpose of increasing their insecticidal efficiency. The incorporation of these materials into an inert white-oil emulsion did not materially increase foliage injury.

The injury shown in items 6, 7 and 8 was probably caused by the copper, sulfur or sodium fluosilicate mixed with the white-oil emulsions. The formulae containing copper injured in 51 per cent of the cases, and those with sulfur in 70 per cent of the cases, where they were tested.

Technical white oils, item 9, made up as a stock emulsion with a soap emulsifier did not injure in the limited number of trials given. The same oils combined as a miscible oil injured in 14 per cent of the tests.

#### Smaller Droplets More Injurious

Petroleum oils containing as much as 9 per cent of unsaturated hydrocarbons will cause injury in most cases if they are combined with soap emulsifiers. The soap emulsifier, item 14, is no doubt responsible for some of the injury obtained with emulsions containing soap. The miscible or soluble oils, items 11 and 12, give relatively more injury than do the stock emulsions, item 13. The smaller oil-droplet size and greater stability of the miscible oils are responsible to some extent for the injury that follows the use of miscible-oil emulsions. It is evident that, other factors being equal, the emulsions with the smaller oil droplets are the more likely to cause injury to foliage.

In Table 2 a large number of cases are reported where no injury was observed with any of the sprays listed in items 1 to 14. These occurrences are significant because they explain to some extent the confusion resulting from reports of injury occurring in the individual experiments of all workers.

Some of the recent work of deOng (1926), deOng, Knight & Chamberlin (1927), and Smith (1929, 1930 and 1931) has again raised the problem of applying oils to plants without the aid of an emul-

stability of such an emulsion was almost negative and the oil droplets so irregular and unstable that they were difficult to measure. The oil drops were very large and coalesced rapidly. Neither of these oils injured foliage at 1½ per cent concentration but the less saturated oil spotted the fruit of apple.

#### Emulsifier Controls Droplet Size

In items 3, 4 and 5 a technical white oil was used that contained a product known as "butylacetyl resinoleate," which has been

Table 3.—Relation between emulsifier, droplet size, saturation and foliage injury to apple. Sprays applied to foliage at 1½ per cent concentration of oil in the water phase.

ITEM	OIL FORMULA	Oil	COMPOSITION				OIL-DROPLET SIZE microns	INJURY TO FOLIAGE	INJURY TO FRUIT
			Viscosity seconds at 100° F	Saturation percentage	Emulsifier	Stability			
1	Technical white oil	Technical white oil	83	99.	None	None	4-24	None	None
2	Paraffin oil	Paraffin oil	104	91.	None	None	4-24	None	Trace
3	13550	Technical white oil	83	99.	2% Bar*	Very quick breaking	1-12	Trace	None
4	13720	Technical white oil	83	99.	4% Bar	Very quick breaking	1-12	Light	None
5	13740	Technical white oil	83	99	6% Bar	Very quick breaking	1-12	Moderate	None
6	Stock 200	Technical white oil	83	99.	Gum	Quick breaking	2-6	None	None
7	Soluble oil 8800	Technical white oil	60	99.	Soap 15	Quick breaking	1-8	Severe	Severe
8	Soluble oil 8790	Technical white oil	83	99.	Soap 15	Quick breaking	1-8	Severe	Severe
9	Soluble oil 17	Paraffin	83	91.	Soap 15	Quick breaking	1-6	Severe	Severe
10	Control							None	None

\* A material which, when added to an oil, permits dispersion of the oil into the water by agitation.

sifier or with only sufficient emulsifier to permit dispersion by agitation in the spray mixture. Such a method of application has several advantages over emulsions containing emulsifiers, as expressed by deOng & Knight (1925). It has been demonstrated that it is possible with the proper machinery to use oils without emulsifiers, but the construction of spray machinery now in operation will not warrant the general adoption of this method of applying oils to deciduous trees.

Some further evidence on the relation of saturation, the amount of emulsifier present in an oil, and oil-droplet size is shown in Table 3. In items 1 and 2 a technical white oil and a less saturated oil were applied without the aid of an emulsifier. The

shown to impart to an oil the property of dispersion in water with limited agitation. This material was added to the oil at 2, 4 and 6 per cent respectively, to study the effect of this emulsifier on droplet size and foliage injury. The range in oil-droplet size does not present a true picture of the condition existing in the dilute sprays of these oils. Oil 13740, item 5, contains many more small oil droplets than oil 13550, item 3. With each increase of this emulsifier there is a corresponding reduction in the average oil-droplet size. This reduction in oil-droplet size produced increased injury to foliage, as is shown in items 3 to 5. None of these emulsions caused injury to the fruit.

Stock emulsion 200 was used in this

experiment as a comparison with the other emulsions. It contains a technical white oil with an inert emulsifier, has quick-breaking properties and is relatively safe on apple foliage.

Soluble oils 8800 and 8790 contain the same ratio of emulsifier as soluble oil 17 but are prepared with 60 and 83-second-viscosity white oils respectively. In items 7, 8 and 9 there was no marked difference between the technical white oils and the less saturated oil in their injury either to fruit or foliage when they were emulsified with certain soaps.

Considering the graduation in the oil-droplet size and stability between items 1, 3, 5 and 8, all containing technical white oils, it is evident that the emulsions with the smaller oil droplets and greater stability are the more injurious to apple foliage. Similar differences are exhibited between items 2 and 9, both of which contain oils with a lower sulfonation test.

## INSECTICIDE TESTS WITH THE EMULSIONS

### Codling Moth

*Carpocapsa pomonella* (Linn.)

White-oil emulsions are practical in the late-brood codling moth sprays in order to avoid arsenical residues on the fruit. The white-oil emulsions alone are not equivalent to lead arsenate in larvicidal efficiency but when combined with nicotine sulfate they are comparable to lead arsenate in the control of the late-brood codling moth larvae.

Addition to emulsions of extracts of plant poisons such as pyrethrum, derris or tobacco materially increases toxicity of the emulsions as contact insecticides. Of the plant poisons, nicotine alone was stable to exposure under field conditions. Toxicity to foliage was not influenced by the addition of plant extracts to the emulsions.

White-oil emulsions can be used as ovicides in codling moth control either alone or included in the lead arsenate sprays. The combined spray has excellent ovicidal and larvicidal properties.

## FIELD TESTS IN CONTROL OF CODLING MOTH

The codling moth is by far the most destructive insect encountered in the production of apples. The annual abundance of codling moth and the difficulty of securing an adequate control by the use of poison sprays have given this pest a rôle as limiting apple production, particularly in the sections where apples are grown commercially. In seasons of abundance the late-brood larvae will destroy 10-40 per cent of the marketable fruit. This condition

persists in orchards receiving six to 12 sprays of lead arsenate.

Arsenical sprays were introduced against codling moth in recommendations by Cook (1881) and have continued to be the most satisfactory method of control, provided a sufficient coating of spray is maintained on the fruit. The number of arsenical sprays applied has increased in many apple-growing sections and as a result the harvested fruit carries residues of arsenic in excess of the legal tolerance (See Table 4).

Table 4.—Analyses\* of harvested fruit for arsenical residue from plots treated in the late-brood codling moth sprays with 2 per cent white-oil emulsions or the recommended strengths of lead arsenate (2-4 pounds per 100 gallons) and hydrated lime (4-8 pounds per 100 gallons). The legal tolerance for 1932 was .01 grain of arsenic trioxide per pound of fruit.

YEAR	NUMBER OF ANALYSES		GRAINS OF ARSENIC TRIOXIDE PER POUND OF FRUIT	
	Oil	Lead Arsenate	Oil	Lead Arsenate
1928	3	1	.0046	.006
1929	1	1	.006	.013
1930	19	4	.0053	.025
1931	1	2	.008	.0185
1932	3	6	.005	.036
TOTALS	27	14		
AVERAGE RESIDUES			.0058	.0199

\* By the U. S. Department of Agriculture, Food and Drug Administration, St. Louis, Mo.

This condition has forced either the development of more efficient arsenical sprays or the use of nonarsenical sprays that can be substituted as sprays for lead arsenate. The most promising development has been the use of summer-oil emulsions either as direct substitutes for lead arsenate sprays or their inclusion with the lead arsenate sprays. Regan & Davenport (1928) used an oil emulsion and lead arsenate mixture in their experiments for the first time in 1925, and reported results favorable to the use of oil emulsions added to the regular lead arsenate sprays. Spuler & Dean (1930) found that fish oil and certain other drying oils were as satisfactory as petroleum oils with lead arsenate sprays.

### Addition of Petroleum Oils to Lead Arsenate Sprays

With the development of adequate washing machinery, orchardists are in position to take advantage of the insecticidal

efficiency of oil emulsions with lead arsenate. Spuler & Dean (1930) state, "when oils are combined with lead arsenate the resultant spray has an ovicidal value equal to that of oil alone and a larvicidal value greater than that of lead arsenate alone." In their tests a three-fourths per cent actual oil gave 80-95 per cent kill of codling moth eggs. Newcomer & Yothers (1932) suggest use of "a medium oil, having a Saybolt test of 65-75 seconds and a high sulfonation test applied in a propor-

burg & Filmer (1930), Flint (1930), and Newcomer & Yothers (1932) have shown that emulsions for the full season, without the use of lead arsenate, cannot be used to control codling moth. There are several reasons for this situation:

1. Oil emulsions are primarily contact sprays and cannot be applied sufficiently often to kill all hatched larvae without disturbing the physiological development of the fruit and tree.

2. The ovicidal effect of oils can be utilized only occasionally.

3. Summer-oil sprays cannot be used with the necessary fungicides early in the season.

4. Summer oils are too expensive when compared with lead arsenate sprays.

The larvicidal effect of an oil deposit is inferior to that given by lead arsenate, as is shown in the results of Flint & Farrar (1931), Lathrop & Szama (1932) and Newcomer & Yothers (1932). Nevertheless, all field tests conducted in many states where oil and lead arsenate sprays have been compared favor the limited use of oil sprays in the control of late-brood codling moth larvae. In most cases the lead-sprayed fruit has had fewer codling moth entrances than the oil-sprayed fruit; but there has not been sufficient difference in control to justify the use of lead arsenate in late sprays in orchards unequipped to wash the fruit. In this regard oil emulsions have served as a valuable aid to codling moth control during the period in which growers have been reorganizing their methods of harvesting and packing of fruit.

The results of Spuler & Dean (1930), Headlee, Ginsburg & Filmer (1930), Flint & Farrar (1931) and Talbert & Swartwout (1931) indicate that oil emulsions can be substituted for lead arsenate in the late-brood sprays. Oil sprays applied at this season do not produce the injurious effects on tree growth that are brought about when the same sprays are used earlier in the season. Two to four applications of 2 per cent oil emulsions have given protection in the late-summer sprays.

Spray recommendations for most sections suggest the direct substitution of oil sprays in place of the usual lead arsenate sprays. This has been done without regard for the most efficient use of oil sprays as ovicides on the codling moth eggs. Newcomer &

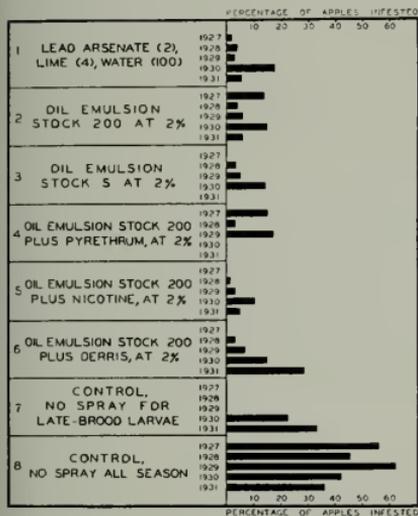


Fig. 1.—Five years' tests of sprays to control codling moth in Illinois.

tion slightly less than 1 per cent." It should not be added to more than three or four of the lead arsenate sprays and in those sprays that occur when the highest percentage of eggs is on the trees and fruit. This statement is in accord with the report of the Western Cooperative Oil Spray Project (1932), and the Washington experiment station recommendations for 1932.

#### White-oil Emulsions as a Substitute for Lead Arsenate

The development of highly saturated white oils emulsified with inert emulsifiers offered the first oil sprays that could be used on foliage during the growing season. The safety of emulsions of this type has been demonstrated by deOng (1926), English (1928), and Headlee, Ginsburg & Filmer (1930). Results of Headlee, Gins-

Yothers (1932) found that from 80 to 97.6 per cent of the eggs failed to hatch if sprayed with a 2 per cent heavy-oil emulsion and that 64.6 per cent of the eggs did not hatch if laid within seven days after application of an oil spray. The ovicidal effect obtained from oil sprays will explain in many cases why the same oil spray has given variable results in succeeding years and in different orchards.

Since 1927, orchard tests have been conducted to compare the efficiency of oil-emulsion sprays with that of lead arsenate sprays. The schedule followed for dates of

furnished the fruit used in scoring spray performance. Apple pickers gathered the fruit from the inside quarters of these trees. A 1000-apple sample was taken from this fruit to be graded in scoring the plot. The population of codling moth varied in the test orchards from light to extremely heavy, including in the five years of records representative orchards in the commercial apple-growing sections of the state.

A summary of five years of data is given in Table 5 and fig. 1. The relative control given by all of the sprays as compared with no spraying is striking, especially in the

Table 5.—Codling moth control in the orchard over a five-year period. Orchard tests were conducted in commercial orchards of western, central and southern Illinois. A test was a count made on 1000 apples taken from the four center trees of a test block.

ITEM	SPRAY TREATMENT FOR SECOND AND THIRD-BROOD LARVAE	TOTAL NO. FIELD TESTS					AVERAGE PER CENT OF FRUIT ENTERED					FIVE-YEAR AVERAGE	
		'27	'28	'29	'30	'31	'27	'28	'29	'30	'31	No. Tests	Per Cent
1*	Lead arsenate (2)†, lime (4), water (100)†	3	10	6	6	3	1.8	3.8	2.7	18.4	5.1	28	6.6
2	Oil emulsion stock 203 at 2%	1	5	3	6	10	14.	3.2	6.	15.9	6.2	25	8.2
3	Oil emulsion stock 5 at 2%		3	2	6			3.7	5.3	21.9		11	13.8
4	Oil emulsion stock 200 plus pyrethrum, at 2%	2	5	2			15.9	3.3	17.2			9	9.2
5	Oil emulsion stock 200 plus nicotine (Ni-SO <sub>4</sub> ½ pt. per 100 gals.), at 2%		1	2	6	7		.3	3.3	10.5	5.1	16	6.6
6	Oil emulsion stock 200 plus derris, at 2%		2	2	7	1		3.3	7.	15.1	25.8	12	12.7
7	Control, no spray for late-brood larvae				1	4				25.8	33.7	5	27.
8	Control, no spray all season	2	4	3	4	2	56.7	46.1	62.8	42.5	36.4	15	49.3

\* The early-season spray schedule for items 1-7 was 3-4 pounds of lead arsenate and 6-8 pounds of hydrated lime per 100 gallons of spray, in the calyx and two or three cover sprays. In

late-brood treatments of 1931, item 1, the lead arsenate was increased to 4 pounds per 100 gallons.

† Pounds per gallons.

spraying was recommended for 1928 to 1932 by the Illinois Agricultural Experiment Station. Close supervision of application of the sprays insured a uniform covering in all of the experimental orchards. Experimental blocks of apples were made up of mature trees 25-40 years of age. Each block contained 25-30 trees of the varieties Jonathan, Grimes Golden, Staymen Winesap or Ben Davis. The spray plots were conducted in duplicate or triplicate in each orchard.

When the fruit was ready for harvesting, the performance of the individual sprays was graded by members of the entomology and horticulture staffs. These men at the time they scored each plot were unfamiliar with the spray treatment the plot had received. The four center trees of the plot

second and third brood. In seasons when the fruit is plentiful and prices are low the cost of second-brood sprays must be low in order to justify their application.

All of the spray mixtures tested show a seasonal variation in their relative efficiency. When codling moth is abundant and the season favors its development, the number of larvae entering the fruit will increase in spite of consistent and careful spraying. This has led to the general conclusion, as put forth by Headlee (1932), that spray materials and spraying alone will never give adequate control of this insect unless the population of moths can be kept within reasonable limits by the use of supplementary measures of control, such as orchard sanitation and tree banding.

Item 1 can be used as a basis of comparison since this treatment conforms with the recommendations for the control of second and third-brood codling moth larvae. Lead arsenate was applied at 2 pounds per 100 gallons in 1927, 1928, 1929 and 1930, and at 4 pounds per 100 gallons in 1931. The change in 1931 gave lead arsenate an advantage, as no change was made in the oil-spray schedule. In items 1 and 2 a direct comparison is shown between lead arsenate plus hydrated lime (1 pound of lead arsenate to 2 pounds of lime) and oil emulsion at 2 per cent concentration. The results in 1927 were decidedly unfavorable to the oil-sprayed plot. The years 1928 and 1930 showed 5 and 16 per cent fewer entrances in the oil-sprayed fruit. In 1929, 55 per cent, and in 1931 18 per cent, more larvae entered the oil-sprayed fruit. For the five-

field trials. Data covering the work with codling moth are given in Table 5, items 4, 5 and 6. Emulsions containing extracts of derris and pyrethrum were found to be less toxic to codling moth larvae under field conditions than the nonimpregnated emulsions. Exposure of derris or pyrethrum products to the action of sunlight and oxygen destroyed their activity toward insects, as is clearly demonstrated by laboratory tests. These same oil emulsions, when tested against codling moth larvae in the laboratory after a relatively short exposure to the air, consistently gave performance superior to nonimpregnated emulsions.

#### White-oil Emulsions with Nicotine

The use of nicotine with oil emulsions is finding a place in the oil-spray program

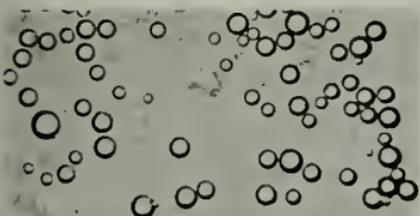


Fig. 2.—Oil stock 200.  $\times 490$ .

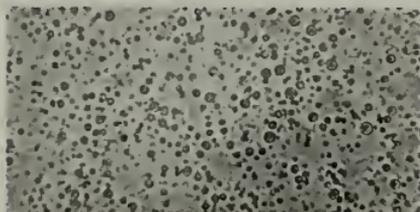


Fig. 3.—Commercial oil stock 5.  $\times 490$ .

year average, 19.5 per cent more larvae entered the oil-sprayed than the lead arsenate-sprayed fruit.

Items 2 and 3 show the performance of two commercial white-oil emulsions. The droplet size of these two oils is illustrated by microphotographs, figs. 2 and 3. The oil-droplet size in stock 200, fig. 2, is much larger. The emulsion contains 15.6 per cent less oil, has a relatively low wetting property, and gives a very spotted type of covering. Commercial oil stock 5, fig. 3, has small oil droplets, high wetting, and leaves a smooth, even oil covering. If the protection given fruit from codling moth larvae and the safety to fruit and foliage be considered, oil stock 200 is superior to the other oil emulsion for second-brood codling moth control.

#### White-oil Emulsions with Pyrethrum and Derris

Poison plant-extracts from pyrethrum flowers, tobacco or derris root, mixed with stock emulsion 200, have been given many

for second-brood codling moth, according to Herbert (1931). The field results with nicotine and oil sprays, Table 5, item 5, show it to be equal or superior to lead arsenate. This is in line with the results of Herbert & Leonard (1929), Regan (1930), Leonard (1930), Spuler & Dean (1930) and Webster (1931).

The most favorable mixture of oil and nicotine has been that of summer-oil emulsion at 1 per cent concentration with nicotine sulfate in dilutions of from 1:800 parts to 1:1600 parts. Free nicotine used in place of nicotine sulfate will give a somewhat quicker kill but is not so effective a mixture as is the oil with nicotine sulfate. The relative persistence of the two nicotine products has not been tested in the field under Illinois conditions. The 1932 report of the Western Cooperative Codling Moth Conference recommends oil and nicotine sprays as the most practical sprays for late-brood codling moth larvae where lead arsenate cannot be used.

### LABORATORY TESTS IN CONTROL OF CODLING MOTH

Standardized laboratory tests were used in making close comparisons between oil emulsions. Many combinations of insecticides were tried in the search for improved killing power of the oil sprays. White-oil stock emulsion 200 served as a basis of comparison for oil emulsions. This formula contains 64.4 per cent of a technical white oil of 83 seconds viscosity, with an inert emulsifier. The formula was varied with respect

water to a 2 per cent concentration by volume and applied at once to test apples by standardized methods to be described.

#### Laboratory Technique

The method used in rearing codling moth larvae for larvicidal tests was described by Farrar & Flint (1930). The apparatus and technique for handling the apples and the larvae were developed in the present work.<sup>4</sup> The method of applying the spray to the fruit was standardized as

Table 6.—Larvicidal efficiency of oil sprays tested in the laboratory against newly hatched codling moth larvae.

ITEM	TYPE OF SPRAY TESTED	FORMULA VARIATIONS, MATERIALS ADDED TO OIL STOCK OR DILUTE SPRAY	NO. FORMULAE TESTED	AVERAGE RELATIVE EFFICIENCY
1	White oil 200	Pyrethrum products. Viscosities 40-150 seconds	10	87.8
2	White oil 200	Nicotine products	7	77.6
3	White oil 200	Miscellaneous group III*	4	68.7
4	White oil 200	A pyrethrum product plus six types of fungicides	10	66.6
5	White oil 200	Derris products	14	58.8
6	White oil 200	Four inert emulsifier combinations	4	58.5
7	White oil 200	10% fluosilicates	3	47.
8	White oil 200	Miscellaneous group II*	6	45.7
9	Commercial white-oil stocks		3	36.3
10	Lead arsenate (2)† lime (4) water (100)†		3	36.3
11	White oil 200	Viscosities 40-200 seconds	15	34.2
12	White oil 200	Five types of fungicides	8	33.6
13	White oil 200	Miscellaneous group I*	6	25.
14	Control, water		1	0.

\* Miscellaneous Group I.—An oxidized oil base, 1 per cent cresylic acid, 1 per cent salol, 10 per cent waste sulfite liquor, 4 per cent *Lethane*, 5 per cent soluble pine oil. Miscellaneous Group II.—One per cent dark cresylic acid, 5 per cent straw cresylic acid, 1 per cent *Penetrol*, 5 per cent salol, 1 per cent tar acid oil, 8 per cent *Alcotate*, 5 per cent soluble pine oil. Miscellaneous Group III.—One per cent low-

boiling petroleum nitrogenous bases, 5 per cent cresylic acid, 1 per cent high-boiling petroleum nitrogenous bases, 1 per cent high and low (composite) petroleum nitrogenous bases. These groups are for convenience in evaluation and do not necessarily contain chemically related formulae.

† Pounds per gallons.

to those ingredients which were thought capable of improving toxicity. In the series of emulsions tested the oil-droplet size varied from 1 to 12 microns in diameter. Where the oil-droplet size was not disturbed by changes within the emulsion or by the addition of chemicals to the emulsion, the size remained relatively constant between 1 and 6 microns, averaging about 4 microns, fig. 2. The greater number of emulsions tested did not depart far in oil-droplet size or in other physical properties from those exhibited by oil-emulsion stock 200. All emulsions were diluted with tap

to distribution, time and pressure. Twenty-four hours after spraying, each apple was infested with 10 newly hatched larvae and then placed in a control chamber maintained at a temperature of 80° F and a relative humidity of 65-70 per cent. This set of conditions was found to be optimal for the entrance of codling moth larvae into untreated fruit. The infested fruit was kept under controlled conditions for 24 hours and then placed under laboratory conditions until it was checked for larval entrance. Three apples with a total of 30

<sup>4</sup> See frontispiece.

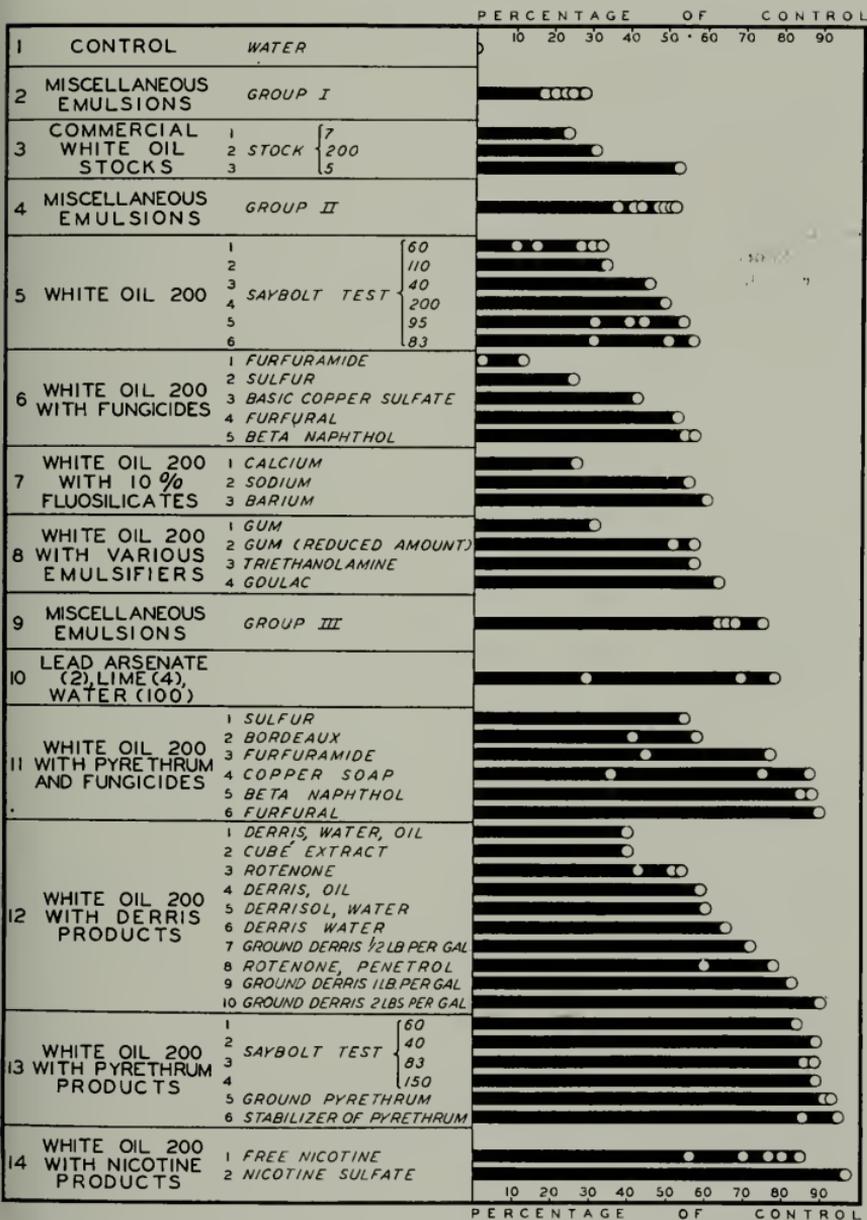


Fig. 4.—Laboratory tests of sprays to control codling moth in Illinois, showing relative efficiency of 13 groups of materials. Each white dot marks the average efficiency of a series of tests.

larvae were considered a series and a check apple with 10 larvae was included with every two series. Seven series of tests were conducted with each emulsion. In the total

test a material thus received 21 or more trials, in which 210 codling moth larvae were given opportunity to enter the sprayed fruit. Because of the natural variation of larval vitality it was found advisable to conduct the seven smaller tests of three apples each over a period of days rather than to make a large single test.

Scoring of treated and untreated fruit was done five days after infestation. All data obtained were calculated against the number of larvae entering untreated fruit. The relative efficiency for each emulsion has been calculated on the basis of the control afforded by the untreated fruit.

For purpose of discussion, emulsions that are related in certain ingredients are grouped together, as shown in Table 6. The emulsions within each group, and the several groups as a whole, have been arranged to show the relative efficiency of the sprays against codling moth larvae. Figure 4 is a graphical illustration of the exact performance of each material tested. Each white dot in the columns of this graph represents the average efficiency of a series of laboratory tests on a respective emulsion, the length of the column then showing the range of efficiency.

#### White-oil Emulsions

The property of an emulsion can be altered by changing the viscosity of the oil. The average efficiency given by 15 changes in viscosity was 34.2 per cent. The changes included cover the entire range in oil viscosities suitable for tree-spray oils. This control is only 2.2 per cent greater than that given by the 83-second oil, which is the same as commercial oil stock 200. The total range in the results by changes of viscosities alone is not much greater than that exhibited by the commercial white-oil emulsions. Laboratory data, fig. 4, item 5, would indicate that oil viscosities under 83 seconds are not so satisfactory as the higher-viscosity oils for the killing of codling moth larvae.

The most efficient white-oil emulsions were obtained by varying the concentration or type of emulsifier. The most efficient emulsion contained the emulsifier *Goulac*, lignin pitch, which according to Hurt (1931) is a by-product of the paper industry. Physically this emulsion has undesirable properties. It is relatively unstable,

has large irregular oil droplets, and the stock tends to jell on standing.

The amount of emulsifier included in an emulsion will determine within certain limits the type of emulsion that will be formed. When the percentage of emulsifier to the oil and water phases is reduced, the size of the oil droplets tends to increase. In the cases of the emulsions shown in fig. 4, item 8, where the gum emulsifier was greatly reduced, the emulsion formed was stiff, had larger oil droplets, and was more difficult to dilute than was oil emulsion 200, item 5. Although the physical change brought about by reduction of the emulsifier resulted in somewhat higher kill of codling moth larvae, the characteristics of this gum emulsion make it impractical.

In general, under laboratory conditions the oil emulsions containing the smaller oil droplets did not give so high a kill of codling moth larvae as did those with the larger oil droplets. The emulsion containing a triethanolamine emulsifier, item 8, did not follow this trend as did some of the other white-oil emulsions.

Need of a fungicide that can be safely combined with an oil emulsion as a summer spray has long been recognized. In this study a number of possible fungicides were tested. Fungicides typical of those tested are shown in fig. 4, items 6 and 11. Fungicides mixed with an emulsion tend to reduce the efficiency of the emulsion below that of the emulsion without the fungicide. This fact is particularly true of those fungicides that have the property of adsorption of a part of the emulsion to the surfaces of their particles. Examples of such fungicides are sulfur and Bordeaux. Furfural, beta naphthol and copper soaps do not seem to have this reaction of adsorption, neither do they reduce larvicidal efficiency as do the more bulky materials. In this study there was no fungicidal material tested that could be included in an emulsion in sufficient quantity to be toxic to the fungi of apple scab, *Venturia inaequalis* (Cke.) Wint., or apple bitter-rot, *Phyllosticta solitaria* Ell. & Ev., under field conditions.

The commercial white oils include two of the most successful summer-oil emulsions. The laboratory efficiency of these oils was 24, 32 and 53 per cent, with an average of 36.3 per cent, Table 6, item 9. Stock oil 5, fig. 3, with the highest efficiency

—53 per cent—has 15.6 per cent more oil, smaller oil droplets and better wetting properties than the other two emulsions. Stock 200, fig. 2, is uniform physically but has low wetting power. Stock 7 is one with poor physical properties, including poor wetting, irregular oil droplets and low stability. The results obtained with these commercial white oils show that they are typical of results that may be obtained with any satisfactory white-oil emulsion. The variations used in experimental emulsions were not sufficient to show marked superiority over the standard emulsions. The physical changes made in emulsions, Table 6 and fig. 4, express about the physical limits possible with strictly white-oil emulsions for use in tree sprays applied to foliage.

#### White-oil Emulsions plus Pyrethrum

Pyrethrum extracts, 1–3 pounds per gallon of oil, combined with the oil phase of emulsions, produced the most efficient codling moth larvicides. Ten formulae containing pyrethrum gave an average relative efficiency of 87.8 per cent. The consistent superiority of pyrethrum emulsions is shown in fig. 4, item 13.

Addition of fungicides to pyrethrum emulsions reduced average efficiency of the latter 21 per cent. Furfural and beta naphthol did not reduce the kill as greatly as did copper soap, furfuramide, copper Bordeaux or sulfur, Table 6, item 4, fig. 4, item 11.

#### White-oil Emulsions plus Nicotine

Oil emulsions with nicotine produced the second most efficient codling moth spray, Table 6, item 2. The seven formulae tested averaged 10 per cent less efficient than the pyrethrum sprays, although the range in control shown by the oil–nicotine sprays is greater than that of pyrethrum sprays, fig. 4, item 14. All sprays of oil emulsion with nicotine were more efficient than white-oil emulsions alone. The use of oil emulsion–nicotine sprays in the field has shown the residue to be as toxic and nearly as persistent for codling moth larvae under field conditions as that of lead arsenate. Oil emulsions containing nicotine are the only mixtures of oil and a plant poison that have withstood exposure to weather approximately as well as lead arsenate.

#### White-oil Emulsions plus Derris

Derris extracts act more slowly and are more stable to oxidation than are pyrethrum extracts. It was with the hope of finding a more stable insecticide than pyrethrum that derris was tried extensively in laboratory and field tests. The results of these tests were disappointing. In many cases emulsions containing derris were inferior to those containing pyrethrum. The efficiency of derris, Table 6, item 5, fig. 4, item 12, is shown to be widely distributed, illustrating the very erratic results obtained with this material. The derris sprays tested are not a dependable group when incorporated with white-oil emulsions for killing codling moth larvae.

#### White-oil Emulsions plus Other Insecticides

Fluosilicates at 10 per cent mixed with oil emulsions are more toxic than white oils alone, but such combinations have very undesirable properties which do not make them practical mixtures, Table 6, item 7, fig. 4, item 7.

In the miscellaneous group III, Table 6, item 3, is a substance called petroleum nitrogenous base. The nitrogenous bases used in the tests have a boiling range between 180 and 520° F. This is the only material other than the extracts of the plant poisons which offered promise as an insecticide with oil. The other materials listed under the miscellaneous groups I and II do not show sufficient promise to justify further study. The materials included in the miscellaneous groups are not all chemically related, which makes the grouping artificial.

#### Laboratory Tests with Lead Arsenate

Two pounds of lead arsenate plus 4 pounds of hydrated lime killed codling moth larvae in the laboratory as efficiently as this spray did in the field. It is of interest to note that with the most uniform coating obtainable with lead arsenate on apples, the efficiency of this spray over unsprayed apples was only 36.3 per cent. This means that relatively 63.7 per cent of the larvae penetrated a coating of lead arsenate and gained entrance to the fruit. The highest control with lead arsenate was 88 per cent, or identical in control with the average efficiency for the pyrethrum-impregnated emulsions, Table 6 and fig. 4, item 10.

## Red Spider

*Tetranychus* sp.

The most satisfactory control of red spider was obtained by the use of a technical white-oil emulsion at a concentration of 1 per cent.

### ON CONIFERS

Conifers are often attacked by red spiders to such an extent that the younger trees are killed. Where the mites are not sufficiently abundant to kill the trees, they so destroy the chlorophyll in the tissues that the trees appear brown. Many of the needles become dry and drop off, leaving the tree very unsightly.

than in a film, as is commercial oil stock 5. This irregular type of coating reduces the danger of injury to foliage and leaves the oil spots scattered over the surface to entangle the red spiders as they crawl about the needles. Immediate kill of red spider by oil stock 200 is not apparent, but its residual effect gives the most satisfactory control of any emulsion tested. Addition of a material to give this oil emulsion higher wetting properties did not cause foliage injury but did reduce protection afforded against red spider.

In two cases oil stock 6990 gave very

Table 7.—Degree of safety and red spider control for oil emulsions on the foliage of conifers.

ITEM	OIL FORMULA NO.	PROPERTIES			OIL-DROPLET SIZE <i>microns</i>	DEGREE OF RED SPIDER CONTROL	NO. OF TESTS AT PER CENT CONCENTRATION*			EXPERIMENTAL DEGREE OF SAFETY TO FOLIAGE AT PER CENT CONCENTRATION		
		Viscosity	Emulsifier	Wetting Power			.5	1.	2.	5.	1.	2.
1	6990	32	Gum	Low	1-5	Low	5	3		60	100	
2	5220	40	Gum	Low	1-5	Low	1	4	1	100	100	
3	5230	60	Gum	Low	1-5	Low	1	4	1	100	100	
4	200	83	Gum	Low	1-5	High	1	17	5	100	94	
5	200 + Blood†	83	Gum	Very high	1-5	Low		10			100	
6	Commercial oil 5		Inert	High	1-3	Medium	1	8	3	100	75	
7	Control		Water			None	17	17	17	100	100	

\* Field-test blocks contained several species of conifers and 50 to 3000 trees.

† Blood is a powdered residue sold as blood

In general it has not been considered safe to apply oil sprays to the foliage of conifers in the summer months or after growth has started. Conifer foliage is more sensitive to oil than deciduous foliage. This does not mean that oil sprays cannot be prepared for relatively safe use on conifers, particularly on the more resistant species, such as juniper, pine, arbor vitae and some forms of spruce. In the course of this project field tests were carried on each year to determine the effect of certain oils on conifer foliage. In Table 7 a summary of these tests is given wherein several facts are brought out regarding foliage tolerance and red spider control. Oil stock 200, fig. 2, gave the best control of red spider of any of the materials tested. This control can be largely attributed to the type of coating given by this oil, as stock 200 does not wet conifer foliage but adheres in the form of drops. When this type of emulsion dries, the oil is deposited in tiny spots over the surface rather

albumen, a by-product of the meat industry. It has about four times the wetting power of sodium oleate.

severe injury, possibly because of its low viscosity and rapid penetration. Oil-stock emulsions 5220 and 5230 were not as persistent as oil stock 200 and did not control red spider. This relation between persistence and control of red spider is in accord with the findings of deOng (1930). Neither oil 5220 nor 5230 cause injury to conifer foliage.

The tolerance of conifers to oils depends on species of the trees, season of the year, concentration, saturation and viscosity of the oil, and the wetting power of the dilute spray. Sprays with high wetting power are more toxic to foliage than sprays without this property. This excludes the use of oils with soap emulsifiers, such as miscible oils and inert emulsified oils with high wetting power. All oils should be of technical white grade and have a viscosity greater than 60 seconds and less than 100 seconds Saybolt. Concentration of the spray should be the lowest that will control the pest involved.

The technical white oils, properly emulsified, may be applied with relative safety at any time of the year except in extremely hot weather. Care should be taken in applying oil sprays to blue spruce, compact arbor vitae and all new plantings. Drenching of conifer foliage with oil sprays should be avoided. Pines and junipers will tolerate one or more applications of 1-2 per cent oil emulsion; spruce, arbor vitae and similar tender species from one-half to 1 per cent oil emulsion. One, or at most two, applications of the proper oil emulsion have given excellent protection for the season against the common red spiders attacking evergreens.

#### ON RASPBERRIES

Oil emulsions have been tested on raspberries for two seasons. In these tests one

mite, *Phyllocoptes oleivorus* Ashm., by the use of oil sprays.

#### San Jose Scale

##### *Aspidiotus perniciosus* Com.

For control of San Jose scale, the most efficient emulsions contained relatively large oil droplets associated with high wetting and quick breaking properties.

Oil emulsions have been used against scale since about 1878. Because of the wide distribution of San Jose scale it has received much attention in the development of control measures. Great impetus was given to the study of oil emulsions for this insect following the complete destruction of many orchards by this scale from 1919 to 1922, according to Ackerman (1923), Davis (1924) and Chandler, Flint & Huber (1926).

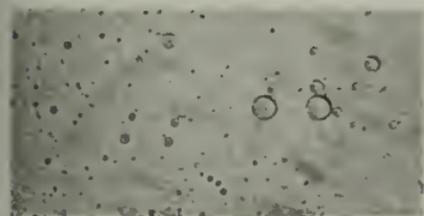


Fig. 5.—Soluble oil 16.  $\times 490$ .

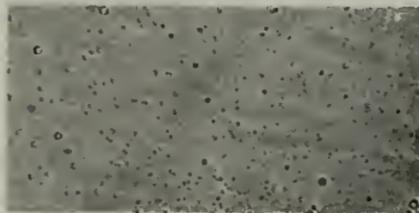


Fig. 6.—Soluble oil 90.  $\times 490$ .

to three applications of stock oil 200 at 1 per cent concentration gave excellent control of red spider without injury to the foliage. The sprays were applied with a power sprayer at a pressure of 200 pounds. For satisfactory results it was necessary to use care to wet the under surfaces of all leaves. For this purpose a short rod carrying three fine nozzles turned upward permitted excellent spraying from the underside. Stock oils 5220 and 5230 did not injure the foliage but failed to control the mites. The low viscosity of these oils, 40 and 60 seconds respectively, would suggest that they penetrated the tissues readily and did not leave a persistent oil film to entangle the crawling spiders.

Favorable results with oils on red spider are reported by Vinal (1917) on cucumbers, by Newcomer & Yothers (1927) on fruit trees, by Whitcomb & Guba (1928) on cucumbers, and by Compton (1931) on greenhouse crops. Yothers & Mason (1930) had unfavorable results in controlling the egg stage of the citrus rust

The scale affords such natural protection that any insecticide to be effective must gain access to the living insect. Ability of oil sprays to form films or coatings that are toxic to scale has made oil emulsions a reliable source of control. The work done in the control of this insect has demonstrated the physical and chemical properties necessary in an emulsion for high efficiency against a number of insects other than scale.

According to Ackerman (1923) and Davis, Yothers, Ackerman & Haseman (1926, 1927), most workers find that at least a 2 per cent actual oil is required to give satisfactory control of scale. The proper concentration will depend entirely on the properties of the emulsion, as is shown in Table 8. The data were calculated according to the formula of Abbott (1925). Abbott (1926) found that mortality counts on San Jose scale made 30 days after the treatment by sprays gave accurate indices of performances. In these tests the mortality counts were made from

four to six weeks after the oil-spray treatments were applied.

Soluble oils 16, fig. 5, and 90, fig. 6, contain the same amount of emulsifier, but oil 16 contains a highly saturated white oil. This emulsion is less stable than the emulsion containing the unsaturated oil. The effect of saturation on the stability of soluble oil 16 is reflected in the difference between these two emulsions in the mortality

in this comparison between soluble oils 47, 48 and 49. All are less stable than the 83-second-viscosity emulsions even though the lighter emulsions contain the emulsifier in greater quantity.

deOng & Knight (1925) found as they decreased the amount of soap emulsifier used in relation to the volume of oil that "the results showed a progressive increase of kill as the amount of soap was decreased,

Table 8.—Relation between viscosity, saturation, ratio of emulsifier, and droplet size, for miscible-oil sprays tested on San Jose scale.

ITEM	OIL FORMULA No.	COMPOSITION*			Ratio of Emulsifier to Oil	OIL-DROPLET SIZE <i>microns</i>	NO. TESTS AT PER CENT CONCENTRATION†					RELATIVE EFFICIENCY AT PER CENT CONCENTRATION					
		Viscosity	Saturation	Emulsifier			1.	1.5	2.	2.5	3.	1.	1.5	2.	2.5	3.	
1	Soluble oil 49	32	100	Sodium oleate	1-1.5	1-5	1	1					37.6	45.1			
2	Soluble oil 47	32	100	Sodium oleate	1-4	1-11	1	1					46.5	63.6			
3	Soluble oil 48	32	100	Sodium oleate	1-5.6	1-20	1	1					44.7	83.2			
4	Soluble oil 16	83	100	Sodium petroleum soap	1-6.7	1-6	1	1	1	1	1	1	93.1	100.	99.7		99.
5	Soluble oil 90	83	91	Sodium petroleum soap	1-6.7	1-3	1	1	4	1	1	1	57.1	87.5	91.8		99.1
6	Soluble oil 22	83	91	Sodium petroleum soap	1-8	1-5	1	7					82.6	96.6			
7	Soluble oil 17	83	91	Sodium petroleum soap	1-9	1-6	1	3	7	4	2	2	91.2	94.	97.4	98.8	97.
8	Control, water 33.3 per cent of scale alive						5	5	5	5	5	0.	0.	0.	0.	0.	0.

\* Items 1 to 4 contain technical white oil, 1 to 5 and item 7 are paraffin oils.

† A test is a field series in which 1000 to 4000 overwintering scales were counted. Data include six years' results.

of scale. The less stable soluble oil 16 is the more toxic.

Emulsions containing oils of 32 seconds of viscosity are not sufficiently persistent to give a satisfactory control of San Jose scale. The effect of the ratio of emulsifier to the oil phase is demonstrated in this series of low-viscosity oils. Soluble oil 49, fig. 7, contains a high ratio of emulsifier to the oil and is less toxic than soluble oil 48, fig. 8, in which the amount of emulsifier is reduced. Soluble oil 47 is intermediate between the other two emulsions in ratio of emulsifier and toxicity to scale.

A comparison of items 1-3 with items 4-7, Table 8, shows decided superiority for the 83-second-viscosity emulsions. Viscosity and not stability is the dominant factor

but with the least amount of soap used, namely 1 per cent, there was not a complete kill of the scales." deOng (1926) gave additional data substantiating this principle. Soluble oils 90, 22 and 17, Table 8, items 5, 6 and 7, demonstrate the effect of the ratio of the emulsifier and oil on droplet size, breaking and toxicity to San Jose scale. Soluble oil 90 contains the most emulsifier, has smaller oil droplets and lower efficiency than either oil 22 or 17, figs. 9, 10. Soluble oil 17 possesses the correct balance between oil and emulsifier. It is an emulsion with relatively large oil droplets, is quick breaking, and has superior kill of San Jose scale. Soluble oils 16 and 17 have similar stability and compare favorably in toxicity to San Jose scale.

It is evident from these data that efficiency is influenced by viscosity, saturation and oil-droplet size. These variations give to an emulsion certain properties that in

with their respective degrees of control, are shown in Table 9. Certain relationships are lacking but those most influential in control of scale are included. Soluble oils

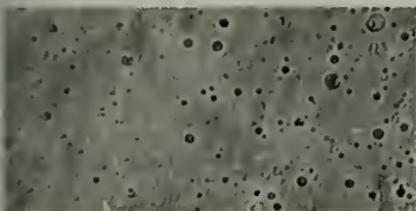


Fig. 7.—Soluble oil 49.  $\times 490$ .

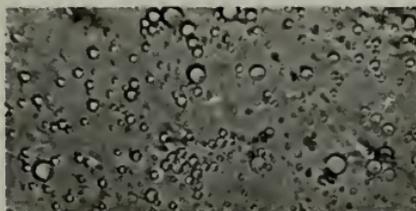


Fig. 9.—Soluble oil 22.  $\times 490$ .

Table 9.—Relation between viscosity, saturation, ratio of emulsifier and oil-droplet size for commercial oil sprays tested against San Jose scale.

ITEM	COM-MERCIAL OIL No.	COMPOSITION*		AVERAGE RANGE OF OIL-DROPLET SIZE microns	NO. TESTS AT PER CENT CONCENTRATION†					RELATIVE EFFICIENCY AT PER CENT CONCENTRATION					
		Vis-cosity	Emul-sifier		Ratio of Emul-sion to Oil										
						1.	1.5	2.	2.5	3.	1.	1.5	2.	2.5	3.
1	Soluble oil 2	47	Soap	High	1-3	1	1	1			52.6	94.5		88.5	
2	Soluble oil 1	350	Soap	High	1-3	2	1	2	1		99.	89.2	99.	93.7	
3	Soluble oil 17	83	Soap	Low	2.5-3.5	1	3	7	4	2	91.2	94.	97.4	98.8	97.
4	Government formula BFOS	104	Potash fish-oil soap	Low	3-4	1	1	2	1	1	91.1	98.4	95.9	100.	98.5
5	Illinois formula BFOS	104	Potash fish-oil soap	High	2-3				4						95.4
6	Stock oil 5	80	Inert	Low	2.5-4.5	1	1	1	1	1	88.9	97.	95.5	99.9	99.
7	Stock oil 8		Gum	Low	1-6			1	2			98.9			98.2
8	Control, water 33.3 per cent scale alive					5	5	5	5	5	0.	0.	0.	0.	0.

\* Item 6 contains a technical white oil. Items 1 to 5 and item 7 are paraffin oils.

† A test is a field series in which 1000 over-wintering scales are counted. Data include six years' results.

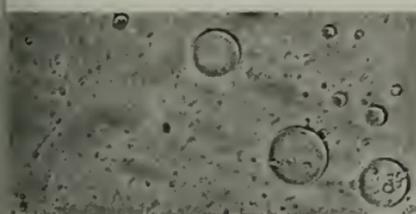


Fig. 8.—Soluble oil 48.  $\times 490$ .

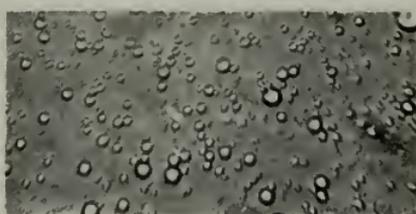


Fig. 10.—Soluble oil 17.  $\times 490$ .

turn influence the degree of control which the emulsion will give against San Jose scale.

The physical properties of proprietary emulsions tested against San Jose scale,

1, 2, 17, items 1, 2 and 3, are typical of soluble oils marketed in Illinois for dormant spraying of fruit trees.

Soluble oil 2, fig. 11, with an oil of 47-seconds viscosity is inferior to soluble oil 1

containing a 350-second oil. The oil-droplet size is not greatly different in these two emulsions. Soluble oil 17 has a lower ratio of emulsifier to the oil than the other solu-

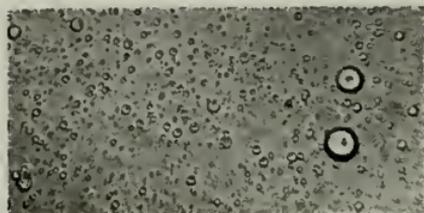


Fig. 11.—Commercial soluble oil 2.  $\times 490$ .

ble oils and is a quicker-breaking emulsion. This oil is consistently superior to the others in its control of scale.

Boiled fish-oil soap emulsions, fig. 12, were as efficient against San Jose scale as was soluble oil 17. Both of the boiled emulsions, Table 9, items 4 and 5, have larger oil droplets and somewhat quicker breaking qualities than soluble oil 17. The government formula<sup>a</sup> contains half as much soap emulsifier and considerably more water than the Illinois formula<sup>b</sup>. This condition imparts to the government formula a slightly larger oil-droplet size and quicker breaking qualities.

There are certain sections in Illinois orchard areas where the extremely hard water will prevent this formula from emulsifying properly. For this reason the Illinois formula is recommended and used. This emulsion contains sufficient soap to permit emulsification in most Illinois waters. Both of these emulsions contain about one third

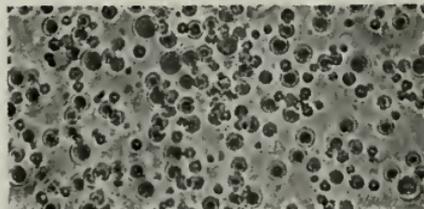


Fig. 12.—Boiled fish-oil soap emulsion stock, Illinois formula.  $\times 490$ .

<sup>a</sup> Government formula:

Potash fish-oil soap.....	1 pound
Water .....	2 quarts
Light-grade lubricating oil.....	1 gallon

Illinois formula:

Potash fish-oil soap.....	1-2 pounds
Water .....	1 quart
Light-grade lubricating oil.....	1 gallon

of their volume in water and soap and are therefore recommended for use at a concentration of 3 per cent, which places them about on a basis of comparison with a soluble oil at 2 per cent concentration. When boiled-soap emulsions are tested and compared with miscible oils on their oil basis they are as effective in their kill of scale as the soluble oils. This accords with findings of Ackerman (1923), Davis (1924), Chandler, Flint & Huber (1926), English (1928) and Swingle & Snapp (1931).

Stock emulsions 5 and 8, Table 9, items 6 and 7, are emulsions containing inert emulsifiers. In both, the ratio of emulsifier to the oil is sufficiently low to impart quick-

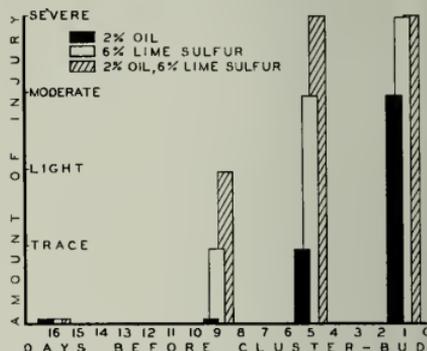


Fig. 13.—Relation in days between bud development of apple and safety to the tree when sprayed with a 2 per cent soluble-oil emulsion, 6 per cent liquid lime sulfur, or a combination of both. The first spray was applied in the following periods of tree development: dormant, tip-green, delayed-dormant, and cluster-bud.

breaking properties, as shown by their respective oil-droplet size. The control of San Jose scale exhibited by these emulsions is comparable with the quick-breaking soluble oils and boiled fish-oil soap emulsions.

Factors other than insecticidal efficiency have entered into public acceptance of the several commercial emulsions. Many of those who have made and used the boiled fish-oil soap emulsions will continue to do so, but there is an increasing trend toward the commercially prepared quick-breaking soluble oils. This has come about from the relatively low cost of soluble oils, the ease with which they can be stored and diluted, and the uniform performance given by such oils as soluble oil 17 in the control of San Jose scale.

### Delayed-dormant Applications of Oil Sprays

For a number of years there has been a tendency to delay the application of oil sprays for the control of San Jose scale as late as possible in the season in order to kill such aphids as were hatched. Very few cases of injury are reported from stable oil sprays applied when the trees are strictly dormant. Felt (1913) reported less injury when oils were applied just before growth started in the spring than in fall applications. deOng (1926) observed that the blooming date was influenced by the season of application, recording that the

have been obtained. In the test are included an unsaturated miscible oil at 2 per cent, applied in the fall, winter and spring dormant, and the delayed-dormant stages; boiled fish-oil soap emulsion at 3 per cent; and the miscible oil at 8 per cent concentration. The last two are applied in the spring dormant. In one year the fish-oil soap emulsion, and for three years the 8 per cent miscible oil, have shown a retarding effect on leaf development. In all cases the retardation was no longer noticeable six weeks after the buds started to open. There have been no injurious effects on any of

Table 10.—Relation between oil-droplet size of a miscible oil and its insecticidal efficiency as tested against aphids.\*

ITEM	FORMULA	COMPOSITION			Ratio of Soap to Oil	OIL-DROPLET SIZE microns	NO. OF TESTS (1000 APHIDS) AT PER CENT CONCENTRATION			RELATIVE EFFICIENCY AT PER CENT CONCENTRATION		
		Oil	Viscosity	Emulsifier			.5	1.	2.	.5	1.	2.
1	Soluble oil 18	Paraffin	83	Soap 15	1-2.6	1-3	3	7	7	96.5	89.4	80.6
2	Soluble oil 90	Paraffin	83	Soap 15	1-6.7	1-3	3	43	33	96.	80.3	95.5
3	Soluble oil 17	Paraffin	83	Soap 15	1-9	1-6	3	17	12	98.	90.	98.
4	Soap 15			Sodium petroleum soap			3	17	7	98	82.3	81.4
5	Control, water						50	50	50	9.3	9.3	9.3

\**H. setariae*, *A. pomi*, *A. spiraeicola*.

early winter applications produced a stimulating effect, whereas applications after the start of bud development had a retarding effect. Kelley (1930a) suggests that the injury observed from early fall applications was due to winter injury that followed the breaking of the rest period by an application of oil.

In Illinois commercial practice, the dormant spraying of apple and peach with oils for scale has been followed for 10 consecutive years without measurable effects on crop production. Experimentally, 10 annual dormant applications of a 2 per cent miscible oil have not produced noticeable changes in tree development. A parallel test, where an 8 per cent oil was applied, gave a distinct retardation of bud development for about seven days. This retardation, although very apparent at the time, was completely covered by normal tree growth in about six weeks after bud development started.

In a series of tests that has been conducted for seven years, quite similar results

the trees receiving the 2 per cent oil spray in the dormant stage, regardless of the season at which they were sprayed.

As shown in fig. 13, if the oil spray is delayed until the leaves begin to unfold or later, injury in the form of burning of the new leaves may result.

### Aphids

*Aphis spiraeicola* Patch

*Aphis pomi* DeG.

*Hysteroneura setariae* (Thos.)

The efficiency of emulsions against aphids depends on high wetting and low stability or the presence of limited quantities of nicotine. An emulsion containing nicotine was more efficient when it contained a substance to promote high wetting.

English (1928) found that "an emulsion in order to be effective against aphids must have 'high wetting' ability coupled with unstability. Either of these factors may vary so as to be dominant. A relatively 'poor wetting' unstable emulsion may be more effective on aphids than a 'good wetting' stable emulsion. If the stability of two emulsions is about the same, then the

one with the greater wetting ability is the more effective on aphids."

Griffin, Richardson & Burdette (1927) found that "under conditions of comparable concentrations and type of oil, miscible

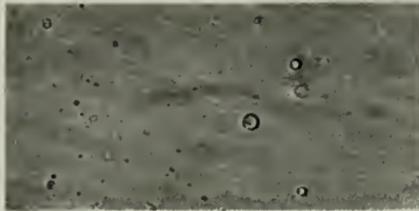


Fig. 14.—Soluble oil 18.  $\times 490$ .

Table 11.—Relation between droplet size and insecticidal efficiency of commercial oils tested against aphids.\*

ITEM	COM-MERCIAL OIL NO.	COMPOSITION			WETTING PROPERTY	OIL-DROPLET SIZE	NO. OF TESTS (1000 APHIDS) AT PER CENT CONCENTRATION			RELATIVE EFFICIENCY AT PER CENT CONCENTRATION		
		Oil	Viscosity	Emulsifier			microns					
							.5	1.	2.	.5	1.	2.
1	Stock 5	Technical white	80	Inert	Low	1-6	3	35	17	93.4	67.2	91.1
2	Stock 4	Paraffin		Soap	Low	1-21	3	17	17	93.4	82.4	93.8
3	Soluble oil 17	Paraffin	83	Soap	Medium	1-6	3	17	12	98.8	90.	98.
4	Illinois formula BFOS	Paraffin	104	Soap	High	3-8	3	35	35	86.1	61.8	84.
5	Soluble oil 1	Paraffin	350	Soap	High	1-4	3	7	7	85.6	74.4	84.7
6	Control, water				Low		50	50	50	9.3	9.3	9.3

\* *H. setariae*, *A. pomi*, *A. spiraeicola*.

oils are probably the less toxic to insects than the ordinary soap emulsions, because they contain smaller oil droplets and the oil therefore adheres to the plant and (no doubt to the insect) less effectively."

Data given in Table 10 include the factors of wetting, quick breaking and droplet size. The miscible oils in items 1, 2 and 3 contain the same oil and emulsifier as in item 4, but are combined with their emulsifier in concentrations that give them entirely different physical properties. Soluble oil 18, fig. 14, is heavily emulsified and the oil droplets are so small that they are hardly visible under high magnification. This emulsion has as high wetting properties as does the emulsifier in item 4. The emulsion is extremely stable and gives a mortality of aphids comparable with the emulsifier. In soluble oil 90, fig. 6, the emulsifier has been reduced to give a quick-

breaking emulsion and a higher mortality of aphids. In soluble oil 17, fig. 10, the emulsifier has been reduced over that of soluble oil 90 with a still greater efficiency against aphids. This oil exemplifies about the maximum killing power obtainable with a miscible oil that is sufficiently stable to be marketed commercially. In all of the tests the toxicity to aphids is greater at the lower concentrations of the emulsions or the emulsifier. This condition illustrates the principle that excess wetting causes a run-off of the spray material and a reduction in the kill of some contact insecticides.

Table 11 includes the results obtained

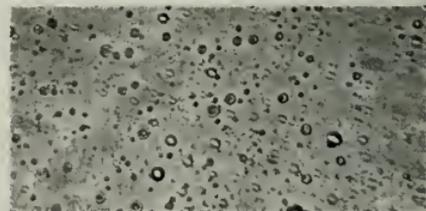


Fig. 15.—Commercial soluble oil 1.  $\times 490$ .

with five commercial emulsions that have a wide range of physical properties. The killing power of these emulsions at concentrations of one-half, 1 and 2 per cent is in line with Table 10, where the mortality was highest at a one-half per cent concentration, lowest at 1 per cent, increasing again at 2 per cent. This effect is produced by the volume and concentration of spray material adhering to the bodies of the insects. The physical properties of wetting

and stability of each emulsion determine to a large extent these factors. The effect of the wetting properties of emulsions on their efficiency can be illustrated by comparing stock oils 5 and 4. Stock oil 5, Table 11, item 1, and fig. 3, contains an inert emulsifier and has quick breaking properties. It is less effective than stock oil 4, which contains a soap emulsifier and has higher wetting and quicker breaking properties.

Soluble oil 17 combines the property of higher wetting than that possessed by the former emulsions with almost as good breaking properties. This oil, however,

dilute emulsion for increasing its toxicity against aphids but soap is not compatible with the stock emulsion when incorporated with it as a concentrate.

Free nicotine is compatible with this emulsion in the concentrate when used in proportions of not more than 1 per cent. Such a combination makes an emulsion that is very efficient against aphids. When one-fourth of 1 per cent of soap is added to the dilute emulsion to give it increased wetting, as in item 6, the mortality of aphids is higher than that given by the emulsion without soap but containing twice the

Table 12.—Laboratory tests on aphids with gum emulsions, demonstrating the necessity for increasing wetting power or for incorporating nicotine into gum emulsions to control aphids.

ITEM	SPRAY BASE	MATERIAL ADDED TO STOCK EMULSION	PER CENT SOAP IN DILUTE SPRAY	NO. COMBINATIONS	TESTS (1000 APHIDS EACH)	RANGE IN PERCENTAGE OF KILL
1	Water	None	0.			0-5.
2	Water	None	.25	3	4	17.
3	Stock 200 at 2%	None	0.	5	24	35-86.
4	Stock 200 at 2%	None	.25	3	7	97.
5	Stock 200 at 2%	.5-1% nicotine	0.	4	13	96-100.
6	Stock 200 at 2%	.2-.4% nicotine	.25	2	6	99.
7	Stock 200 at 2%	1 lb. pyrethrum per gal.	0.	1	4	63.
8	Stock 200 at 2%	1 lb. pyrethrum per gal.	.25	3	4	96.
9	Stock 200 at 2%	1 lb. cubé per gal.	0.	1	2	94.
10	Stock 200 at 2%	1-5% sulfur; petroleum nitrogenous bases; chinchona alkaloid salts; pine oil	0.	7	17	25-82.

gives maximum kill. Of the commercial emulsions, the Illinois formula of boiled fish-oil soap emulsion contains an excess of soap necessary for emulsification in hard waters. This excess soap gives to this emulsion very high wetting which offsets its advantages of larger droplet size and quicker breaking properties. Soluble oil 1, fig. 15, is both high wetting and slow breaking, a combination of properties which would seldom give a satisfactory control of aphids at comparable concentrations.

The addition of one-fourth of 1 per cent of soap, Table 12, item 2, to diluted stock emulsion 200, item 3, increased the mortality of aphids 52 per cent over the use of the emulsion alone, and 80 per cent over soap alone. A soap may be added to the

actual nicotine, item 5. Free nicotine and nicotine sulfate both tend to reduce the stability of a stock emulsion, especially in the higher concentrations. For this reason the more practical combination would be one that contains a very low nicotine content to be used with soap at the time of application for increased wetting.

Extracts of pyrethrum, derris or cubé are not as efficient as nicotine when mixed with oil emulsion against aphids. The addition of soap will increase the killing power of an oil containing such extracts, item 8, but not enough to warrant the added cost of the extracts.

Sulfur (2-5 per cent), petroleum nitrogenous bases, chinchona alkaloid salts, or pine oil did not increase the toxicity of the oil emulsions to aphids.

Nicotine, added to either the stock emulsion or the diluted spray, was the only really efficient spray for aphids. These tests demonstrate the toxic nature of nicotine to aphids.

Experiments were conducted with 25 different oil emulsions, most of which were tested at 5, 8 and 10 per cent concentrations. The results are shown in Table 13. These experiments demonstrate clearly

Table 13.—Results of laboratory tests with various concentrations of oil emulsions on eggs of oyster-shell scale.

ITEM	TYPE OF EMULSION TESTED	NO. EMULSIONS TESTED	NO. TESTS AT PER CENT CONCENTRATION*			RELATIVE EFFICIENCY AT PER CENT CONCENTRATION		
			5.	8.	10.	5.	8.	10.
1	Commercial oils	6	4	2	24	25.4	80.	88.
2	Experimental miscible oils	9	9	4	16	50.	52.	94.
3	Boiled fish-oil soap emulsions	6	4		13	32.2		96.4
4	Experimental oils (White-oil stocks)	4			14			92.5
5	Control, water	1	6	6	6	0.	0.	0.

\* A test is considered 10 twigs with 10 overwintering oyster-shell scales each. Each of the

100 scales per test contained from 40 to 80 eggs.

### Oyster-shell Scale

*Lepidosaphes ulmi* (Linn.)

Oyster-shell scale was adequately controlled with a 2 per cent white-oil emulsion applied about the time the young scales hatched. A miscible or soluble oil applied in the dormant stage of development at high concentration gave a satisfactory control of this insect.

that only a high concentration (10 per cent) of oil emulsion is effective against the eggs of this scale. Even at high concentration good wetting must be secured if control is to be obtained.

The tests of dormant-oil emulsions against the eggs of the oyster-shell scale

Under field conditions somewhat lower dilutions have given good results due to the effect of the residual oil left on the bark following an application of oil spray. The

Table 14.—Results of field tests for efficiency of oil sprays on oyster-shell scale at time of hatch.

ITEM	FORMULA	COMPOSITION		INJURY TO FOLIAGE	NO. FORMULAE TESTED	NO. TESTS AT 2 PER CENT CONCENTRATION	RELATIVE CONTROL
		Emulsion	Emulsifier				
1	Soluble oil 17	Paraffin oil, miscible	Petroleum soap	Yes	1	3	99.3
2	Stocks 3050, 3060	White oil stock, pyrethrum, sulfur	Gum	Yes	2	14	99.7
3	Stock 430	White oil stock, pyrethrum	Gum	No	1	6	96.
4	Commercial	White oil stocks	Inert	No	2	11	95.5
5	Control	Water		No	0	8	0.

were conducted in the laboratory by a standard procedure. Twigs having overwintering scale were collected, graded, sprayed and placed in moist sand to grow until the young scale hatched. The young scales were removed and counted as fast as they hatched.

presence of oil on the twigs destroys many of the young migrating scale.

The best results in control of this insect were secured by the application of an oil spray at the time the young scales were hatching. At this season the young scales are sensitive to oil and are easily killed by

oil sprays. The results of field trials are shown in Table 14. Young oyster-shell scale hatch at a season of the year (May-July) when their host plant is in full foliage. Although practically any oil applied at 2 per cent concentration will give control of this scale, the oil selected for application should be safe to apply on foliage. The white-oil emulsions marketed as summer oils have proved the most satisfactory.

similar to soluble oil 17, at 5 per cent concentration, have been tested against this pest. This oil has given a very high degree of control where good wetting is obtained and when the oil is applied in the spring before the elm foliage appears.

The control of young European elm scale by summer-oil sprays has not been as satisfactory because of the wide distribution of the young over the leaves. To obtain

Table 15.—Results of leaf roller ovidic tests in the laboratory at three concentrations of emulsions. Each egg mass averaged 57 viable eggs.

ITEM	FORMULA No.	GENERAL COMPOSITION	VISCOSITY	RATIO OF EMULSION TO STOCK	RANGE OF OIL-DROPLET SIZE <i>microns</i>	PHYSICAL PROPERTIES OF DILUTE SPRAY	No. EGG MASSES TESTED AT PER CENT CONCENTRATION			RELATIVE EFFICIENCY AT PER CENT CONCENTRATION		
							4.	6.	8.	4.	6.	8.
1	Stock	<i>Diamond paraffin</i> oil in Bordeaux*	104	1-20	1-11	Very quick breaking	50	30		100.	100.	
2	Stock	<i>Diamond paraffin</i> oil in Kayso†	104	1-20	1-19	Very quick breaking	10			100.		
3	Commercial oil 7	Soluble	140		0-100	Very quick breaking	20	20		100.	100.	
4	Illinois formula BFOS	<i>Diamond paraffin</i> oil in BFOS	104	1-5.7	3-8	Very quick breaking	40	30	10	96.	100.	100.
5	8350	Soluble	225	1-9	1-2	Very quick breaking	50	20		95.	88.	
6	5110	Soluble +5% creylic acid	83	1-6.7	1-5	Quick breaking	40	40		79.	83.	
7	22	Soluble	83	1-8	1-5	Quick breaking	30	40	20	72.	94.	98.
8	8340	Soluble	104	1-9	1-3	Quick breaking	40	20		62.	57.	
9	8360	Soluble +1% free nicotine	83	1-9	1-4	Quick breaking	30	30		61.	89.	
10	8370	Soluble + petroleum bases	83	1-9	1-6	Quick breaking	40	20		52.	58.	
11	17	Soluble + nicotine sulfate 1:800	83	1-9	1-6	Quick breaking	30	10	10	50.	69.	94.
12	17	Soluble	83	1-9	1-6	Quick breaking	50	60	30	47.	75.	96.
13	Commercial oil 1	Soluble	350		1-4	Not quick breaking	30	20	10	26.	61.	67.
14	Commercial oil 2	Soluble	47		1-4	Not quick breaking			20			6.
15	Control	Water					110	110	110	0.	0.	0.

\*4:4:50 Bordeaux.

†2 ounces Kayso per gallon of oil.

### European Elm Scale

*Gossyparia spuria* (Mod.)

A miscible or soluble oil used at a concentration of 4 per cent adequately controlled European elm scale when applied as a delayed-dormant spray. Some difficulties were encountered in controlling this insect with summer sprays.

The rapid spread of European elm scale in nurseries and cities has attracted considerable attention. Dormant-oil emulsions

the highest degree of control by summer applications (at the time of hatch), the oil must possess a high wetting power and should contain nicotine at the same concentration as that recommended for aphids. Complete covering of the foliage with the spray is essential if a satisfactory control is to be obtained.

Cleveland (1931) found that stock emulsion 200 used at 2 per cent concentra-

tion gave excellent control of hatching scale when 4 pounds of 30 per cent potassium fish-oil soap were added to each 100 gallons of dilute emulsion. He found the addition of soap necessary in order to secure adequate wetting of the foliage and insects. No injury resulted from his sprays on American and Cornish elms, applied July 15 at Monroe, Mich.

### Fruit-tree Leaf Roller

*Archips argyrospila* Walk.

Stability was the dominant physical property of an emulsion that was efficient in killing eggs of the fruit-tree leaf roller. The less stable emulsions were the most efficient.

The control of fruit-tree leaf roller by the application of lead arsenate sprays has not given uniformly satisfactory results,

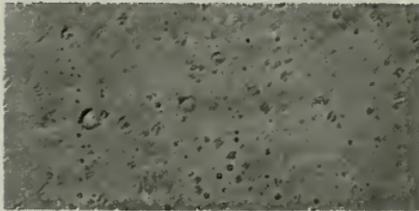


Fig. 16.—Soluble oil 8350.  $\times 490$ .

according to Regan (1923), Wakeland (1925), Flint & Bigger (1926) and Harman (1928). Feeding of the larvae can be checked with lead arsenate sprays, but special sprays using high dosages of lead arsenate are necessary. Authors agree that the logical method of control is one directed against the egg stage of the insect.

Oil emulsions have given the most satisfactory control of leaf roller eggs in the laboratory and in the field. Wide variations have been found to exist between the various oil emulsions tested. Under field conditions it is seldom that sprays can be applied thoroughly enough to strike every egg mass on the tree. For this reason field trials of the same oils and concentrations have not given so high a mortality as have laboratory tests. This is in accord with the findings of Penny (1921). Comparable results were obtained in field tests (not included in this paper) where the oil sprays listed in Table 15, items 1, 5, 6, 7 and 12 were given field trials.

Regan (1923) asserts that unless 75 per

cent of the eggs can be killed the expense of the spray is not warranted.

Experiments of Flint & Bigger (1926), Harman (1928), Tolles (1931), and Parrott, Hartzell, Glasgow & Harman (1931) show that less than 6–8 per cent actual oil in an emulsion will not give control of leaf roller eggs. These tests further indicate that the quicker-breaking emulsions will kill the eggs at a lower concentration than the slow-breaking emulsions. The cold-mixed Bordeaux or *Kayso* emulsions have been the most efficient because of their quick-breaking properties.

Laboratory data on leaf roller eggs given in Table 15, items 1 and 2, illustrate the superior killing power of cold-mixed emulsions. With an actual oil content of 4 per cent, the 4:4:50 Bordeaux and calcium caseinate emulsions gave 100 per cent kill of eggs. Commercial soluble oil 7 is the only soluble oil giving complete kill at a low concentration. The non-miscible properties of this oil in hard water would not make it a practical commercial emulsion for other than leaf roller or similar insect control. Only a small portion of this emulsion would remain in suspension without constant agitation. Boiled fish-oil soap emulsion, item 4, with a large oil-droplet size and quick-breaking property, gave almost as high mortality of eggs as did the oils under items 1, 2 and 3.

Soluble oil 8350, item 5 and fig. 16, has the same emulsifier ratio as soluble oil 17, item 12, but contains a 225-second-viscosity oil. The higher-viscosity oil produces an emulsion that does not disperse as readily as does oil 17. As a result the diluted soluble oil 8350 tends to separate out of the water phase, giving to the emulsion a quick-breaking property. The same characteristic is exhibited to an even greater extent by commercial soluble oil 7. Neither oil has sufficient emulsifier to disperse the oil particles completely when diluted with hard water.

Emulsions included in items 6 to 11 vary in certain ingredients from soluble oil 17. The cresylic acid in soluble oil 5110 and extra emulsifier in soluble oil 22 did not increase the toxicity materially. The addition of 1 per cent free nicotine as in oil 8360, fig. 17, nicotine sulfate at 1:800, or petroleum base, as in oil 8370, fig. 18, did not increase the kill over that exhibited by

soluble oil 17. In all of the experiments the quick-breaking soluble oils tested at 8 per cent concentration gave a satisfactory control of leaf roller eggs. This is significant because of the wide use of soluble oils commercially for the control of this insect.

As ovicides for leaf roller eggs, emulsions with large oil droplets, such as occur in cold-mixed emulsions, are more efficient than commercially prepared emulsions when compared at equal concentrations. Certain quick-breaking soluble oils will give a commercial control of leaf roller if they are carefully applied at a concentration of 8 per cent or greater. The viscosity

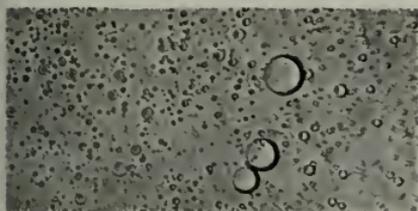


Fig. 17. Soluble oil 8360.  $\times 490$ .

will cover the average farmstead. One application is sufficient for light infestations but two or three treatments at intervals of two weeks are recommended in heavily infested areas.

#### OILS WITH FUNGICIDES

Dormant-oil emulsions can be used with sulfur fungicides in the dormant stage of tree development. If used after the buds start to swell, serious injury may result. There is danger of injury if oil emulsions are applied in the delayed-dormant stage of tree development, particularly when sulfur is to be used in the later sprays for the control of fungous diseases.

It is doubtful whether fungicides of the more common types can be used with summer emulsions without disturbing the efficiency of the emulsion or causing injury to the plant tissue when they are applied to foliage.

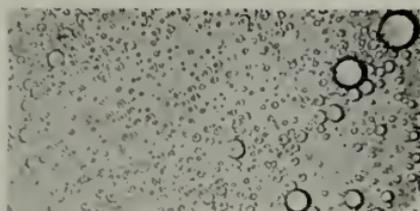


Fig. 18.—Soluble oil 8370.  $\times 490$ .

of oils between 83 and 350 seconds is not of major importance except as it affects the breaking property of the emulsion. A soluble oil containing an oil of 47 seconds of viscosity was not efficient against the eggs of the fruit-tree leaf roller.

#### Fleas

*Pulex irritans* Linn.

Oil emulsions at a concentration of 5 per cent gave excellent control of fleas on farmsteads.

The economic importance of fleas as a pest of rural communities is not generally recognized nor appreciated. The author made a survey of several counties in central Illinois and found a large number of farmsteads infested with fleas. Reports from farm advisers located in other counties indicated that similar conditions were present over a large section of the state.

Tests carried on over a period of three years indicate that soluble oil 17 at 5 per cent concentration will give a satisfactory control of fleas. Premises (interiors of barns, outbuildings, etc.) must be thoroughly cleaned of litter, dust and other refuse. The area is then sprayed with a 5 per cent oil emulsion and the floors thoroughly soaked. From 300 to 800 gallons of dilute spray

#### Dormant Oils with Fungicides

Under some conditions it is practical to use sprays that contain an emulsion and a fungicide. The most common fungicides contain either copper or sulfur. Dormant peach and apple trees will withstand relatively high concentrations of either oil emulsion or lime sulfur without injury. It is therefore possible to spray dormant trees with oil emulsions mixed with some fungicides. Such sprays are very useful in the control of scale and peach-leaf curl on peach, and scale and apple scab on apple. The properties of such sprays will depend on the fungicide added.

The use of copper in the form of Bordeaux has been widely tested and has proved successful in most respects. Emulsions containing soap can be added to Bordeaux if the concentration of the uncombined copper or calcium is not so high as to reverse the type of emulsion.

Most soap emulsions flocculate in the presence of inert forms of sulfur. "Flotation," a type of very finely divided precipitated sulfur obtained in the manufactured-gas industry from a process known as liquid purification, combines with an inert

emulsified oil, such as oil 210, to make an oil-sulfur combination possessing unusual properties, figs. 19, 20. These properties are described by Farrar & Smith (1930). Emulsions made with extremely stable emulsifiers, as oil 210, will mix with lime sulfur without separation. Such sprays can be used on dormant trees without noticeable injury.

The addition of sulfur to emulsions, particularly in the form of lime sulfur, has many objectionable features, the most serious of which is separation of the emulsion in the presence of lime sulfur. All miscible oils and stock emulsions that contain soap as the emulsifier will not mix with lime sulfur without separation of the emulsion and the liberation of free oil in the spray

the tip-green stage,<sup>6</sup> the emulsion alone did not injure, but lime sulfur either alone or mixed with oil emulsion caused very noticeable injury. In the delayed-dormant period, when the leaves were beginning to unfold, all of the sprays produced some injury. Least injury occurred on the oil emulsion-sprayed trees; those receiving lime sulfur were badly burned, and those receiving the mixture of oil and lime sulfur were so severely burned that the leaves did not develop further. The oil emulsion sprayed in the cluster-bud stage resulted in very noticeable injury to the unfolding leaves and flower clusters. Dutton (1932) finds that "there is evidence that the presence of oil with lime sulfur renders lime sulfur injury more severe or causes its develop-

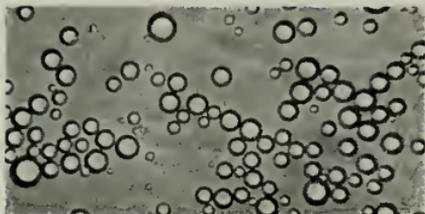


Fig. 19.—Oil stock 210.  $\times 490$ .

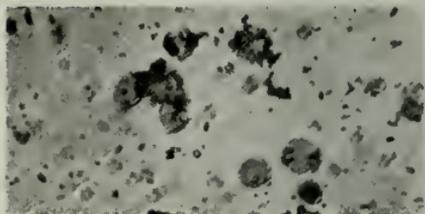


Fig. 20.—Oil stock 210 plus sulfur.  $\times 490$ .

mixture. This finding is in accord with the results of Ackerman (1923) and Yothers & Winston (1924). It is dangerous practice to apply partly separated emulsions to trees even in the dormant stages of their development. Yothers & Winston (1924) suggest the addition of stabilizers to oil-lime sulfur mixtures. Cutright (1929) describes the 10 oil-fungicide combinations which he thought possible to use under Ohio conditions. deOng (1930) suggests the use of organic sulfur in the cyclic series with oil emulsions to increase their fungicidal value.

The results of two years of tests with sprays containing lime sulfur and oil emulsion are shown in fig. 13. In these experiments three distinct types of emulsions were tested—a miscible oil at 2 per cent concentration, a proprietary emulsion recommended for use with lime sulfur, and stock 210. All were applied in the dormant, tip-green, and delayed-dormant stages of tree development. No injury from any of the materials was apparent among those trees sprayed while dormant. With the trees in

ment when lime sulfur without oil would not produce injury." Although sometimes recommended, the spraying of fruit trees with oil emulsion and lime sulfur is not a safe practice.

In many sections spray schedules on apples call for a spray of lime sulfur very early in the season, for the control of apple scab. This spray is often applied in the cluster-bud stage of development. Figure 13 shows the effect of oil emulsion and lime sulfur on foliage. Serious burning will usually result. The same condition can be approached where the oil spray is delayed and followed soon after by an application of summer-strength lime sulfur. Figure 21 summarizes the experiments to determine the interval of time that should elapse between the oil spray and a spray of lime sulfur. It appears to be relatively safe to apply lime sulfur two weeks after an application of oil emulsion.

<sup>6</sup> The tip-green stage of bud development is the time at which the bud scales have parted sufficiently to show the new green tissue that has been developing within the expanding bud. This stage precedes by a few days the rapid expansion of new leaves.

Yothers & Mason (1930) found that two or three weeks should elapse before an oil spray on citrus was followed by a sulfur spray or dust for the control of citrus rust mite. Overholser & Overley (1930) found under Washington conditions that oil sprays previous to July 1 caused injury to fruit and foliage following a delayed-dormant application of lime sulfur.

### Summer Oils with Fungicides

The need of an oil emulsion with fungicidal properties has been recognized. Many attempts have been made to combine sulfur,

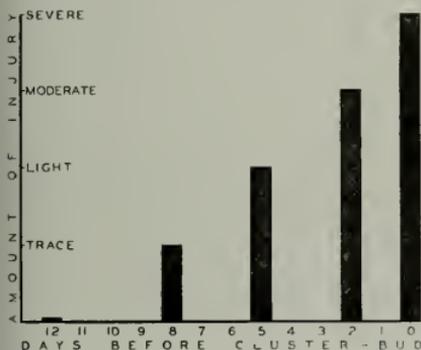


Fig. 21.—The incompatibility of dormant-oil spray and sulfur makes necessary an interval of 10 days to two weeks between applications of the two mixtures. The graph shows the injury to the tree caused by applying a dormant oil too late in the season; that is, just before the cluster-bud stage.

copper and their derivatives with both summer and dormant-oil emulsions. Other materials that have exhibited fungicidal properties have been tested but most of them have been discarded as unsatisfactory. Although sulfur is widely used as a fungicide, it will produce injury even when used in small quantities with oil, according to deOng (1928c). Hoerner (1929) suggests that *Penetrol* is compatible with flowers of sulfur and safe on apple foliage if the two are mixed with water before they are combined. Talbert & Swartwout (1931) state, "Lubricating-oil emulsions have been used throughout the summer in applying the regular summer combination applications, using the oil at 1 per cent and 2 per cent with the standard insecticidal and dormant spray, lime sulfur and Bordeaux with lead arsenate."

This finding is not in accord with the general knowledge of sulfur and oil combinations. Oil emulsions containing certain forms of copper are relatively safe on foliage but the spray has low insecticidal efficiency and it is difficult to store because of its corrosive action on metal. Oil emulsions may be added to well-made Bordeaux without danger of injury but the Bordeaux reduces the efficiency of the oil emulsion, according to Porter & Sazama (1930).

Oil emulsions containing derivatives of furfural show promise but are not completely satisfactory as insecticides or fungicides.

To our present knowledge there is no material sufficiently toxic to fungi that can be added to an oil emulsion without interfering with either the insecticidal efficiency of the oil emulsion or with the toxicity of the fungicide to fungi. The reduced efficiency of emulsions with fungicides was demonstrated in experiments with codling moth larvae, Table 6 and fig. 4. In these experiments, fungicides added to the pyrethrum sprays reduced their average efficiency from 88 to 66 per cent, and that of the white oils without pyrethrum from 34 to 33 per cent. Fungicides that were partially soluble in the oil phase of the emulsion decreased efficiency of the sprays less than did the flocculent materials, such as flowers of sulfur or Bordeaux.

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Volume 21

BULLETIN

Article 2

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# Responses of the Large-mouth Black Bass to Colors

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FRANK A. BROWN, JR.

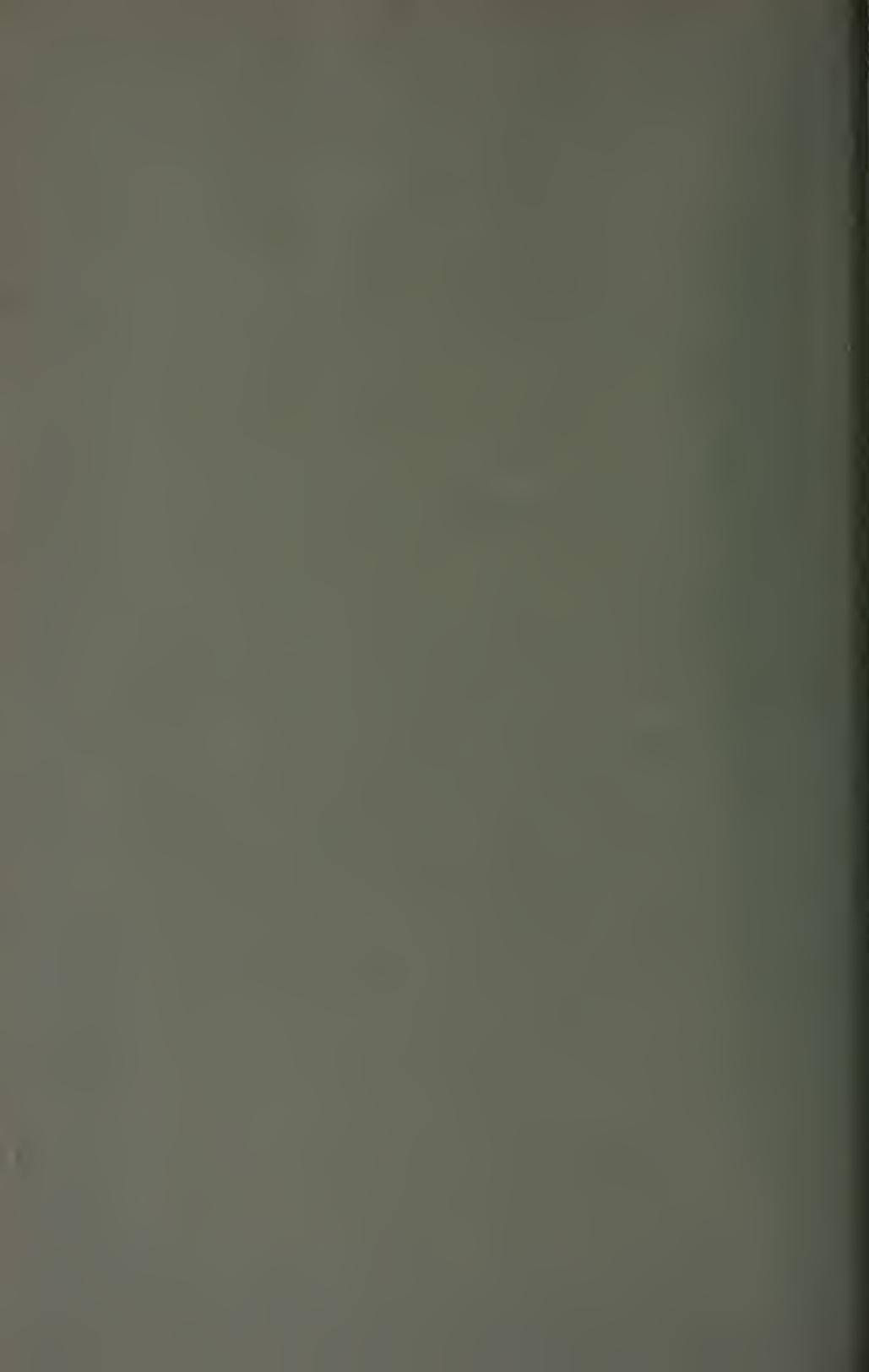


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LARGE-MOUTH BLACK BASS, *Aplites salmoides* (Lacépède)

# Responses of the Large-mouth Black Bass<sup>1</sup> to Colors

FRANK A. BROWN, JR.<sup>2</sup>

## PROBLEM OF COLOR VISION IN FISHES

BECAUSE an excellent review of color vision in fishes has been written recently by Warner (1931), a detailed historical introduction here is considered unnecessary. A brief statement of the work done in this field, however, is included to permit a clearer understanding of the results and interpretations that are to be found in this report.

### Survey of Literature

The problem of color vision in fishes was one which rather early attracted the attention of zoologists. Four general modes of attack upon this problem have been used, that of colored light preference, that of choice of variously colored foods, that of the responses of the integumentary pigmentary system to colored backgrounds, and finally, that of training fishes to discriminate among colors through the formation of associations. These methods are listed in the order in which they have received the most of their popularity, the oldest experiments being almost exclusively of the preference type while the latest ones are almost always of the association type.

Thus far nearly all zoologists are agreed that if a fish responds in a specific manner to light of a particular color in contrast to light of all other colors and intensities of white, *i.e.*, if it can be established that the difference of be-

havior is in response to wave length and not intensity, then the fish may be spoken of as having color vision for that particular wave length of light. Those few who are not contented with such a broad interpretation of color vision must certainly be content with the results derived from the formation of an association between colors and foods.

It is generally accepted that the form and function of animals are primarily concerned with feeding, protection of self, and reproduction. The methods of training fishes used by most investigators utilize the first, second, or both of these. Thus we may reason that any differential responses to wave lengths of light which involve such fundamental factors as these, together with modification of behavior in the face of a new situation, will concern the most highly evolved functional regions of the central nervous system. Even here, however, we need not consider such speculative aspects as the degree of consciousness of the fish with respect to the stimulus quality, or whether light of any particular wave length produces the same sensation in a fish as in man.

Graber (1884, 1885), utilizing the phototactic responses of the fishes, determined that *Corbitus barbatula*, *Alburnus spectabilis*, *Gasterosteus spinchia*, and *Syngnathus acus* selected areas illuminated by light of one color in preference to areas lighted by another color. Bauer (1910, 1911) similarly used a

<sup>1</sup>*Aplites salmoides* (Lacépède).

<sup>2</sup>Assistant zoologist, ILLINOIS NATURAL HISTORY SURVEY, July-August 1935.

preference method with the fishes *Charax puntazzo*, *Atherina hepsetus*, *Box salpa* and *Mugil* sp., and came to the conclusion that these fishes likewise had a color vision. On the other hand, Hess (1910, 1911, 1913, 1914) published a series of papers upon color vision in a number of kinds of young fishes. He too used chiefly the preference method. His interpretation of his experiments indicated that fish vision was approximately that of a color-blind man, and that the apparent differences in response to different colors were based solely upon differences in intensities. Hess severely criticised the work of Graber and Bauer in not having eliminated the possibility that the effects they obtained were due to brightnesses.

Upon similar grounds Hess discredited as evidence establishing color vision the observations of Zolotnitsky (1901) and Reighard (1908). Zolotnitsky had found that fish that had been fed for some time upon red chironomid larvae would snap only at red pieces of yarn when a number of variously colored bits of yarn were attached to the outside of the glass container. Reighard (1908) had noted that *Lutianus griseus* selected baits of one color in preference to baits of another.

Sumner (1911) and Mast (1916), working upon the adaptations of flat-fishes to colored backgrounds, arrived at the conclusion that their color vision was much like that of man. Haempel & Kolmer (1914), experimenting with *Cottus gobio* and *Phoxinus laevis*, found that these fishes became reddish when upon a red background. Connolly (1925) showed that *Fundulus heteroclitus* would modify its pigmentary system in a different fashion in red and yellow lights than in blue light. That color change in fishes in response to colored backgrounds proves color vision to exist has been seriously questioned by Schnurmann (1920). He shows that the color adaptations in the minnow *Phoxinus* appear to be the reactions of a color-blind fish with approximately the characteristics of vision of a color-blind man looking through a yellow-tinted screen. A screen of this sort would absorb the short wave lengths much more than the long ones and thereby

the differential response may result from intensity.

A rather conclusive work upon the color vision of fishes was performed by von Frisch (1913) who trained *Phoxinus laevis* to respond positively to a particular color and then had the fish select that color out of a long series of grays. He also demonstrated that red, yellow and purple-red were much alike to the fish. Green and blue were distinguishable from one another and from red and yellow. Burkamp (1923), using in principle the same kind of technic, arrived at essentially similar conclusions for *Phoxinus laevis*, *Rhodeus amarus*, *Idus melanotus* and *Tinca vulgaris*. Both von Frisch and Burkamp controlled the intensities of their colors principally in using a confusing series of grays. The latter worker also used colors diluted with black and white.

Washburn & Bentley (1906) trained *Semotilus atromaculatus* to accept food from a red pair of forceps and to refuse it when offered from green. An attempt was made to control the intensity by reversing the order of brightness of the colors as they appeared to the human eye. White (1919) and Hine (1927), employing color filters, showed that *Umbra limi* and *Eucalia* appear to distinguish between all colors with the exception of the combination green and blue. The latter work has also been criticized in that it has not sufficient control of the intensity factor.

Reeves (1919) was the only one to equalize two colors in the brightnesses that they appeared to the fishes themselves and then to have the fishes distinguish between them. Miss Reeves has demonstrated quite conclusively that *Semotilus atromaculatus* and *Eupomotis gibbosus* distinguish red from blue by virtue of the color values.

Schiemenz (1924) used a method in which he trained *Phoxinus* to respond positively to a white enameled stick upon which was shone light of a particular wave length and to refuse to respond to other colors. These colors were obtained by screening off small portions of a spectrum obtained with a prism. The intensity factor was controlled by varying the variously colored

lights through a broad range of intensities. Wolff (1926) permitted trained fish to select their training color from a series of spectral colors presented simultaneously. These two researches have demonstrated quite conclusively that *Phoxinus laevis* is able to distinguish among about 20 colors of the visible spectrum and ultraviolet by virtue of color as opposed to brightness. These last two are perhaps the most complete experiments which have been carried out in the field of color vision of fishes.

A critical summary of the field now indicates that the minnow *Phoxinus laevis* is able to distinguish about 20 colors from one another by virtue of the wave length of the light. Furthermore, it appears to be proved that *Semotilus atromaculatus* and *Eupomotis gibbosus* are able to distinguish red from blue solely by differential effects of the colors as distinct from intensity. Beyond these statements all we can say is that it is quite probable that about 15 or 20 more genera of fishes also have a kind of color vision although this has not been decisively proved.

#### Significance of Determining Color Vision in Black Bass

In view of the small amount of conclusive data upon the color vision of fishes and the fact that the best of what there is has been for all practical purposes confined to few genera of fishes, it was believed profitable to investigate the color vision of the large-mouth black bass, *Aplites salmoides* (Lacépède). The fact that there is a color vision in some fishes does not preclude the possibility of some other fishes being color blind or having modified color vision.

In addition to the purely scientific outlook upon this problem, there are some economic aspects to the study of this particular fish. Thousands of dollars are spent annually for the purchase of highly colored bass lures by sportsmen. Bass in some regions are believed to prefer one color or combination and those of other regions, others. Furthermore, there is often voiced the belief that at different times of day or in different weathers there are changes in the choice of colors by this fish. Thus this work has a double interest.

#### Acknowledgments

This investigation was carried out during the summer of 1935. I should like to take this opportunity to acknowledge my indebtedness to Dr. David H. Thompson, of the ILLINOIS STATE NATURAL HISTORY SURVEY, at whose suggestion this work was undertaken and who was extremely generous with constructive criticism throughout the course of the work. Furthermore, I wish to express my gratitude to Francis X. Lueth, student assistant with the SURVEY, who served as an invaluable aid, and to O. C. McMillin, who kindly constructed certain pieces of the apparatus.

#### MATERIALS FOR THE EXPERIMENTS

##### Fish

All the fish used in the following experiments were large-mouth black bass which were caught in Crystal lake, Urbana, Ill. One lot of animals was taken on July 5 and the second lot on July 23. The fish varied in length from 2.5 to 4.8 cm. at the time they were caught. Upon being brought into the laboratory the fish were first allowed to remain in large aquaria for a day or more in order to accustom them to the laboratory temperatures and water supply. Thereafter they were placed in individual white enameled basins, where they remained for the rest of the experimentation.

##### Apparatus

Twelve white enameled basins were lined up along one side of a room. There were no windows along this side and as a result the illumination was independent of the changing sky light to a considerable degree. Never at any time did the fish receive direct sunlight. Throughout the actual experimentation the fish were lighted by a number of incandescent lamps in such a way that the dishes were all quite uniformly illuminated to the extent of 12 to 20 foot-candles, depending upon the amount of daylight entering through the single window of the room.

The water in the basins was maintained at a depth of 2.5 cm. and was changed every second day.

The circular bottoms of the pans were 15 cm. in diameter. These bottoms were marked off in arcs of circles differing 1 cm. in radius from one another and all having a common center at a point upon the circumference of the bottom of the pan nearest the observer, fig. 1. The marking of the bottoms of the pans in this manner enabled an observer quite accurately to record the distance of the bass at any given moment from the given point upon the periphery of the dish where training pipettes were to be presented and the fish fed or shocked in association.

For shocking the fish, each dish was provided with a pair of fixed copper electrodes 12 cm. apart, dipping into the water at the edge of the pan approximately equidistant on either side of the common center of the arcs of the circles, fig. 1, EE. A 12-way switch permitted the experimenter to shock any fish without disturbing the others. Thus, everything in the pans was constant

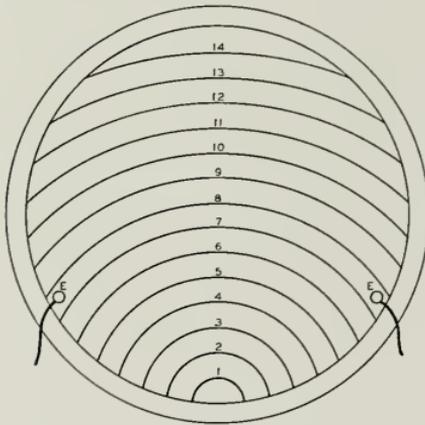


Fig. 1.—Diagram of the markings upon the bottom of a training basin, and the position of the electrodes, EE.

except for the pipettes, which were presented at a given spot from time to time.

The electric current for the shock was furnished by two dry-cell batteries and a Harvard inductorium with the secondary coil set at about 7 upon the scale of the instrument. A button switch was attached to an extension cord in

order that the observer could conveniently carry out the whole training procedure.

#### Colored Pipettes

It was found that an ordinary pipette (medicine dropper) covered neatly with white adhesive tape could be readily

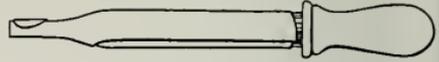


Fig. 2.—Training pipette, showing the manner in which the white adhesive tape was applied.

colored by wax crayons or water colors and at the same time act as an opaque container in which the *Daphnia* or mosquito larvae which were used as food material could be held concealed until the time for feeding arrived.

The adhesive tape was applied to all the pipettes as shown in fig. 2. This was done in such a way as to cover the whole of the glass even to the tip.

The colors involved in the experiment were standard according to Ridgway (1912). Wax crayon was used to color the tape on the pipettes for the following:

- Rose red
- Scarlet
- Flame scarlet
- Lemon yellow
- Scheele's green
- Meadow green
- Helvetia blue
- Seal brown

The following could be obtained only by using water colors:

- Orange rufous
- Aniline yellow
- Calliste green
- Thulite pink
- Pale greenish yellow
- Pale turquoise green
- Light Columbia blue

#### Black, White and Gray Pipettes

For the series of gray pipettes the adhesive tape was first applied to the outside of the pipettes in the same manner as for the colored ones. White 0 was constructed by first whitening the surface of the tape with shoe whitening and, after drying, the whole was rubbed with hard paraffin. Grays 1-6 inclusive

were obtained by dipping the tape-covered pipettes into black India ink of different dilutions. Paraffin was applied to the dried outer surface of the pipettes. Black 7 was the result of rubbing a covered pipette with a black wax crayon and then paraffining it.

Measurements of the relative light reflection of these gray pipettes were made with a MacBeth illuminometer. A petri dish filled with water was placed upon a milk glass plate and 2 inches above the surface of the water the illuminometer was directed in such a manner that light, emitted from a light source making an angle of 60 degrees with the water surface, was reflected up into the illuminometer at the same angle, fig. 3. The pipettes were lowered one by one just beneath the surface of the water of the petri dish and the relative values of the light reflected from the side of each was measured.

The relative brightnesses of the pipettes as measured by this method were as follows:

White 0.....	63
Gray 1.....	49
Gray 2.....	32
Gray 3.....	26
Gray 4.....	21
Gray 5.....	15
Gray 6.....	7
Black 7.....	1

It is thus seen that the range of intensity of the gray pipettes was considerable and it was very reasonable to expect that it would cover the range of intensities of the colors used.

#### Color Rods

From a good quality, 1 mm. thick, water-color board, small 6 by 65 mm. strips were cut. Twenty-eight of these were painted with water colors in such a way that the strips could be arranged into a complete visible spectrum divided into 28 grades of color of roughly equal degrees of difference. The stages were made by imitating the pure spectral colors given by Ridgway in his "Color Standards and Color Nomenclature." The colored paper rods were finally dipped in warm paraffin to render them waterproof and to obviate any possible odor of the pigments. The paraffin

coating had practically no detrimental effect as far as changing the original color was concerned.

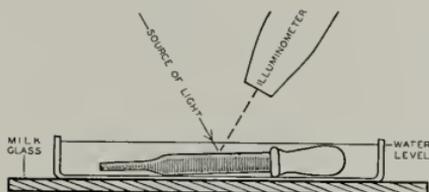


Fig. 3.—Method used to determine the relative brightness of the gray pipettes.

The following is a list of the 28 colors in order from red to violet:

- |                         |                     |
|-------------------------|---------------------|
| 1. Spectrum red         | 15. Neva green      |
| 2. Scarlet red          | 16. Emerald green   |
| 3. Scarlet              | 17. Vivid green     |
| 4. Grenadine red        | 18. Skobeloff green |
| 5. Flame scarlet        | 19. Benzol green    |
| 6. Orange chrome        | 20. Italian blue    |
| 7. Cadmium orange       | 21. Cerulean blue   |
| 8. Orange               | 22. Methyl blue     |
| 9. Cadmium yellow       | 23. Spectrum blue   |
| 10. Light cadmium       | 24. Bradley's blue  |
| 11. Lemon chrome        | 25. Phenyl blue     |
| 12. Lemon yellow        | 26. Blue-violet     |
| 13. Greenish yellow     | 27. Bluish violet   |
| 14. Bright green-yellow | 28. Spectrum violet |

### TRAINING AND RESPONSES OF LARGE-MOUTH BLACK BASS

#### Method

In all the training experiments the fish were shown a number of pipettes one after another. From a particular pipette the fish were fed either *Daphnia* or mosquito larvae, whereas from all the others nothing was fed, but instead, if the fish approached closer than a certain distance from the pipette a shock was given. In some of the training experiments that distance was 6 cm. and in others it was 3 cm. Whenever the same series of pipettes was shown to a fish time after time, the sequence was continually changed in order that the responses of the fish could not possibly be a result of a learned sequence, but rather must be a response unmodified by anything other than color or intensity. That the presence of the living food in the pipette might have had some attracting influence upon the fish was highly improbable. It was impossible that the effect could be chemical for the fish responded within a second or two

and from a distance ranging from two to 15 cm. from the entering pipette. The other possibility, that the bass might have heard the swimming movements of the *Daphnia* or mosquito larvae, was eliminated by repeatedly presenting an empty pipette of the color to which the fish was trained and obtaining exactly the same results as when food was present. Furthermore,

of the pipette and then retreat. The distance they would retreat was inversely related to the frequency with which they struck. A well trained fish would strike repeatedly at its own color, retreating very little between strikes. Occasionally it would strike at another color but in this case it would rapidly retreat considerably farther and appear very timid. Striking a color other than

Table 1.—The distance away in cm. that each of 12 untrained black bass remained from colored, black and light gray pipettes. Each value is the average of four trials.

FISH No.	ROSE RED	LEMON YELLOW	SCHEELE'S GREEN	HELVETIA BLUE	GRAY 1	BLACK 7
19	1.	1.	3.	2.	1.	1.5
20	1.5	1.5	2.5	2.	2.	2.25
21	2.	1.	2.	1.5	1.	1.
22	1.5	1.5	1.	1.	1.	1.5
23	1.5	1.5	2.	3.	1.5	3.5
24	1.5	2.	2.5	3.5	1.5	3.
25	1.	2.	2.5	3.25	2.	2.
26	1.5	1.	1.	2.	1.	1.5
27	1.	2.	1.5	1.5	2.	3.
28	11.75	11.75	13.	13.	13.	13.
29	5.25	4.	7.25	7.25	6.5	7.25
30	1.5	3.25	2.	2.5	2.5	3.
<i>Average*</i>	1.75	1.88	2.48	2.68	2.	2.68

\*This average does not include fish No. 28, which showed no active response.

the same response of the fish could be obtained by holding the pipette just above the surface of the water. Without the continuity of water between the food and the fish sound could not have travelled from one to the other with intensity sufficient to have evoked response from the fish. A further check was made by putting the food material into all the pipettes used. The responses remained unaffected.

Three seconds was the time given the fish to respond to the pipette. At the end of this time the position of the fish was recorded and food was ejected from the end of the pipette to which the fish was being trained, or, the animal was shocked if it was within the "limit" distance from any pipette other than its training color. All the records are statements of the distance from the end of the pipette at which the fish was found the moment the observation was completed. The fact that no observations of less than about half a centimeter were recorded was a result of the manner in which the bass responded to a pipette. They would strike at the end

its own seemed to be very frequently a result of the habit of bass of striking at moving objects. These strikes would usually occur about the time the pipette touched the surface of the water. These facts suggested that the distance from the end of the pipette at which a fish was found three seconds from the time the pipette broke the surface of the water was a sufficiently faithful representation of the strength of the positive or negative reaction of trained fish.

Another variable with which it was necessary to cope was the hunger of the fish. A fish which was hungry would remain nearer the pipette, on the average, than one which was not hungry. It seemed safer therefore, for the sake of obtaining more or less comparable results, to keep the fish hungry throughout the experimentation. A few initial experiments were carried out to determine the capacity of bass for *Daphnia*. It was determined that a well fed bass of the size which were used would eat at the rate of one *Daphnia* every five to eight minutes, and that a bass that had not been fed for about six hours would

Table 2.—Records obtained during the training of bass to approach one of the four colors, rose red, lemon yellow, Scheele's green, or Helvetia blue, and at the same time retreat from the other three colors. Each value for an individual fish is the average number of cm. a fish remained away from the color during five training trials.

eat rapidly and continuously from 15 to 20 of these. In all the experiments at training and measuring response this capacity was borne in mind and a safe margin of hunger was always maintained. With practically no exceptions the bass eyed attentively all the pipettes and rods which were shown them and their other general movements and behavior also indicated clearly to an observer that the fish were actively responding to them.

**Reactions of Untrained Fish to Colors and Grays**

Bass Nos. 19 to 30 inclusive were placed in the individual, white enameled training dishes and *Daphnia* were added to the water. At first the fish refused to eat and were very nervous. They were permitted to remain unmolested until they had become accustomed to their new surroundings, which required two or three days. At the end of this time they would dash to a pipette and strike futilely at a *Daphnia* which was clearly visible through the glass wall and then promptly seize the *Daphnia* when it was ejected from the end.

These fish were now considered sufficiently at ease in their laboratory environment to permit a fair test of the responses of the untrained fish to rose red, lemon yellow, Scheele's green, Helvetia blue, gray 1 and black 7. The same procedure as in training was used except that here there was neither food nor shock associated with the pipettes. The series was shown to each fish four times over a period of two days. The average distance away from each pipette for each fish for the four trials was recorded to the nearest half of a centimeter and can be seen in Table 1.

These results indicated that red was the most attractive color; yellow was next; then in order came light gray, green, blue and black. This experiment presented reactions upon which the modification of response in the bass

FISH No.	ROSE RED	LEMON YELLOW	SCHLEE'S GREEN	HELVETIA BLUE
<i>Training to Rose Red</i>				
7	1.4	1.6	5.	6.4
	4.2	5.8	12.	11.4
	2.	6.8	13.2	13.
	2.8	9.8	12.8	12.4
	1.	11.2	13.	12.8
11	1.4	1.4	5.2	6.8
	1.	5.4	10.2	9.8
	1.	8.2	12.	8.8
	1.	9.8	9.2	9.6
	1.	7.4	7.	9.4
14	1.8	2.4	3.6	4.6
	1.8	4.4	10.2	9.
	1.	4.2	9.8	11.
	1.4	7.8	12.	12.2
	1.	10.	12.	13.6
Average	1.5	1.8	4.6	5.9
	2.3	5.3	10.8	10.1
	1.3	6.4	11.7	10.9
	1.7	9.1	11.3	11.4
	1.	9.5	10.7	11.9
<i>Training to Lemon Yellow</i>				
8	4.8	1.5	4.4	5.
	8.	2.6	8.4	9.
	9.6	4.8	11.6	7.8
	5.8	1.2	10.8	11.2
	8.6	1.	9.8	8.8
12	3.8	3.6	4.	4.6
	8.6	4.6	9.	5.6
	9.8	4.6	10.	10.
	8.2	1.6	8.	8.6
	9.	1.	10.	7.8
15	4.	2.	3.	4.8
	10.	1.4	8.	10.
	10.	1.	11.	10.6
	9.4	1.	13.2	11.4
	11.4	1.	10.6	9.8
Average	4.2	2.4	3.8	4.8
	9.1	2.9	8.5	8.2
	9.8	3.5	10.9	9.5
	7.8	1.3	10.7	10.4
	9.7	1.	10.1	8.8
<i>Training to Scheele's Green</i>				
9	6.	7.6	3.6	5.6
	5.	10.2	3.8	4.
	3.8	11.4	3.8	7.
	6.	13.2	2.8	4.8
	6.4	10.6	2.4	5.6
13	3.4	3.	2.8	4.4
	7.8	7.	9.	9.2
	7.	6.6	4.	6.6
	7.2	5.4	3.2	5.4
	5.6	6.	2.2	4.8
16	2.8	4.4	2.2	3.
	7.	9.6	5.2	6.6
	9.2	8.	4.8	6.
	9.8	7.8	8.4	7.2
	9.8	10.2	3.4	11.
Average	4.1	5.	3.9	4.3
	6.6	8.9	6.	6.6
	6.7	8.7	4.2	6.5
	7.7	8.8	4.8	5.8
	7.3	8.9	2.7	6.8
<i>Training to Helvetia Blue</i>				
6	8.4	7.6	8.2	8.
	9.6	7.4	8.2	7.2
	8.2	8.2	5.6	6.4
	6.2	8.4	5.8	5.8
	7.4	6.8	6.4	4.4
10	4.4	3.6	5.2	5.4
	7.4	8.2	8.6	6.2
	5.6	5.4	5.	6.6
	8.4	10.	8.2	5.
	11.6	7.4	10.4	8.6
17	4.8	4.8	6.8	6.8
	4.8	6.8	4.6	5.4
	4.6	7.6	4.2	3.2
	8.2	6.6	6.6	3.2
	6.2	7.6	7.4	2.6
Average	5.9	5.3	6.7	6.7
	7.3	7.5	7.1	6.3
	6.1	7.1	4.9	5.4
	7.6	8.3	6.9	4.7
	8.4	7.3	8.1	5.2

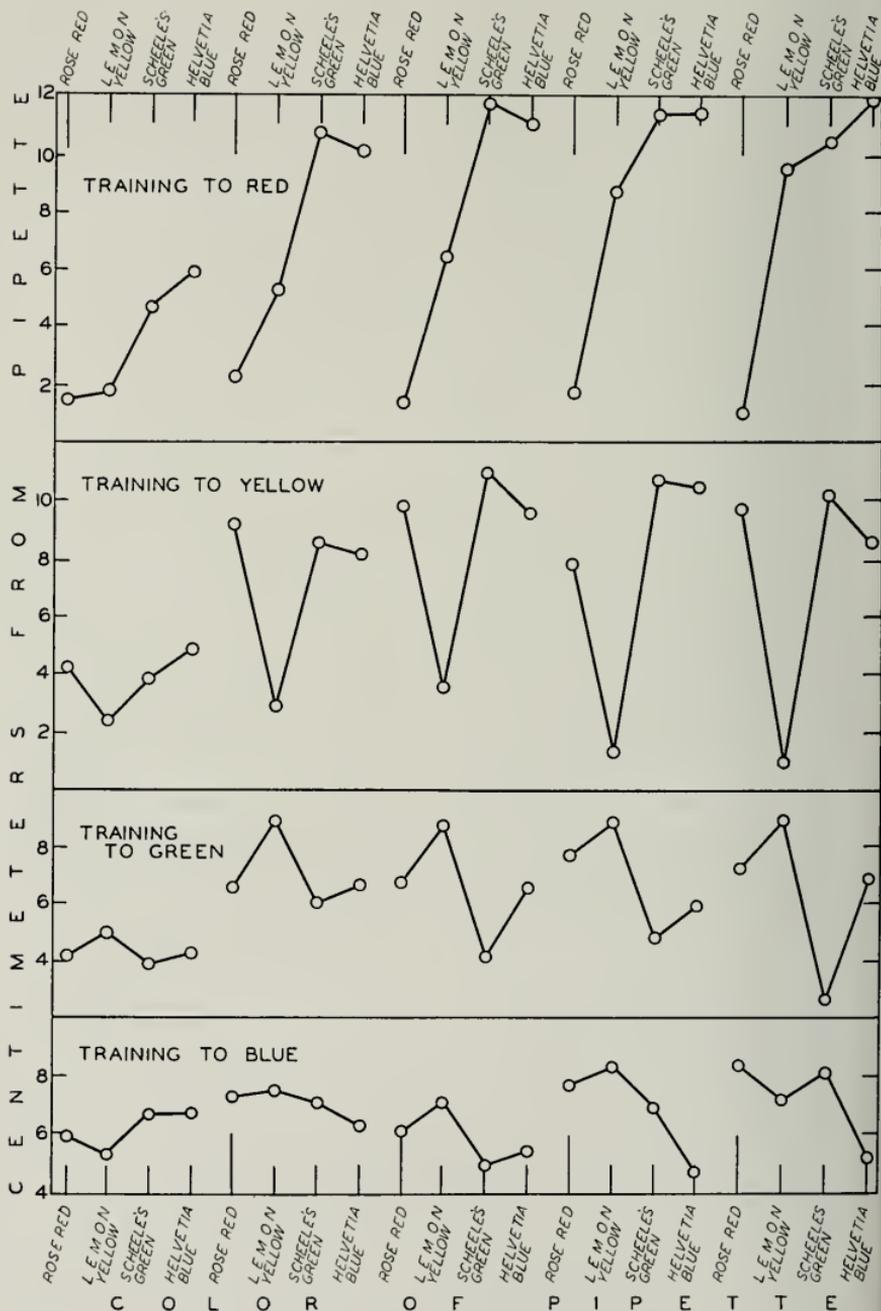


Fig. 4.—Average data for groups of three fish trained to each color, showing stages in the learning process. See Table 2.

was to be superimposed. It was borne in mind, however, that the attractiveness of red for the fish might have been the result of the feeding upon *Daphnia* which were reddish brown.

#### Training to Each of Four Colors

Twelve bass were now subjected to training to four colors. Numbers 7, 11 and 14 were trained to rose red as contrasted with Scheele's green, lemon yellow and Helvetia blue; Nos. 8, 12 and 15 were trained to lemon yellow as contrasted with the other three colors; Nos. 9, 13 and 16 were trained to Scheele's green, and Nos. 6, 10 and 17 to Helvetia blue as contrasted with the remaining three colors. Throughout this experiment the bass were fed *Daphnia* from the pipette of their training color and were shocked whenever they were less than 6 cm. from the end of any other pipette after three seconds had elapsed. Each fish was shown the series of four pipettes five times each half day for two and a half days. At the end of this period the fish were considered trained for the purposes of the experiment.

Table 2 and fig. 4 show the records that were obtained during the course of the training of these fish. The average of each group of five trials on each color has been calculated and every record in the table is thus an average of five

Table 3.—The average distance in cm. away from colors and grays that color-trained fish remained. Each value is the average of nine trials taken with three fish.

	TRAINED TO RED	TRAINED TO YELLOW	TRAINED TO GREEN	TRAINED TO BLUE
Rose Red	1.22	4.38	5.	4.5
Scarlet	1.56	3.38	5.33	4.17
Shrimp pink	1.75	2.33	5.17	5.5
Flame scarlet	1.22	5.13	5.5	5.34
Lemon yellow	5.8	1.88	4.66	6.
Scheele's green	7.23	5.63	1.84	1.5
Meadow green	7.	6.13	1.5	1.5
Helvetia blue	7.23	6.88	1.33	1.33
Seal brown	6.78	7.38	1.33	1.5
Gray 1	5.9	1.12	5.33	5.33
Gray 2	5.77	1.62	4.17	4.67
Gray 3	5.9	3.62	3.66	3.66
Gray 5	6.66	6.5	2.67	2.17
Gray 6	7.	6.13	2.5	1.33
Gray 7	7.23	6.63	2.	1.5

trials. From this data a series of curves illustrating the learning process has been constructed. These indicate that even at the end of six to eight trials the

bass have become considerably modified in their behavior towards the colors. The learning with respect to the red and yellow has been most striking and that to green and blue much less so. Thus, for the same kind of training for the same length of time the results of training to the four colors are by no

Table 4.—Results obtained in an attempt to train yellow-trained fish to approach lemon yellow and retreat from gray 1 and 2 and shrimp pink. Values for individual fish are average distances in cm. from the pipettes for 10 training trials.

FISH NO.	LEMON YELLOW	GRAY 1	GRAY 2	SHRIMP PINK
8	8.09	7.54	7.81	9.27
12	3.63	5.	3.63	4.41
15	4.81	6.45	5.63	6.72
Average	5.51	6.33	5.69	6.8

means identical. The probable significance of these results will become more evident later.

#### Responses of Fish Trained to Four Colors

Having completed their training, bass Nos. 6-17 inclusive were next shown a series of pipettes including the colors with which they had been trained. In addition there were several strange colors and shades of gray. During this experiment the fish were neither fed nor shocked, the distance away from the end of the pipette after an interval of three seconds being taken as an index of the degree of attraction of the color for the particular bass. Each bass was shown each color in the series three times, and consequently with three bass trained to each one of the four colors nine observations were available for averaging to determine the response of bass trained to a particular color, to other colors and grays. The following were the colors used in this experiment: Rose red, scarlet, shrimp pink, flame scarlet, lemon yellow, Scheele's green, meadow green, Helvetia blue, seal brown, gray 1, gray 2, gray 3, gray 5, gray 6 and black 7. Table 3 and fig. 5 give the average distance that fish trained to each of the four colors remained away from each pipette. The results for individual fish were remarkably similar.

It is of great interest to note that red-trained fish selected all colors having a

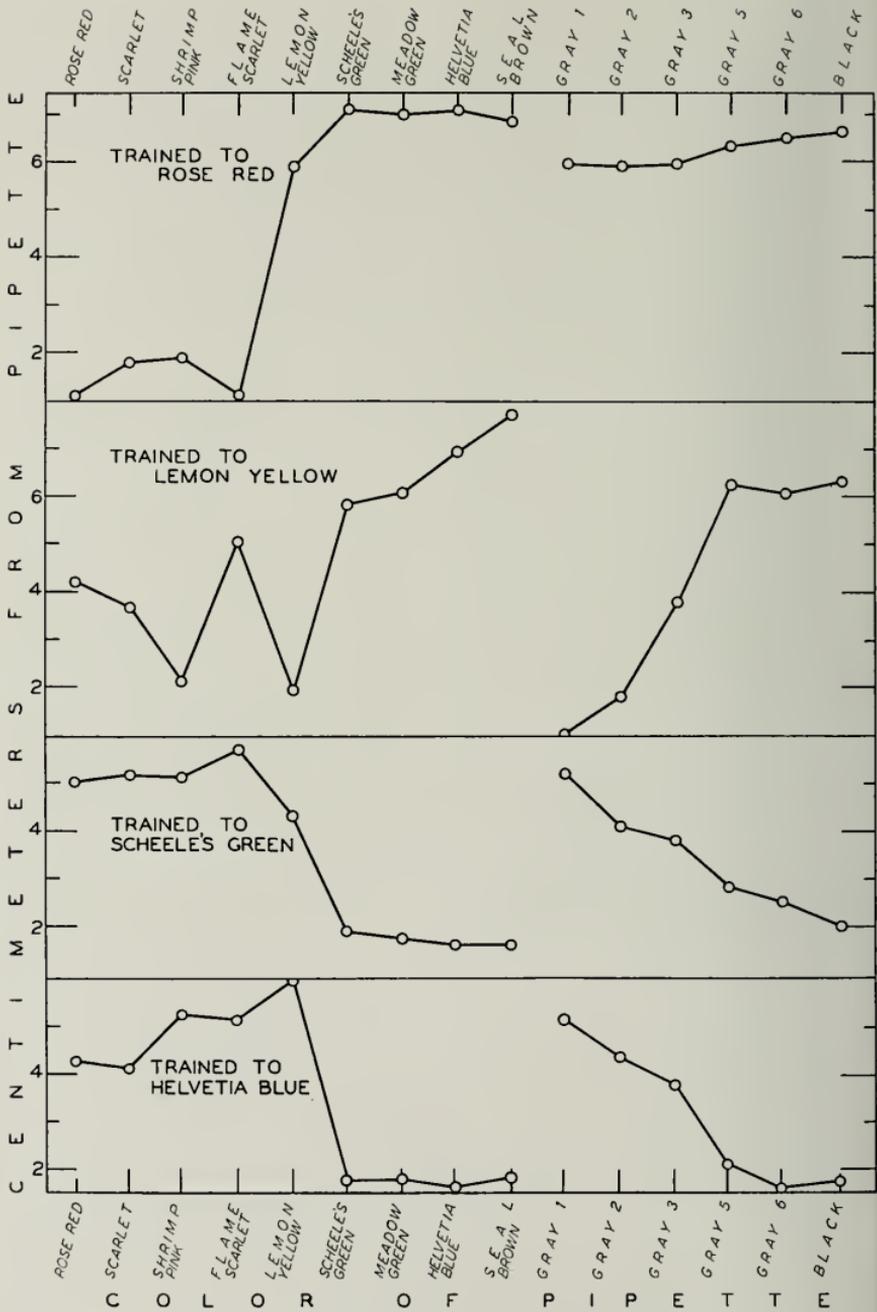


Fig. 5.—Responses of trained bass Nos. 6-17 to variously colored pipettes. The pipettes are the same as in Table 3.

reddish tint in strong contrast to all other colors and shades of gray, and secondly, that among the grays the light grays were slightly more attractive to these fish than were the dark.

Fish trained to yellow were not nearly so color specific but responded equally well to the lightest gray and to the yellow to which they were trained. They were also somewhat positive to shrimp pink, a very pale-colored pipette.

Lastly, fish trained to green or blue were almost equally positive to green, blue and dark grays. Unlike the fish trained to red and yellow, these fish were quite negative to the light grays.

In the light of the similarity of yellow, light grays and shrimp pink to animals trained to yellow it was deemed advisable to determine whether the fish had been trained to yellow only as a bright pipette because no other equally bright color was present in the original training series, or whether it was because the fish distinguished very little between yellow and light gray. Five trials training to lemon yellow in contrast to gray 1, gray 2 and shrimp pink pipettes were given to each of the fish trained to yellow and then the average of the next 10 trials (still training trials, *i.e.*, feeding upon yellow and shocking upon the other pipettes) was taken as a criterion of the degree of learning of the fish. The original training had shown that five to eight trials were sufficient to produce a strikingly modified behavior to pipettes the colors or intensities of which were quite distinct for the fish. Table 4 gives the averages of the 10 trials for each of the fish.

Still a light gray and the yellow were quite indistinguishable and the very pale reddish pipette, shrimp pink, was becoming the most different from the yellow though to the human eye it appeared of a brightness intermediate between the two lightest shades of gray. In other words, here again red was distinctive.

Bass were next shown two pipettes simultaneously in order to determine what the effects of choice would be. The pipettes were placed 7 cm. apart in a metal rack and then the rack lower-

ed in such a fashion that the pipettes broke the surface of the water at the same instant. When the fish struck at one of the pipettes or remained before one for two seconds, that pipette was

Table 5.—Choice of fish trained to each of four colors when presented simultaneously with two colors.

GIVEN CHOICE OF PIPETTES		PIPETTE SELECTED		
1	2	7	11	14
<i>Trained to Rose Red, Fish Nos.</i>				
Thulite pink	Gray 4	1	1	1
Thulite pink	Gray 3	1	1	1
Thulite pink	Gray 5	1	1	1
Shrimp pink	Gray 4	1	U*	1
Rose red	Gray 6	1	1	1
Flame scarlet	Lemon yellow	1	1	1
Orange rufous	Lemon yellow	1	U	1
Aniline yellow	Lemon yellow	1	1	2
Rose red	Seal brown	1	1	1
Flame scarlet	Seal brown	1	1	1
<i>Trained to Lemon Yellow, Fish Nos.</i>				
Lemon yellow	Flame scarlet	1	1	1
Lemon yellow	Orange rufous	1	1	1
Lemon yellow	Aniline yellow	1	2	U
Lemon yellow	Gray 1	1	2	U
Lemon yellow	Pale turquoise green	1	2	U
Lemon yellow	Calliste green	1	U	U
Lemon yellow	Thulite pink	1	1	1
Lemon yellow	Gray 3	1	1	1
Lemon yellow	Shrimp pink	1	2	1
<i>Trained to Scheele's Green, Fish Nos.</i>				
Pale greenish yellow	Gray 3	2	U	1
Scheele's green	Black 7	1	1	1
Scheele's green	Gray 6	2	1	2
Pale turquoise green	Light Columbia blue	1	2	2
Meadow green	Helvetia blue	2	U	U
Scheele's green	Lemon yellow	1	1	1
Calliste green	Lemon yellow	1	1	1
Scheele's green	Helvetia blue	2	2	1
<i>Trained to Helvetia Blue, Fish Nos.</i>				
Light Columbia blue	Gray 1	1	U	1
Light Columbia blue	Gray 3	1	1	U
Light Columbia blue	Gray 5	U	U	U
Light Columbia blue	Lemon yellow	1	1	1
Light Columbia blue	Thulite pink	U	U	U
Light Columbia blue	Scarlet	U	1	1
Helvetia blue	Pale turquoise green	U	2	2
Helvetia blue	Scheele's green	2	U	2
Helvetia blue	Lemon yellow	U	1	1
Helvetia blue	Calliste green	2	2	2
Helvetia blue	Black 7	2	1	U
Helvetia blue	Seal brown	1	1	1

\*Undecided.

regarded as the choice of the fish. On the other hand, if the fish approached neither or swam back and forth between them, then the response of the fish was termed "undecided." Table 5 gives the results of these experiments.

Glancing through this table we are again impressed with the distinctness

of red as a color. Several different reds were selected very decisively from a number of confusing colors and grays. The blues, greens and grays appeared to be more or less confused by the fish, the blues being the most often confused with grays.

from those other colors shown it. The results of 30 training trials made after the completion of the first 10 trials were averaged together and are shown in Table 6 and fig. 6. The results are fully comparable since all the fish had had equivalent training.

Table 6.—Results of a second experiment of training fish to approach certain colors and to retreat from others. Each value for individual fish is the average distance from the pipettes in cm. for 30 training trials after the initial 10 training trials have been excluded.

FISH No.	ROSE RED	FLAME SCARLET	LEMON YELLOW	GRAY 1	SCHEELE'S GREEN	HELVETIA BLUE
<i>Trained to Rose Red</i>						
19	3.45	3.9	5.41		4.4	4.5
23	2.3	2.89	4.35		5.15	5.23
<i>Average</i>	<i>2.88</i>	<i>3.39</i>	<i>4.88</i>		<i>4.82</i>	<i>4.81</i>
27	4.3		5.96		6.25	7.16
<i>Trained to Lemon Yellow</i>						
20	5.55		4.05	4.93	6.05	7.
24	3.26		1.89	2.37	3.52	4.2
<i>Average</i>	<i>4.4</i>		<i>2.97</i>	<i>3.65</i>	<i>4.78</i>	<i>5.6</i>
28	8.12		5.91		11.3	10.98
<i>Trained to Scheele's Green</i>						
21	6.65		5.98		4.74	5.61
25	4.		3.68		2.23	3.
<i>Average</i>	<i>5.33</i>		<i>4.83</i>		<i>3.48</i>	<i>4.3</i>
29	5.24		4.43		2.39	
<i>Trained to Helvetia Blue</i>						
22	5.4		5.88		2.9	2.4
26	5.65		4.77		3.78	2.67
<i>Average</i>	<i>5.53</i>		<i>5.33</i>		<i>3.34</i>	<i>2.54</i>
30	3.57		2.98			2.26

#### Training to Each of Four Colors Plus Tints

The usual training procedure was now applied to bass Nos. 19-30 inclusive, except that in this instance shocking was employed only when the fish came within a distance of 3 cm. from a pipette other than the one to which they were being trained. After 10 training trials the fish were considered sufficiently trained. Unlike the first training experiment, two of the three fish trained to rose red were trained against flame scarlet in addition to lemon yellow, Scheele's green and Helvetia blue; and two of those fish trained to lemon yellow had gray 1 included among those colors to which they were shocked upon too close approach. Also, one of the fish trained to green had blue omitted, and one of the fish trained to blue had green omitted

Here, the similarities between red and flame scarlet and between yellow and light gray are shown in relatively measurable quantities. There is seen repeated the difficulty of the fish in distinguishing between green and blue. Again there is indicated a greater distinctness of red than any other color. In short, the results of this second training experiment with a new lot of animals have corroborated the results obtained in the first one in many fundamental respects.

With the disadvantage of not knowing at what brightnesses the training colors appeared to the bass it was impossible to make a complete comparison of the apparent colorfulnesses of the pipettes used, for it was unknown whether the response difference between some colors was partly due to brightness, or even wholly so. Presenting the

shades of gray to the first lot of bass had given a clue that seemed worth following up. Did rose red and lemon yellow actually appear to the fish as bright colors and did Helvetia blue and Scheele's green appear as colors of low intensity? To the light-adapted human

at about this time, the number of trials that are available for red is somewhat smaller. One red-trained animal was given 15 series, and the only one which survived at the end of the training, No. 27, was given 35 series.

The results of this experiment are

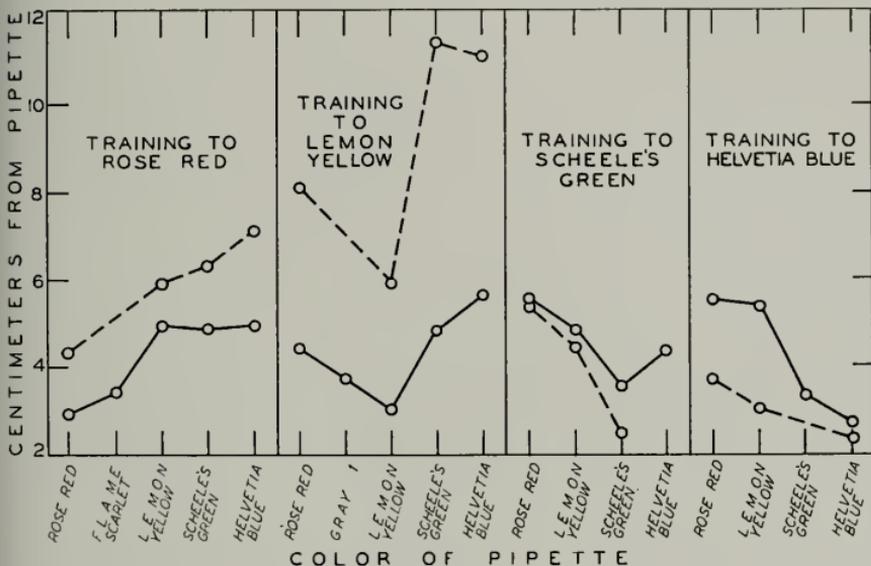


Fig. 6.—Responses of trained bass Nos. 19-30. See Table 6. The broken line is the result obtained with those fish trained with the shorter series of colors in each case.

eye Scheele's green and rose red appeared of approximately equal intensity, about that of gray 3 or 4, the red being perhaps a trifle darker. The yellow appeared about as gray 1 and the blue as gray 6. It was deemed profitable to repeat the work upon the response of trained fish to shades of gray.

**Responses of Fish Trained to Four Colors Plus Tints**

**RESPONSE TO COLOR AND THREE SHADES OF GRAY.**—Each of the 12 bass was now subjected to a secondary training in which the color to which the bass had previously been trained and the three shades of gray—gray 1, gray 4 and black 7, were used. Thirty training series were given to each of the fish trained to yellow, green and blue. Due to the misfortune of having two of the fish trained to red leap out of their pans

given in Table 7 and fig. 7. These results parallel those of the earlier work. Animals trained to red and yellow are most attracted by the light grays and those trained to green and blue are most attracted by the dark grays. This differential response continued without abatement over the 30 trials and hence it appears a very plausible conclusion that the bass see lemon yellow and rose red as colors of high intensity, and Scheele's green and Helvetia blue as colors of low intensity.

Again the red pipette was the most distinctive one for the bass, judging from the difference in response between the red and the nearest shade of gray. Upon this same basis, green came next, yellow next, and finally blue, the response to which was for all practical purposes just like that to black. The next question to be answered was

Table 7.—Data obtained in teaching trained fish to approach the color toward which they had been trained and to retreat from each of three shades of gray. Each value for individual fish is the average distance in cm. the fish remained away from the color during five training trials.

FISH NO.	TRAINING COLOR	GRAY 1	GRAY 3	GRAY 4	BLACK 7
<i>Trained to Rose Red</i>					
23	1.1	1.9	2.3	3.	3.
	2.2	2.4	3.	3.4	4.5
	1.	3.2	2.3	3.8	3.8
	3.	6.	7.	7.4	7.4
	1.9	3.	4.3	4.8	4.8
27	2.2	5.2	5.2	5.1	5.1
	1.8	4.1	3.9	5.3	5.3
	1.9	2.9	3.1	3.9	3.9
	1.4	3.1	3.5	4.	4.
	1.4	3.2	3.	4.2	4.2
Average	1.8	3.5	3.8	4.5	4.5
<i>Trained to Lemon Yellow</i>					
20	2.8	3.4	3.9	5.	5.
	1.8	3.9	3.6	5.2	5.2
	2.5	3.	3.1	4.5	4.5
	2.4	2.7	3.	3.8	3.8
	3.1	3.1	3.	5.3	5.3
24	2.2	2.2	2.9	4.8	4.8
	1.4	1.3	1.6	2.	2.
	1.1	1.2	1.5	1.8	1.8
	1.	1.3	1.7	3.2	3.2
	1.3	1.5	1.6	2.3	2.3
28	1.3	1.4	2.2	2.2	2.2
	1.3	1.4	1.3	1.9	1.9
	3.7	4.3	6.5	7.	7.
	2.4	2.7	4.9	6.9	6.9
	2.1	3.	4.6	6.3	6.3
Average	3.8	4.5	5.1	9.1	9.1
	3.7	4.4	4.5	6.	6.
	2.6	3.1	3.7	5.6	5.6
Average	2.3	2.7	3.3	4.6	4.6
<i>Trained to Schtele's Green</i>					
21	3.	5.2	4.	4.4	4.4
	2.5	3.5	3.5	3.3	3.3
	2.6	4.2	4.4	4.1	4.1
	1.8	3.	3.2	2.6	2.6
	2.	3.5	3.2	2.6	2.6
25	1.9	4.5	3.7	3.3	3.3
	2.	2.6	2.	3.	3.
	1.2	1.5	1.8	1.8	1.8
	1.1	1.9	2.4	2.7	2.7
	1.1	1.9	1.8	1.6	1.6
29	1.9	1.6	1.7	1.6	1.6
	1.9	2.	2.2	1.7	1.7
	1.8	4.	2.6	2.2	2.2
	1.5	4.2	3.3	2.4	2.4
	1.9	7.	5.9	2.8	2.8
Average	1.2	3.8	3.5	2.5	2.5
	1.2	3.3	2.6	1.6	1.6
	1.3	4.	4.5	1.6	1.6
Average	1.7	3.4	3.1	2.5	2.5
<i>Trained to Helvetia Blue</i>					
22	1.6	3.3	2.7	1.5	1.5
	1.6	3.8	2.2	1.7	1.7
	1.5	4.	2.6	1.9	1.9
	1.3	3.8	2.4	1.8	1.8
	1.5	3.6	1.5	2.1	2.1
26	1.3	2.7	1.6	1.5	1.5
	1.6	3.1	2.8	1.7	1.7
	1.8	2.6	2.3	2.3	2.3
	3.4	4.6	4.4	2.8	2.8
	2.3	2.4	2.8	2.2	2.2
30	3.	5.2	3.1	2.8	2.8
	2.1	3.1	2.7	1.9	1.9
	1.7	2.9	2.7	1.8	1.8
	1.6	2.2	2.3	1.7	1.7
	5.6	6.	5.8	6.4	6.4
Average	1.4	2.7	2.	1.4	1.4
	1.3	2.	1.6	1.4	1.4
	1.4	2.9	2.2	1.7	1.7
Average	2.	3.4	2.6	2.1	2.1

whether these apparent distinctivenesses of the colors were related in any way to differences in intensity, for the bass, of the particular colors used and the nearest gray. For example, was yellow more nearly like gray 1 in intensity than was red, and similarly was blue much more nearly like black for the fish than was green?

The obvious solution to the problem lay in the use of a longer series of grays and determining what shade of gray most closely resembled the intensity of the color for the fish. This would establish conclusively whether red and green were actually the colors most easily distinguished from any shade of gray for the bass.

RESPONSE TO COLOR AND EIGHT SHADES OF GRAY.—The bass were individually trained with a series of grays, white 0, gray 1, gray 2, gray 3, gray 4, gray 5, gray 6 and black 7, and the certain color to which each fish had been trained. The usual procedure was followed, the fish being fed in this instance mosquito larvae upon its own color and shocked whenever it came within 3 cm. of any one of the grays. With the exception of the fish trained to red, each fish was given 20 training series. This red-trained fish was given 50 series since it was desirable to have a good number of observations for averaging. The results of this experiment are recorded in Table 8 and fig. 8, A.

Now, the conclusions reached in the training of fish to three shades of gray have become more evident. Blue is seen to be closest to black 7 in intensity for the fish, green most closely resembles gray 6, yellow resembles gray 1 or 2, and red appears about the same intensity as the yellow and light grays, but due to the apparent distinctiveness of red as a color set apart from every other color and shade of gray it is considerably more difficult to determine which shade of gray is most like red.

The differences in the responses of the fish to their training color and to the shade of gray which most closely resembles it have become more obvious and it is seen still that red is the most distinct color a bass sees and green is second in that respect. Yellow is some-

Table 8.—Data obtained in teaching trained fish to approach the color toward which they had been trained and to retreat from each of eight shades of gray. Each value for individual fish is the average distance in cm. the fish remained away from the color during five training trials.

FISH NO.	TRAINING COLOR	WHITE 0	GRAY 1	GRAY 2	GRAY 3	GRAY 4	GRAY 5	GRAY 6	BLACK 7	
<i>Trained to Rose Red</i>										
27	}	1.2	2.8	2.8	2.2	2.8	2.6	3.7	3.3	3.7
		1.4	3.4	3.3	3.	4.3	4.3	3.5	4.3	4.2
		.9	3.4	3.3	4.6	4.2	4.6	5.2	4.3	3.7
		1.1	3.7	3.6	4.8	4.4	3.9	4.3	5.	3.9
		.9	3.2	2.3	2.5	2.	2.4	3.5	2.7	3.
		.9	3.	3.1	2.2	3.9	3.7	2.4	3.5	3.6
		.7	2.9	2.3	2.4	2.9	2.2	3.	2.8	2.4
		.9	2.6	2.8	3.4	3.1	4.1	3.3	4.4	4.
		.8	3.3	3.2	3.	2.4	2.7	3.3	3.6	3.7
		.9	3.1	2.9	3.3	3.7	2.6	3.7	2.5	3.6
Average	1.	3.2	3.	3.2	3.4	3.4	3.4	3.6	3.6	
<i>Trained to Lemon Yellow</i>										
20	}	2.8	3.4	2.4	3.5	2.5	7.1	5.5	6.5	8.
		2.7	3.9	3.5	2.8	3.3	3.4	5.9	5.3	6.4
		3.3	6.2	6.1	7.4	9.6	8.1	7.2	12.	10.6
		3.1	4.4	3.7	4.	6.4	6.3	8.6	8.3	9.
24	}	1.4	1.8	1.5	1.7	1.9	2.1	2.3	2.9	2.5
		1.3	1.6	1.5	2.	2.2	2.3	2.	2.3	3.
		1.4	1.4	1.3	1.6	1.7	1.7	2.	1.9	2.8
		1.2	1.4	1.3	1.4	1.9	2.2	1.9	2.	2.3
28	}	3.6	7.	5.9	4.9	7.2	6.5	8.7	7.4	9.1
		2.6	7.	6.	5.	7.1	5.6	7.	7.4	8.6
		2.5	4.6	4.2	4.1	4.8	5.7	6.6	9.2	7.6
		2.6	3.9	3.	2.9	3.9	4.3	6.1	6.5	6.1
Average	2.3	3.9	3.4	3.4	4.4	4.6	5.3	6.	6.5	
<i>Trained to Scheele's Green</i>										
21	}	1.8		4.9	4.3	4.3	4.8	4.5	3.2	4.4
		2.1		5.1	4.6	4.8	5.6	4.6	2.7	2.9
		2.2		6.5	6.5	7.3	3.	6.3	5.1	5.8
		1.4		5.5	4.3	5.7	6.1	3.7	1.9	3.1
25	}	1.		2.5	2.1	2.3	1.9	1.9	2.3	2.1
		1.		2.6	2.5	2.8	2.2	2.9	2.4	2.2
		.9		2.7	2.7	2.6	2.3	2.2	2.4	2.2
		1.		3.3	4.4	2.8	3.	2.4	1.9	2.4
29	}	1.2		3.5	4.5	3.8	2.9	2.	1.9	2.5
		1.8		3.2	2.7	3.5	2.7	2.8	1.7	2.5
		1.1		4.	3.	2.5	2.4	2.9	2.	3.1
		1.1		2.6	2.8	2.4	2.4	1.6	2.1	2.
Average	1.4		3.9	3.7	3.7	3.4	3.2	2.5	2.9	
<i>Trained to Helvetia Blue</i>										
22	}	1.3		4.3	3.3	3.1	3.3	2.3	1.4	1.7
		1.3		2.4	2.2	2.	1.7	1.7	1.5	1.6
		1.1		3.2	1.5	1.6	1.8	1.7	1.2	1.1
		1.1		2.8	1.8	1.8	1.6	1.4	1.5	1.3
26	}	1.6		3.7	2.7	2.9	2.5	2.	1.7	1.5
		2.3		2.7	3.2	2.8	3.3	2.9	2.5	2.4
		1.5		4.2	3.6	3.9	3.3	2.5	2.1	1.7
		1.4		3.8	3.7	2.3	2.6	2.3	2.	1.6
30	}	1.2		2.8	3.1	3.7	1.7	2.2	2.9	2.7
		1.6		2.2	2.1	1.9	1.9	1.9	1.7	1.5
		1.2		2.4	2.7	3.5	2.6	2.1	1.6	1.6
		1.3		2.	1.7	1.6	1.6	1.5	1.2	1.3
Average	1.3		3.	2.6	2.6	2.4	2.	1.8	1.6	

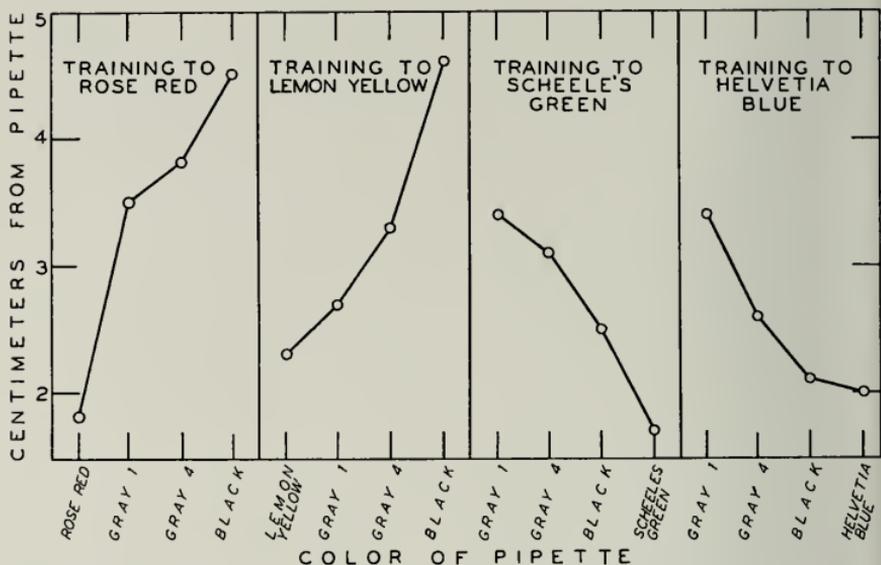


Fig. 7.—Responses of trained bass to three shades of gray and their own training color. See Table 7.

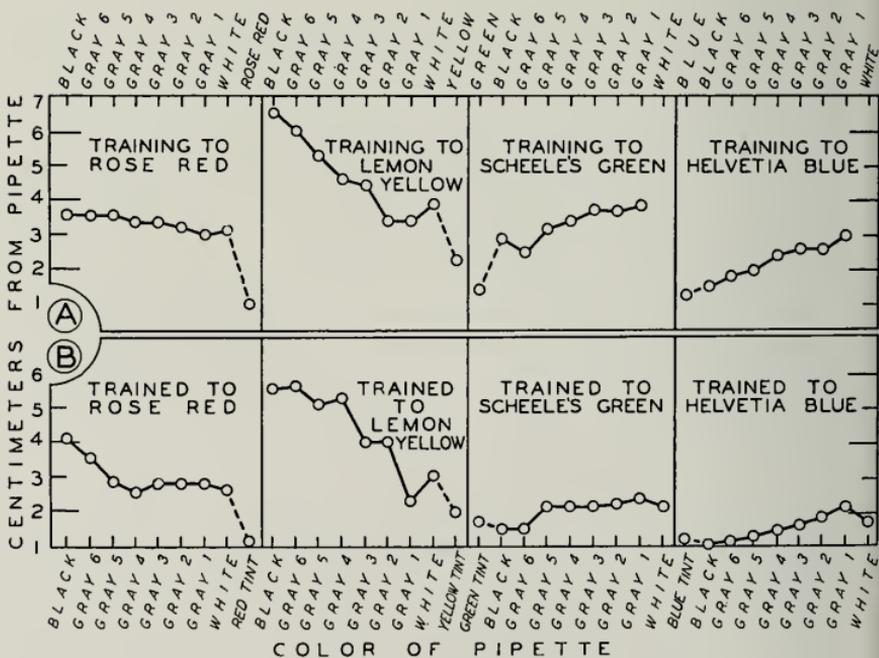


Fig. 8.—Upper, Responses of color-trained bass to their own color and eight shades of gray. See Table 8. Lower, Responses to a strange pale tint of their own training color and to eight shades of gray. See Table 10.

what less distinct and blue appears almost identical with the black.

All these results strongly suggest that the bass is relatively yellow-blue blind.

Bass trained to yellow were once again subjected to an intensive training for distinguishing yellow and gray 1, with the intention of ascertaining whether there was actually any color vision for yellow. A total of 100 series were carried out on the three fish. The results are indicated in Table 9. The proportional difference in the response to the two pipettes did not increase with the extra training and it was definitely below that difference between green and gray 6 for bass with considerably less training.

**RESPONSE TO STRANGE DILUTE COLOR AND EIGHT SHADES OF GRAY.**—In order further to establish just what part was played by intensity and what part by color the bass were shown a pale tint of the color to which they had been trained and the series of grays, white 0 to black 7 inclusive. The pale colors were light Columbia blue, pale greenish yellow, thulite pink and pale turquoise green. The fish had never before been shown these pale colors and the sudden appearance of one of these in the series of grays should have completely baffled them if they were color blind. The distinctness with which they saw the various colors should show up in the results with considerable significance in settling the question of color vision.

The bass were shown the series of grays with the color three times with neither food nor shock associated with the trials. Results, the averages of the three test trials, are shown in Table 10, A, and in fig. 8, B.

The interpretation of these results is simple and clear in the instances of the fish trained to red and yellow. Here one can again draw conclusions in complete accord with those of all previous work. However, more must be considered in reading the meaning of the results in the cases of the animals trained to green and blue. Unlike the pale red and yellow pipettes, the green and blue were doubtless much lighter to the fish than the original colors and hence there must be considered the effect of the low intensity of the original training color.

If the original training Scheele's green had an equivalent intensity for the fish with gray 6, then pale turquoise green probably would equal in intensity gray 3 or 4. The behavior of the fish trained to Scheele's green was still positively influenced by low intensities of gray, but the fact remains that the pale green was being selected from among grays of its own intensity with the same relative precision of earlier experiments.

Table 9.—Results obtained in attempting, by intensive training, to have fish trained to yellow distinguish between lemon yellow and gray 1. Each value for individual fish represents the average number of cm. away from the pipettes the fish remained during 10 trials.

FISH No.	LEMON YELLOW	GRAY
20	2.8	5.1
	5.1	6.8
	3.2	4.6
<i>Average</i>	3.7	5.5
24	1.3	1.4
	1.4	1.5
	1.1	1.3
<i>Average</i>	1.3	1.4
28	2.5	3.5
	4.2	5.3
	3.2	4.2
	2.8	3.6
<i>Average</i>	3.2	4.15
<i>Total Average</i>	2.7	3.7

This is particularly noticeable with fish Nos. 21 and 29. In a similar manner the Helvetia blue-trained animals were positively and profoundly influenced by the intensity of their original training pipette. If the intensity of Helvetia blue resembled for the bass that of black 7, then light Columbia blue probably had the intensity of gray 4 or 5, in which case these results may be favorably compared with the earlier work.

Five training trials were now given to each fish except No. 27 with the complete gray series and the pale substitute for the color to which it had been trained. These few training trials, averaged, are seen in Table 10, B, and fig. 9. It is interesting to notice the rapidity with which the bass have learned to distinguish the new green

from the grays of all shades, and the failure to do likewise for the yellow and blue.

RESPONSE TO SPECTRAL COLOR SERIES.—The bass which now remained, Nos. 20, 21, 22, 24, 25, 26, 27, 29, 30

value taken. Nine trials were made upon the remaining fish trained to each of the four colors, with the average results shown in Table 11 and fig. 10.

In addition to the orderly change in intensity of positive or negative response

Table 10.—The average distance in cm. that bass remained away from a strange pale tint of the color towards which they had been trained and eight shades of gray, as shown by (A) three nontraining trials, and (B) five training trials.

FISH NO.	TRAINING COLOR	TINT OF TRAINING COLOR	WHITE 0	GRAY 1	GRAY 2	GRAY 3	GRAY 4	GRAY 5	GRAY 6	GRAY 7	BLACK 7
(A) Nontraining Trials											
27	Rose red	1.2	2.6	2.8	2.9	2.9	2.5	2.8	3.5	4.1	
28	Lemon yellow	1.3	1.9	1.4	1.6	1.5	2.1	2.5	3.1	3.5	
24	Lemon yellow	1.2	1.2	1.1	1.3	1.3	1.3	1.3	1.3	1.6	
20	Lemon yellow	3.4	6.2	4.5	9.1	9.2	12.5	11.5	12.8	11.8	
<i>Average</i>		2.	3.1	2.3	4.	4.	5.3	5.1	5.7	5.6	
21	Scheele's green	1.5	2.6	2.1	2.1	1.7	1.9	2.1	1.6	1.8	
25	Scheele's green	2.4	2.4	2.9	3.1	3.	2.9	2.6	1.4	1.5	
29	Scheele's green	1.1	1.7	2.1	1.6	1.8	1.7	1.7	1.6	1.4	
<i>Average</i>		1.7	2.2	2.4	2.3	2.2	2.2	2.1	1.6	1.6	
22	Helvetia blue	1.2	2.	2.2	1.8	1.6	1.4	1.4	1.2	1.1	
26	Helvetia blue	1.4	2.1	2.9	2.4	2.1	1.9	1.8	1.5	1.4	
30	Helvetia blue	1.3	1.4	1.3	1.5	1.4	1.3	1.	1.	.9	
<i>Average</i>		1.3	1.8	2.1	1.9	1.7	1.5	1.3	1.2	1.1	
(B) Training Trials											
28	Lemon yellow	2.3	3.1	2.8	3.	3.7	4.	4.1	4.9	5.3	
24	Lemon yellow	1.1	1.4	1.1	1.2	1.3	1.7	1.4	1.6	2.	
20	Lemon yellow	4.1	8.1	4.2	7.1	8.5	8.8	10.3	9.7	11.7	
<i>Average</i>		2.5	4.2	2.7	3.8	4.5	4.8	5.3	5.4	6.3	
21	Scheele's green	1.9	4.7	5.	4.7	5.3	5.5	2.8	3.8	5.7	
25	Scheele's green	1.1	2.8	3.2	3.4	2.1	2.3	1.9	1.7	1.9	
29	Scheele's green	1.3	2.7	3.4	2.6	2.6	2.3	1.9	1.6	2.3	
<i>Average</i>		1.4	3.4	3.9	3.6	3.3	3.4	2.2	2.4	3.3	
22	Helvetia blue	1.2	2.5	2.1	2.1	1.7	1.7	1.3	1.2	1.1	
26	Helvetia blue	2.1	2.8	3.	3.2	2.4	2.5	2.4	2.4	1.6	
30	Helvetia blue	1.1	2.1	1.5	1.2	1.1	1.2	1.3	1.1	.9	
<i>Average</i>		1.5	2.5	2.2	2.2	1.7	1.8	1.7	1.6	1.2	

and 31<sup>3</sup>, were now subjected to the final experiment. The fish were shown the four colors to which they had been originally trained—rose red, lemon yellow, Scheele's green and Helvetia blue. They were fed three times (four mosquito larvae each time) from their respective feeding colors and shocked an equal number of times to each of the other three colors. Immediately thereupon they were shown in order 28 colors of the spectrum ranging from red to violet. The preparation of the colored rods used here has already been described. They had never before been shown to the bass. For some of the trials the order in which the rods were shown was from red to violet and for the remainder the order was reversed. The distance away from the colored rod at the end of three seconds was the

of the fish to gradually changing wave length, the similarity between green and blue shows up with diagrammatic clarity, and there is a similarity of response between reds and violets, the last of which are a totally new color for the fish during the course of this experimentation. And finally, there are seen differential responses to different wave lengths of light which cannot be explained by response to intensity solely, in view of the other results that have been obtained. An illustration of this last is seen in the responses of the red and yellow-trained fishes to red and yellow (roughly of the same brightness to bass) and to yellow and green (of greatly different intensities to bass).

#### INTERPRETATION OF THE RESPONSES

The rate of learning of the young bass that have been used in the experiments has varied somewhat, depending, in

<sup>3</sup>Bass No. 31 was brought in and trained to take the place of those red-trained bass, Nos. 19 and 23, that were lost.

general, upon whether the difference between two objects with which they were being trained was greatly different in intensity, color or both. Colors of greatly different intensity, as for example red and blue or green, have been easily and quickly distinguished by the bass. Likewise, yellow and green or blue have been readily distinguished

more closely that one to which they were being trained. In other words bass learn much more quickly to avoid an unpleasant stimulus than to react positively to a pleasant one.

Although no special experiments were carried out to determine the extent of the memory of bass, it has been observed that there was nearly perfect

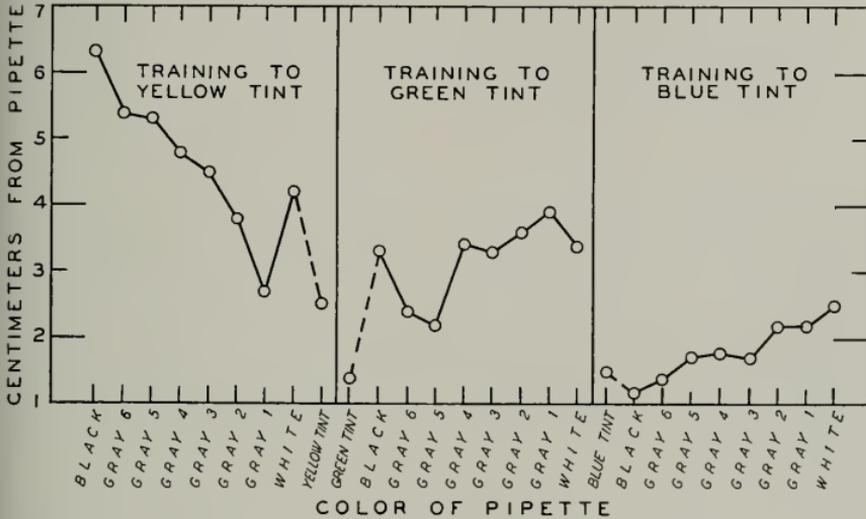


Fig. 9.—Results of five training trials towards strange pale tints and against eight shades of gray, of the fish trained to lemon yellow, Scheele's green and Helvetia blue.

from one another. On the other hand, those colors which to the fish were more similar in intensity, such as the combinations of red and yellow or green and blue, have been distinguished with much less speed and thoroughness. Red occupied a unique position as a color. Although to all appearances it was about the same intensity as the yellow to the bass, yet to bass trained to yellow, red was observed to be quite distinctly different and the rate of learning to avoid it approached the rate at which the fish learned to avoid the much darker blue and green pipettes. It would appear that, in general, intensity is an important item in the responses of bass to their visible environment.

Another general conclusion reached was that in learning, those fish that had become somewhat tamed prior to the experimentation learned more quickly to avoid certain colors than to approach

retention of training effects from day to day. Furthermore, two or three times during this investigation it was noted that trained fish had retained effects of their training to color for a week during which no training had been given. This was to be expected in the light of the work of Wolff (1926) and Hafen (1935) upon the memory of *Phoxinus*, in which they found a trace of retention of training effects several months after all training had ceased.

In answer to the question as to whether bass distinguish among colors other than through light intensity, this research gives a positive reply. Bass were able to select their training color out of a confusing series of grays, and furthermore have been able to pick from the same series of grays a strange pale color of approximately the same color value as their original training color. This was most outstandingly

true for red. Green stood second in this respect, then came yellow and finally blue.

Vision of the bass through the surface film of the water was remarkably acute. During the experiments the pipette was always quickly lifted above the rim of the pan and immersed. It was astounding to notice the response of the trained

Table 11.—The responses of bass trained to colors, to a series of colored rods. Each record is the average number of cm. away from a colored rod that a fish remained during nine nontraining trials.

	TRAINED TO			
	Rose Red	Lemon Yellow	Scheele's Green	Helvetia Blue
Spectrum red	1.92	3.56	4.42	3.68
Scarlet red	2.4	3.12	4.50	3.54
Scarlet	2.56	2.92	4.59	3.49
Grenadine red	2.61	3.12	5.1	3.31
Flame scarlet	2.76	2.89	4.55	3.86
Orange chrome	3.02	2.68	4.75	3.51
Cadmium orange	2.92	2.81	4.25	3.66
Orange	2.83	2.29	4.38	3.54
Cadmium yellow	2.98	1.93	3.94	3.52
Light cadmium	3.04	2.06	3.67	3.24
Lemon chrome	3.32	1.77	4.04	2.94
Lemon yellow	3.19	1.79	3.8	2.98
Greenish yellow	3.21	1.8	3.61	2.8
Bright green-yellow	3.62	1.93	3.19	2.45
Neva green	3.5	2.11	2.47	2.07
Emerald green	3.59	2.41	1.72	1.85
Vivid green	3.56	2.59	1.76	1.48
Skobeloff green	3.69	2.9	1.53	1.53
Benzol green	3.74	2.92	1.83	1.6
Italian blue	3.56	3.1	1.75	1.47
Cerulean blue	3.88	2.87	1.76	1.54
Methyl blue	4.	3.18	1.78	1.35
Spectrum blue	3.87	3.17	1.89	1.29
Bradley's blue	3.6	3.07	1.82	1.22
Phenyl blue	3.34	2.81	2.06	1.41
Blue-violet	2.76	2.94	2.66	1.93
Bluish violet	2.1	2.74	4.	3.32
Spectrum violet	1.85	2.56	4.2	3.59

fish, either positively or negatively, to a pipette at almost the instant it was lifted above the rim of the pan and long before it reached the surface of the water. With an accuracy of vision of this degree through the surface of the water it is quite understandable that bass are exceedingly adept at catching flies and other insects in the air.

As to which plays the more important rôle in the life of the bass, color or brightness, there is much to be considered. While casting about in search of why red might be such a distinctive color to the fish, solutions of variously colored dyes had been used in order to find some color filter which would cause the spectral colors to appear to the human eye just as the results of this research had indicated them to appear to fish. The requirements of the filter

were that it would cause yellow and white to appear very closely alike, green and red must be quite distinctive colors with red a little the more so, and finally blue must appear an intermediate between a very dark gray and green. These requirements were satisfied with a yellowish filter. After arriving at this conclusion, the work of Schnurmann (1920) and a review of it (Warner 1931) were discovered. Schnurmann concluded upon the basis of chromatophore response in *Phoxinus* that vision of this fish could be much like that of a color-blind human being viewing through a pair of yellow-tinted spectacles. In the eye of the light-adapted fish there is a yellow filter in the form of a yellowish retinal pigment which migrates outwards to cover to some extent the sensory elements of the eye. This pigment absorbs the shorter wave lengths much more than the longer ones. My own results indicate that the vision of light-adapted bass would more closely resemble that of a human being with perfectly normal color vision, looking through a pair of yellowish glasses. In looking at the spectral colors through such a yellow filter it is interesting in the light of the results obtained upon the bass to note that yellows and white have about the same yellowish tint; that in passing from greens to blues both look greenish but the greens appear to grow darker and darker until the deep blues have become much like black. The behavior of bass to the colors of the spectrum, fig. 10, is in itself another argument in favor of color vision, for, were there merely a decrease in the luminosity of colors as they viewed shorter wave lengths, then this would probably be an orderly one rather than one which is to be expected in the light of the properties of colors as such, with the intervention of a yellowish screen. It is thus seen that without knowledge of the absorption spectrum of the yellow pigment of the eyes of bass it is impossible to determine the quantitative fractional parts that color and intensity play in responses of light-adapted bass, but if we may judge from reactions to red, color when clearly seen is more prominent than intensity.

The response of trained bass to the

28 colors of the spectrum also demonstrates a similarity of response to red and violet. Here appears to be more evidence for the actuality of the "color circle" in fishes. Bass that were trained against red reacted negatively to violet, and those that were trained towards red reacted positively to violet although

SUMMARY

Thirty-one specimens of the large-mouth black bass, *Aplites sabnoides* (Lacépède), have been trained to respond positively to pipettes of one color and to give negative responses to pipettes of other colors. They have been trained positively to one of four

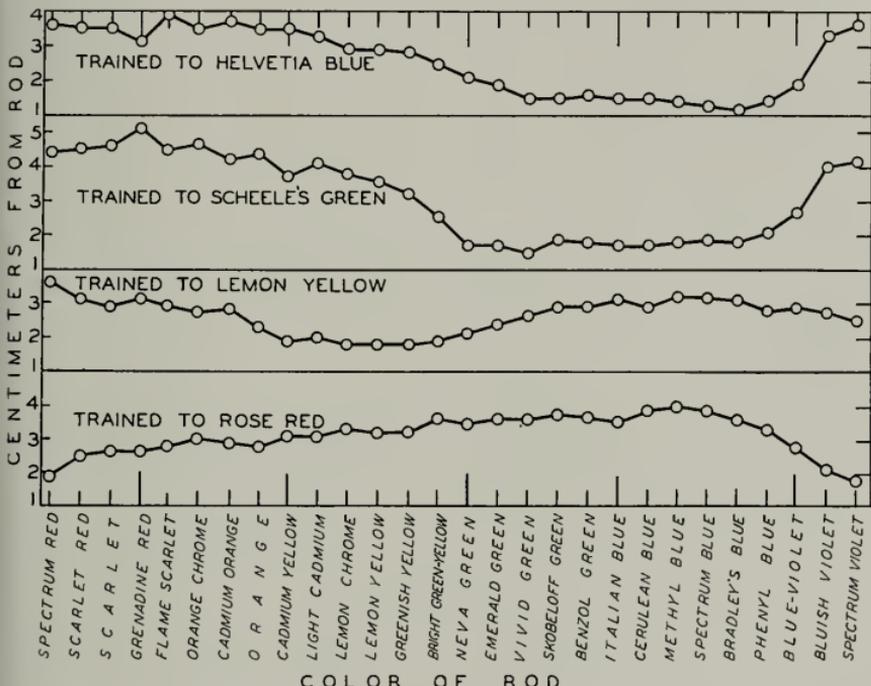


Fig. 10.—Average responses of color-trained bass to a spectral series of colors. See Table 11.

violet had never before been shown to the fish. This response also indicates that the yellow pigment of the eye does not absorb violet very strongly.

Disregarding for the moment the similarity between certain grays and certain colors, it is seen that, excluding violet, the difference between colors for light-adapted bass is a function of the difference in wave length. Colors that differ most in wave length are most strongly contrasted by training. As to how far this is a response to differing brightnesses brought about by the differentially absorbing yellow pigment of the retina and how far it is due to changing in color value proper, remains for further research.

colors—red, yellow, green, blue—in the instances of different fish, and negatively to the remaining three colors. All experiments were carried out upon light-adapted bass kept upon a white background in a light intensity of 12 to 20 foot-candles.

Freshly collected bass which have been in the laboratory no more than two days, and fed *Daphnia* during that time, are most attracted by red, then in order of decreasing attraction of the colors used come yellow, white, green, blue and black.

For pipettes which are distinctly different from one another for the bass, learning is accomplished in five to 10 trials, but when the difference is less the

training must be somewhat longer to produce a definitely modified behavior.

Both color and intensity play parts in the responses of the bass to objects. There has not yet been given a sufficient amount of training to have them respond solely to color.

Red appears to be the outstanding color, as such, in the responses of the bass. This color is easily and readily selected from everything else, with the exception of violet.

Bass learn very readily to respond preferentially to yellow as contrasted with red, green and blue, but there is great difficulty experienced in distinguishing between yellow and very light gray.

Green and blue are colors towards which the bass learned to respond positively with the most difficulty. Although these colors were readily distinguished from red and yellow, yet they were distinguished from one another much more poorly. Blue, dark grays and black were distinguished from one another with little accuracy, and greens were more confused with blues than with the grays. Blue would therefore appear to occupy a tinted shade intermediate between green and dark gray.

Bass trained to red and yellow responded more positively to the lighter of the grays, while those trained to green and blue responded more positively to the darker grays. This was interpreted to signify that reds and yellows are colors of high intensity to the fish while greens and blues are colors of low intensities.

The gray most nearly corresponding in apparent brightness to each of the training pipettes was determined, and from the relative differences in response to these pairs of pipettes it was determined that the order of distinctness from gray of the four colors for the bass was first, red, then in order came green, yellow and blue. The evidence indicates that bass are relatively yellow-blue blind.

The conclusion of Schnurmann (1920) that light-adapted fish respond in vision as if they were seeing through a yellowish screen has been confirmed. The re-

sults of this experiment indicate that the fish are able to distinguish among colors in about the same manner as would a human being with perfectly normal color vision looking through a yellowish filter.

The similarity of the reds and violets is further evidence in favor of similarity of color vision of man and bass. It further suggests that the yellow screen of the eye of the fish does not absorb violet very strongly.

The responses of bass to 28 colors of the visible spectrum not only demonstrate a quite definite specificity to a particular color, but bring out strongly the degrees of similarity and dissimilarity of colors differing to a greater or lesser extent in wave length. In general, and excepting the violets, the degree of difference of different colors to bass is a function of the difference in wave length.

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Volume 21

BULLETIN

Article 3

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# Studies of Nearctic Aquatic Insects

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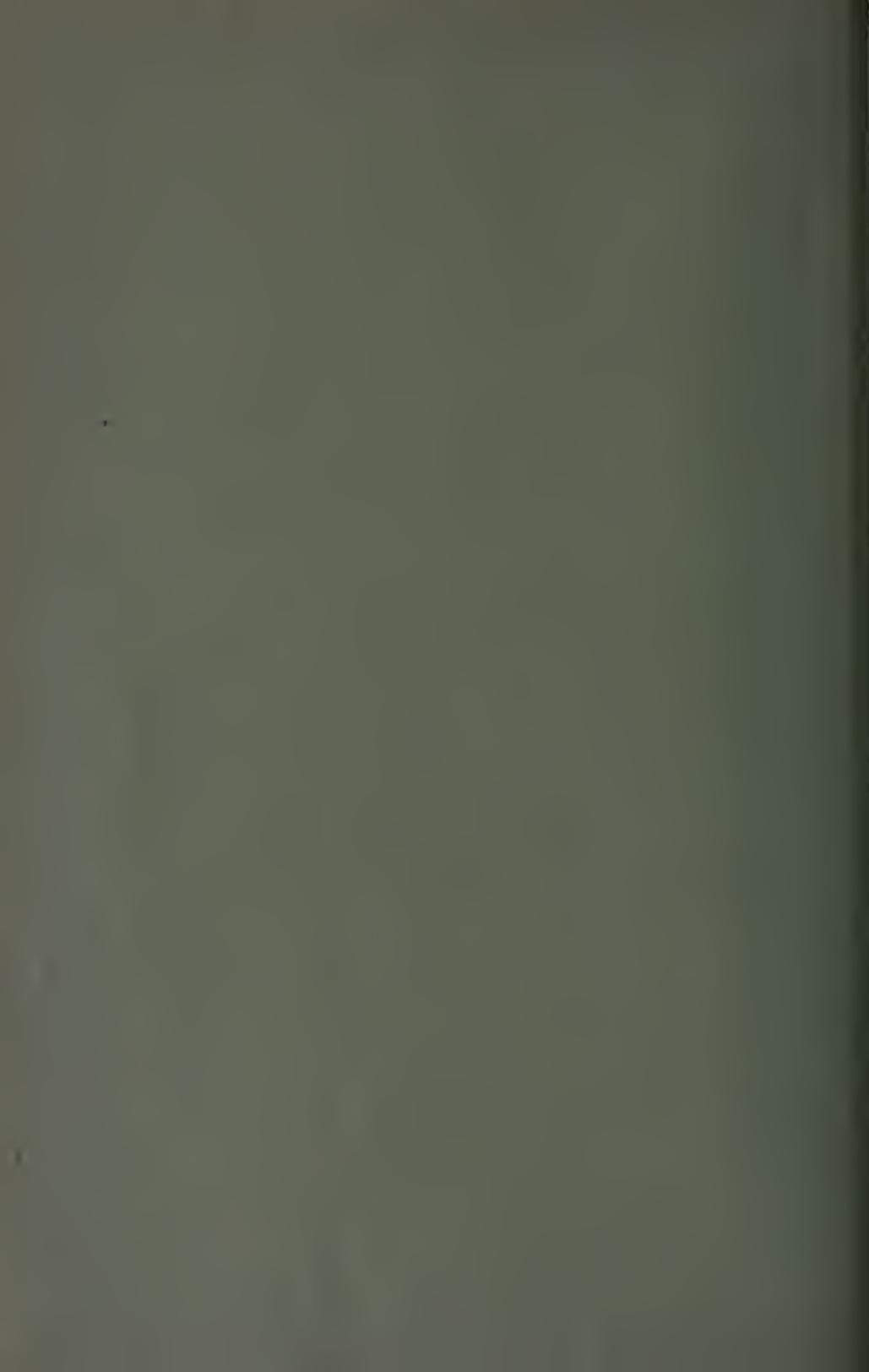
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Article 3

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### I. NEARCTIC ALDER FLIES OF THE GENUS *Sialis* (MEGALOPTERA, SIALIDAE)

H. H. ROSS

### II. DESCRIPTIONS OF PLECOPTERA

T. H. FRISON



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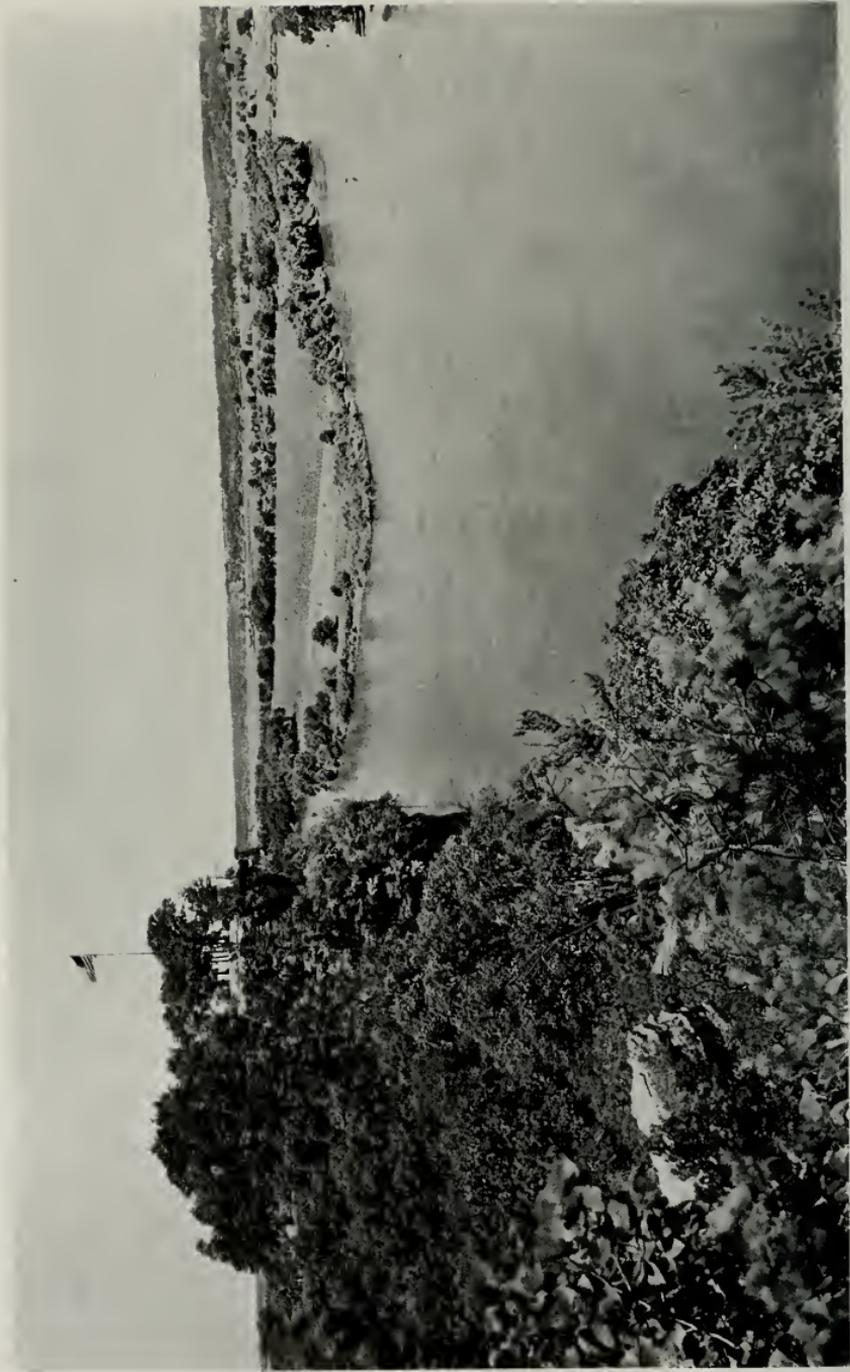
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Illinois River, Largest River of the State

# Studies of Nearctic Aquatic Insects

## I. Nearctic Alder Flies of the Genus *Sialis*

(Megaloptera, Sialidae)

HERBERT H. ROSS

### BIOLOGY AND ECOLOGY

IN American literature the genus *Sialis* has been in confusion for some time because of the fact that all authors, except Banks, have recognized only three nearctic species, *americana*, *nevadensis* and *infumata*. *Americana* and *nevadensis* differ from *infumata* in color and sculpturing and have long been recognized correctly. Everything else has been grouped under *infumata*. The only effort to enlighten the problem was made by Banks, who described four species chiefly on the basis of genital characters. In spite of this prophetic indication, no other extensive work has been done.

Critical study of the genitalia has revealed no less than 10 eastern and six western species grouped under the name *infumata*. As a result the observations and records in literature of "*Sialis infumata*" can have no specific validity unless the actual specimens involved are re-identified.

The biology and habits of the genus have been treated in detail by Davis (1903), so that only a brief resumé taken chiefly from his study need be given here. The *Sialis* adults, fig. 1 (p. 58), with few exceptions are fairly large, black, broad insects, only moderately rapid in their movements. They are diurnal, most active during the middle of the day. The eggs, fig. 2, are cylindrical, rounded at the top and have an apical curled tassel. They are laid in rows forming large masses, situated on branches, bridges, and other objects hanging over water. Upon hatching, the larvae, fig. 3, presumably fall into the water,

where development takes place. The larvae are predaceous, hunting under stones, etc., for their prey. Respiration occurs through the tracheal filaments on the sides of the abdomen. When full grown the larvae crawl out of the water and dig into the bank to form an earthen cell several feet from the water's edge. Here pupation occurs, the adult emerging from this pupal cell. The life of the adult is probably short, since it has soft mouthparts which do not appear fitted for extensive feeding.

#### Habitat Preference

Judging from present data the species inhabit all variety of fresh-water situations in which aeration is good. The habitat range, therefore, is from small streams to large rivers and lakes, and for the same species it may be equally variable. Thus in Illinois *S. velata* has been taken only along rivers whereas *mohri* has been taken abundantly along rivers and around the northern lakes. In Michigan, however, Dr. T. H. Frison has taken both these species in large numbers on Houghton lake, associated unmistakably with the lake fauna.

SEASONAL SUCCESSION.—The adults occur with the early spring fauna in Illinois, and at a proportionately later date farther north. Data on hand certainly indicate a seasonal succession of species within the genus. Collecting dates for the three commoner eastern species indicate that *velata* appears earliest in the season, *mohri* soon after and *itasca* last. Average dates for the collection of males of these three in Illinois are, respectively, April 27,

May 21 and June 13. This tells neither the duration of the emergence period nor the overlapping between species, but it gives some approximation of the difference in time between peaks of abundance. Dr. Frison made a large collection of *velata* and *mohri* at Houghton lake, Mich., June 15 to 18, 1935, which gives a good illustration of the overlapping of these species where they occur in the same habitat. The earlier species *velata* was represented by 76 specimens, of which 67 per cent were females, all extremely gravid; *mohri* was represented by 353 specimens of which only 47 per cent were females, half of which appeared relatively fresh. From this it would seem that the population wave of one species breaks over that of the preceding species soon after the latter begins to wane.

#### Distribution

With the small amount of material collected at present, plotted records of individual species give only scanty maps. Even so a few interesting points are brought out. Some species, such as *velata* and *mohri*, are widespread, occurring from the Atlantic to the eastern base of the Rocky mountains. On the other hand, *iola* is restricted to the Appalachian region. Several species are distinctly western, occurring in the Rocky mountain region or westward, as for example, *californica*, *hamata* and *rotunda*.

#### Physiological Segregation of Species

There are several pairs of species in *Sialis* which are very closely related, such as the combinations *velata-itasca*, *aequalis-vagans*, *iola-joppa* and *californica-occidens*. Analysis of their known distribution records brings out the following points:

(1) Both members of such a pair of species have never been collected together at the same time and place. In the case of *iola* and *joppa* the geographic range and seasonal timing of both species are apparently quite similar, but in no case have specimens of both been submitted bearing exactly the same collection labels. This would indicate that each species has a different habitat preference within the same range.

(2) In the case of *velata* and *itasca* we have two forms with approximately the same range. All data indicate, however, that the two species have radically different

seasonal adjustments, *velata* appearing early and *itasca* late, their average collection dates for the same locality being four to six weeks apart.

(3) The pair *californica* and *occidens* present an interesting type of difference in range. *Californica* occurs through the Rockies from north of 50° to at least northern California, and down the coastal range to Kern county, Calif. On the other hand, *occidens* has so far been collected only

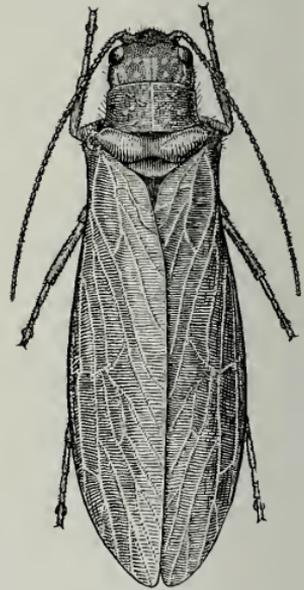


Fig. 1.—Adult of *Sialis mohri*.

around Reno, Nev., and the upper Sierra Nevada in California.

A similar marked difference in range is shown by the eastern pair, *aequalis* and *vagans*. The former is distinctly a southern and eastern species of restricted range, having been collected in Virginia, Maryland, New Jersey and southern Pennsylvania. The range of *vagans* begins where that of *aequalis* ends, and continues north to Quebec and west to Illinois and Michigan. The northern species has a much more extensive range than the southern one.

This information shows that the morphological differences which are the tangible characters separating the species recognized in this paper coincide with physiological differences expressed by ecological orientation.

#### Preservation and Preparation of Material

The most satisfactory method of preserving specimens seems to be in fluid. We have used 80 per cent ethyl alcohol with good results. Genitalia and other diagnostic parts of specimens so preserved usually may be seen without injuring the specimen or performing other preparation. If a specimen is pinned, its abdomen must usually be removed and cleared before it is possible to give a complete diagnosis. The follow technic has been used with fine results: soak the abdomen for three to six hours in cold 10 per cent caustic potash (KOH) solution, change to distilled water for an hour or more, then with forceps and needle gently press out the dissolved viscera. This leaves a fairly transparent shell which may be preserved and studied in 80 per cent alcohol or glycerin.

#### Illustrations

The illustrations of genitalia used in this paper are made from specimens treated in caustic potash solution. They are drawn with the parts considerably expanded, since it is only in such a position that some details can be seen clearly.

#### Value of Characters

Genitalia have provided the best characters for separation of species, although other characters may be of value. Differences in wing venation are subject to considerable individual variation and may be expressed at best as averages and not as absolute characters. For example, *californica* usually has three or four branches of  $R_2$ , but may have only two, whereas *velata* and some others usually have only two branches of  $R_2$  but may have three or four. The cross-veins of the costal area of the front wing vary in the same fashion: *americana* has four to six, *mohri* has four to 10, averaging seven, and the others have 10 to 15, averaging 12 or more. Differences in punctuation and gloss of the head are quite constant, but offer no differences between many species. It is difficult to express some of these characters, since the differences are relative and can be recognized only after acquaintance with the various types.

#### Terminology of Genitalia

Use of genitalia necessitates a terminology for its components, and since no one has homologized them definitely with those of other insects an original set of

terms is proposed for them. No attempt is made here to homologize these parts; instead the names are purely descriptive and are used as a convenience. The names applied to the genital parts are as follows:

- (1) **Lateral plates:** a pair of plates on the venter beyond the eighth sternite, fig. 4, l, p. 000.
- (2) **Terminal plate:** a single plate on the caudal end of the abdomen, which assumes many shapes, fig. 4, t.
- (3) **Genital plate:** a pair of sclerites forming a more or less solid plate on the venter between the above two parts, fig. 4, g. From this arise various appendages called **genital hooks**, figs. 12, 28.

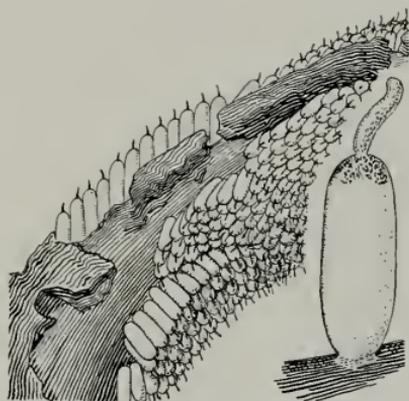


Fig. 2.—Eggs of *Sialis mohri*.

#### TAXONOMY

From the standpoint of phylogenetic position *Sialis* is an interesting genus. Many generalized features of its structure and biology place it as one of the most archaic genera of holometabolous insects. The group comprising *Sialis*, *Corydalid*, *Chauliodes* and allied genera has been considered by some authors as a member of the order Neuroptera and by others as a separate order Megaloptera. Due to its apparent axial position with reference to the phylogeny of the Neuroptera, Mecoptera and Hymenoptera, it seems clearer to designate the group as a distinct order.

Most recent authors consider that the family of Sialidæ is composed of two well-marked subfamilies: the Sialinæ, including *Sialis*, and the Corydalidæ, including *Corydalid*, *Chauliodes* and their allies. The separating characters between the two groups seem of sufficient magnitude to warrant recognition of each as a distinct

family. Recognition was accorded by Brues & Melander (1932, p. 179), using the name first proposed by Burmeister (1839, p. 948).

Table 1.—Distinguishing features of *Sialidae* and *Corydalidae*.

SIALIDAE	CORYDALIDAE
<i>Adult</i>	
No ocelli	Three distinct ocelli
Fourth tarsal segment dilated and deeply bilobed	Fourth tarsal segment cylindrical
<i>Larva</i>	
Abdomen with a long terminal filament on the meson, fig. 3.	Abdomen with a pair of apical prolegs each bearing a strong hook.

Table 1 gives distinguishing features of the two families, *Sialidae* and *Corydalidae*<sup>1</sup>. Townsend (1935) has separated the larvæ of these groups from others with which they might be confused.

#### Acknowledgments

Members of the staff of the following institutions have kindly loaned material for study: Academy of Natural Sciences of Philadelphia, American Museum of Natural History, California Academy of Sciences, Canadian National Museum, Carnegie Museum, Cornell University, Field Museum, Ohio State University, Oregon Agricultural College, Museum of Comparative Zoology, University of

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I am especially indebted to Dr. C. O. Mohr, of the ILLINOIS NATURAL HISTORY SURVEY, for making the illustrations, which are so essential to the elucidation and use of this paper.

#### Present Holders of Material: Symbols

AM.	American Museum of Natural History
ANS.	Academy of Natural Sciences of Philadelphia
BM.	British Museum
CAS.	California Academy of Sciences
CM.	Carnegie Museum
CNM.	Canadian National Museum
CU.	Cornell University
FM.	Field Museum
INHS.	ILLINOIS NATURAL HISTORY SURVEY
KAC.	Kansas Agricultural College
MCZ.	Museum of Comparative Zoology
MMZ.	University of Michigan Museum of Zoology
NM.	U. S. National Museum
OAC.	Oregon Agricultural College
OSU.	Ohio State University
UAC.	Utah Agricultural College
UI.	University of Idaho
UK.	University of Kansas
UM.	University of Minnesota
UW.	University of Wisconsin

## DESCRIPTION OF SPECIES

### SIALIDAE

This family contains only one nearctic genus, *Sialis*, which is characterized in table 1.

#### *Sialis* Latreille

*Sialis* Latreille (1802, p. 290; 1803, p. 287; 1810, p. 435); Burmeister (1839, p. 945); Hagen (1861, p. 187); Davis (1903, p. 443). Genotype *Semblis lutaria* Fabricius by subsequent designation of Latreille (1810, p. 435).

*Semblis* Rambur  *nec* Fabricius (1842, p. 446). *Protosialis* Wheeler (1909, p. 263; 1910, p. 74). Monobasic, genotype *Semblis americana* Rambur. *New synonymy*.

#### Generic Characteristics

ADULT, FIG. 1.—Head broad and long, prognathous, with eyes situated on anterior half; clypeus narrow; labrum wide, entire

in the female and cleft almost to its base in the male; antennae long, slender and multi-segmented. Posterior part of head with raised bars and dots forming a constant pattern, these raised areas always at least shining if not glossy. Pronotum large and rectangular, about 2½ times as wide as long, dull to slightly shining. Mesonotum no longer than pronotum, extremely convex transversely. Metanotum similar in size and shape to mesonotum. Wings with venation as illustrated by several authors. Abdomen cylindrical, the apex with genital apparatus as illustrated for each species.

LARVA, FIG. 3.—Head and thorax considerably flattened, smooth and shining. Head quadrate, eye-spot composed of about six facets, antennae four segmented, clypeus

<sup>1</sup>The type of genitalia also, is different in each group.

wide and narrow, labrum produced into a long, pointed flap covering the elongate mouthparts. Pronotum quadrate, as long as head. Mesonotum and metanotum subequal, together as long as the pronotum. Thoracic legs well developed and long, with coxae almost as long as the femora.

Abdomen fairly robust, the first seven segments with a pair of lateral processes.

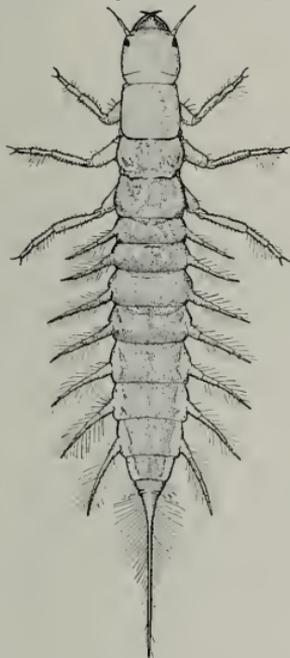


Fig. 3.—Larva of *Sialis* sp.

Each of these is slender and tapers to a fine point, and is composed of five distinct segments, the apical one sometimes with a trace of a division. The apex of the abdomen is produced into a median process which is broad at the base and tapers to a long fine point. The entire process is almost as long as the abdomen.

The genus *Protosialis* is considered a synonym of *Sialis*. It was erected for *S. americana* on the basis of this species having a reduced number of cross-veins in the costal area of the front wing. A complete intergradation between both extremes of this character may be found in *S. mohri*, so that wing venation alone will not serve as a basis for generic separation of *Protosialis* from *Sialis*. The entire lot of species, however, may be grouped into several units on

the basis of the male genitalia, supplemented by other characters, as shown in table 2.

The segregations shown undoubtedly represent distinct phylogenetic units within the genus, but their designation as separate genera seems an unnecessary complication. Hence the dropping of *Protosialis*.

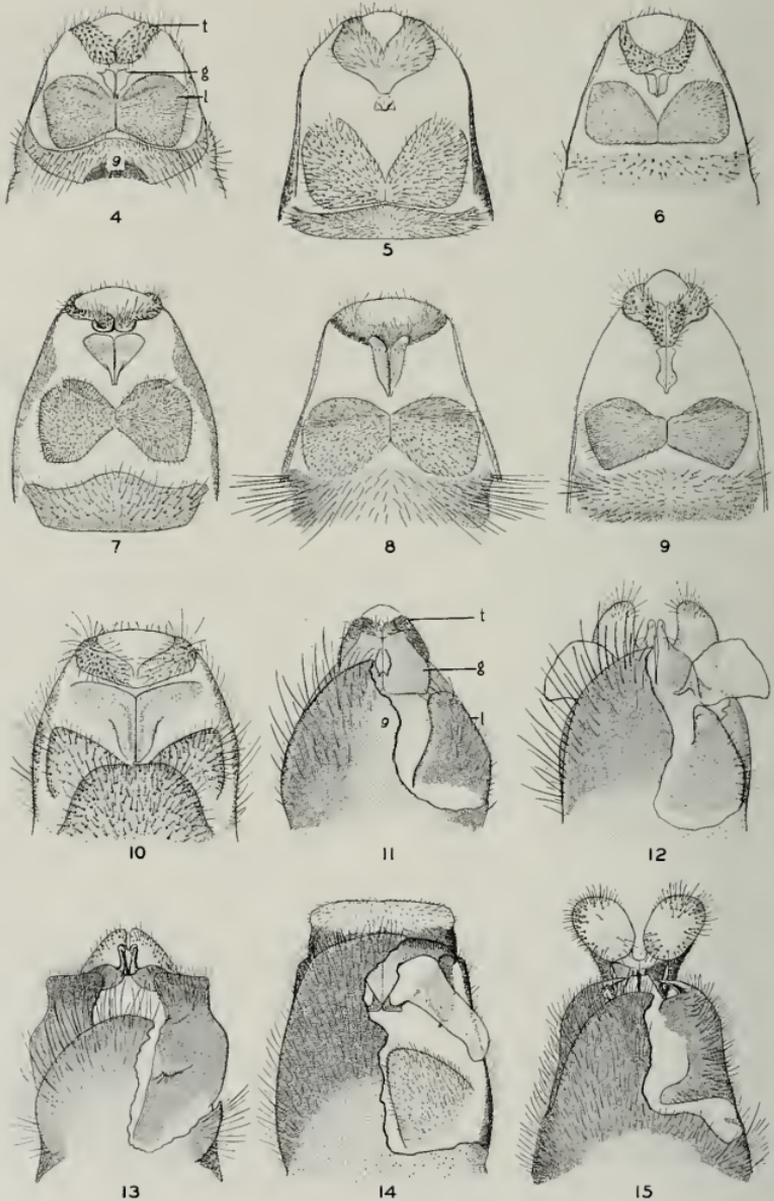
Table 2.—Phylogenetic units of North American species of *Sialis*.

*Genitalia Relatively Simple, Fig. 4; No Parts Greatly Enlarged*

	CALIFORNICA GROUP
	<i>arvalis</i>
	<i>californica</i>
Genital arms very short,	<i>iola</i>
hooked, fig. 18.....	<i>cornuta</i>
	<i>hamata</i>
	<i>yoppa</i>
	<i>occidens</i>
	AMERICANA GROUP
Genital arms long, straight,	<i>americana</i>
fig. 22.....	<i>glabella</i>
<i>Genital Plate with Long Hooks, Figs. 28-33</i>	
	INFUMATA GROUP
Terminal plate produced	<i>velata</i>
only along vertical axis,	<i>itasca</i>
figs. 28-31.....	<i>concava</i>
	<i>infumata</i>
	<i>hasta</i>
Terminal plate with a long	
forked process at right	
angles to its axis, fig. 32.	<i>mohri</i>
<i>Ninth Sternite Produced into a Flap</i>	
<i>Covering Genitalia, Fig. 23</i>	
Head of male with a horn-	
like process, fig. 43.....	<i>rotunda</i>
Terminal plate with a pair	
of large knobs, fig. 27...	<i>nevadensis</i>
	AEQUALIS GROUP
Terminal plate without	<i>aequalis</i>
knobs, fig. 25.....	<i>vagans</i>

The genotype of *Sialis*, which is *lutaria* (Fabricius) belongs to the *aequalis* group. It is typical in color, size and general structure for these species but differs in male genitalia as follows, figs. 14, 26; ninth sternite produced into a flap which is semi-truncate at apex; lateral plates small, pointed at tip; genital plate with long hooks and a membranous pair of flaps at base, fig. 26a; terminal plate large and truncate at apex, fig. 26b.

Application of the name *Semblis* to this group was proposed by Rambur (1842), but application of the name to a genus of Phryganeidae by Milne (1934), with *Semblis phalaenoides* (L.) as its genotype, seems a better disposition and is so accepted.



VENTRAL ASPECT OF GENITALIA AND NINTH SEGMENT OF SIALIS MALES

Fig. 4.—*S. joppa*.

Fig. 5.—*S. hamata*.

Fig. 6.—*S. arvalis*.

Fig. 7.—*S. cornuta*.

Fig. 8.—*S. californica*.

Fig. 9.—*S. iola*.

Fig. 10.—*S. americana*.

Fig. 11.—*S. vagans*.

Fig. 12.—*S. aequalis*.

Fig. 13.—*S. rotunda*.

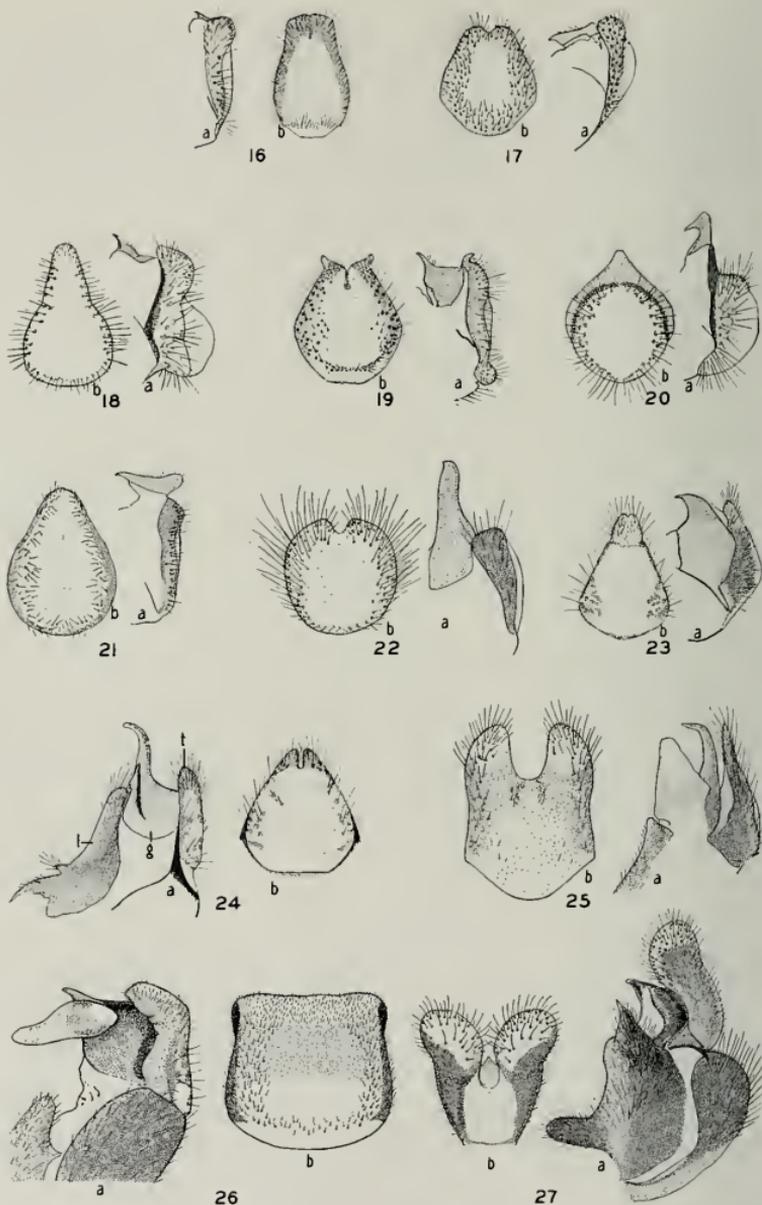
Fig. 14.—*S. lutaria*.

Fig. 15.—*S. nevadensis*.

ABBREVIATIONS.—l, lateral plate; t, terminal plate; g, genital plate; 9, ninth sternite.

## KEY TO NEARCTIC SPECIES OF SIALIS

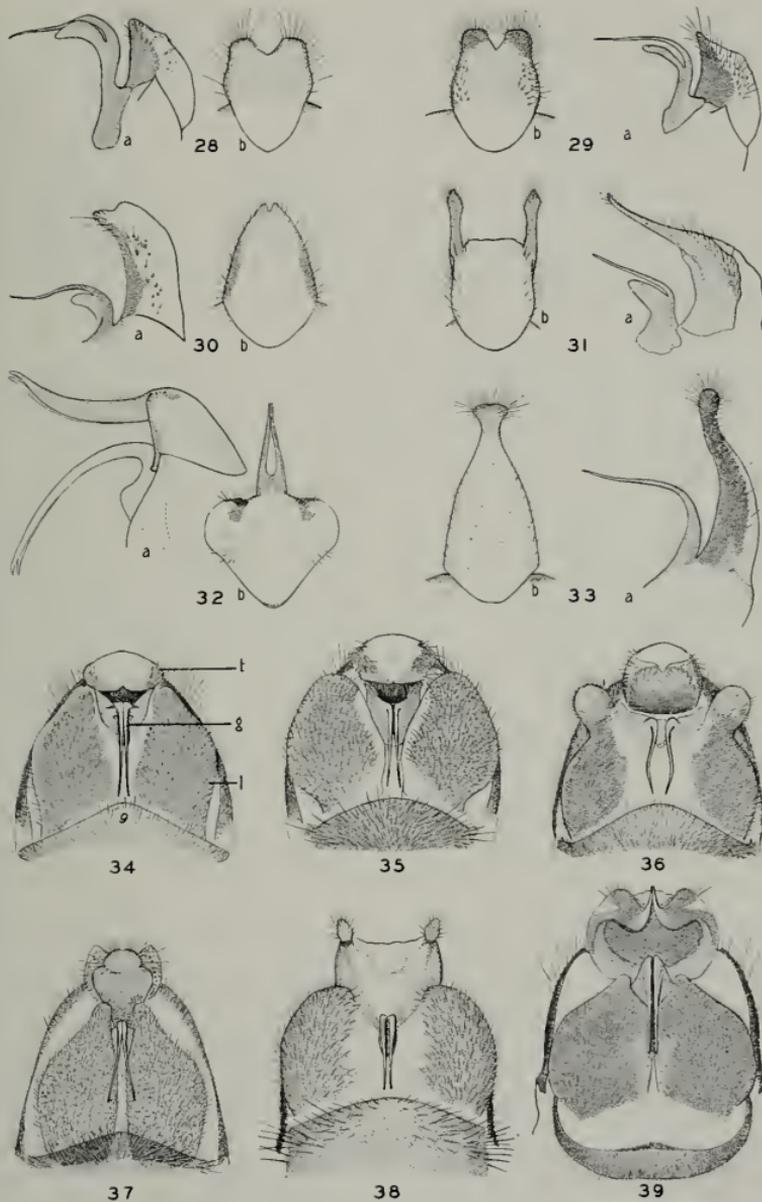
1. Apex of abdomen with broad, rounded ovipositor, fig. 51 (females).....20  
Apex of abdomen without an ovipositor but with a more or less complicated assemblage of parts, figs. 4-15 (males)..... 2
2. Front between eyes with a prominent hornlike process, fig. 43.....*rotunda*  
Front between eyes without a hornlike process..... 3
3. Ninth sternite produced into a flap covering most of the genitalia, figs. 11-15..... 4  
Ninth sternite not produced into a flap, figs. 4, 34..... 6
4. Apex of lateral plates with a strong tooth, fig. 15..... *nevadensis*  
Apex of lateral plates without a tooth... 5
5. Terminal plate wide with apex divided into two large processes, fig. 25b.....  
..... *aequalis*  
Terminal plate narrowed at apex and not markedly incised, fig. 23b. *vagans*
6. Terminal plate produced at apex into a pair of long arms, figs. 31b, 32b... 7  
Terminal plate sometimes with an apical incision, fig. 28b, or a pair of short "horns," fig. 19b, but not with a pair of long arms..... 8
7. Apical arms of terminal plate separated at their base by a distance almost equal to their length, fig. 31b..... *hasta*  
Apical arms of terminal plate close together at base and converging at tip, fig. 32b..... *mohri*
8. Legs with femora rufous and tibiae the same color or blackish..... 9  
Legs black, or with tibiae slightly lighter than femora..... 10
9. Head smooth and polished..... *glabella*  
Head punctured and dull..... *americana*
10. Genital hooks long and whiplike, figs. 28-33, extending forward between the lateral plates, figs. 34-39..... 11  
Genital hooks short, never longer than the plate from which they arise, figs. 16-21; lateral plates always closely appressed on meson, figs. 4-9..... 14
11. Apex of lateral plates produced into large knobs, fig. 36..... *infumata*  
Apex of lateral plates not knoblike... 12
12. Terminal plate long, its apex slightly enlarged but not cleft, fig. 33b; genital hooks simple, without a basal lobe, fig. 33a..... *concava*  
Terminal plate short, its apex markedly cleft, fig. 29b; genital hooks with a basal lobe, fig. 29a..... 13
13. Basal lobe of genital hooks smaller, as in fig. 29a; terminal plate as long as genital hooks are high, fig. 29b... *velata*  
Basal lobe of genital hooks markedly robust compared with distal lobe, fig. 28a; terminal plate shorter than genital hooks are high, fig. 28b... *itasca*
14. Apex of terminal plate produced into two short, stout, curved "horns," fig. 19..... *cornuta*  
Apex of terminal plate not with hornlike processes..... 15
15. Apex of terminal plate produced into a thin, flat "neck," at the end of which the genital hook articulates, fig. 20; this hook, fig. 20a, strongly recurved to form the swan's neck type of hook..... *hamata*  
Apex of terminal plate without a necklike process, fig. 21; genital hooks not recurved..... 16
16. Basal portion of genital plates, figs. 21, 49, projecting above apex of terminal plate; ninth sternite with lateral setae long and whiskerlike, fig. 8..... 17  
Basal portion of genital plates neither enlarged nor projecting over terminal plate, figs. 16 to 18a, ninth sternite with fairly short lateral setae, figs. 4, 9..... 18
17. Genital plate as in figs. 8 and 21a, the base narrow and produced into two bulbous elevations..... *californica*  
Genital plate as in fig. 49, the base wider, and not produced into two bulbous knobs..... *occidens*
18. Terminal plate with the apex narrow, tapered to a blunt point and not incised on meson, fig. 18b..... *iola*  
Terminal plate with apex wider, and either markedly incised or almost truncate, figs. 16, 17b..... 19
19. Terminal plate almost as wide as long, more or less pentagonal, fig. 17b; genital plates more than a third as long as terminal plate, fig. 17a... *joppa*  
Terminal plate  $1\frac{1}{2}$  times as long as wide, more or less quadrangular, fig. 16b; genital plates less than a fourth as long as terminal plate, fig. 16a... *arvalis*
20. Ninth sternite large, triangular and distinctly sclerotized, fig. 56... *mohri*  
Ninth sternite apparently membranous and difficult to distinguish in uncleared specimens..... 21
21. Eighth sternite large and with a long narrow cleft on the apical margin, fig. 63..... *nevadensis*  
Eighth sternite never with such a cleft. 22
22. Legs with femora rufous and tibiae the same color or darker than femora... 23  
Legs either entirely black or with the tibiae lighter than the femora..... 24
23. Head smooth and polished..... *glabella*  
Head punctured and dull..... *americana*
24. Both clypeus and front just above it with a small but fairly conspicuous tuft of black hairs on the meson. Median depression of eighth sternite very large and deep, fig. 55... *rotunda*  
Clypeus and front without any trace



## GENITALIA OF SIALIS MALES

Fig. 16.—*S. arvalis*.Fig. 17.—*S. joppa*.Fig. 18.—*S. iola*.Fig. 19.—*S. cornuta*.Fig. 20.—*S. hamata*.Fig. 21.—*S. californica*.Fig. 22.—*S. americana*.Fig. 23.—*S. vagans*.Fig. 24.—*S. rotunda*.Fig. 25.—*S. aequalis*.Fig. 26.—*S. lutaria*.Fig. 27.—*S. nevadensis*.

ABBREVIATIONS.—a, lateral view of genital and terminal plates; b, caudal view of terminal plates; g, genital plate; l, lateral plate; t, terminal plate.



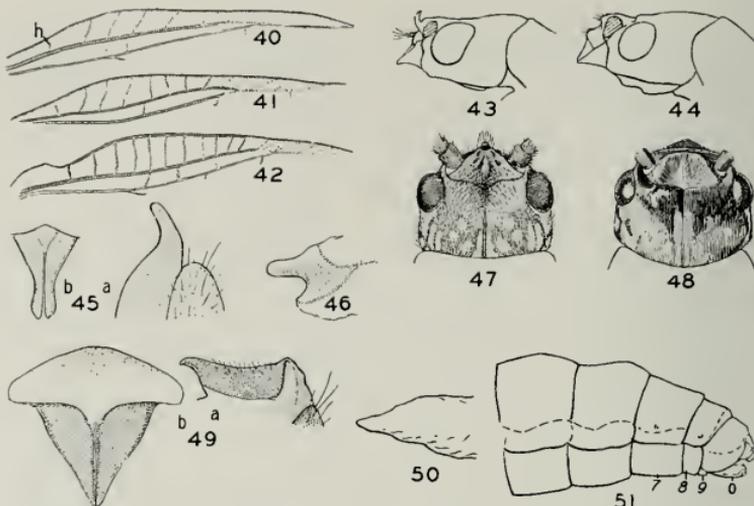
GENTILIA OF SIALIS MALES

Fig. 28.—*S. itasca*.  
 Fig. 29.—*S. velata*.  
 Fig. 30.—*S. infumata*.  
 Fig. 31.—*S. hasta*.

Fig. 32.—*S. mohri*.  
 Fig. 33.—*S. concava*.  
 Fig. 34.—*S. itasca*.  
 Fig. 35.—*S. velata*.

Fig. 36.—*S. infumata*.  
 Fig. 37.—*S. concava*.  
 Fig. 38.—*S. hasta*.  
 Fig. 39.—*S. mohri*.

ABBREVIATIONS.—a, lateral view of genital and terminal plates; b, caudal view of terminal plate; g, genital plate; l, lateral plate; t, terminal plate; 9, ninth sternite.



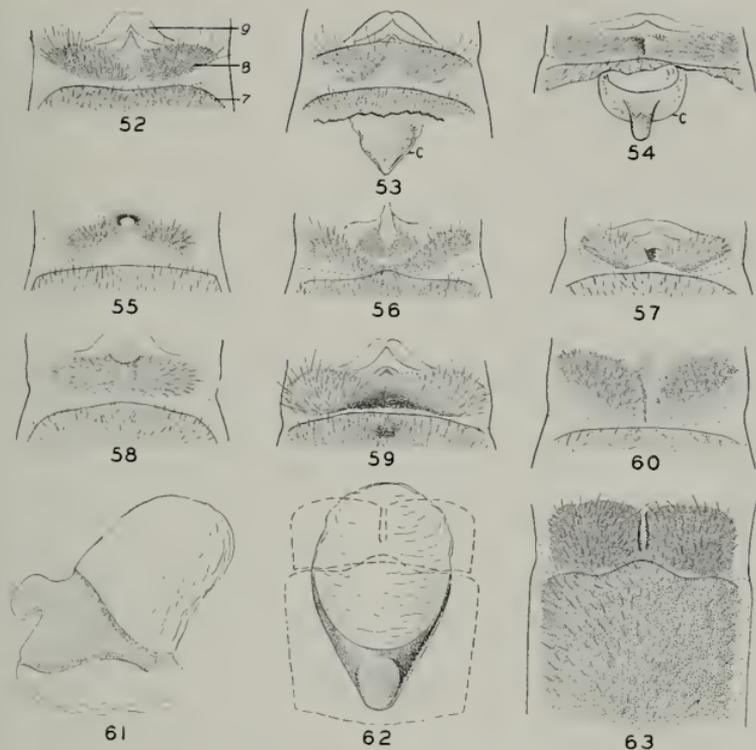
STRUCTURES OF SIALIS MALES AND FEMALES

- Fig. 40.—Costal area of front wing of *S. glabella*.
- Fig. 41.—Costal area of front wing of *S. mohri*.
- Fig. 42.—Costal area of front wing of *S. infumata*.
- Fig. 43.—Lateral view of head of male *S. rotunda*.
- Fig. 44.—Lateral view of head of female *S. rotunda*.
- Fig. 45.—Genitalia of male *S. glabella*.
- Fig. 46.—Lateral view of bursa copulatrix of *S. infumata*.
- Fig. 47.—Dorsal view of head of male *S. rotunda*.
- Fig. 48.—Dorsal view of head of *S. nevadensis*.
- Fig. 49.—Genitalia of male *S. occidens*.
- Fig. 50.—Lateral view of bursa copulatrix of *S. joppa*.
- Fig. 51.—Lateral view of abdomen of female *S. infumata*.

ABBREVIATIONS.—a, lateral view of genital and terminal plates; b, ventral view of genital plate and hooks; h, humeral distal cross-veins; o, ovipositor; 7, 8, 9, abdominal sternites.

KEY TO NEARCTIC SPECIES OF SIALIS—Concluded

- of a tuft of hairs. Median depression of eighth sternite not as large. . . . . 25
- 25. Eighth sternite narrow and divided into two separate lobes by a median depression, fig. 57. . . . . *aequalis, vagans*
- Eighth sternite either wider, fig. 60, or not divided so completely into two separate parts, fig. 54. . . . . 26
- 26. Eighth sternite as in fig. 60, rectangular and with the distal portions set out as distinct swellings. . . . . *infumata*
- Eighth sternite not as in fig. 60, either with apex rounded out, fig. 53, or not set off with such conspicuous lobes. . . . . 27
- 27. Eighth sternite flat, not tilted so that the apical margin is raised, fig. 54. Bursa copulatrix with a terminal fingerlike process. . . . . *velata, itasca*
- Eighth sternite tilted so that the apical margin is markedly raised and basal margin depressed, figs. 53, 59. Bursa copulatrix with terminus triangular, fig. 53. . . . . 28
- 28. Species occurring only east of the Great Plains region. . . . . *iola, joppa*
- Species occurring only west of the Great Plains region. . . . . 29
- 29. Median depression situated near the tip of a long, slender mesal process on the apical margin of the eighth sternite, fig. 52. . . . . *hamata*
- Median depression not situated on such a long slender process. . . . . 30
- 30. Apex of eighth sternite not evenly rounded, fig. 59. Lateral area of eighth sternite with abundant and dark setae. . . . . *californica, occidens*
- Apex of eighth sternite evenly rounded, much as in fig. 53. Lateral area of eighth sternite with considerably less abundant and light-colored setae. . . . . *cornuta*



APICAL STERNITES OF SIALIS FEMALES

Fig. 52.—*S. hamata*.

Fig. 53.—*S. joppa*, showing bursa copulatrix *in situ*.

Fig. 54.—*S. velata* showing bursa copulatrix *in situ*.

Fig. 55.—*S. rotunda*.

Fig. 56.—*S. mohri*.

Fig. 57.—*S. aequalis*.

Fig. 58.—*S. americana*.

Fig. 59.—*S. californica*.

Fig. 60.—*S. infumata*.

Fig. 61.—Lateral view of bursa copulatrix of *S. nevadensis*.

Fig. 62.—Bursa copulatrix of *S. nevadensis* as seen through venter of abdomen.

Fig. 63.—*S. nevadensis*.

ABBREVIATIONS.—c, bursa copulatrix; 7, 8, 9, abdominal sternites.

*Sialis joppa*—NEW SPECIES

MALE.—Length 12 mm. Head, body and appendages black with the following exceptions: raised lines and dots on head and narrow ring around eye, yellowish; legs shading to brown; wings dark brown, slightly lighter towards apex.

GENERAL STRUCTURE.—Front and adjoining portion of vertex slightly roughened but highly polished, concave. Remainder of head dull and shagreened except raised areas on front and vertex. Front wing with eight to 12 supernumerary cross-veins in costal area; radius 3 with two or three branches.

Abdomen and genitalia as in figs. 4 and 17. Ninth sternite narrow and bandlike, clothed with abundant short setae, and sometimes with depressed area on the meson of the basal margin. Lateral plates more or less ovoid, typically closely appressed on meson. Genital plate small, as wide as its mesal length, with a pair of short, closely appressed genital hooks, fig. 17b. Terminal plate ovoid, fig. 17a, tending to be pentagonal, ventral margin or apex forming two low rounded lobes separated by a slight incision on the meson.

FEMALE.—Length 14 mm. Color and general structure as in male, except for the

head, which may be swollen behind the eyes.

Abdomen and genitalia as in fig. 53. Seventh sternite heavily sclerotized, appearing longer than wide due to convexity; sometimes with a small swelling on meson near apex. Eighth sternite tilted, the base depressed and apex raised; the mesal portion slightly depressed longitudinally; the setae only moderately long. The apical margin of the segment bears a small round depression on the meson; if the segment is stretched out there can be seen a small pointed process running forward from under this depression. Ninth sternite membranous but fairly rigid, forming a wide V. Tip of bursa copulatrix entirely membranous, fig. 50, triangular in dorsal view, fig. 53.

**Holotype, male.**—Newfound Gap, Great Smoky Mountain National Park, N.C.: May 28, 1934, T. H. Frison, INHS.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—Same data as for holotype and allotype, 1♂, 1♀.

ILLINOIS.—Eichorn, Buck creek: Apr. 22, 1932, Ross & Mohr, 1♂, INHS.

MAINE.—Naples: Farley, 1♂, INHS.

NEW HAMPSHIRE.—White mountains, Alpine: 1♂, INHS. Gorham: 1♂, MCZ.

NEW YORK.—Crosby: May 20, 1920, 1♂, cu. Ithaca: May 23, 1915, 1♂, cu. McLean: June 2, 1923, 1♂, INHS. Stanley: May 17–20, C. R. Crosby, 1♂, INHS; 1♀, cu. Williams: May 31, 1913, 2♂, 2♀, cu; 1♂, 1♀, INHS.

NORTH CAROLINA.—North fork Swannanoa river, May, 1♂, MCZ.

OHIO.—Sugar Grove: April 17, 1902, 1♂, OSU.

PENNSYLVANIA.—Castle Rock: May 21, 1908, 1♂, ANS. Jeanette: H. G. Klages, 1♂, cm. Two miles north of Narberth, Montgomery county: May 16, 1925, E. T. Cresson, Jr., 1♂, ANS. Philadelphia: May 11, 1♂, INHS.

This is a decidedly eastern species, its distribution resembling that of *iola*. The Ohio and Illinois records, however, are more western than any records of *iola*.

Total size and color of wings vary considerably in both sexes. This species is closest to *arvalis* and *iola* but may be separated from them in the male by the shape of the terminal plate. The females of this entire group are difficult to separate.

#### *Sialis arvalis*—NEW SPECIES

**MALE.**—Length 11 mm. Color and general structure similar to *joppa*. Differs only in details of abdomen and genitalia figs. 6, 16. Ninth sternite handlike, clothed with scattered short setae. Lateral plates somewhat ovoid, mesal side angular and

appressed on meson for a short distance. Genital plate very small, quadrate and with a pair of short genital hooks, fig. 16a. Terminal plate, fig. 16b, rectangular in general outline, the apex divided into two lobes which are considerably swollen.

**FEMALE.**—Unknown.

**Holotype, male.**—Mokel Hill, Calif., April, F. E. Blaisdell, CAS.

**Paratypes.** CALIFORNIA.—Mokel Hill: F. E. Blaisdell, 1♂, CAS; 1♂, INHS. Yorkville, Mendocino County: April 30, 1934, E. P. Van Duzee, 1♂, CAS.

#### *Sialis iola*—NEW SPECIES

**MALE.**—Length, color and general structure similar to *joppa*. Differs only in details of genitalia, figs. 9, 18. Ninth sternite handlike and with only moderately long setae. Lateral plates more or less ovoid and appressed on meson. Genital plate small, narrower than its mesal length, with a pair of short, closely appressed genital hooks, fig. 9. Terminal plate triangular in general outline, the apex round and very narrow, without an incision on the meson.

**FEMALE.**—Apparently identical with that of *joppa*.

**Holotype, male.**—Pittsburgh, Pa. INHS.

**Allotype, female.**—Same data as for holotype.

WASHINGTON, D. C.—April 1928, 3♂, 1♀, NM; 2♂, 1♀, INHS.

NEW JERSEY.—Riverton: May 4, 1903, 2♂, INHS. Paterson: June 10, 1♂, AM.

NEW HAMPSHIRE.—Durham: 1♂, cu.

NEW YORK.—Axton, Adirondack mountains: June 12–22, 1901, 5♂, 1♀, cu; 2♂, 1♀, INHS. Black brook, Clinton county: June 11, 1916, 1♂, 1♀, cu. McLean: May 31, 1913, 1♂, 1♀, INHS; 1♂, 1♀, cu. McLean bogs, Tompkins county: May 29, 1915, 1♂, cu. Ringwood, Ithaca: June 26, 1920, 1♂, 1♀, cu.

PENNSYLVANIA.—Inglenook: May 31, 1914, 1♂, MCZ. Pittsburgh: May 22, 1899, 1♂, cm.

QUEBEC.—Fairy lake: June 1, 1927, 1♀, CNM. Knowlton: June 5–14 and July 12, 5♂, 5♀, CNM; 5♂, 5♀, INHS. Lachine: June 4, 1930, L. J. Milne, 1♂, CNM.

#### *Sialis californica* Banks

*Sialis fuliginosa* Davis (1903, p. 449) in part [nec Pictet].

*Sialis infumata* Davis (1903, p. 448) in part [nec Newman].

*Sialis californica* Banks (1920, p. 326).

**MALE.**—Length 11–14 mm. Color and general structure as in *joppa* except that many specimens are larger and have the wings solid iridescent black. This darker coloration intergrades to a light brown in a long series.

Abdomen and genitalia, figs. 8, 21. Ninth sternite bandlike, the mesal portion clothed with only moderately long setae, but the lateral portions bearing many long setae which project considerably beyond the lateral margins of the segment to give the appearance of a bushy set of cat's whiskers, fig. 8. Lateral plates ovoid, appressed for a distance on the meson. Genital plate narrow, evenly tapered to apex where it is produced into a pair of short hooks; the base of the plate, fig. 21a, bulbous and raised above the apex of the terminal plate. Terminal plate, fig. 21b, triangular in outline, the extreme apex rounded but not divided into two lobes.

**FEMALE.**—Length 12-16 mm. Color and general structure as in male.

Abdomen and genitalia as in *joppa* with the following differences: eighth sternite, fig. 59, with the apical margin raised, incised on meson, the mesal depression fairly large and bounded apically by a narrow bridge; basally from this extends a fan-shaped, concave area with few or no setae; on either side of this the segment is raised and these raised areas are clothed with setae which are longer than those on other females in the *californica* group. Bursa copulatrix with the tip more or less sclerotized, triangular from the ventral aspect, somewhat beaked from the lateral aspect.

**Lectotype, male, by present designation.**—San Emigdio cañon, Kern county, Calif.: F. Grinnell Jr., June 3, 1904, Type #10844, MCZ.

**ALBERTA.**—Jasper to Buffalo Prairie: June 30, 1915, 1♂, INHS.

**BRITISH COLUMBIA.**—Alta lake, Mons: June 11, 1926, J. McDunnough, 1♂, 1♀, CNM.

**CALIFORNIA.**—Alameda county: 1♂, INHS. Berkeley: April 14, 1928, 1♂, CAS; April 27, 1921, 1♂, INHS. Big Basin Park, Santa Cruz county: May 12, 1918, 1♂, CAS. Carrville, Trinity county, altitude 2400-2500 feet: May 19, 1935, 1♂, 2♀, CAS; 1♂, 1♀, INHS. Eureka: June 6, 1♂, NM. Phoenix lake, Marin county: April 4, 1927, 1♂, 1♀, CAS. San Emigdio cañon, Kern county: 1♂, MCZ, paratype; 1♂, INHS, paratype. San Jeronimo: 1♂, MCZ, paratype; 1♂ INHS, paratype. Yorkville, Mendocino county: May 1, 1924, CAS.

**OREGON.**—Albany: April 25, 1934, J. Schuh, 1♀, INHS. Alsea: May 23, 1931, H. A. Scullen, 1♀, OAC; 1♀, INHS. Cannon Beach: June 10-18, 1927, 1♂, 3♀, CAS; 1♂, INHS. Corvallis: June 9, 1930, Loring G. Hudson, 1♂, INHS; April 29, 1930, H. A. Scullen, 1♂, OAC; May 15, 1925, 1♂, OAC. Oak creek: May 4, 1934, Eldon Ball, 2♀; May 22, 1934, Dimick, 1♂, INHS; May 26, 1898, 1♀, OAC. Philomath,

Rock creek: May 1, 1934, R. E. Dimick, 1♀, OAC. Santiam road, Cash creek: July 20, 1910, 1♀, OAC. Siletz river: May 24, 1934, R. E. Dimick, 1♀, OAC. Tidewater: July 3, 1933, 1♀, OAC. Warner mountains, Lake county: June 19, 1922, 1♂, 1♀, CAS.

**WASHINGTON.**—Stabler: June 20, 1928, K. Gray, 1♂, OAC; elevation 1500-2000 feet, 3♀, OAC; 2♀, INHS.

### *Sialis occidens*—NEW SPECIES

*Sialis fuliginosa* Davis (1903, p. 449) in part [nec Pictet].

**MALE.**—Length 11-13 mm. Similar in all respects to *californica*, except for the genital plate. Ninth sternite, lateral plates and terminal plate as described and illustrated for *californica*. Genital plate, fig. 49, wide at base and tapering to apex, basal portion curved upward above apex of terminal plate but not forming two bulbous lobes.

**FEMALE.**—Apparently identical with that of *californica*.

**Holotype male.**—Wolverton, Sequoia National Park, Calif., altitude 7000-9000 feet: June 25, 1929, E. C. Van Dyke, CAS.

**Allotype, female.**—Same data as for holotype.

**Paratypes.** CALIFORNIA.—1♂, NM, Wolverton, Sequoia National Park, altitude 7000-9000 feet: June 23-25, 1♂, 1♀, CAS; 2♂, 1♀, INHS. Fallen Leaf lake, Lake Tahoe: July 2, 1♂, CAS; June 26, 1♀, CAS. Placer county: June, 1♂, INHS. Sierra Nevada: Crotch, 1♂, 1♀, MCZ.

**NEVADA.**—Reno: 1878, Morrison, 1♂, 2♀, MCZ; 1♂, 2♀, INHS; 1♂, 2♀, NM; 1♂, 1♀, KAC; June 27, 1927, E. P. Van Duzee, 1♀, CAS.

This species is apparently restricted to a more southern distribution than *californica*. The specimens from Reno, Nevada, collected by Morrison were recorded as *fuliginosa* by Davis.

### *Sialis cornuta*—NEW SPECIES

**MALE.**—Length 12 mm. Color and general structure similar to *joppa*. Differs in details of abdomen and genitalia, figs. 7 and 19. Ninth sternite bandlike, clothed with only moderately long setae. Lateral plates more or less ovoid, mesal margins somewhat angled and appressed for a distance. Genital plate wide and deep, narrowing towards apex and produced into a pair of narrow hooks half as long as the plate; these hooks, fig. 19a, projecting almost straight upward from the plate and scarcely curved. Terminal plate ovoid and flat, fig. 19b, its apex divided into two lobes by a narrow mesal incision, each lobe produced into a short, stout, hornlike process curved laterad.

**FEMALE.**—Similar in all respects to that of *joppa*, with the exception of the apical mesal projection of the eighth sternite, which is slightly longer.

**Holotype, male.**—Horseshoe lake, Blue mountains, Ore., elevation 7500 feet: July 26, 1929, H. A. Scullen, INHS.

**Allotype, female.**—Same data as holotype.

**Paratypes.** ALBERTA.—Nordegg: July 7–11, 1921, J. McDunnough, 2♂, 2♀, CNM; 1♂, 2♀, INHS. Waterton: July 12, 1923, H. L. Seamans, 1♂, CNM; July 14, 1923, E. H. Strickland, 1♂, CNM; 1♂, INHS.

IDAHO.—Moore's lake: July 10, 1907, J. M. Aldrich, 1♂, INHS. Moscow: J. M. Aldrich, 1♀, INHS.

UTAH.—Fruitland: March 20, 1937, F. C. Harmston, 1♂, INHS. Red creek: March 20, 1937, F. C. Harmston, 1♂, UAC.

The male of this species is readily distinguished by the hornlike processes on the terminal plate, but the female is difficult to separate from others of the *californica* group (see key).

#### *Sialis hamata*—NEW SPECIES

**MALE.**—Length 12 mm. Color and general structure as in *joppa*. Differs in details of abdomen and genitalia, figs. 5 and 20. Ninth sternite bandlike, clothed with sparse, moderately short setae. Lateral plates more or less ovoid, appressed for a distance on the meson. Genital plates small from ventral aspect, but with a large recurved hook at apex which is apparent only in lateral view, fig. 20a. Terminal plate flat and round, the basal part produced at the apex into a thin flat neck, fig. 20b, at the end of which the genital plate articulates. This neck varies in length but is always as long as shown in the illustration.

**FEMALE.**—Apparently identical with that of *joppa* except for the eighth abdominal sternite, fig. 52. This is emarginate along the apex except at the meson where a narrow projection juts forward. This projection is on the same plane as the remainder of the segment. The bursa copulatrix is membranous and amorphous.

**Holotype, male.**—Logan, Utah: April 16, 1933, J. A. Meacham, INHS.

**Allotype, female.**—Blacksmith Fork cañon, Utah: July 9, 1935, C. F. Smith & G. F. Knowlton, INHS.

**Paratypes.** ALBERTA.—Lethbridge: Aug. 4, 1922, E. H. Strickland, 1♂, CNM. Waterton lakes: June 26–July 13, 1♂, 1♀, INHS; 3♀, CNM. Watertown: June 30, 1924, H. L. Seamans, 1♂, CNM; 1♂, INHS; July 1, 1924, H. L. Seamans, 1♀, CNM.

BRITISH COLUMBIA.—Creston: May 28, 1926, A. A. Dennys, 1♂, CNM.

MONTANA.—Lake Saint Mary, Glacier National Park: July 21, 1930, E. C. Van Dyke, 1♂, CAS; 1♀, INHS. Spring Creek, Yellowstone National Park: July 15, 1923, A. L. Melander, 1♂, MCZ.

OREGON.—Warner lake, Lake county, high tablelands: June 21, 1922, E. C. Van Dyke, 1♂, 1♀, CAS; 1♂, INHS.

UTAH.—Parley cañon, Salt Lake City: June 24, 1922, E. P. Van Duzee, 1♂, CAS.

WASHINGTON.—Pullman: May 10, 1928, 1♂, UM.

WYOMING.—West Yellowstone: June 14, 1930, E. C. Van Dyke, 2♂, CAS.

This western species is one of the few in the *californica* group having a distinguishing character in the female. The male is readily distinguished from other members of the genus by the "neck" on the terminal plate and the swan's-neck hook articulating with it.

#### *Sialis americana* (Rambur)

*Sembris americana* Rambur (1842, p. 447).

*Sialis ferrugineus* Walker (1853, p. 195).

*Sialis americana* Hagen (1861, p. 188); Banks (1892, p. 357); Davis (1903, p. 450).

*Protosialis americana* Van der Woele (1909, p. 263; 1910, p. 75).

**MALE.**—Length 12 mm. Yellowish orange with the antannae, eyes, tibiae and tarsi almost black. Abdomen, posterior half of head, palpi and margins of pronotum suffused with blackish. Wings and veins yellowish orange.

Head dull with fine reticulations, concave around branching of epicranial stem. Front wing with five to seven supernumerary cross-veins in costal cell.

Abdomen and genitalia as in figs. 10 and 22. Ninth sternite produced caudad into a fairly long, truncate sclerite, clothed with sparse but moderately long pubescence and covering bases of lateral plates. Lateral plates small and triangular, the posterolateral portion angulate; appearing as appendages of the ninth sternite and not appressed on the meson. Genital plate forming a broad collar in front of terminal plate, and bearing a pair of broad, straight arms. These appear in fig. 22a, so that at first glance they appear as appendages of the terminal plate. Terminal plate round, the margins clothed with long setae, the apex with a small, semicircular incision.

**FEMALE.**—Size, color and general characteristics as in male. Seventh sternite, fig. 58, rectangular, neither larger nor more heavily sclerotized than the preceding segments; produced into a convex area on the meson; the entire segment together with

the eighth clothed with sparse but fairly long setae. Eighth sternite small and rectangular, the apical margin with a diamond-shaped shining area on the meson. Ninth sternite and bursa copulatrix indistinct in cleared specimens.

MARYLAND.—Laurel: June 22, 1912, E. B. Marshall, 1♂, NM.

OHIO.—Kent: June 18-22, 1900, R. C. Osburn, 2♂, 1♀, OSU; 2♂, 1♀, INHS.

The character of "black antennae" mentioned for *americana* by Van der Woele and for *ferrugineus* by Walker indicate that both names apply to the species herein described. It is possible, however, that Rambur's name *americana* could apply to the species *glabella* described herein as new. At the present time it seems better to follow the synonymy of previous authors.

#### *Sialis glabella*—NEW SPECIES

**MALE.**—Length 12 mm. Yellowish orange with the following exceptions: mesal two-thirds of vertex dark reddish brown with the usual bars and spots yellow, forming a regular pattern, fig. 49; dorsum of abdomen dark brown; sutures of mouthparts, thorax and legs light brown; and antennae, tibiae and tarsi slightly darker and browner than body ground color.

Head and pronotum smooth and polished, without any trace of sculpturing, clothed with very fine short pubescence; concave at branching of epicranial stem. Venation as in *americana*.

Abdomen and genitalia very similar to those of *americana* with the following differences: Ninth sternite only two-thirds as long, lateral plates longer and closer together, terminal plate identical, genital plate with a pair of long arms whose apical half is markedly narrowed, fig. 45.

**FEMALE.**—Size, color and general structure as in male, abdomen as in *americana*.

**Holotype, male.**—Mt. Carmel, Ill.: May 28, 1884, sweeping (acc. no. 1796), INHS.

**Allotype, female.**—Same data as holotype.

**Paratypes.** ILLINOIS.—Muncie: June 16, 1908, H. E. Ewing, 1♀, INHS.

This species looks very much like *americana*, but is easily distinguished from it by the shining, impunctate head, paler antennae and tibiae, and the narrowed genital arms of the male. Both records are points on the Wabash river drainage system.

#### *Sialis velata*—NEW SPECIES

**MALE.**—Similar to *itasca*, p. 72, in size,

color and general structure. The wings are on the average darker and only rarely present a banded appearance.

Abdomen and genitalia, figs. 29 and 35, similar to *itasca* with these differences: ninth sternite with apical margin rounded; lateral plates shorter, their apex broad and rounded and the lateral margin not angulate; genital hooks bending just below level of terminal plate and with a slender basal appendage which runs some distance from top prong; terminal plate longer, raised more than its width from the sclerite at its base.

**FEMALE.**—Apparently identical with that of *itasca*.

**Holotype, male.**—Houghton lake, Mich.: June 15-18, 1935, T. H. Frison, INHS.

**Allotype, female.**—Same data, collected *in situ* with holotype.

**Paratypes.** ALBERTA.—Medicine Hat: May 24, 1923, 1♂, CNM.

BRITISH COLUMBIA.—OSOYOOS: May 20-21, 1923, C. B. Garrett, 3♂, 4♀, CNM; 3♂, 1♀, INHS.

ILLINOIS.—Calvin: April 14, 1930, Frison & Ross, 3♂, INHS. Charleston: April 23, 1932, Ross & Mohr, 1♂, INHS. Dixon Springs: April 21, 1935, T. H. Frison, 2♂, INHS. Dubois: April 24, 1919, creek valley, 1♂, INHS. Havana, Illinois river front: April 27, 1896, C. A. Hart, 3♂, INHS. Homer: May 6, 1911, 1♂, INHS. Mt. Carmel: April 19, 1932, Ross & Mohr, 1♂, INHS. New Columbia, Clifty creek: April 22, 1932, Ross & Mohr, 1♂, INHS. Parker: April 17, 1914, 1♂, INHS. Rock Island: May 10, 1934, Ross & Mohr, 1♂, INHS; May 16, 1931, 2♂, INHS. Shawneetown: April 26, 1926, Frison & Auden, 1♂, 1♀, INHS. Spring Grove, along Nippersink creek: May 14, 1936, Ross & Mohr, 5♂, 12♀, INHS. Urbana: May 22, 1923, 1♂, INHS; April 26, 1890, C. A. Hart, at light, 1♂, INHS. Vienna: April 21, 1932, Ross & Mohr, 1♂, INHS.

KANSAS.—Douglas county: April 14, 1922, R. Guentert, 34♂, 10♀, KU; 7♂, 5♀, INHS; April 1923, R. H. Beamer, 3♂, KU. Manhattan: April 2, 1932, F. E. Whitehead, 1♂, KAS; April 18, 1930, A. Audant, 1♂, KAS. McPherson county: April 16, 1932, 1♂, KAS. Onaga: May 30, 1926, 1♂, INHS. Riley county: April 29, Popenoe, 1♂, KAS.

MAINE.—Waldoboro: May 1902, Lovell, 1♂, CU.

MANITOBA.—Aweme: June 14, 1912, N. Criddle, 1♂, CNM; May 27, 1925, R. M. White, 1♂, INHS; 1♀, CNM; June 13, 1926, N. Criddle, 1♂, CNM; June 4, 1926, R. D. Bird, 3♂, CNM; Criddle, 1♂, CU.

MARYLAND.—Plummer's Island: April 17-22, 1903, W. V. Warner, 2♂, 2♀, NM; April 22, 1915, J. C. Crawford, 2♂, INHS; April 18, 1915, H. S. Barber, 1♂, NM; May, 1♂, 1♀, NM.

MASSACHUSETTS.—Cambridge: May 28, 1900, S. Henshaw, 4♂, MCZ. Lake Cochicuate: May 28, 1♂, INHS. Wellesley: May 1895, A. P. Morse, 5♂, MCZ.

MICHIGAN.—Ann Arbor, Washtenaw county: May 16, 1917, 1♂, MMZ. Detroit: May 5, H. G. Hubbard, 1♂, MCZ; May 27, 1897, 1♀, AM; 1♂, MCZ; May, 2♂, 1♀, MCZ. Grayling, power dam on Au Sable river: June 17, 1935, T. H. Frison, 1♂, INHS. Higgins lake, Crawford county: June 19, 1932, G. Kelker, 1♂, 2♀, MMZ. Houghton lake: June 15–18, 1935, T. H. Frison, 2 mating pairs, 22♂, 48♀, INHS. Margurite lake: May 23, 1936, Frison & Ross, 2 mating pairs, 391♂, 662♀, INHS. Mio, along Au Sable river: May 21, 1936, Frison & Ross, 35♂, 3♀, INHS. Omer, along Rifle river: May 21, 1936, Frison & Ross, 1♂, 1♀, INHS. Washenaw county: May 22, 1930, 1♂, MMZ.

MINNESOTA.—Big Cormorant lake: May 14, 1900, R. C. Osborn, 1♂, 2♀, OSU. Coon creek: May 20, 1933, D. J. Pletsch, 2♂, UM. Itasca county: 1♂, UM. Itasca Park: May 30, 1932, C. H. Hoffman, 14♂, 1♀, UM; 5♂, INHS; June 13, 1928, L. W. Orr, 3♂, 2♀, UM; June 9, 1934, W. A. Riley, 1♀, UM.

MISSOURI.—Columbia: April 21, 1905, 1♂, INHS.

NEW HAMPSHIRE.—Three-mile island: June 2, 1♂, MCZ.

NEW YORK.—Cortland county, Labrador lake: May 14, 1921, 2♂, CV. Crosby, Yates county: May 18, 1918, 1♂, CV. Cranberry lake: June 23, 1919, J. C. Clark, 1♂, CV; June 26, 1920, C. J. Drake, 1♂, INHS. Litchfield: May, 1903, 1♂, AM. Oswego: May, 1894, 1♂, NM. Peru: May, 1914, 2♂, CV. Stanley: May 1920, 1♂, CV. Syracuse: Cook & Collins, 1♂, NM. Westport: May 1921, 1♂, INHS; May 20, 1922, 4♂, 1♀, AM; 1♂, 1♀, INHS.

NORTH DAKOTA.—Fargo: June, 1♂, INHS.

ONTARIO.—Casselman: May 23, 1♂, CNM; April 21, 1904, 1♂, CNM. Jock river: May 23, 1927, G. S. Walley, 1♂, INHS. Maitland: June 12, 1931, L. J. Milne, 4♂, 11♀, CNM, 1♂, 1♀, INHS. Ottawa, Rideau river: May 27, 1930, L. J. Milne, 1♂, CNM; June 9, 1920, J. Mc Dunnough, 2♂, CNM; May 29, 1920, J. Mc Dunnough, 2♂, 3♀, CNM; 1♂, 1♀, INHS. Rat Portage island: June, 1905, J. C. Bradley, 1♂, CV. Sand lake: July 3, 1926, F. P. Ide, 3♂, CNM. Sioux Lookout: June 25, 1929, J. Russell, 1♂, CNM. Southampton: June 20, 1931, G. S. Walley, 1♂, CNM. Trenton: May 5, 1900, 1♂, CNM.

QUEBEC.—Knowlton: June 21, 1929, L. J. Milne, 1♂, CNM. Lachine: June 8–9, 1926, F. P. Ide, 11♂, 3♀, CNM. La Prairie: June 14, 1927, G. S. Walley, 4♂, 4♀, CNM; 1♂, 3♀, INHS; June 9, 1926, F. P. Ide, 2♂, CNM.

SASKATCHEWAN.—Scudder, 3♂, 1♀, INHS. Saskatchewan river: 1♂, MCZ.

TEXAS.—Kerrville: March 24, 1906, F. C. Pratt, 1♂, INHS.

VIRGINIA.—Great Falls: April 19–30, 6♂, MCZ; May, 1♂, NM; May 2, 1916, 1♂, NM.

WASHINGTON, D. C.—May, Ashmead, 2♂, NM; Apr. 3, 1♀, NM; Apr. 20, 1♂, MCZ; Apr. 29, 1♂, NM.

WEST VIRGINIA.—Millville: Apr., 1921, 1♂, INHS.

WISCONSIN.—Washington Island, Door county: June 7, 1905, 1♂, 1♀, MCZ. Sturgeon bay: June 7, 1929, A. Granovsky, 2♂, 6♀, UW; 1♂, 2♀, INHS. Madison: May 1934, 1♂, UW;

May 31, 1912, A. C. Burrill, 1♂, UW. Lake Mendota: June 7, 1910, J. G. Sanders, 1♂, UW. Trout lake: June 1, 1934, H. L. Chada, 1♂, UW.

### *Sialis itasca*—NEW SPECIES

MALE.—Length 11 mm. Black with these exceptions: head with bars and spots, narrow margin around eye and malar space orange. Wings dark brown with apical two-thirds varying from slightly paler to completely hyaline. Specimens of this type present a striking banded appearance when the wings are spread.

GENERAL STRUCTURE.—Dorsum of head dull with coarse and abundant shagreening. Vertex usually concave along meson, but sometimes robust and even slightly convex. Front wing with about 10 accessory cross-veins in costal area, remainder of venation normal.

Abdomen and genitalia as in figs. 28 and 34. Ninth sternite narrow, apical margin angular. Lateral lobes long, their lateral margins more or less angular; apex bluntly pointed so that the apical portion is somewhat triangular. Genital plate collarlike, situated below terminal plate, and giving rise to a pair of long, bent arms, fig. 28a, projecting forward almost to the ninth sternite; the two arms are closely appressed, usually appearing as one; each arm angles forward just above level of terminal plate and at its base has a lobe thicker than the arm and running very close to it. Terminal plate, fig. 28b, with a wide angular incision at apex; the plate rising less than its width above the sclerite at its base.

FEMALE.—Length 13 mm. Color and general structure as in male.

Abdomen and genitalia as in fig. 54. Seventh sternite wider than long, only slightly arcuate at apex. Eighth flat, wide and narrow, with a median shallow depression. Apex of bursa copulatrix sclerotized and rounded, with a long straight fingerlike process on the ventral side at extreme tip, figs. 46, 54.

**Holotype, male.**—Momence, Ill., along Kankakee river: June 1, 1937, B. D. Burks, INHS.

**Allotype, female.**—Same data as holotype.

**Paratypes.**—ILLINOIS.—Charleston: June 19, 1931, H. H. Ross, INHS. Maywood, DesPlaines river: June 7, 1912, 1♂, INHS. Momence: same data as holotype, 2♂, 1♀, INHS. White Heath: June 9, 1929, C. O. Goff, 1♂, INHS; June 18, 1906, woods, 1♂, INHS. White Pine State Park: May 30, 1936, Ross, 1♂, INHS.

KANSAS.—Manhattan: May 20, 1925, R. E. Sears, 1♂, INHS.

MICHIGAN.—Douglas lake: July 4, 1927, L. K. Gloyd, 1♂, INHS.

MISSOURI.—Bryant's Point: May 13–15, 1915, P. Bartsch, 1♂, INHS; 2♂, NM.

NEW YORK.—Cranberry lake: July 8, 1920, C. J. Drake, 1♂, cu. Ithaca: June 20, 1907, 1♂, INHS; June 12, 1914, 1♂, INHS; June 12–14, 1915, 2♂, cu; 2♂, INHS; June 17, 1916, 1♂, cu; June 25, 1916, 1♂, cu; June 16, 1915, 1♂, cu; 2♂, INHS; June 12, 1913, 1♂, cu; May 18, 1♂, cu. Rochester Junction: June 9, 1914, M. D. Leonard, 1♂, cu.

NORTH DAKOTA.—Fargo: June 3, 1901, R. C. Osborn, 1♂, OSU.

OHIO.—Huron: June 24, 1914, 1♂, 13♀, cu; 1♂, 4♀, INHS. Marietta: 1♂, MCZ.

ONTARIO.—Arguin park: June 18, 1922, J. McDunnough, 1♂, CNM. Britannia: June 23, 1920, G. Beaulieu, 3♂, 2♀, CNM; 2♂, 2♀, INHS. Ottawa West: June 21, 1920, C. B. Hutchings, 1♂, CNM; 1♂, INHS.

PENNSYLVANIA.—Candy Hill: May 28, 1♂, INHS. Harrisburg: May 30, 2♂, INHS. West Chester: May 19, 1924, 1♂, cu; 1♂, INHS; 1♂, ANS.

QUEBEC.—Lacolle: July 5, 1928, G. H. Hammond, 1♂, CNM. Laprairie: June 17, 1925, F. P. Ide, 3♂, 2♀, CNM; 2♂, 2♀, INHS.

VIRGINIA.—Dyke: May 28, 1915, W. L. McAtee, 1♂, NM. Great Falls: May 25, N. Banks, 10♂, MCZ; 4♂, INHS; June 3, 1♂, MCZ; June 18, 1♂, MCZ; June 5, 1♂, MCZ. Mt. Vernon: June 6, 1915, W. L. McAtee, 1♂, INHS.

WASHINGTON, D. C.—F. C. Pratt, 1♂, NM.

### *Sialis infumata* Newman

*Sialis infumata* Newman (1838, p. 500).

**MALE.**—Similar in size, color and general structure to *velata* and *itasca*. Differs in genitalia as follows, figs. 30 and 36: ninth sternite narrow and slightly angulate at apex; lateral lobes long, the apical fourth constricted and forming a large round knob; genital hooks long and slender, bending at half the height of the terminal plate, the appendage near their base ovate and short, no longer than a third of the horizontal portion of the hook; terminal plate twice as high as wide, its sides convex and narrowing towards apex, the latter with a shallow, narrow incision on the meson.

**FEMALE.**—Similar to that of *velata*, differing only in the structure of the eighth sternite, fig. 60. This is fonger and rectangular, with a narrow V-shaped depression extending along the meson of the entire segment. The halves have the apical half somewhat raised into a lobe and the posterior half flat.

**Holotype, female.**—Trenton Falls, N. J.: Doubleday, BM.

**Allotype, male.**—Wilmington, Ill., along Kankakee river: May 17, 1935, H. H. Ross, INHS.

ILLINOIS.—Algonquin: May 12, 1906, W. A. Nason, 2♂, 1♀, INHS. Cedar lake: 3♂, 1♀, INHS; 3♂, OSU. Easton, central ditch: May 1, 1914, 1♂, INHS. Galena: 1♂, 1♀, MCZ. Oakwood: April 26, 1936, Eugene Ray, 2♂, INHS. Rantoul: April 24, 1929, Frison & Ross, 1♂, INHS. Wilmington: May 12, 1935, Frison & Ross, 3♂, INHS; May 17, 1935, H. H. Ross, 3♂, 1♀, INHS.

KANSAS.—Manhattan: April 30, 1933, D. E. Musser, 2♂, INHS; April 7, 1930, R. H. Painter, 1♂, KAS; May 15, 1933, 1♂, KAS; Sept. 10, 1932, M. W. Allen, 2♂, KAS.

MICHIGAN.—Vassar branch of Cass river: May 20, 1936, Frison & Ross, 1♂, INHS.

NEW YORK.—Ithaca: May 3–25, 4♂, 9♀, INHS; 2♂, 15♀, cu; inlet valley, May 3, 1913, 1♂, cu. Syracuse: Cook & Collins, 1♂, NM.

OHIO.—Columbus: April 23, 1899, R. C. Osborn, 1♂, OSU.

PENNSYLVANIA.—Harrisburg: May 11, 1909, 1♂, INHS. Manayunk: April 26, 1♂, ANS.

The identity of this species is still a trifle uncertain. D. E. Kimmins of the British Museum has kindly compared specimens with the female type and says that it agrees most closely with this determination. The differentiation of the females of the *infumata-itasca-velata* group, however, is not as definite as might be wished. Mr. Kimmins, however, cleared the abdomen of the type, so that the present treatment is as satisfactory as possible under the circumstances.

The bibliography of this species includes only the original description. The other references to the species in literature cannot be placed with certainty due to the confusion of so many species under this name by various authors.

### *Sialis concava* Banks

*Sialis concava* Banks (1897, p. 22)

**MALE.**—Similar in size, color and general structure to *infumata* and *itasca*. Differs in genitalia as follows, figs. 33 and 37: lateral plates smaller, more or less triangular, flat and angled at apex; genital hooks, fig. 33a, long, slender for their whole length, angled at half or less the height of the terminal plate, and without an appendage at their base; terminal plate, fig. 33b, long, slender, tapering almost to apex, which is slightly widened and beset with a cluster of fairly long setae.

**FEMALE.**—Unknown.

**Holotype, male.**—Ithaca, N. Y., MCZ.

MARYLAND.—1♂, INHS.

NEW YORK.—Ithaca: May 29, 1913, 1♂, INHS.

ONTARIO.—Power Glen: June 25, 1926, G. S. Walley, 1♂, CNM.

The type has the genitalia expanded so that the parts are readily seen.

**Sialis hasta**—NEW SPECIES

**MALE.**—Similar in size, color and general structure to *infumata*. Differs in genitalia as follows, figs. 31 and 38: ninth sternite broad, apical margin evenly rounded; lateral plates broad, their apex wide and evenly rounded; genital hooks, fig. 31a, broad at base, tapering beyond bend to a point, very low, the outer margin of the bend angular; appendage at base of hooks triangular, short and with an angular apex; terminal plate quadrate, fig. 31b, each lateral corner prolonged into a long, straight apical process, these processes surmounted by a tuft of setae and separated by a distance almost equal to their own length.

**FEMALE.**—Similar in color and general structure to male. Genitalia very similar to those of *infumata*, fig. 54, differing as follows: seventh sternite with only apical half sclerotized, apical margin broadly and shallowly emarginate, eighth sternite with antero-lateral portions slightly more rounded than in fig. 54.

**Holotype, male.**—Lovells, Mich., along Au Sable river: May 22, 1936, Frison & Ross, INHS.

**Allotype, female.**—Same data as holotype.

**Paratypes.** MICHIGAN.—Hale, along Au Gres river: May 21, 1936, Frison & Ross, 1♂, INHS. Lovells: 4♂, 8♀, same data as holotype; May 24, 1936, J. W. Leonard, 1♂, 15♀, INHS. Whittemore along Johnson creek: May 21, 1936, Frison & Ross, 2♂, INHS.

PENNSYLVANIA.—Allegheny county, 1♂, CM; 1♂, INHS. Washington county, 1♂, CM.

**Sialis mohri**—NEW SPECIES

**MALE.**—Similar in size and color to *infumata*. Differs in general structure as follows: median area of vertex concave, velvety in appearance due to fine setae and punctures; costal area of front wing with six to 10 accessory cross-veins, averaging seven or eight.

Abdomen and genitalia as in figs. 32 and 39. Ninth sternite angular on meson, not very long; lateral lobes broad, narrowed at apex to a rounded point; genital plate, fig. 32a, broad at base, with a long, thin, curving blade three times as long as the basal portion; terminal plate, fig. 32b, more or less heartshaped, bearing a pair of long arms at apex which come off at right angles to the main sclerite, and curve slightly upward; each arm is stocky at its

base and tapers to a fine point, is very heavily sclerotized, and sinuate, fused with each other at base, and beyond that separate.

**FEMALE.**—Similar to male except for genitalia and larger size. Abdomen and genitalia, fig. 56, very characteristic of species: seventh sternite as for genus; eighth very narrow on meson, the lateral portions more or less triangular; apparent ninth sternite sclerotized, fitting within the cut-out margin of the eighth, having a sclerotized carina along the meson at apex, the entire segment somewhat diamond shaped.

**Holotype, male.**—Boulder Junction, Wis., on Trout river: June 20, 1934, Frison & Mohr, INHS.

**Allotype, female.**—Same data as holotype, and collected *in coitu* with it.

**Paratypes.** CONNECTICUT.—New London: June 23, 1917, R. C. Osborn, 2♂, OSU.

ILLINOIS.—Algonquin: May 20, 1906, W. A. Nason, 5♂, 2♀, INHS; May 29, 1909, 1♀, INHS. Antioch; Channel lake: June 5, 1919, T. H. Frison, 2♂, 2♀, INHS; May 16, 1936, Ross & Mohr, 2♂, 9♀, INHS. Near Cooperstown, Illinois river: May 20, 1932, Ross & Mohr, 1♂, INHS. Dubois: April 24, 1914, Creek valley, 5♂, 7♀, INHS. Fox Lake, along lake: May 15, 1936, Ross & Mohr, 214♂, 60♀, INHS; May 28, 1936, Ross, 2♂, 10♀, INHS; May 28, 1936, Ross, 2♂, INHS. Glenn Ellyn: May 30, 1908, W. J. Gerhard, 2♂, FM; 1♂, INHS. Grays lake: May 26, 1936, Ross, 3♂, 7♀, INHS. Havana, Illinois river: June 3, 1933, Mohr, 1♂, INHS; May 4, 1895, Hart, 1♂, 1♀, INHS; May 8, 1932, Mohr, 1♂, 8♀, INHS; May, 1895, 1♀, INHS; May 21, 1895, 2♀, INHS; May 21, 1932, Ross & Mohr, 3♂, 8♀, INHS; April 27–30, 1896, C. A. Hart, 2♂, 3♀, INHS. Henry, Lake Senachwine: May 30, 1932, D. H. Thompson, 1♂, 3♀, INHS. Kankakee: June 6, 1935, Ross & Mohr, 1♂, INHS. Lake Forest: May 1905, J. G. Needham, 1♂, 1♀, cu. Meredithia, Illinois river: May 15, 1934, Frison & Mohr, 2♂, 3♀, INHS. Paris: 1931, 1♂, INHS. Pistakee lake: June 12, 1936, 1♂, 1♀, INHS. Rockford: W. Bebb, 1♂, INHS; June 10, 1897, 1♀, INHS. Rock Island, near Rock river: 1863, Walsh, 1♀, MCZ; 1♀, INHS; May 18, 1934, Ross & Mohr, 1♀, INHS; Walsh, 1♀, MCZ. South Chicago, Calumet river: June 9, 1880, 3♀, INHS. Wilmington, Kankakee river: May 17, 1935, H. H. Ross, 1♂, INHS.

INDIANA.—Wolf lake: May 26, 1912, A. B. Wolcott, 3♂, 1♀, FM; 2♂, INHS.

KENTUCKY.—Near Mammoth Cave: May 2, 1874, J. G. S., 1♂, MCZ; 1♂, INHS.

MASSACHUSETTS.—Cambridge: May 28, 1900, S. Henshaw, 2♂, MCZ; 1♂, KAS. Framingham: May 23, 1930, C. A. Frost, 1♂, INHS. Haverill: June 7, 1866, 1♀, MCZ. Minot county: June 10, 1871, Sharon, 2♂, 1♀, MCZ. Holliston: May, 3♂, MCZ. Wellesley: May 1900, A. P. Morse, 8♂, 3♀, MCZ.

MICHIGAN.—Ann Arbor, Washtenaw county: May 22, 1919, F. M. Gaige, 1♂, MMZ. Bryant

bog: July 12, 1924, H. B. Hungerford, 1♀, KU. Cedarville: June 1929, 1♂, CM. Cheboygan county: July 4 and 24, 1935, D. S. Shetter, 1♂, 1♀, MMZ. Clinton along Raisin river: May 19, 1936, Frison & Ross, 1♂, INHS. Detroit: June 1874, 1♂, 4♀, MCZ. Douglas lake: July 3, 1927, L. K. Gloyd, 3♂, KAS; July 8, 1929, H. B. Hungerford, 5♀, KU; 2♀, INHS; July 20, 1926, H. B. Hungerford, 2♀, KU; June 6, 1925, Charles Martin, 1♂, 1♀, KU; 1♂, 1♀, INHS; June 22-25, 1926, Charles Martin, 3♀, KU; June 25, 1928, Charles Martin, 1♀, KU. Fontenalis Run, Burt lake: July 7, 1926, H. B. Hungerford, 1♂, INHS; 1♀, KU. Houghton lake: June 15-18, 1935, T. H. Frison, 1 mating pair, 188♂, 165♀, INHS. Mill lake, Washtenaw county: May 24, 1919, R. F. Hussey, 1♂ MMZ. Mio, along Au Sable river: May 21, 1936, Frison & Ross, 6♂, 1♀, INHS. Portage lake, Washtenaw county: May 30, 1905, N. A. Wood, 8♂, 3♀, MMZ.

MINNESOTA.—Bemiji: June 19, 1932, J. Karlovich, 2♂, INHS. Frontenac, shore of Lake Pepin: May 25, 1930, W. C. Stehr, 5♂, 1♀, UM; 2♂, 1♀, INHS; May 29, 1930, C. E. Mickel, 2♂, 2♀, UM; May 22, 1932, Theodore Olson, 8♀, UM; 2♀, INHS. Goodhue county: May 25, 1930, Carl T. Schmidt, 6♂, UM. Hennepin county: May 30, 1921, A. T. Hertig, 2♀, UM. Lake Superior: 1♂, 1♀, UM. Minneapolis: June 7, 1916, 1♂, INHS. Ramsey county, Lake Johanna: May 17, 1922, Wm. E. Hoffman, 2♀, UM; June 17, 1920, H. H. Knight, 1♂, UM. Red Lake county: June 12, 1920, Jonson, 1♀, UM. Staples: June 22, 1924, C. B. Philip, 2♀, UM.

NEW ENGLAND.—A. Agassiz, 1♀, INHS.

NEW JERSEY.—Lakehurst: May 24, 1914, R. C. Osborn, 1♂, OSU. Lake Hopatcong: May 30, 2♂, 1♀, AM. Newfoundland: May, R. C. Osburn, 1♀, OSU.

NEW YORK.—Nepperhan: May 27, 1905, 2♂, CU; 1♂, INHS. Mosholu: 6♂, 4♀, AM; 1♂, 1♀, INHS.

OHIO.—Sandusky, Cedar Point: June 22, 1913, 2♂, 1♀, OSU; June 20, 1912, 1♂, OSU; 1♂, CU.

ONTARIO.—Honey Harbor: June 4 and 6, 1932, G. S. Walley, 2♂, 1♀, CNM; Ottawa West: June 21, 1920, C. B. Hutchings, 1♀, CNM. Point Pelee: June 8, 1925, G. S. Walley, 4♂, 1♀, CNM; 2♂, 1♀, INHS. June 1, island, 1♂, 1♀, CNM. Rondeau park: June 13, 1929, G. S. Walley, 1♂, 1♀, CNM.

NEW BRUNSWICK.—Frederickton: 192-, 1♀, CNM. Greys Mills: June 1, 1921, R. P. G., 2♀, CNM.

PENNSYLVANIA.—Huntsville: May 23, 1918, M. W. Eddy, 1♂, KAS. Mt. Pocono: June 9, 1906, A. S. Calvert, 1♀, ANS. Poyntelle: June 17, 1904, 1♂, ANS. Wilkes Barre: May 1918, J. N. Knull, 1♂, MCZ, 1♂, INHS.

QUEBEC.—Knowlton: June 11, 1930, L. J. Milne, 3♂, 60♀, CNM; 1♂, 4♀, INHS.

WISCONSIN.—Chetek: June 6, 1925, 1♀, UM. Sawyer, Plum lake: June 20, 1931, Orlando Park, 1♂, 2♀, INHS. Delavan: April 27, 1916, G. A. Chandler, 1♂, UW. Madison: June 9, 1931, 1♂, INHS; June 10, 1932, 2♀, UW; June 1, 1912, 1♂, UW; June 13, 1♂, UW; June 6,

1927, 1♀, INHS; 1911, 1♂, INHS; 1914, 1♀, UW. Sturgeon Bay: June 7, 1929, A. Granovsky, 1♀, UW. Trout lake: May 6, 1934, H. L. Chada, 1♂, UW.

### *Sialis rotunda* Banks

*Sialis rotunda* Banks (1920, p. 327).

**MALE.**—Length 12 mm. Color as for *vagans*, p. 76. General structure very similar to *vagans* with the following radical difference: head between eyes raised, forming a ridge bearing a blunt point surmounted by a conspicuous, close tuft of black setae, fig. 43; middle of clypeus with a similar tuft of setae.

Abdomen and genitalia as in figs. 13 and 24. Ninth sternite produced into a large flap, somewhat orbicular, clothed with long setae. Lateral plates long, the apical portion narrower than the base, the apical margin truncate or emarginate in the middle; in the middle of the basal portion there is a small, rounded protuberance surmounted by a conspicuous group of setae, fig. 24a. Genital plate large and wide; the genital hooks arising at right angles to the apical margin, slender, gracefully curved and touching at base and apex; the apical margin of the plate upturned to form a thin, extensive lamella along the entire apex of the plate. Terminal plate, fig. 25b, flat and triangular with a narrow notch dividing the tip.

**FEMALE.**—Length 14 mm. Color as for the male. Head, fig. 44, lacking the prominent frontal horn but with a low but distinct elevation between antennae above clypeus. Center of this hump and clypeus each with a small cluster of dark setae.

Abdomen and genitalia as in fig. 55. Seventh segment rectangular. Eighth fairly small, angulate and produced posteriorly, mesal depression oval and large. Basal portion of segment semimembranous, apex strongly sclerotized and clothed with fairly short setae. Bursa copulatrix entirely amorphous.

**Lectotype, male, by present designation.**—Bon Accord, B. C.: May 20, type #10845, MCZ.

**Lectoallotype, female.**—Same data as lectotype.

BRITISH COLUMBIA.—Agassiz: April 4 to May 27, 4♂, 3♀, CNM; 3♂, 1♀, INHS. Bear Lake: July 20, 1903, R. P. Currie, 2♂, NM; 1♂, INHS. Cultus lake, Chilliwack: June 5, 1929, H. H. Ross, 1♂, INHS.

OREGON.—Alsea Mt.: May 3, 1936, R. G. Rosentiel, OAC. Blodgett: June 29, 1927, Darlington, 1♂, MCZ. Cannon Beach: June 14, 1927, E. C. Van Dyke, 1♀, INHS. Corvallis: Mar. 29, to July 6, 12♂, 13♀, OAC; 6♂, 6♀,

INHS. Crater lake, 7000 feet elevation: July 18, 1922, E. C. Van Dyke, 1♂, CAS. East lake: July 8, 1933, R. E. Dimick, 1♀, OAC; 1♀, INHS. Independence: June 8, 1934, N. P. Larson, 1♂, 1♀, OAC. Lacombe, South Fork Crabtree creek: March 21, 1934, Gray & Edwards, 7♂, 3♀, OAC; 5♂, 2♀, INHS; Apr. 10, 1936, OAC. Lebanon, Santiam river: March 21, 1934, R. E. Dimick, 1♂, OAC. Marshfield: March 22, 1931, 1♀, INHS. Mt. Hood: July 1, 1927, Darlington, 1♂, 1♀, MCZ. Mt. Jefferson, 3000 feet elevation: July 1907, J. C. Bridwell, 2♀, INHS. Olney: June 15, 1925, E. C. Van Dyke, 1♀, CAS. Portland: 1927, E. Walley Jones, 1♀, UM. Scott lake, Three Sisters, 4650 feet elevation: July 17, 1927, Scullen, 1♂, OAC; July 12, 1936, R. E. Rieder, OAC. Slide lake, Grant county, 7200 feet elevation: July 16, 1936, H. A. Scullen, 1♂, OAC. Strawberry lake, Grant county, 6400 feet elevation: July 17, 1936, H. A. Scullen, 2♀, OAC; 1♂, 1♀, INHS. Valsetz lake: April 5, 1934, J. Schuh, 9♂, 2♀, OAC; 5♂, 2♀, INHS. Wauhink lake, Lane county: May 19, 1933, R. E. Dimick, 2♂, 1♀, OAC; 2♂, INHS.

WASHINGTON.—Bellingham: June 8, 1932, 1♀, OAC. Seattle: June 19, 1920, E. C. Van Dyke, 1♀, CAS.

### *Sialis nevadensis* Davis

*Sialis nevadensis* Davis (1903, p. 450).

*Sialis morrisoni* Davis (1903, p. 450).

**MALE.**—Length 15 mm. Black with the following exceptions: head usually with an orange band covering lateral area of head and posterior half of vertex, and legs sometimes partly or entirely suffused with reddish. Wings dark brown, almost black.

**GENERAL STRUCTURE.**—Head and prothorax dull with scattered shagreening, sometimes shining; front and adjacent part of vertex evenly concave. Front wing with eight or 10 accessory cross-veins, remainder of venation normal for genus.

Abdomen and genitalia as in figs. 15 and 27. Ninth sternite produced into a large flap rounded at apex and clothed with long setae. Lateral plates long, with a fingerlike lobe on mesal side at base, fig. 27a; apex armed with a stout and sharp tooth curving mesad. Genital plate small, fairly high, and forming a stubby, sharp tooth on meson; its anterior face membranous, bisected on meson by a linear sclerotized strip. Terminal plate produced at apex into a pair of divergent arms; the inner margin of these is membranous, swelling in treated specimens as illustrated, but in dry specimens sometimes collapsing into a narrow, cylindrical structure.

**FEMALE.**—Length 18 mm. Color and general structure as in male, except that the head is usually shining and impunctate.

Abdomen and genitalia as in figs. 61 to 63. Seventh and eighth sternites heavily sclerotized, clothed with moderately long setae. Seventh sternite almost as long as wide, apical margin sinuate and produced on the meson. Eighth sternite, fig. 63, rectangular, divided on the meson for two-thirds its length by a narrow, deep fissure, forming almost quadrate halves. Tip of bursa copulatrix well sclerotized, figs. 61 and 62, and bearing a large knob.

**Types, male and female.**—Reno, Nev.: NM. The male has the genitalia showing to allow certain diagnosis.

**Paratypes.** NEVADA.—RENO: 2♂, 1♀, MCZ.

The type of *morrisoni* is a female from Reno, Nev., which shows the characteristic genital plate, MCZ.

CALIFORNIA. — Carrville, Trinity county, 2400–2500 feet elevation: June 7–9, 1935, E. C. Van Dyke, 1♂, 2♀, CAS; 1♀, INHS. Meadow valley, Plumas county, 3500–4000 feet elevation: June 10, 1934, E. C. Van Dyke, 1♂, CAS; 1♂, INHS. Mt. Lassen, 7000 feet elevation: July 14, 1935, E. P. Van Duzee, 1♂, CAS. Mt. Shasta: June 23, 1914, 1♂, INHS; 1♀, CU.

### *Sialis vagans*—NEW SPECIES

**MALE.**—Length 11 mm. Black with only the usual marks on head yellowish. Wings almost black, sometimes with apical half or more almost hyaline, giving the wing a banded appearance.

**GENERAL STRUCTURE.**—Head dull with dense shagreening, front sloping to clypeus. Vertex slightly concave along meson. Pronotum shagreened. Front wings with about 10 accessory cross-veins, radius 2 with two or three branches.

Abdomen and genitalia as in figs. 11 and 23. Ninth sternite forming a large flap covering the genitalia when folded in repose; apical margin rounded and very slightly notched on the meson; covered with fairly sparse, long setae. Lateral plates broad at base, tapering to a bluntly rounded apex, clothed with short setae. Genital plate broad, forming a wide collar in front of the terminal plate; produced at apex into a closely appressed pair of short, wide processes which are bent forward at their extremity to form a small "beak," fig. 23a. Terminal plate flat and triangular, the apex forming a small knob notched slightly on the meson, fig. 23b.

**FEMALE.**—Length 12 mm. Color and general structure identical with male.

Abdomen and genitalia as in fig. 57. Seventh sternite rectangular, its apical

margin gently rounded. Eighth sternite narrow, with a deep median groove, the two lateral areas raised into two ovate lobes clothed with moderately long setae. Ninth sternite membranous and almost transverse, the angle it forms on the meson very wide. Bursa copulatrix amorphous and membranous.

**Holotype, male.**—Columbia City, Ind., along Eel river: May 19, 1936, Frison & Ross, INHS.

**Allotype, female.**—Same data as holotype.

**Paratypes.** ILLINOIS.—Easton, central ditch: May 1, 1914, 1♂, INHS. Palos Park: June 3, 1934, W. J. Gerhard, 1♂, INHS; 1♀, FM. Spring Grove, along Nippersink creek: May 14, 1936, Ross & Mohr, 8♂, 2♀, INHS.

INDIANA.—19♂, 18♀, same data as holotype.

MAINE.—Norway: S. J. Smith, 3♂, MCZ (two are paratypes of *aequalis*). Waldoboro: May 28 to June 5, 1902, J. H. Lovell, 4♂, 1♀, CU; 1♂, INHS.

MASSACHUSETTS.—Boston: 1♂, AM; 2♂, INHS. Forest Hills: May 14, 1881, T. Henshaw, 1♂, MCZ. Holliston: June 5, N. Banks, 1♂, MCZ. Wellesley: May 11, 1911, A. P. Morse, 1♂, MCZ.

MICHIGAN.—Big Rapids, along Muskegon river: May 22, 1936, Frison & Ross, 1♀, INHS. Breedsville: June 1932, Nettie Fuller, 1♂, 1♀, NM. Bronson, along Prairie river: May 19, 1936, Frison & Ross, 6♂, 2♀, INHS. Goodrich, along Thread river: May 20, 1936, Frison & Ross, 5♂, INHS. Grayling, along Manistee river: May 22, 1936, Frison & Ross, 1♂, 4♀, INHS. Hale, along Au Gres river: May 21, 1936, Frison & Ross, 6♂, 1♀, INHS. Lovells along Au Sable river: May 22, 1936, Frison & Ross, 1♂, 1♀, INHS; May 24, 1936, J. W. Leonard, 4♂, MMZ. Vassar, along branch of Cass river: May 20, 1936, Frison & Ross, 4♂, 2♀, INHS. Whittemore, along Johnson creek: May 21, 1936, Frison & Ross, 1♂, INHS. Ypsilanti township, Washtenaw county: May 19, 1918, M. H. Hatch, 1♂, MMZ.

NEW BRUNSWICK.—Frederickton: 192-, 3♂, CNM; 2♂, INHS.

NEW HAMPSHIRE.—Durham: Weed & Fiske, 2♂, CU; 2♂, INHS.

NEW JERSEY.—Lakehurst: May 24, 1914, R. C. Osburn, 1♂, AM; 1♂, INHS; 3♂, OSU; May 31, 1912, 1♂, INHS.

NEW YORK.—New York: July 19, 1902, R. C. Osburn, 1♂, INHS.

NOVA SCOTIA.—Greene county: June 22, 1921, 1♂, MCZ.

ONTARIO.—Algonquin Park: June 18, 1922, J. McDunnough, 1♂, CNM; 1♂, INHS. Lake of Bays: June 22, 1920, J. McDunnough, 1♂, INHS. St. Davids: June 11, 1926, G. S. Walley, 1♂, CNM. Waubamic: July 10, 1915, H. S. Parish, 1♂, CU.

PENNSYLVANIA.—May 19, 1♂, ANS. West Chester: May 24, 1919, 1♂, CU.

QUEBEC.—Kazubazua: June 7-10, 1927, J. McDunnough, 1♂, CNM. Knowlton: July 21, 1929, L. J. Milne, 1♀, CNM; June 10, 1930, L. J. Milne, 2♂, 2♀, CNM; June 7, 1♂, INHS. South Bolton: June 16, 1928, J. A. Adams, 1♂, CNM.

WISCONSIN.—Spooner, along Namakagon river: June 5-6, 1936, Frison & Ross, 2♂, INHS.

### *Sialis aequalis* Banks

*Sialis aequalis* Banks (1920, p. 326).

**MALE.**—Size, color and general structure similar to *vagans*. Differs only in details of genitalia, figs. 12 and 25, as follows: lateral plate slightly more pointed, the apex upturned, short and subconical; genital plate with a pair of pennantlike membranous flaps attached to sides at base: apical processes of genital plate long and slender, fig. 25a, the tip curved over almost at right angles to remainder of process; terminal plate large, flat and wide, fig. 25b, produced at apex into a pair of wide, remote lobes.

**FEMALE.**—Practically identical with that of *vagans*.

**Lectotype, male, by present designation.**—Falls Church, Va.: April 25, Nathan Banks, type #10843, MCZ.

MARYLAND.—Cabin John bridge: April 28, 1901, E. A. Schwartz, 1♂, NM.

NEW JERSEY.—Jamesburg: April 30, 1911, 1♂, AM.

PENNSYLVANIA.—Lansdowne, Delaware county, in woods: April 30, 1900, 1♂, ANS.

VIRGINIA.—Arlington: Ashmead, 1♂, NM; 1♂, INHS. Falls Church: April 13, 1♂, MCZ; May 25, N. Banks (cotype) 1♂, INHS. Vienna: April 18, 1915, W. L. McAtee, 3♂, 1♀, NM; 2♂, INHS.

NORTH CAROLINA.—Morganton: 1877, Morrison, 1♂, KAS.

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## II. Descriptions of Plecoptera

### with Special Reference to the Illinois Species

T. H. FRISON

#### RESULTS FROM NEW MATERIAL

SINCE publication of "The Stoneflies, or Plecoptera, of Illinois" (Frison 1935a), some effort has been expended to fill gaps in our knowledge which existed at that time. Particularly important in furthering our information was the discovery of an abundance of certain species of stonefly nymphs in the White river of Indiana, at a place not far from the Illinois boundary line. The collecting of this material and its subsequent rearing at Urbana has made possible (1) specific determination of three different nymphs previously named only to genera, (2) recognition of the previously unknown female of *Hydroperla varians* (Walsh), and (3) recognition of a new species of *Acroneuria*. These specific placements bring the total of Illinois stoneflies to 38, with the certainty that two additional species will be added by future studies, one a questionable identification of a female *Capnia* as *vernalis* Newport and the other an *Isoperla* represented as yet by a single nymph not placeable to species.

In addition to securing material of special interest to our Illinois studies, the SURVEY has been fortunate also in having material sent from various places in North America for determination. Most of these specimens have belonged to species previously described or comparatively well known. Some, however, have been found to be new to science and their description is presented. Others, too, are so little known to entomologists to date as to warrant the description of a previously unknown sex and additional comments pertaining to distribution or matters of nomenclature.

The material upon which this paper is based has been obtained in part by the field work of various SURVEY entomologists and by the donation or loan of material from the following sources: G. F. Knowlton, Utah State Agricultural College, Logan, Utah; J. W. Leonard, Institute of Fisheries Research, Ann Arbor, Mich.; D. C. Mote and R. E. Dimick, Oregon State Agricultural College, Corvallis, Ore.; W. E. Ricker, Biological Board of

Canada, Vedder Crossing, B. C.; and H. B. Mills, Montana State College, Bozeman, Mont.

I am especially indebted to Dr. Carl O. Mohr, associate entomologist with the SURVEY, for the many drawings.

All holotypes, allotypes and part of the paratypes of the species described in this paper are deposited in the collection of the ILLINOIS NATURAL HISTORY SURVEY. Paratypes of some of the species collected in Oregon are deposited in the collection of the Oregon State Agricultural College, Corvallis.

#### ADDITIONS TO THE ILLINOIS PLECOPTERA<sup>1</sup>

##### *Acroneuria evoluta* Klapalek

*Acroneuria evoluta* Klapalek (1909, p. 245). Original description.

*Acroneuria* sp. a, Frison (1935a, p. 405). Nymphal description and illustration.

Among the series of stonefly nymphs found in the White river near Rogers and Petersburg, Ind., in 1936 were the nymphs of a species of *Acroneuria* which I have listed as "sp. a" in my Illinois report (1935a) on the basis of exuviae found at Keithsburg, Ill. The rearing of males and females from these nymphs confirmed my previous opinion that this was a different species from our other Illinois stoneflies.

In 1935 I considered *evoluta* Klapalek (1909) as a synonym of *arida* Hagen (1861), based mainly upon Klapalek's drawing which certainly resembles *arida*, and failure to find two species in Illinois with female subgenital plates of so similar appearance, at least in line drawings. A study of specimens named *evoluta* in the Cornell University collection, kindly placed at my disposal by Professor P. W. Claassen, revealed that the Kansas material so named was similar to the adults reared from nymphs of my "sp. a." Although I am still doubtful whether the female type of *evoluta* Klapalek from New Orleans is the same as my material now called *evoluta*, I am using this specific name for this species on the basis of its being used by Needham & Claassen (1925) for similar specimens from Kansas. If future critical studies of the type of *evoluta* do reveal it to be the same as *arida*, and not as used here, the species here recorded will require a new name.

<sup>1</sup> For previous listing, see Frison (1935a, p. 311).

As just mentioned, the nymph of what I am now calling *evoluta* was described in my Illinois report (1935a) as "*Acroneuria* sp. a." Illustrations of its important structural features in the adults are now presented, fig. 64. In my key to the adults of *Acroneuria* (Frison 1935a, p. 390) the

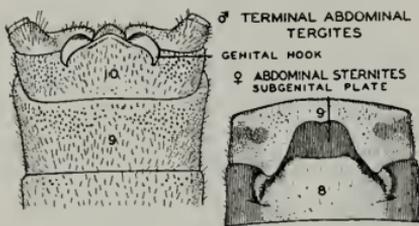


Fig. 64.—*Acroneuria evoluta*.

male and female will both run to *arida*. The subgenital plate of *arida* is wider throughout and its apical portion is not depressed or declivitous as it is in what I am now calling *evoluta*. Also, the subgenital plate of *arida* is more constricted on its lateral margins. In the males *evoluta* averages larger and the tips of the genital hooks seem to be slightly more curved inwards at their tips but to date I have been unable to find good concise characters for separating *evoluta* and *arida*. The nymphs are readily separated upon the basis of their color pattern as noted in the previous descriptions and key.

ILLINOIS.—Alton: June 26, 1934, DeLong & Ross, 1♂, 1♀. Homer park: June 30, 1927, Frison & Glasgow, 1♀, at light. Keithsburg, Mississippi river: June 14, 1931, Frison & Mohr, 2 exuv.; June 9, 1932, Ross & Mohr, 2 exuv. Oakwood, Salt Fork river: July 7, 1936, Mohr & Burks, 2♀, at light. Topeka, Quiver creek: July 9, 1936, Mohr & Burks, 1 nymph.

A series of males and females of this species was reared at Urbana from nymphs collected in the White river at Rogers, Ind., June 1936.

##### *Acroneuria perplexa*—NEW SPECIES

MALE.—General color light to dark brown. Head, fig. 65, with a yellowish brown transverse area extending between compound eyes across ocellar region, most of area anterior and posterior to this transverse patch a dark brown. Pronotum light brown, with lateral margins and raised rugosities or embossings much darker. Legs mostly light brown, with a small conspicuous black band at tip of each

femur and at base of each tibia. Antennae and cerci brown.

Head scarcely wider than pronotum; three ocelli arranged in a triangle, and lateral ocelli closer together than to median ocellus and slightly closer to each other than to inner margins of compound eyes.

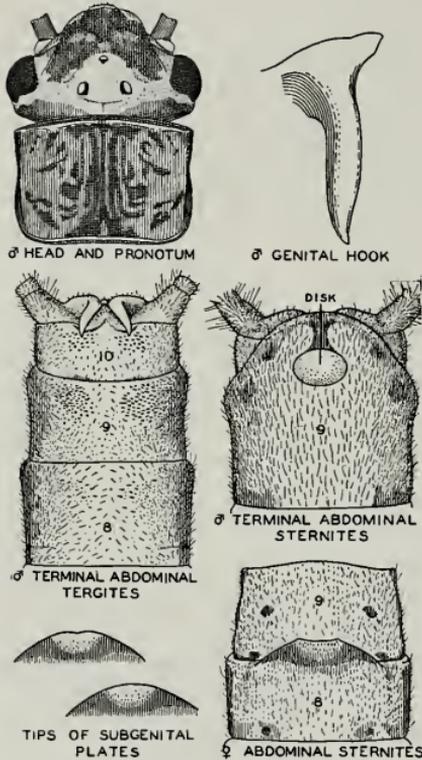


Fig. 65.—*Acroneuria perplexa*.

Pronotum, fig. 65, approximately quadrangular, much broader than long, hind angles rounded, front angles rather sharp, rugosities arranged in a definite pattern and corresponding well with color pattern in a nymph; median longitudinal depressed area narrow.

Wings long, extending well beyond tip of abdomen; membrane hyaline with veins dark brown; venation somewhat variable in regard to numbers of cross-veins but otherwise essentially typical for the genus, several cross-veins in forewing in area beyond the cord, and veins 9-11 of hind wing reaching margin of wings variable.

Abdomen, fig. 65, without special structures except for terminal segments. Tenth

tergite not cleft; genital hooks prominent, recurved upwards, narrow for most of length and tapering to a point; small spinulae numerous on ninth and tenth tergites; ninth sternite with a small, slightly transversely oval padlike disk.

Two groups of gill remnants are on the side of each thoracic segment and on upper part (usually concealed) of subanal lobes, thus correlating with gills of nymph.

Length to tip of wings 27 mm.; length to tip of abdomen 18 mm.

**FEMALE.**—In general very similar to the male as here described, but somewhat larger. Differs from male in important characters as follows: eighth abdominal sternite, fig. 65, with posterior margin somewhat produced over ninth sternite, in most specimens with posterior margin of subgenital plate rounded but sometimes slightly truncate or notched.

**Holotype, female.**—Petersburg, Ind., White river: June 16, 1936, Mohr & Burks, reared from nymph.

**Allotype, male.**—Petersburg, Ind., White river: June 8, 1936, Frison & Mohr, reared from nymph.

**Paratypes.** ILLINOIS.—Shawneetown, at light: June 21, 1927, Frison & R. Glasgow, 1♀.

INDIANA.—Rogers, White river: May 26-27, 1936, Frison, Ross & Mohr, 3♀, reared. Petersburg, White river: June 4-24, 1936, Frison, Mohr & Burks, 1♂, 4♀, reared.

OHIO.—Ironton: June 1, 1899, 1♀.

PENNSYLVANIA.—Philadelphia, at light: June 15, F. Haimbach, 1♀.

WASHINGTON, D. C.: 1♀.

The nymph of this species has not previously been recognized and therefore its description is now presented. Most of our adult material has been obtained by rearing and therefore the association of the adult with nymph and males with females rests upon a reliable foundation.

**NYMPH.**—General color of head, thorax and abdomen pale whitish yellow with dark markings as in illustration, fig. 66. The most important dark markings are the broad patch on head, pattern of pronotum and the band on basal half of each abdominal tergite. The light-colored W-shaped mark anterior to median ocellus and two light spots associated with each lateral ocellus on the dark part of the head are also prominent. Cerci and antennae pale whitish yellow.

Head with three ocelli arranged in a triangle, lateral ocelli much closer to each other than to median ocellus. No occipital

ridge. Labium and maxillae approximately the same as described for other members of the genus.

Pronotum about twice as wide as long, all angles well rounded. Legs, tarsal segments and cerci approximately the same as described for other species of the genus.

Two pairs of gill tufts on each thoracic segment placed as in *Acroneuria internata* (Frison 1935a, fig. 266). No submental gills. Caudal gills at apex of abdomen are present.

Approximately mature specimens with a body length, exclusive of appendages, of about 22 mm.

**Nymphs and exuviae.**—All from the White river, near Rogers, Portersville and Petersburg, Ind., collected from one to several weeks prior to emergence of reared adults recorded above.

This species has been described as new with full knowledge that a few specimens of the same species in other collections have been determined in the past as *pennsylvanica* (Rambur). This specific name has been applied to so many different species, however, and so much doubt exists regarding the important structural details of the type, if still in existence, that clarity and certainty in diagnostic work cannot be obtained at the present time by the use of this old name. It has seemed best, therefore, in view of the fact that my specimens of male, female and nymph are reliably associated upon the basis of reared material, to name my specimens as new. If ever the type of *pennsylvanica* Rambur is definitely proved to be the same as the species I am now naming, then my name can be shelved in synonymy. Meanwhile the present species will not have been confused with other forms going under the same name.

In my Illinois report (Frison 1935a, p. 395) a single adult female specimen of this species from Shawneetown, Ill., June 21, 1927, was erroneously recorded as *abnormis*. Due at the time to the lack of additional Illinois material and knowledge of the nymph, the observable difference in the subgenital plate was considered as an instance of unusual variation. This same specimen, too, was named by Professor P. W. Claassen in 1928 as *pennsylvanica* Rambur, indicating that part or all of his specimens recorded as *pennsylvanica* may be the species here described. Evidently, based upon its rareness in this state, Illinois

may be on the extreme limits of its range.

That some slight variation exists in the shape of the subgenital plate, fig. 65, is evident from my reared specimens. The posterior margin of this plate in most of my specimens is rounded, but in one specimen it is slightly notched, and in another somewhat truncate.

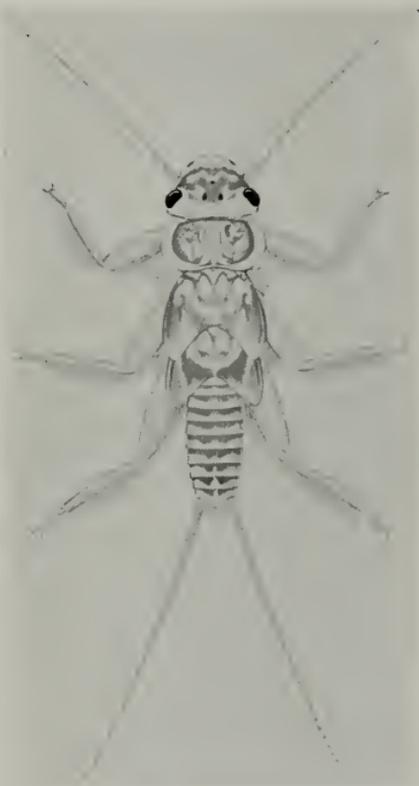


Fig. 66.—Nymph of *Acroneuria perplexa*.

My experience with the identification of *Acroneuria* to date is such as to warrant the statement that the fundamental units or species are not always easy to recognize. In Illinois there are six species as proved by important structural characters, association of reared males and females, kinds of nymphs, etc. Certainty in recognizing these species has come only through the rearing of adults from distinctive nymphs. This suggests that further revision of the genus and description of species should await the association of adults with nymphs by rearings and field work.

**Togoperla kansensis** (Banks)

*Perla kansensis* Banks (1905, p. 56). Original description.

*Togoperla* sp. a, Frison (1935a, p. 414). Nymphal description.

In the report on stoneflies of Illinois (Frison 1935a) a nymph was figured as "*Togoperla* sp. a" based upon several small specimens collected at Alton and Grafton, Ill., on the Mississippi river. At that time

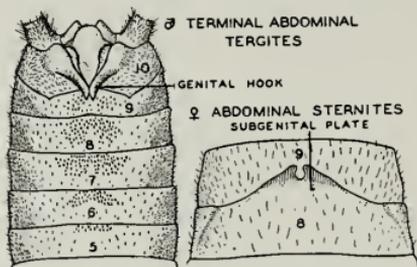


Fig. 67.—*Togoperla kansensis*.

it was stated, "It may be that this is the nymph of *Perla kansensis* Banks which is known from Kansas." Discovery of this nymph in numbers in the White river, Ind., has permitted the rearing of both sexes of the adult and the definite association of this nymph with *kansensis* Banks.

Since illustrations of the adults were not included in my 1935 report, figures of the most important structural features are presented here in fig. 67. The specific placement of this stonefly necessitates a key for separation of the adults of our two Illinois species of this genus as follows:

KEY TO SPECIES OF TOGOPERLA

**Males**

- Eighth abdominal tergite (Frison 1935a, fig. 206) with its posterior margin produced backwards into a definite lobe; genital hooks of tenth tergite with ends rounded. . . . . *media* (Walker)
- Eighth abdominal tergite, fig. 67, without a produced lobe on posterior margin; genital hooks of tenth tergite with ends pointed. . . . . *kansensis* (Banks)

**Females**

- Subgenital plate of eighth abdominal sternite (Frison 1935a, fig. 254) but slightly produced backwards over ninth sternite. . . . . *media* (Walker)
- Subgenital plate of eighth abdominal sternite, fig. 67, considerably produced backwards as a triangularly shaped projection over ninth sternite. . . . . *kansensis* (Banks)

No Illinois records for this species have been obtained in addition to those already

recorded (Frison 1935a). My Indiana records are as follows:

INDIANA.—Petersburg, White river: May 10, 1936, Frison & Mohr, 1♂, reared; June 3-4, 1936, Mohr & Burks, 12♂ nymphs, 13♀ nymphs, 6 small nymphs, 3 exuv.; June 9, 1936, Frison & Mohr, 1♀, reared; June 17-20, 1936, Frison & Mohr, 7♂, reared; June 22-27, 1936, Frison & Mohr, 3♀, reared, 4♂, reared; July 1-6, 1936, Frison & Mohr, 1♂, 3♀, reared, 2♂, reared. Portersville, East Fork river: June 3, 1936, Mohr & Burks, 3♂ nymphs. Rogers, White river: May 13, 1936, Mohr & Burks, 1 small nymph.

**Hydroperla varians** (Walsh)

*Perla varians* Walsh (1863, p. 364). Original description (♂, ♀).

*Hydroperla varians* Frison (1935a, p. 426). Male description and records.

In my previous treatment of the Illinois stoneflies (1935a) I did not have available for illustration the female of this species, and its nymph was unknown. In the original description of *variens* by Walsh the female was recorded but the description of it might well have applied to either of the other two Illinois species of this genus. Recently I have studied a female specimen belonging to the Academy of Natural Sciences of Philadelphia, which was named by Walsh as *variens*, and two specimens, male and female, reared from similar nymphs collected in the White river near Rogers, Ind. This reared female agrees with the female specimen now in the Philadelphia Academy, which was named by Walsh, and therefore establishes the correct association of the male and female of this species in his original description.

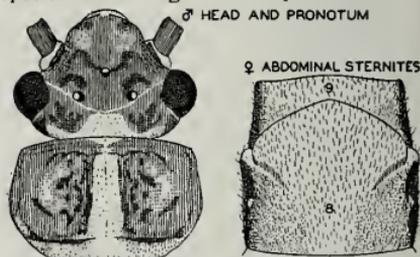


Fig. 68.—*Hydroperla varians*.

The subgenital plate and head, not illustrated in 1935, are shown in fig. 68. *Hydroperla varians* seems to be best distinguished from the females of the other Illinois species (*crobyi* and *harti*) by the subgenital plate covering a much greater area of the ninth sternite (Frison 1935a, figs. 324 and 325).

Since the nymph, fig. 69, has not been previously recognized a description of it is given as follows:

**NYMPH.**—General color of head, thorax and abdomen pale yellowish with brown markings. Prominent of the brown markings are the dark area between ocelli, the dark ring connecting dark area between ocelli and compound eyes, the dark border of pronotum, and pattern of meso- and metathorax. Antennae, legs and cerci pale yellowish.

Head with three ocelli forming a triangle with distance between lateral ocelli longest; lateral ocelli situated about on a line through front margin of compound eyes. No real occipital ridge but posterior margin of the dark ring connecting dark area between ocelli and compound eyes is lined with short stout spinulae. Labium and maxillae practically the same as those of *H. harti* and *H. crosbyi*.

Pronotum about twice as wide as long, all angles well rounded, fringed with short setae and stout spinulae on anterior and posterior margins; marginal groove well developed on the anterior and posterior margins and weakly so on sides. Short stout setae delineating the dark markings on meso- and metathorax.

Legs somewhat flattened, posterior margins of femora, tibiae and tarsi with a fringe of long fine setae.

Abdomen with short stout spinulae very prominently lining posterior borders of tergites and also with scattered spinulae on tergites in addition to short hairs. Cerci long, many segmented, segments progressively longer apically, a longitudinal row of long fine hairs in middle of segments from base to apex.

Submentum with a small fingerlike gill at each outer posterior corner.

Body length, exclusive of appendages, 15 mm.

INDIANA.—Rogers, White river: April 21, 1936, Frison & Mohr, 1 nymph. Portersville, East fork White river: June 3, 1936, Mohr & Burks, exuv. Petersburg, White river: June 3, 1936, Mohr & Burks, exuv. Rogers, White river: April 21 and 30, 1936, Frison & Mohr, exuv.

A revised key for the Illinois nymphs of this genus is as follows:

KEY TO NYMPHS OF HYDROPERLA

1. Dorsal segments of abdomen with basal portions dark and apical portions light



Fig. 69.—Nymph of *Hydroperla varians*.

- so that abdomen appears distinctly transversely banded (Frison 1935a, fig. 329)..... **crosbyi** (N. & C.)
- Dorsal segments of abdomen not thus distinctly banded..... 2
- 2. Dorsum of head with a round open eyelike spot ringed with brown back of epicranial arm between compound eye and lateral ocellus on each side of head; abdominal tergites without brown spots except those associated with stout spinulae..... **variens** (Walsh)
- Dorsum of head with a wide dark transverse band crossing head anterior to lateral ocelli, no open eyelike spots; abdominal tergites with some small dark spots in addition to those associated with stout spinulae..... **harti** Frison

ADDITIONS TO NEARCTIC PLECOPTERA NOT KNOWN IN ILLINOIS

**Nemoura oregonensis** Claassen

*Nemoura oregonensis* Claassen (1923, p. 288). Original description.

This species was originally described from a single male collected "June 21, 1922, Blitzen Valley, Harney county,

Oregon," and has not been recorded since. A series of specimens of this species, including the previously undescribed female, have been recognized among an assortment of material sent to me for determination by entomologists of the Oregon Agricultural College.

**FEMALE.**—Similar in most morphological features to the male. Wings, fig. 70, with the same pattern as for the male. Seventh abdominal sternite, fig. 70, with posterior

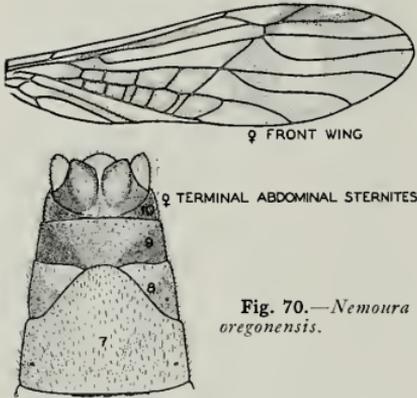


Fig. 70.—*Nemoura oregonensis*.

margin produced bulblike, over eighth sternite. Four fingerlike gill remnants in ventral cervical region.

**Allotype, female.**—Corvallis, Ore., Oak creek: Apr. 13, 1934, E. E. Ball.

**OREGON.**—Corvallis: Apr. 10, 1933, R. E. Dimick, 1♀; Apr. 16, 1931, 1♂; Dixon creek, March 10, 1935, R. E. Dimick, 1♂; Oak creek, March 18, 1934, R. W. Prentiss, 1♀, and March 31, 1934, E. E. Ball, 1♂, and Apr. 7, 1934, E. E. Ball, 1♀. Benton county, Woods creek: Apr. 11, 1936, R. E. Rieder, ♂♂, ♀♀.

#### *Nemoura tuberculata*—NEW SPECIES

**MALE.**—Body and appendages essentially brown with paler intersegmental areas and patches on body; particularly noticeable because of lighter color is the area on head between compound eyes and posterior to ocelli, a tendency for a light median stripe extending longitudinally across dorsal parts of thorax and abdomen, most of legs and venter of body. Length to tip of wings 10 mm.; length of body 6.5 mm.

Head much wider than pronotum. The pronotum broader than long, angles rounded, and with width of anterior margin greater than that of posterior margin. Lateral ocelli slightly closer to compound eyes than to one another, located on a line

with middle of compound eyes, median ocellus located somewhat anterior to a line between front margin of compound eyes. Wings, fig. 71, stained with brown except for clear spots in scattered areas; subcosta ending before cord. Ventral cervical region without gill remnants.

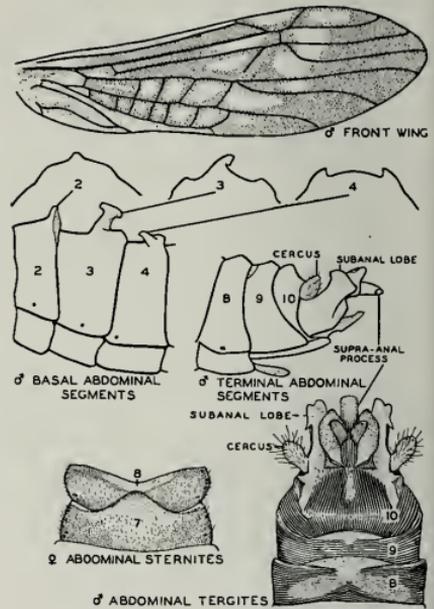


Fig. 71.—*Nemoura tuberculata*.

Abdomen with tergites 2, 3 and 4, fig. 71, with prominent tubercles; tubercle on second tergite small, conical and on median line; one tubercle on third tergite large and bent over at tip, flanked by a smaller hump on each side, the whole with a somewhat asymmetrical arrangement; fourth tergite with two small humps, one each side of median line. Abdominal tergites 5 through 9 without special structures. Tenth tergite modified into two flat plates sloping downwards towards base of supra-anal process. Cerci one-segmented, bulbous and without special structures. Supra-anal process a bluntly tipped pronglike structure bent upwards and backwards between an encasing sheath composed of subanal lobes and two lobes originating each side of base of supra-anal process. Sub-anal lobes well developed, extending backwards and upwards to form a kind of protecting sheath for supra-anal process and flanking lobes.

Ninth abdominal sternite with a well-sclerotized subgenital plate which extends posteriorly somewhat over lower base of subanal lobes and is almost truncate on posterior margin, arising beneath the tip of this plate and extending upwards between subanal lobes to supra-anal process is a fingerlike tongue or projection; a small lobe, slightly longer than broad, at base of subgenital plate.

**FEMALE.**—Similar in most morphological features to the male. Seventh abdominal sternite, fig. 71, with a poorly developed subgenital plate, partly overlapping base of eighth sternite and rounded.

**Holotype, male.**—Rock creek near Philomath, Ore.: March 28, 1935, F. Foley.

**Allotype, female.**—Hillsboro, Ore.: March 19, 1936, Gray & Schuh.

**Paratypes.** OREGON.—Same data as for allotype, 3♂. Corvallis, Dixon creek: March 10, 1935, R. E. Dimick, 2♂.

This species is easily recognized from all other described *Nemoura* known to me by descriptions or specimens because of the extraordinary humps or tubercles on the basal abdominal tergites.

#### *Leuctra forcipata*—NEW SPECIES

**MALE.**—Body and appendages brown. Wings with membrane uniformly light brown, veins but slightly darker, venation practically typical for genus in that there is no cross-vein beyond the tip of subcosta and radial sector originated from the radius apart from media. Second tarsal segment much shorter than either first or third. Length to tip of wings 8 mm.; length of body 6 mm. No gill remnants evident.

Head much wider than pronotum, lateral ocelli about twice as far apart as from inner margin of compound eyes; median ocellus about as far forward from lateral ocelli as distance between the latter; maxillary palpi large.

Pronotum much longer than wide, with a slightly impressed median longitudinal area or stripe which is about one-fifth as wide as pronotum, and some dark embossed markings flanking this stripe.

Abdomen with the first nine segments normal, darkly sclerotized and essentially similar, except that eighth tergite has its middle basal portion more membranous, with result that crescent-shaped anterior margin of ninth tergite is plainly visible. Tenth tergite, fig. 72, partly cleft, supra-anal process small, somewhat fingerlike and

concealed by other structures; subanal lobes modified into a long produced lobe, curving upward beneath cerci; cerci sclerotized, pincher shaped, main upper prong with small tooth at base and tip strongly pointed, main lower prong similarly shaped, tips of two main prongs widely divergent, base of cerci from which prongs project narrow; ninth sternite produced into a short, feebly indented plate.

**FEMALE.**—Similar in most morphological features to the male. Terminal and ab-

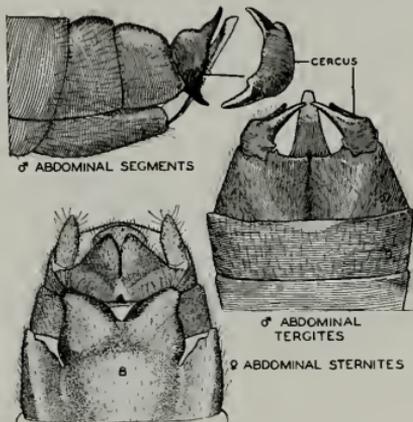


Fig. 72.—*Leuctra forcipata*.

dominal sternites with a well-developed subgenital plate, the lobes of which are widely divergent. Dorsal tergites of abdomen I through 3 darkly sclerotized, through 8 mostly membranous with a median longitudinal darkly sclerotized stripe, ninth and tenth tergites darkly sclerotized.

**Holotype, male.**—Corvallis, Ore.

**Allotype, female.**—Same locality as holotype.

**Paratypes.** OREGON.—Same locality as holotype, 3♂, 1♀. Alsea Mt.: March 18, 1936, J. Schuh, 1♂.

This species is closely related to *L. occidentalis* Banks and to *L. purcellana* Neave. It differs from both in the shape of the cerci. In *purcellana* the cerci have the upper projection or prong truncate and in *occidentalis* the upper prong is much longer than the lower and its base is more elongate.

#### *Eucapnopsis brevicauda* (Claassen)

*Capnia brevicauda* Claassen (1924b, p. 55). Original description.

*Eucapnopsis brevicauda* Neave (1934, p. 5).

This species has had a short but interest-

ing history to date. The original description was based upon females, the male being unknown at the time, and placed in the genus *Capnia*. Needham & Claassen (1925) recognized the short cerci as aberrant for *Capnia* and noted the assignment of *brevicauda* to *Eucapnopsis* Okamoto (1922); the latter, however, they considered a sub-genus.

Since then Neave (1934) has found this species in British Columbia and has de-

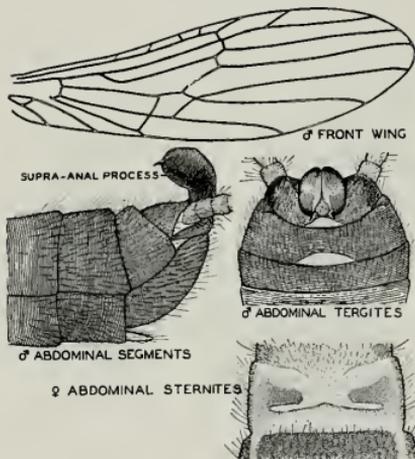


Fig. 73.—*Eucapnopsis brevicuda*.

scribed the previously unknown male. It has a combination of characters which caused him to consider *Eucapnopsis* as a valid genus and with this conclusion the writer is in agreement (1935a).

Illustrations, records and notes pertaining to this species are given here because of its peculiar combination of morphological characters, the likelihood of its being overlooked and redescribed as new because it is not keyed to genus in any present key of North American forms, and the scarcity of information regarding its geographical range. The small elongate lobe on the ninth sternite of the male, fig. 73, is an outstanding character for its separation from *Capnia*. The presence of a cross-vein beyond the tip of the subcosta, which in this instance has real significance, is sufficient to separate it from *Leuctra*. The short cerci, not exceeding six segments in any of the specimens recorded here, contrasts with the one, modified or unmodified, found in *Leuctra*, and the many in *Capnia*. I still

consider my assignment of *Eucapnopsis* to the Leuctridae (1935) as the present best family placement for this genus.

New records are as follows:

OREGON.—Corvallis, Oak creek: March 31, 1934, E. E. Ball, 3♂, 6♀; Apr. 1, 1934, R. Dimick, 1♂, 2♀; Apr. 13, 1934, E. E. Ball, 1♀. Philomath, Rock creek: March 19, 1933, R. Dimick, 6♂, 10♀; March 28, 1935, 1♂, 2♀; Greasy creek, Apr. 1, 1936, V. E. Starr, 1♂. King's Valley, tributary of Luckimute river: May 11, 1933, Prentiss & Dimick, 1♀.

#### *Capnia distincta*—NEW SPECIES

MALE.—Body and appendages brown to black. Wings abbreviated and extending only to base of abdomen. Cerci long, many segmented. Length of body 6.5 mm. No gill remnants visible.

Head much wider than pronotum; lateral ocelli about three times as far apart as from inner margins of compound eyes; median ocellus about as far forward from lateral ocelli as distance between them; maxillary palpi less than thickness of basal flagellar segments.

Pronotum slightly wider than long, with a distinct median line, with indistinct embossings.

Abdomen with the first four segments normal or without special structures; beginning with fifth tergite and extending to ninth with a transverse swollen ridge or hump on each tergite, except that membranous cleft of tenth tergite carries forward on middle area of ninth and eighth tergites. Supra-anal process, fig. 74, very

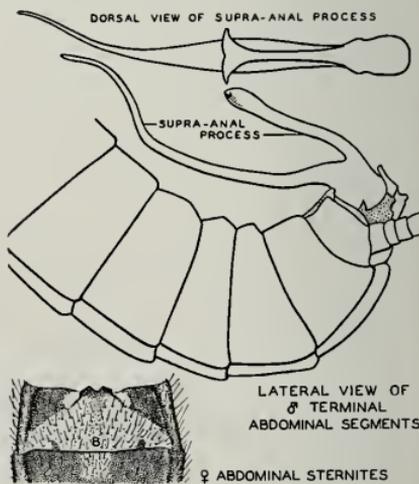


Fig. 74.—*Capnia distincta*.

long, extending about to third segment, divided into two pronglike processes, the upper shorter than the lower and with tip slightly fan shaped, lower prong curving to right of body and tapering to a point. Subanal lobes or plates heavily sclerotized, extending up between bases of cerci as two fused plates with outer upper corners slightly hooked and middle prolonged towards supra-anal process as a fingerlike projection. Ninth sternite without a lobe at base, posterior margin prolonged and slightly recurved upwards to meet subanal lobes.

**FEMALE.**—Similar in most morphological features to the male. Eighth abdominal sternite, fig. 74, forming a subgenital plate, tip darkly sclerotized, basal portion pale or lightly sclerotized, triangular areas in lateral posterior corners of sternite darkly sclerotized, tip of plate distinctly indented. A broad membranous median stripe extends longitudinally across tergites 1 through 7 and slightly onto the basal part of the eighth.

**Holotype, male.**—Hayden Valley, Yellowstone National park, Wyo.: April 4, 1935, H. B. Mills.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—Same data as for holotype, 39.

This is a very distinctive species. It runs in the key to species of the genus *Capnia* in Needham & Claassen (1925) to the couplet keying the species *manitoba* Clsn. and *columbiana* Clsn. It differs markedly from both in the shape of the supra-anal process. Its relationship with *columbiana* is further indicated in the female by character of the subgenital plate but here too it differs markedly.

#### *Capnia excavata* Claassen

*Capnia excavata* Claassen (1924a, p. 47). Original description.

Among a series of specimens of *Capnia* sent to me from Oregon I have recognized this species, originally described by Claassen on the basis of males from California. In addition to extending the known range for this species, this lot of material has revealed what I consider to be the female, hitherto undescribed.



Fig. 75.—*Capnia excavata*.

**FEMALE.**—Similar in most morphological features to the male. Eighth abdominal sternite, fig. 75, with posterior edge slightly projecting backwards in middle portion and evenly sclerotized, a transverse membranous band separating seventh and eighth sternites. A broad membranous median stripe extends longitudinally across tergites 1 up to 9.

**Allotype, female.**—Alsea Mt., Ore.: March 16, 1936, K. Gray.

**OREGON.**—Alsea Mt.: March 16, K. Gray, 1♂, 5♀; March 18, 1936, J. Schuh, 1♀. Corvallis, Oak creek: Jan. 24, 1934, J. Roaf, 3♂, 2♀.

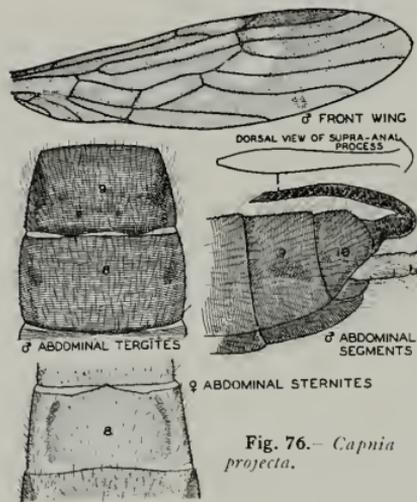


Fig. 76.—*Capnia projecta*.

#### *Capnia projecta*—NEW SPECIES

**MALE.**—Body and appendages brown. Wings, fig. 76, with membrane mostly light brown, except that portions of cells in middle area of wing are more hyaline, forming spots; veins dark brown; venation in essentials typical for genus. Length to tip of wings 7 mm.; length of body 4.5 mm. No gill remnants evident.

Head much wider than pronotum; lateral ocelli about three times as far apart as from inner margin of compound eyes; median ocellus about as far forward from lateral ocelli as distance between them; maxillary palpi less than thickness of basal flagellar segments.

Pronotum scarcely longer than wide, with a feebly impressed median longitudinal area or stripe which is about one-sixth as wide as pronotum, some indistinct embossings flanking impressed stripe.

Abdomen with the first nine segments normal or without special structures except that median area of first few basal tergites is less sclerotized. Tenth tergite cleft; supra-anal process, fig. 76, recurved back over tergites 9 and 10, slightly enlarged before pointed tip, extending to posterior margin of eighth tergite; eighth and ninth tergites without any special structures or tubercles; in a few specimens median area of ninth tergite is somewhat membranous. Subanal lobes or plates small, somewhat transverse, with median posterior margin produced slightly upward. Ninth sternite without a ventral lobe at base, posterior margin produced and rounded behind. Cerci many segmented.

**FEMALE.**—Similar in most morphological features to the male. Eighth abdominal sternite, fig. 76, with posterior margin in middle produced into a small point; seventh and eighth sternites otherwise unmodified and separated by membranous area. A broad membranous median stripe extends longitudinally across tergites 1 up to 9.

**Holotype, male.**—Corvallis, Ore., Oak creek: Jan. 24, 1934, J. Roaf.

**Allotype, female.**—Same data as for holotype.

**Paratypes.** OREGON.—Same data as for holotype, 1♂, 2♀. Corvallis: Dec. 23, 1933, A. W. Larson, 1♂, 14♀; March 2, 1937, R. E. Rieder, 1♂; roof of agriculture bldg., Jan. 22, 1934, J. Roaf, 2♂; Feb. 4, 1935, R. W. Prentiss, 1♀; Dixon creek, Jan. 19, 1935, R. W. Prentiss, 3♂, 3♀, and Jan. 23, 1935, R. W. Prentiss, 2♀; Oak creek, Jan. 21, 1936, R. W. Prentiss, 1♀, and Jan. 30, 1935, R. W. Prentiss, 2♀. Alsea, Alsea river: Jan. 5, 1935, R. Dimick, 1♂. Lincoln county, north fork Alsea river: May 2, 1936, R. E. Rieder, 1♀. Philomath, Rock creek: Dec. 2, 1934, R. Dimick, 1♂, 3♀. Benton county, Woods creek: Apr. 11, 1936, R. E. Rieder, 1♀.

In the key to males of the genus *Capnia* by Needham & Claassen (1925) this species will run closest to *gracilaria* Clsn. It differs from the latter in having a much shorter supra-anal process, *gracilaria* having a supra-anal process which reaches to the seventh tergite, whereas in *projecta* the supra-anal process extends only to the posterior margin of the eighth tergite. *Capnia oenone* Neave (1929) is another very closely related species and possibly future studies will show that they are identical, in which case *oenone* will have priority. According to the drawing of Neave the female of *oenone* has a subgenital plate which is not produced, whereas in

the females of *projecta* there is an evident medial projection of the posterior margin, fig. 76, of the eighth abdominal sternite. Both sexes of *projecta* have wings with clear spots in the cells adjacent to the cord, which are not mentioned in the original description or evident in paratypes of *oenone* sent to me by Neave.

#### *Capnia promota*—NEW SPECIES

**MALE.**—Body and appendages brown. Wings in general with membrane rather uniformly light brown, in some specimens darker near veins, area in proximal position

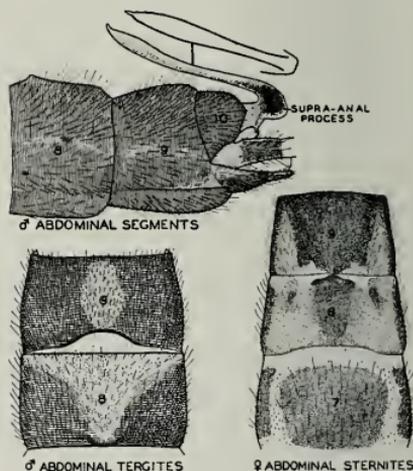


FIG. 77.—*Capnia promota*.

of area beyond costa darkened and usually contrasting with rest of wing membrane; venation in essentials typical for genus, radius where joined by the radial sector somewhat bowed or humped. Length to tips of wings 7-8 mm; length of body 4-5 mm. No gill remnants evident.

Head much wider than pronotum; lateral ocelli about three times as far apart as from inner margin of compound eyes; median ocellus about as far forward from lateral ocelli as distance between them; maxillary palpi less than thickness of basal flagellar segments.

Pronotum slightly wider than long, with a feebly impressed median longitudinal area or stripe which is about one-sixth as wide as pronotum, some indistinct embossings flanking impressed stripe.

Abdomen with the first six segments normal or without special structure; seventh tergite with a somewhat V-shaped

membranous area on posterior margin; eighth, ninth and tenth tergites, fig. 77, with median longitudinal membranous area for reception of supra-anal process, this area on eighth tergite more V-shaped and terminating on anterior margin in a small raised ridge. Supra-anal process elongate, slightly enlarged before pointed tip, recurved back over tergites 8, 9 and 10 and extending about to anterior margin of the eighth. Subanal lobes or plates small, somewhat transverse, with median posterior margin slightly produced upwards. Ninth sternite without a ventral lobe at base, posterior margin produced and rounded behind. Cerci with many segments.

**FEMALE.**—Similar in most morphological features to the male. Eighth abdominal sternite, fig. 77, with middle portion of posterior margin produced into a short projection with its middle part slightly pointed; seventh and eighth sternites separated by a membranous area. A broad membranous median stripe extends longitudinally across tergites 1 up to 9.

**Holotype, male.**—Corvallis, Ore., roof of agriculture bldg.: Jan. 23, 1934, K. Gray & D. Edwards.

**Allotype, female.**—Same data as for holotype.

**Paratypes.** OREGON.—Same data as for holotype, 16♂, 46♀. Same places: Jan. 22, 1934, J. Roaf, 4♀; Jan. 26, 1935, R. Prentiss, 1♂, 18♀; Jan. 30, 1934, 18♂, 10♀, 2 mating pairs. Corvallis, Oak creek: Jan. 1, 1936, 3♂, 6♀; Jan. 15, 1934, Roaf, 1♂, 1♀; Jan. 16, 1935, R. Dimick, 1♀, and R. W. Prentiss, 1♀; Jan. 24, 1934, Roaf, 1♀; Jan. 24, 1935, R. W. Prentiss, 1♂, 4♀; Jan. 30, 1935, R. W. Prentiss, 3♂, 4♀; March 29, 1935, S. Jewett, Jr., 1♀; Apr. 2, 1935, J. Schuh, 1♀. Corvallis: Jan. 23, 1935, R. W. Prentiss, 1♀; Jan. 27, 1933, J. Roaf, 1♀; Jan. 31, 1934, N. P. Larson, 1♂; Feb. 27, 1933, R. Dimick, 1♀; March 15, 1935, J. Schuh, 1♀. Philomath, Rock creek: March 19, 1933, R. Dimick, 15♀. Wrens, Mary's river: March 16, 1935, R. Dimick, 1♂, 2♀; March 19, 1933, R. Dimick, 3♀. King's Valley, tributary of Luckinmute river: May 11, 1933, Prentiss & Dimick, 1♀. Woodburn: Jan. 31, 1935, 1♂. Stayton, Stayton creek: March 20, 1934, R. Dimick, 1♀. Hillsboro: March 19, 1936, Schuh & Gray, 2♂, 3♀.

This species is very closely related to *C. gracilaria* Clsn., described from Manitoba, and to *C. oenone* Neave, described from Alberta. It is not improbable that large series of specimens from many localities would reveal that the differences at present noted between them break down. The only safe procedure at this time is the recognition of this Oregon material as representing a

new species. In the original description of *C. gracilaria* it is stated that the supra-anal process extends to the seventh tergite and that there is a slight indication of a small median knob on this tergite. This Oregon material does not have a knob on the seventh tergite but there is a small raised ridge on the anterior margin of the eighth tergite. It differs, too, from the illustration of the supra-anal process of *gracilaria* as given by Needham & Claassen (1925) in having the tip more abruptly pointed and in being slightly enlarged before its end. *C. oenone* Neave differs in the description of the male by the lack of reference to a raised ridge on anterior margin of the eighth tergite and in the female by the eighth sternite, which is stated to be "not produced." Two paratypic specimens of *oenone* kindly given to me by Neave do not have the ridge on the anterior margin of the eighth tergite visible. It should be noted, too, that the supra-anal process of these paratypes extends only to the posterior margin of the eighth segment, a condition shown in Neave's drawing but contrary to his statement in the original description that this process extends "forward to the posterior margin of the seventh abdominal tergite." If the type and other males of the paratypic series have a supra-anal process extending to the posterior margin of the seventh tergite, this would be another point of difference between *oenone* and *promota*.

#### *Dictyopterygella knowltoni*—NEW SPECIES

**MALE.**—General color yellowish brown to dark brown. Head, fig. 78, mostly dark brown with some lighter areas, the spot between ocelli and extending back to pronotum particularly conspicuous. Pronotum, fig. 78, chiefly dark brown with a medial longitudinal stripe and dark embossed markings; meso- and metathorax mostly black or brownish. Abdomen apparently mostly brown, with basal tergites and sternites somewhat lighter. Legs yellowish to dark brown. Antennae and cerci light brown.

Head wider through compound eyes than width of pronotum; three ocelli forming a nearly equilateral triangle, distance between lateral ocelli greatest, lateral ocelli placed on a line slightly back of front margin of compound eyes, somewhat farther

removed from one another than from compound eyes.

Pronotum approximately quadrangular, much broader than long, diameter at front angles apparently greater than at hind angles, front margin bowed, front angles appear sharp, a distinct pattern of raised rugosities on surface each side of median stripe.

Legs with first tarsal segment much longer than second and third together, the second much shorter than third.

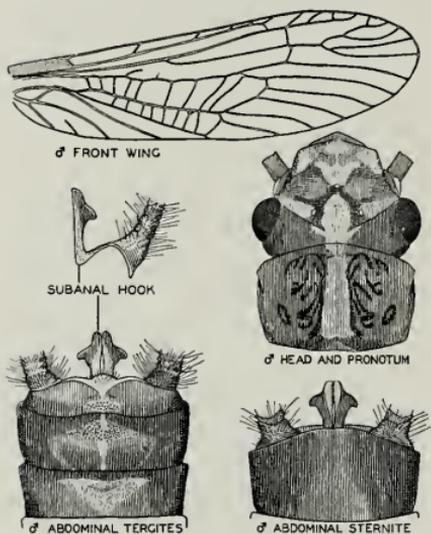


Fig. 78.—*Dictyopterygella knowltoni*.

Wings, fig. 78, with venation as in illustration, tip of wing with branches of radial sector somewhat turned upwards. Wing membrane stained with brown and veins dark brown. Hind wing with eight branches of anal veins reaching margin of wing.

Abdomen, fig. 78, with tergites normal except for small areas on terminal segments which are heavily covered with spinulae; tenth tergite not cleft for reception of the supra-anal process. Ninth sternite not produced and recurved upwards, without a disklike pad. Subanal hook very peculiar, prolonged backwards as a projection from body, the two plates together when viewed from above or below forming a mushroom-shaped structure.

Length to tip of wings, 15 mm.; length to tip of abdomen, 12 mm. No gill remnants found on any body area.

**Holotype, male.**—Logan, Utah: June 23, 1929, G. F. Knowlton.

This new species is unique among North American stoneflies described to date by virtue of the peculiarly prolonged subanal plates, fig. 78. Tentatively, pending the collection of fresh material and the female, it is placed in the genus *Dictyopterygella* Klapalek (1904). This genus is characterized among other things by the peculiar subanal plate which in such a European species as *D. nansenii* Kempny is very suggestive of *knowltoni* as here described.

*Dictyopterygella* is placed by Klapalek in the Perlodidae. According to the author's studies the Perlodidae of North America (*Perlodes*, *Isogenus* and *Hydroperla*) all have peculiar fingerlike gills on the submentum of the nymphs and remnants of such gills in the adults. I cannot find such remnant submental gills on the submentum of *knowltoni* but it must be said that the type was originally a pinned specimen and it is possible that either such gills cannot now be located in the relaxed specimen, have been accidentally lost through handling or never were present. My judgment is that they never existed and accordingly I am skeptical regarding the placement of this new species in Perlodidae. As far as I am aware the species previously assigned to *Dictyopterygella* are rarities, have never been studied with reference to the presence of remnant submental gills or have never been associated with their nymphs. It will not be surprising, therefore, if *knowltoni* and the genus to which it belongs will eventually be placed in the group of genera now going by the family name of Perlidae in North American literature. The type of wing venation is not sufficient to place the genus as to family.

I take pleasure in naming this species for its collector, Dr. G. F. Knowlton, who has sent to me for study many specimens of Plecoptera from Utah.

#### *Hydroperla parallela* Frison

*Hydroperla parallela* Frison (1936, p. 261). Original description.

The original description of this species was based upon a single male (Frison 1936). Since then additional specimens of the male have been received, and also the undescribed female, a brief description of which is here presented.

**FEMALE.**—Similar in most morphological respects to the male (Frison 1936). Color

pattern of dorsum of head and pronotum as in fig. 79. Subgenital plate, fig. 79, well developed but only slightly extending over ninth sternite, posterior margin essentially straight with corners angulate.

**Allotype, female.**—Cultus lake, B. C., Sweltzer creek: Apr. 28, 1935, W. E. Ricker.

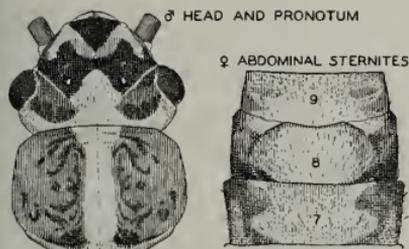


Fig. 79.—*Hydroperla parallela*.

Other records for this species which have accumulated since it was originally described are as follows:

**BRITISH COLUMBIA.**—Cultus lake: Apr. 18, 1936, W. E. Ricker, 1♀; Apr. 21, 1936, W. E. Ricker, 1♂.

**OREGON.**—Clatskanie, Beaver creek: May 9, 1936, J. Schuh, 1♂. Hillsboro: March 19, 1936, Gray & Schuh, 1♂.

#### *Chloroperla orpha*—NEW SPECIES

**MALE.**—Dominant color a pale greenish white in life and pale yellowish white when preserved. Dark or black areas are as follows: ocelli and compound eyes, fig. 80, lateral margins of pronotum, and a narrow longitudinal stripe extending across abdominal tergites as in fig. 80. Cerci and antennae at base concolorous with body, segments of antennae beginning a short distance from base progressively becoming darker to black. Wings with membrane and veins pale.

Head wider through compound eyes than width of pronotum; three ocelli forming a nearly equilateral triangle, lateral ocelli placed about on a line with posterior margin of compound eyes, about twice as far apart as each lateral ocellus is distant from compound eye. Antennae many segmented, basal segments not much longer than broad, middle and apical segments about of equal length and much longer than broad.

Pronotum slightly broader than long angles rounded, pronotal flange not well developed, embossings not evident.

Legs slender; first and second tarsal segments very short, third tarsal segment over

twice as long as length of first and second together.

Wings extending well beyond tip of abdomen; with membrane and veins pale; no anal lobe on hind wing and in this important respect, as well as venation in general, agreeing with *Chloroperla* as now recognized for North America.

Dorsal segments of abdomen without special structures. Tenth tergite somewhat cleft for reception of a small tablike supra-anal process. Subanal lobes not specialized. Ninth sternite produced and turned upward over tenth segment so that it is not visible from below, without a padlike disk near middle of apical portion.

Length to tip of wings 7 mm.; length to tip of abdomen 5.5 mm. No gill remnants on any body area.

**FEMALE.**—Not known.

**Holotype, male.**—Namakagon river, Spooner, Wis.: June 5, 1936, Frison & Ross.

**Paratypes.**—Same data as for holotype, 11♂.

This species is of special interest because the genus was considered by Needham & Claassen (1925) to contain but a single North American species and all my material, previous to the collecting of these specimens, has supported this view. The lack of an anal lobe on the hind wing separates this small delicate species from other

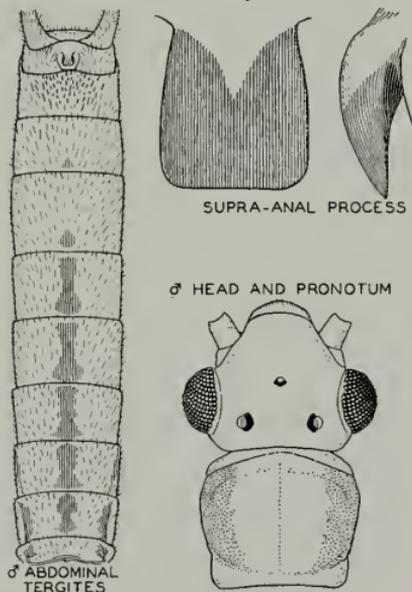


Fig. 80.—*Chloroperla orpha*.

superficially similar forms belonging in the genera now going in North America under the generic names of *Alloperla* and *Iso-perla*. The dark stripe on the abdominal tergites and the dark lateral margins of pronotum are sufficient to separate this species from the only other North American species now placed in *Chloroperla*, namely *cydippe*.

Kimmins (1936) has recently shown that the generic name *Chloroperla* Newman has as its type the European species *tripunctata* (Scopoli) and that *Isopteryx* is synonymous with *Chloroperla*, as originally pointed out by Banks (1906). It is questionable whether the species now going in North America under the name *cydippe* Newman (probably an *Alloperla* according to a recent letter from W. E. Ricker who has seen the types) has been correctly identified. There also is a point to be settled regarding placing the species now called *cydippe* in North America (Needham & Claassen 1925) in *Chloroperla*. When some of these points are finally cleared it is likely that the species here described will be placed in another genus together with the species to date called *cydippe*. *Brevis* Banks (1895) is the specific name which must replace *cydippe* if the latter is an *Alloperla*.

*Hastoperla* was originally proposed by Ricker (1935a) as a new genus for the reception of his new species *calcareo*. This latter species, however, is an outright synonym of *cydippe* as recognized by Needham & Claassen (1925). If *Chloroperla* of Europe proves not to be the same as *Chloroperla* of American authors then the name *Hastoperla* may by accident be available to serve for the American species placed to date in *Chloroperla*. The species *Chloroperla idei* Ricker and *C. milnei* Ricker (1935a) do not belong in *Chloroperla*, as used to date in America, but in *Alloperla*.

#### *Isoperla pinta*—NEW SPECIES

**MALE.**—General color black or brown with conspicuous yellow spots or areas, particularly on head and thorax. Head, fig. 81, black with yellow areas as follows: small spot in ocellar space and anterior to median ocellus, large area between compound eyes and lateral ocelli, and spots on anterior margin beyond articulation of antennae. Pronotum chiefly black or brownish with a median longitudinal yellow

stripe, interrupted in middle with line of black, and other spots on disk and lateral margins as indicated in fig. 81; meso- and metathorax mostly black or brownish. Abdomen mostly black or brownish, except for yellowish median longitudinal stripe on

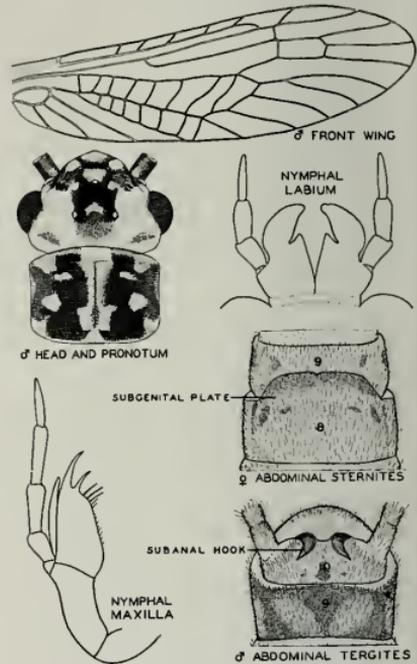


Fig. 81.—*Isoperla pinta*.

sternites and partially yellowish ninth and tenth tergites. Legs brownish with basal two-thirds of femora mostly yellowish. Antennae brown. Cerci yellowish brown, each segment with basal portion lighter than apical part.

Head much wider through compound eyes than width of pronotum; three ocelli forming a nearly equilateral triangle, lateral ocelli placed about on a line with middle of compound eyes, about as far removed from one another as from compound eyes. Antennae many segmented; basal segments wider than long, middle and apical segments progressively becoming longer than wide.

Pronotum approximately quadrangular, much broader than long, angles rather sharp; pronotal flange well developed on anterior and posterior margins but weakly developed on sides; an indistinct pattern of

raised rugosities on surface; and with a faint longitudinal median depressed stripe somewhat less in width than distance between lateral ocelli.

Legs with first tarsal segment slightly longer than second, third segment about twice as long as first.

Wings long, extending well beyond tip of abdomen; membrane but slightly tinged with brown, veins dark brown and contrasting; venation slightly variable in right or left wings or between individuals but essentially typical for the genus as now recognized in North America.

Abdomen with dorsal segments without special structures. Tenth tergite not cleft; subanal lobes modified into a pair of up-turned or recurved pointed hooks which are about as wide at base as diameter of basal segments of cerci. Ninth sternite strongly produced and turned upward around tenth segment so that it is not visible from below, without a distinct padlike disk near middle of apical portion. Eighth sternite with a small lobe, wider than long, in middle of posterior margin.

Length to tip of wings 14 mm.; length to tip of abdomen 10.5 mm. No gill remnants on any body area.

**FEMALE.**—Head, thorax, basal abdominal segments and appendages in general similar to those of male. Slightly larger than male, and differs as follows: eighth abdominal sternite, fig. 81, with posterior margin or subgenital plate produced about one-third over ninth sternite, posterior margin rounded and in some specimens slightly indented at middle.

**Holotype, male.**—Curry county, Ore., Floras creek: May 20, 1933, R. Dimick.

**Allotype, female.**—Corvallis, Ore.: April 5, 1933, N. F. Larson.

**Paratypes.** BRITISH COLUMBIA.—Cultus lake: June 5, 1927, H. H. Ross, 1♀. W. E. Ricker has supplied the following material of his collection from Cultus lake, for inclusion in the paratype series. Apr. 1932, 1♂, 1♀; Apr. 22, 1932, 1♂, 2♀; Apr. 24, 1935, 5♂, 11♀; Apr. 26, 1935, 4♂, 3♀; Apr. 28, 1935, 4♂, 10♀; May 13, 1935, 1♂, 1♀; May 18, 1933, 1♂; May 18, 1935, 1♂, 1♀; May 20, 1935, 2♀; May 26, 1932, 1♂; May 28, 1935, 1♂, 4♀; June 3, 1935, 1♀; June 7, 1934, 1♀.

OREGON.—Philomath, Woods creek: Apr. 24, 1936, W. Graf, 1♂. Beatty, Swan river: June 17, 1934, J. Schuh, 3♀. Winchester, North Umpqua river: March 22, 1933, R. Prentiss, 1♀. Alesa, Alesa river: May 28, 1933, R. Dimick, 1♀.

Mr. Ricker has also supplied me with four cast nymphal skins, among other

nymphs, collected at Cultus lake, British Columbia, April 24, 1935, and May 28, 1935, which I am certain belong with this species. Besides belonging to *Isoperla* (l. s.) these nymphal skins have a color

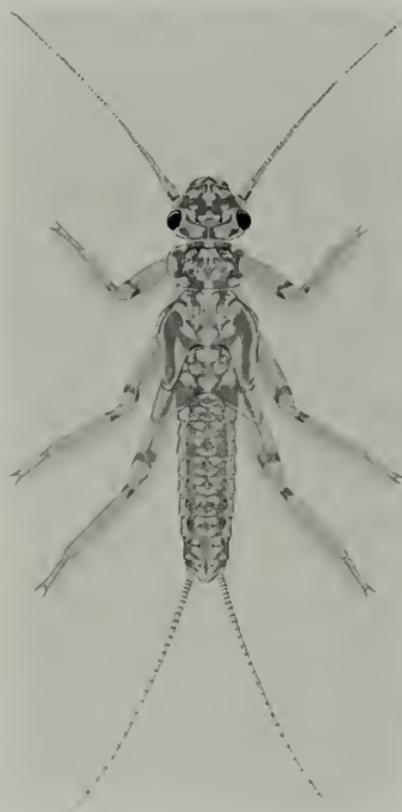


Fig. 82.—Nymph of *Isoperla pinta*.

pattern on the head and thorax which is practically identical with that of the adults and therefore the basis of my association.

**NYPH.**—General color of head, thorax and abdomen pale yellow with dark markings as in fig. 82. Markings on dorsum of pronotum are very suggestive of pattern shown by adult. Antennae yellowish with a dark spot on large basal segment. Cerci with tips of segments narrowly ringed with black or brown.

Head with three ocelli forming a nearly equilateral triangle, lateral and median ocelli occupying the same relative position as in adult. No occipital ridge. Labium and maxillae as in fig. 82.

Pronotum about twice as wide as long, all angles well rounded; fringed with numerous small setae and occasional long ones, marginal groove well developed on anterior and posterior margins but absent on lateral margins. Mesonotum with wing pads extending almost straight backwards, those on metanotum extending slightly outward.

Legs very little flattened; hind margins of femora, tibiae and tarsi with a fringe of long fine setae; femora with a narrow dark band before apex.

Cerci long, many segmented, segments progressively longer apically, distal half with a row of long fine setae on dorsal surface in addition to shorter ones encircling segments.

Approximately mature specimens with a body length, exclusive of appendages, of about 15 mm. Submental, thoracic and abdominal gills entirely lacking.

**Nymphs.** BRITISH COLUMBIA.—Cultus lake, Switzer creek: March 28, 1937, W. E. Ricker; April 24, 1935, cast skins; Reservoir creek, May 30, 1935, W. E. Ricker, cast skins.

#### *Isoperla truncata*—NEW SPECIES

**MALE.**—Dominant color a pale whitish yellow with some light brown and dark markings. Head, fig. 83, mostly pale whitish yellow; compound eyes and area im-

mediately surrounding ocelli black; lateral ocelli connected with median ocellus by short dark brown stripes which connect with a large solid transverse quadrate brown patch adjacent to median ocellus. Prothorax mostly pale whitish yellow with two longitudinal brown stripes, particularly accentuated in depth of brown at anterior margin; dorsum of meso- and metathorax mostly pale brown. Abdomen pale with weakly indicated brownish median and lateral longitudinal stripes on dorsum. Antennae, cerci and most of legs pale brown.

Head much wider through compound eyes than pronotum; three ocelli forming a nearly equilateral triangle, lateral ocelli placed on a line slightly anterior to middle of compound eyes, farther removed from one another than from compound eyes. Antennae many segmented; basal segments but slightly longer than wide, middle and apical segments progressively becoming longer than wide. Mandibles flabby and nonfunctional.

Pronotum essentially quadrangular, much broader than long, angles somewhat rounded, pronotal flange well developed on anterior and posterior margins but weakly so on sides; embossings indistinct.

Legs with first tarsal segment but slightly longer than second, third tarsal segment more than twice as long as first and second together.

Wings long, extending well beyond tip of abdomen; membrane and veins pale, a few veins more brownish; hind wing rarely with intercubital cross-veins, venation essentially typical of this genus, as now recognized in North America.

Abdomen with dorsal segments without special structures. Tenth tergite, fig. 83, not cleft; subanal lobes essentially weakly sclerotized lobes, without well-developed upturned or recurved hooks. Ninth sternite strongly produced and turned upward over tenth sternite so that it is not visible from below, without a padlike disk near middle of apical portion. Eighth sternite with a small but rather broad lobe in middle of posterior margin.

Length to tip of wings 11 mm.; length to tip of abdomen 8 mm. No gill remnants on any body area.

**FEMALE.**—Head, thorax, basal abdominal segments and appendages in general

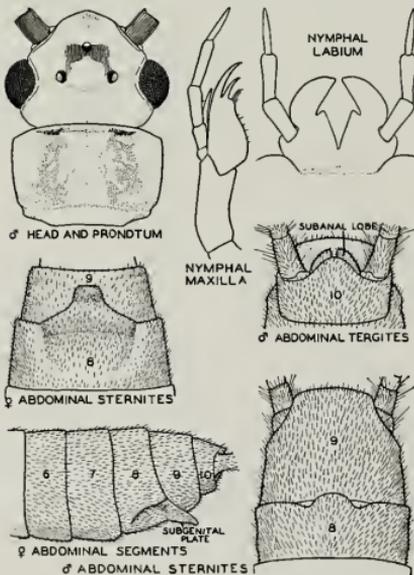


Fig. 83.—*Isoperla truncata*.

similar to those of male. Differs from male as follows: eighth abdominal sternite, fig. 83, with a well-developed process or subgenital plate which projects well over the ninth sternite, truncate at tip and in side view turns down from body at an angle.

**Holotype, female.**—Spooner, Wis., Namakagon river: June 5-6, 1936, Frison & Ross, reared from nymph.

**Allotype, male.**—Same data as for holotype.

**Paratypes.** INDIANA.—Knox, Yellow river: May 24, 1937, H. H. Ross, 21♂, 4♀.

MICHIGAN.—Omer, Rifle river: May 21, 1936, Frison & Ross, 1♂. Big Rapids, Muskegon river: May 22, 1936, Frison & Ross, 1♂, 8♀. Grayling, Manistee river: June 17, 1935, T. H. Frison, 4♂, 4♀. Lovells, Au Sable river: May 22, 1935, 1♂; north branch, May 24, 1936, J. W. Leonard, 1♂. Crawford county, north branch Au Sable river: June 16, 1935, J. W. Leonard, 2♂, 3♀. Cheboygan county, Pigeon River State Forest, Pigeon river: July 21, 1935, J. W. Leonard, 6♂, night at light. Otsego county, Pigeon river: June 23, 1936, J. W. Leonard, 1♀.

WISCONSIN.—Same data as for holotype, 3♀; same data except not reared, 18♂, 8♀.

The adults of this species are best distinguished from other species of this genus by the characteristic dark patch on head near ocelli and in the female by the truncate subgenital plate which sticks out from the body at an angle, fig. 83. In all respects this is a typical species of *Isoperla* (r. s.), as now recognized in North America, belonging to the group of species now having *I. bilineata* (Say) as type.

The nymph of this species has been collected as well as the adult and therefore its description is given. Association of the nymph with this new species is based upon reared specimens. The nymph is quite characteristic of other *Isoperla* (r. s.) as this genus is now recognized in North America. It is perhaps most easily separated from other species known to me by the two longitudinal rows of prominent spots on dorsum of thorax.

**NYPH.**—General color of head, thorax and abdomen a whitish yellow with dark markings as in fig. 84. The most important dorsal dark markings are the broad transverse band across head, the two longitudinal rows of spots on thorax, and the three narrow longitudinal stripes on abdomen. Cerci pale yellowish brown.

Head with three ocelli forming a nearly equilateral triangle, lateral and median ocelli occupying the same relative position as in adult. No occipital ridge. Labium and maxillae as in fig. 83.

Pronotum about twice as wide as long, all angles well rounded; fringed with short as well as some long hairs; marginal groove well defined on anterior and posterior margins but absent on lateral margins. Mesonotum with wing pads extending almost straight backwards, those on metanotum extending slightly outward.

Legs very little flattened; hind margins of femora, tibiae and tarsi with a fringe of long fine setae. Tarsal segments 1 and 2 very short; third segment long, about three times as long as first and second combined.

Cerci many segmented, moderately long, stout at base, segments progressively longer apically, distal half with a row of long fine setae on dorsal surface in addition to shorter ones encircling segments.

Approximately mature specimens with a body length, exclusive of appendages, of about 10 mm. Submental, thoracic and abdominal gills entirely lacking.

**Nymphs.** MICHIGAN.—Omer, Rifle river: May 21, 1936, Frison & Ross. Grayling, Manistee river: May 22, 1936, Frison & Ross. Mio,

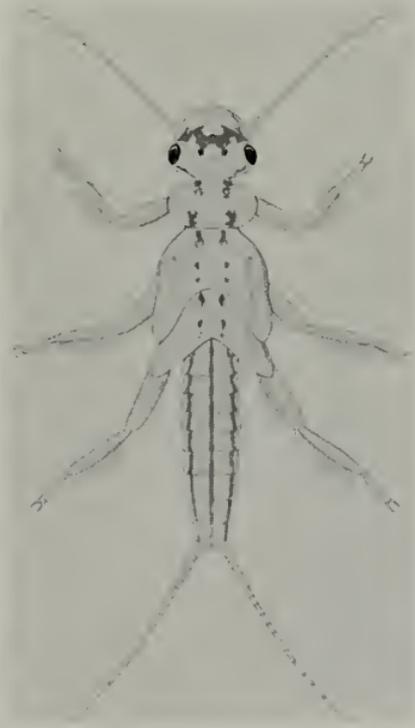


Fig. 84.—Nymph of *Isoperla truncata*.

Au Sable river: May 21, 1936, Frison & Ross. Lovells, Au Sable river: May 22, 1936, Frison & Ross. Hale, Au Gres river, May 21, 1936, Frison & Ross.

WISCONSIN.—Dells, Wisconsin river: June 5, 1936, Frison & Ross. Spooner, Namakagon river: June 5-6, 1936, Frison & Ross.

Cast nymphal skins. MICHIGAN.—Honor, Platte river: Sept. 16, 1936, Ross & Burks.

WISCONSIN.—Spooner, Namakagon river: June 5-6, 1936, Frison & Ross.

### *Alloperla exquisita* Frison

*Alloperla exquisita* Frison (1935b, p. 337).

This species was originally described from males only and from material collected in Oregon. Additional material from Washington and British Columbia has

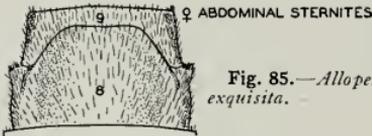


Fig. 85.—*Alloperla exquisita*.

made available the previously unknown female and therefore the description of this sex is now given.

**FEMALE.**—Similar in most morphological features to the male (Frison 1935b). Eighth abdominal sternite, fig. 85, with subgenital plate produced backwards over about one-half of ninth sternite and with posterior margin approximately truncate.

**Allotype, female.**—Shucksan, Wash., Bagley creek, 2700 feet elevation; July 24, 1936, H. H. Ross.

**BRITISH COLUMBIA.**—Cultus lake, Smith Falls creek: May 20, 1935, W. E. Ricker, 1♂, 1♀.

**WASHINGTON.**—Shucksan, Bagley creek, 2700 feet elevation: July 24, 1936, H. H. Ross, 5♂, 11♀; Razorhone creek, 3200 feet elevation: July 24, 1936, H. H. Ross, 14♂, 11♀.

### *Alloperla occidentis*—NEW SPECIES

**MALE.**—Body, cerci, antennae and legs in general a pale yellowish white. Dark or black areas are as follows: ocelli and compound eyes, fig. 86, lateral margins of pronotum, a U-shaped mark on meso- and metanotum, a broad median longitudinal stripe extending across all abdominal tergites up to the ninth, and basal segments 1 through 3 with a small dark stripe on each lateral margin running parallel to median stripe.

Head wider through compound eyes than width of pronotum; median ocellus located about in line with anterior margins of compound eyes, lateral ocelli located well anterior to line connecting posterior

margins of compound eyes, distance between lateral ocelli greater than distance between a lateral ocellus and adjacent compound eye.

Pronotum much wider than long, front angles rather sharp, hind angles more rounded.

Dorsum of abdomen as in fig. 86. Supra-anal process small, inset on tenth tergite, forming a fingerlike projection which in lateral view is slightly swollen at tip; eighth and ninth tergites without raised ridges. Tenth tergite cleft for reception of supra-anal process, without distinct inward-pointing lobes or hooks at bases of cerci.

Wings extending well beyond tip of abdomen; with membrane and veins pale; a well-formed anal lobe on hind wing and in this respect, as well as venation in general, agreeing with *Alloperla* as now recognized in North America.

Length to apex of wings 8 mm.; length to tip of abdomen 6 mm. No gill remnants on any body area.

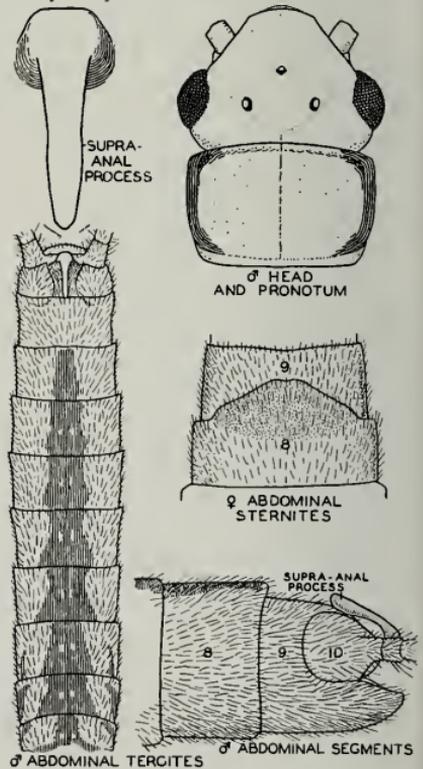


Fig. 86.—*Alloperla occidentis*.

**FEMALE.**—Similar in most morphological characters to the male. Median longitudinal dark stripe on abdominal tergites extending only to eighth tergite, and lateral stripes only on first and second tergites. Eighth abdominal sternite, fig. 86, with subgenital plate extending in middle area over about one-half of ninth sternite, posterior margin somewhat broadly triangular and depressed.

**Holotype, male.**—Shucksan, Wash., Razorhone creek: July 24, 1936, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—Same data as for holotype, 1 ♂, 4 ♀.

This species resembles *A. exquisita* Frison (1935b) in general color pattern. It differs in the male, however, in lacking a transverse ridge on ninth tergite and in the female the subgenital plate is more triangular.

#### SYNONYMY

##### *Acroneuria lycorius* (Newman)

*Acroneuria cuetae* Ricker (1935b, p. 260). New synonymy (♂, ♀).

A male and a female paratype of *Acroneuria cuetae* Ricker, kindly sent to me for the SURVEY collection by W. E. Ricker, prove upon close study and comparisons with other material to be the species *A. lycorius* as defined by Needham & Claassen (1925). The name *cuetae*, therefore, must be relegated to synonymy.

##### *Togoperla media* (Walker)

*Acroneuria salvelini* Ricker (1935b, p. 261). New synonymy (♀).

A study of a paratypic female sent to me for the SURVEY collection by W. E. Ricker and a second paratypic female loaned by the Canadian National Museum prove that these are the same as the common northern and eastern American species now going by the name of *media* (Walker). The name *salvelini*, therefore, must be synonymized.

##### *Togoperla immarginata* (Say)

*Acroneuria fumosa* Ricker (1935b, p. 262). New synonymy (♀).

Examination of a paratypic female of *A. fumosa* Ricker, loaned by the Canadian National Museum, and comparisons with other material, including a female specimen and a nymphal skin named as *fumosa* by Ricker and sent to me by him, have enabled me to recognize this as *immarginata* (Say)

as defined by Needham & Claassen. The name *fumosa* must therefore be placed in synonymy.

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Volume 21

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Article 4

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# Descriptions of Nearctic Caddis Flies

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HERBERT H. ROSS



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URBANA, ILLINOIS

March 1938



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*This paper is a contribution from the Section of Insect Survey*

(44257—1200—12-37)



## FOREWORD

This paper, describing new species of caddis flies from Illinois and other localities in North America, is the initial report on a project of the Illinois Natural History Survey pertaining to these aquatic insects. A complete report treating of the Illinois fauna is planned for later publication. This latter, more comprehensive faunistic study will be fashioned after some recent Survey reports on insect groups and will include keys to the adults and larvae, illustrations of the diagnostic characters, and data on the biology and distribution of these insects occurring in Illinois. The role of these insects in the economy of our lakes and streams makes their study of special interest.

This investigation was started as a major enterprise of the Insect Survey Section during the summer of 1931. Dr. Cornelius Betten of Cornell University was employed by the Illinois Natural History Survey during the summer of that year to initiate the extensive field work and acquaint the systematic entomological staff of the survey with the characters used in the classification of caddis flies and, in so far as possible, with the identity of the various species inhabiting the waters of our state. Since 1931, Dr. H. H. Ross, Systematic Entomologist of the Illinois Natural History Survey, has been responsible for the continuation of this project. In addition to the great assistance received from Dr. Betten, our studies have profited greatly by Dr. Ross' study of the Hagen and Banks types in the Museum of Comparative Zoology, Cambridge, Massachusetts, kindly made available for detailed study and designation of lectotypic specimens by Dr. Nathan Banks.

As these studies progressed, it became apparent that a study of the entire North American fauna would be necessary to identify properly the Illinois species. Therefore, specimens were assembled from localities representing as many parts of the continent as possible. Some of this material was obtained by Illinois Natural History Survey field trips, whereas other material was submitted for study by outside individuals and institutions. When all of this material was finally determined, it was found that a large proportion of it represented new species. It now seems advisable to describe these forms new to science so that the names may be known to others and made available for use in future publications of the Survey.

T. H. FRISON



**Kankakee River near Momence, Illinois**

Many of Illinois' rarest and most interesting species of caddis flies have been found in this clear, fast-flowing stream.

# Descriptions of Nearctic Caddis Flies (Trichoptera)

With Special Reference to the Illinois Species

HERBERT H. ROSS

DESCRIPTIONS of the new species of caddis flies (Trichoptera) treated in this paper are based for the most part upon specimens collected by various members of the ILLINOIS NATURAL HISTORY SURVEY. They are based in part, also, upon other collections sent to the SURVEY by the following members of other institutions: G. F. Knowlton, Utah State Agricultural College, Logan, Utah; J. W. Leonard, Institute of Fisheries Research, Ann Arbor, Michigan; D. C. Mote and R. E. Dimick, Oregon State Agricultural College, Corvallis, Oregon; R. W. Kaiser, Oklahoma Agricultural College, Stillwater, Oklahoma; and various staff members of the University of Wisconsin, Madison, Wisconsin. I wish to thank these individuals and others who have been of assistance to me at various times for their welcome cooperation.

In several cases, notably in *Hydropsyche*, the differences used to separate the adults into species will appear slight. Collections of thousands of specimens and the association of larvae with adults, however, have shown that these small differences are (1) constant and visible through the large series I have studied, (2) correlated with marked differences in the larvae, (3) correlated with distinct ecological habits and distribution patterns and (4) frequently associated with distinct differences in the color pattern of the males.

Many of the species herein described have been reared. The descriptions of

the larvae and pupae will not be presented now but will be treated in the forthcoming report on the caddis flies of Illinois. These descriptions will be much more valuable when taken up in conjunction with a synopsis of the entire Illinois group.

Most of the drawings have been made by Dr. C. O. Mohr, of the ILLINOIS NATURAL HISTORY SURVEY, to whom I wish to express my deep gratitude.

The drawings of genitalia in all cases have been made from genital capsules cleared in caustic potash (KOH) solution, washed in distilled water and mounted in glycerin. Many structures necessary for accurate identification cannot be seen clearly unless the specimen is treated in this manner.

Except for the few paratypes otherwise noted, the types of the species described in this paper are deposited in the collection of the ILLINOIS NATURAL HISTORY SURVEY.

The structures hitherto called preanal appendages, socii, anal appendages, etc., appear to be indubitably associated with the lateral margins of the tenth tergite. For this reason they are considered the true cerci. In many of the more primitive genera there is no doubt that these cerci are homologous to the same structure in Hymenoptera, Mecoptera and other orders.

The general order of families and genera is, with few exceptions, that used in Dr. Cornelius Betten's *Caddis Flies of New York State*. Wherever reference

is made in the text to "Betten (1934)" this book is the one indicated.<sup>1</sup>

### Family RHYACOPHILIDAE

#### *Rhyacophila fenestra* new species

This handsome species, fig. 1, is related to members of the *carolina* group but differs from previously described forms in the digitate spurs on the lateral arms of the oedagus as well as in other points of the genitalia.

MALE.—Length 11 mm. Head straw color with a quadrangular dark brown spot between the ocelli; antennae and palpi dark brown; eyes black. Thorax brown with the venter, prothorax and lateral sutures yellowish. Abdomen straw color, the dorsum with a purplish cast. Legs straw color with the tarsi suffused with brown. Front wings gray with white markings in the membrane, each marking supplemented with a

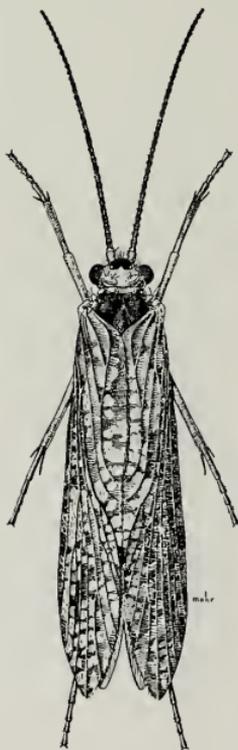


Fig. 1.—*Rhyacophila fenestra*, adult ♀

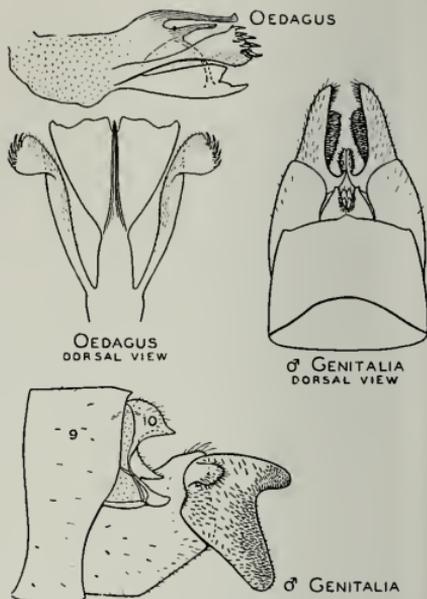


Fig. 2.—*Rhyacophila fenestra*

patch of silvery pubescence on the dorsal side; these light markings are all situated between the darker veins and are so arranged that they form more or less diagonal bands of spots across the wing. Hind wings uniform bluish-gray. The various warts, raised areas and the veins on the wings are provided with rows or clusters of long setae which are either brown, golden or a mixture of these two colors. The blue-gray patches of the front wings are clothed with minute, dark setae matching the color of the wing membrane. The pubescence of the legs is straw color.

General structure typical for genus. Tibiae with small, straw colored spines in addition to the usual number of very long ones. Front wing with fork of  $R_{2+3}$  distinctly beyond fork of  $R_{4+5}$ ;  $M_{1+2}$  branching very close to margin;  $M_{3+4}$  branching midway between *m-cu* and margin of wing. Seventh sternite with a small, pointed mesal projection.

Genitalia as in fig. 2. Claspers relatively short and broad, the dorsal margin of the apical segment subequal to the dorsal margin of the basal seg-

<sup>1</sup>New York State Museum, Bulletin 292. December, 1934.

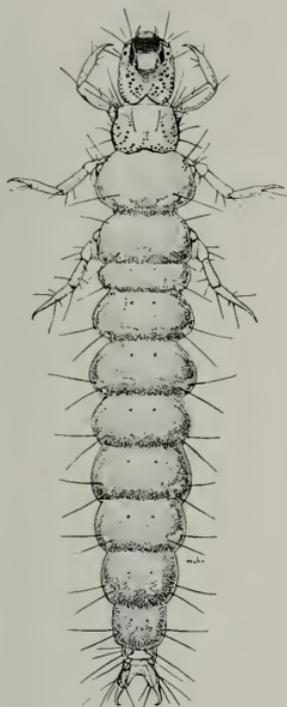


Fig. 3.—*Rhyacophila fenestra*, larva

ment; the apical segment incised for one-third its lateral and one-fourth its mesal length; both lobes straight and rounded, the dorsal one small and the ventral one large. At the base of the segment there is a mesal incurving lobe; most of the apical segment and this lobe are covered with short, dark setae. Tenth tergite narrow, the dorsal lobe cleft down the meson for more than one-half its length; the lateral lobes so produced have convex dorsal margins with a rather short, sharp apical point; below these the segment is produced into two closely appressed concave plates which articulate with the dorsal band of the oedagus. Oedagus consisting of a basal bandlike structure that articulates with the tenth segment and an apical cluster of structures at the end of a membranous tube. This cluster is composed of (1) a semimembranous pair of arms arising at its base, these arms enlarged at the apex and bearing usually five large, incurved spines, each surrounded by

small spines; (2) a dorsal, sclerotized median process which is thin and blade-like from the dorsal view and from lateral view is divided into two sinuate rods; and (3) a mesal structure that has a vertical membranous connection with a pair of fanlike ventral lobes which are thin, colorless, only semisclerotized and together are slightly concave on the meson.

**FEMALE.**—Length 12 mm. Color and general structure exactly the same as for male. Sixth sternite with a narrow process on the meson. Eighth segment tubular, the dorsum carinate, the apical opening circular except for the emargination caused by the dorsal carina.

**Holotype, male.**—Herod, Illinois: May 12, 1936, reared from Gibbons Creek, Ross & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Herod: May 29, 1935, Ross & Mohr, 1 ♂; pupae collected May 5, Ross & Mohr, adults emerged at Urbana, May 7-12, 1936, 4 ♂, 1 ♀; pupae collected May 12, Mohr & Burks, adults emerged at Urbana, May 14-June 6, 1936, 18 ♂, 17 ♀; pupae collected May 13, Frison & Ross, adults emerged at Urbana, May 17-24, 1937, 10 ♂, 11 ♀.

The larvae, fig. 3, are common in the rocky streams of the Ozark region in southern Illinois.

***Rhyacophila iranda* new species**

This species most closely approaches *vofixa* Milne but differs radically in the elongate apical portion of the oedagus, fig. 4.

**MALE.**—Length 9 mm. Head and thorax black; the setiferous warts and antennae dark brown. Abdomen with

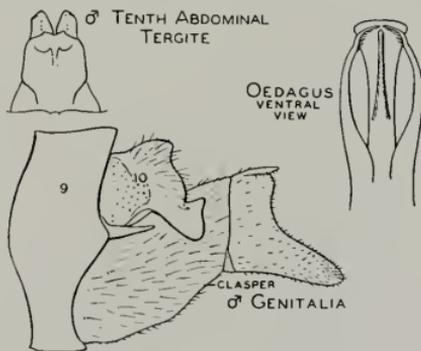


Fig. 4.—*Rhyacophila iranda*

venter straw color and dorsum purplish. Legs with coxae and femora dark brown; remaining parts yellowish-brown. Wings dark brown with light patches in the membrane at the end of each apical cell and in the subcostal, cubital and anal cells; the pubescence dark brown except over the light areas, where it is almost white.

General structure typical for genus. Genitalia as in fig. 4. Ninth segment with ventral portion narrower than dorsal. Clasper with basal segment about as long as depth of ninth segment, its dorsal and ventral margins slightly convex; the apical segment is slightly more than twice as long ventrally as dorsally, the apical margin scooped out and evenly concave, the dorsal angle slightly but sharply produced. Tenth tergite short, the dorsal angle produced into a pair of short points, the ventral angle produced into a pair of truncate lateral areas; most of the surface covered with sparse setae. Apical portion of oedagus with a pair of narrow lateral processes which taper to a thin curved apex, this extreme apical portion with a row of fine setae on the mesal margin; the mesal portion sclerotized, divided into a thin ventral process and a wide, somewhat spatulate, dorsal process.

**Holotype, male.**—Mount Baker, Washington: July 21, 1936, along Razorhone Creek, H. H. Ross.

#### *Rhyacophila manistee* new species

Belonging to the same small group as *minora* Banks, this species differs from it in the narrower tenth tergite and in the arrangement of the dorsal setae at the apex of the oedagus in two regular, parenthesislike bands, fig. 5.

**MALE.**—Length 9 mm. Color dark brown, the legs below coxae yellowish brown, the wings with membrane lighter than the venation, with slightly lighter spots at the ends of the apical cells; most of setae dark brown, intermixed with patches of golden setae.

General structure typical for genus. Genitalia as in fig. 5. Tenth tergite, seen from above, almost twice as long as wide, the apex divided into two short, somewhat pointed lobes; laterally tergite is produced into a postero-ventral lobe with the apex pointed. Claspers with api-

cal segment slightly shorter than basal one; basal segment almost twice as long as wide, the ventral margin straight; apical segment of ventral margin straight at base and upturned at apex; dorsal margin sinuate, so that the clasper is rounded off to a short apical lobe. Oedagus composed of two distinct parts: (1) a short compact basal portion which is sclerotized and has one ventral and three short, apical dorsal projections and (2) a membranous extensible tube at the apex of which is situated a semisclerotized ovate structure which is hollowed out dorsally and has a conspicuous band of small, black setae bordering margin of depression.

**FEMALE.**—Length 10 mm. Color and general structure same as for male. Genitalia very simple; eighth segment

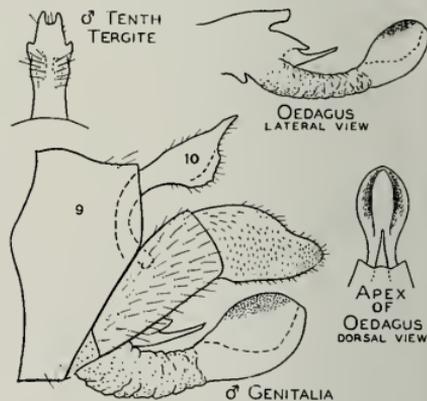


Fig. 5.—*Rhyacophila manistee*

tubular, tapering evenly from base to apex; the remaining segments of the abdomen extensible, tubular and sub-membranous.

**Holotype, male.**—Grayling, Michigan: May 21, 1936, along Manistee River near town, Frison & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MICHIGAN.—Grayling: Same data as for holotype and allotype, 74♂, 56♀. Lovells: May 22, 1936, along Au Sable River, Frison & Ross, 3♂.

#### *Rhyacophila melita* new species

This is distinct from all other North American species not only in the poorly set off and ovate terminal segment of

the clasper but also in the oedagus with its short, heavy, five-tined process, shown in fig. 6.

**MALE.**—Length 11.5 mm. Head dark brown with setiferous warts and antennae light brown. Remainder of body

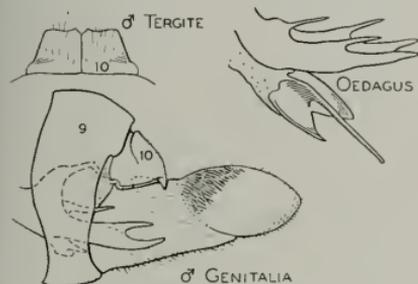


Fig. 6.—*Rhyacophila melita*

dark brown, with the legs and venter of the abdomen straw color. Wings uniformly brown, the veins and stigmal region darker.

General structure same as for genus, the diagnostic differences being almost entirely in the genitalia. Genitalia as in fig. 6. Seventh sternite with the small, triangular mesal projection just above apex. Ninth segment cylindrical, only slightly longer dorsally than ventrally. Claspers only one-tenth longer than depth of ninth segment; the basal segment has the ventral margin slightly more than twice as long as the dorsal margin, the two being parallel; the apical segment, viewed laterally, appears egg shaped, the dorsal side longer than the ventral side, the basal suture indistinct dorsally, the inner margin with the dorso-basal region thickly set with long, stout setae. Tenth tergite, viewed laterally, appears short and beaklike; the dorsal aspect is divided into two halves, each one tapering toward apex and produced near meson into a short, pointed projection; the entire surface is sparsely set with setae. Oedagus as illustrated, the ventral process consisting of a narrow mesal style with a pair of semimembranous flaps at base; the dorsal portion is a heavily sclerotized structure with a single mesal spine at base and with the apex divided into a pair of bifid processes.

**Holotype, male.**—Crawford County, Michi-

gan: June 16, 1935, north branch of Au Sable River, J. W. Leonard.

### *Rhyacophila perda* new species

This species closely resembles *montana* Carpenter and *lobifera* Betten, but differs from both in the dorsal prolongation of the ninth segment which consequently overhangs the basal segment of the clasper.

**MALE.**—Length 13 mm. Head with lower portion yellowish brown, dorsal portion black with setiferous warts brown, antennae brown with a tawny ring at the base of each segment. Thorax light brown with the scutal lobes darker in the middle. Abdomen yellowish brown, the dorsum with a purplish tinge. Legs entirely yellowish brown. Wings completely infuscate with purplish brown, the veins darker; the membrane around the edge of the wing and in the radial area has small pale areas which do not contrast much with the darker part of the wing.

General characteristics same as for genus. Front wing with fork of  $R_{2+3}$  slightly before fork of  $R_{4+5}$ . Genitalia as in fig. 7. Ninth segment with the dorsal portion twice as long as the ventral half and forming a quadrate angle into which fits the basal segment of the clasper. Clasper (lateral view) with basal half slightly longer than its width at apex; both upper and lower margins concave. Apical segment with its greatest diagonal length almost equal to basal segment and with a dorso-apical incision which forms a long, narrow dorsal lobe and a wide, truncate ventral lobe jutting out considerably

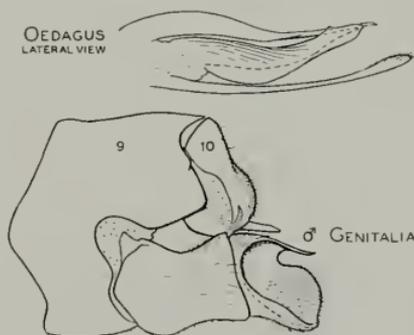


Fig. 7. *Rhyacophila perda*

beyond the dorsal lobe; the entire lateral face sunken except for the dorsal, basal and ventral margins. Tenth tergite fitting beneath meso-dorsal projection of ninth; it is a relatively small, padlike area, appearing somewhat heart-shaped when viewed from above and as a plate when seen from the side. Oedagus has apical portion composed of two main parts: (1) a pair of slender lateral appendages set with small setae at apex and (2) a mesal sclerotized process which bears approximately the same parts as illustrated for *fenestra* but which have become so completely fused that they appear as a single structure.

**Holotype, male.**—Mount Baker, Washington: July 21, 1936, along Razorhone Creek, H. H. Ross.

#### *Agapetus artesus* new species

Practically identical with *minutus* and *illini* in size and general characteristics, this species differs in the short tenth tergite, particularly the vasiform side

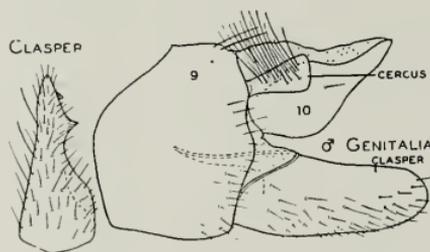


Fig. 8.—*Agapetus artesus*

pieces or lateral pieces which have no spines on their distal margin.

**MALE.**—Length 5 mm. Color identical with *illini* (see below), the body brown and the legs a lighter shade. General characteristics, such as spurs, antennae, ocelli and wings, typical of genus. The abdomen has the usual ovate organ on the fifth sternite and the long tapering process on the sixth.

Genitalia as in fig. 8. Claspers short and deep; seen from the ventral aspect they appear to have a wide base and abruptly narrowed apex, the apical half having a pair of dark, sclerotized points, the larger on the ventral margin, the smaller near the dorsal margin, the two connected by a sclerotized ridge.

Tenth tergite composed of two vasiform lateral plates markedly narrowed and pointed at apex, connected by membranous folds. Cerci narrow at base, broader and almost truncate at apex; slightly more than one-third the length of the claspers, pointed latero-caudad and with a cluster of long setae on their lateral face. Oedagus simple with the apex slightly enlarged.

**FEMALE.**—Slightly larger than male, similar to it in color and general structure. To date no distinguishing characters have been found between this female and that of *illini*.

**Holotype, male.**—Greer Spring, Missouri: June 7, 1937, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MISSOURI.—Greer Spring: Mar. 28, 1937, T. H. Frison, 1♂; same data as for holotype, 1♂, 3♀

#### *Agapetus illini* new species

This species is indistinguishable from *minutus* except on the basis of genitalia. It is characterized by the longer tenth tergite with a smaller cluster of spines at its apex and a short apical spur on the clasper, fig. 9.

**MALE.**—Length 5 mm. Body dark brown, clothed with brown setae. Legs with basal half dark brown, apical half lighter, clothed with straw colored setae. Wings dark brown with slightly lighter setae. Spurs, antennae, ocelli and wings typical of genus. Fifth sternite with a bulbous organ and sixth with a stout mesal projection which is slightly longer than the segment itself.

Genitalia as in fig. 9. Claspers narrowed toward apex, the upper margin convex; the mesal margin armed with two heavily sclerotized points, one on the dorsal and one on the ventral margin, connected by a sclerotized ridge. Cerci curved outward and bearing on their lateral surface long setae. Tenth tergite composed of a dorsal membranous region and a pair of ventro-lateral sclerotized plates; these are truncate at the apex, which is armed with many spiny projections; the tenth tergite has at its base a pair of dorso-lateral sclerotized projections which can be readily seen only from the dorsal aspect.

**FEMALE.**—Slightly larger than male,

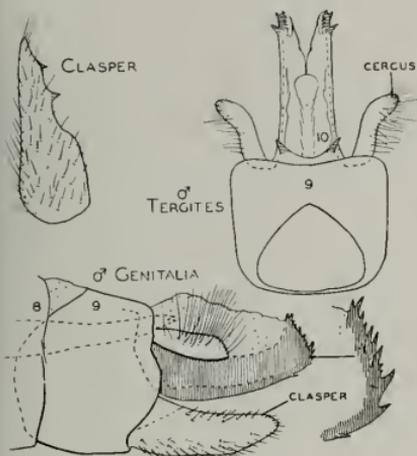


Fig. 9.—*Agapetus illini*

similar to it in color and general structure; middle tibia and basi-tarsus compressed. Fifth, sixth and seventh sternites with a crescentic ridge running from the baso-lateral corner through the meso-apical region. Sixth sternite with a definite mesal projection at apex. Genitalia consists of a simple type of sclerotized tube with the apical segments invaginated.

**Holotype, male.**—Herod, Illinois: May 1, 1936, Ross & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Eichorn: May 11, 1935, C. O. Mohr, 4♂. Herod: Same data as for holotype, 24♂; May 29, 1928, along Gibbons Creek, T. H. Frison, 11♂; May 10, 1935, C. O. Mohr, 11♂, 1♀; May 29, 1935, Ross & Mohr, 11♂, 7♀; July 11, 1935, Ross & DeLong, 1♂; May 12, 1936, Mohr & Burks, 7♂, 3♀; May 13, 1937, Frison & Ross, 70♂, 7♀.

***Agapetus medicus* new species**

Another species indistinguishable from the *minutus* group on the basis of general characteristics but radically different on the basis of genitalia, having the claspers long and truncate and the tenth tergite also long and truncate but lacking the apical dentation of *minutus* and *illini*.

**MALE.**—Length 5 mm. Color and general structure as given for *illini*.

Abdomen and genitalia as in fig. 10. Tenth tergite bilobed from base, each lateral lobe long and deep but narrow; truncate at the apex and bladeliike, the

ventral and apical margins without serrations or teeth, the upper margins concave and joined by membranous folds. Cerci slender and slightly sinuate; the apex narrowly rounded and the dorsal half bearing a cluster of long, slender setae; the appendage attaining half the length of the lobes of the tenth tergite. Claspers, seen from the side, rectangular, four times as long as high, the apex truncate except for a slight production near ventral margin and having a sclerotized ridge running across the mesal face at apex. Seen from above, the clasper is fairly uniform in thickness for about three-fifths its length, beyond which it tapers to a rounded tip reinforced mesally by the apical sclerotized ridge. The oedagus is a simple tube, as in the other species of the group.

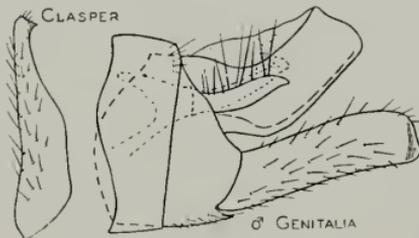


Fig. 10.—*Agapetus medicus*

**Holotype, male.**—McFadden Springs, Arkansas: June 5, 1937, H. H. Ross.

**Paratypes.**—ARKANSAS.—Same data as for holotype, 3♂.

***Agapetus pinatus* new species**

Although this species is indistinguishable from some previously described forms in color and general structure, the genitalia are markedly different.

**MALE.**—Length 5 mm. Body light brown, the antennae and legs even paler. Color and general characteristics same as for other members of the genus.

Genitalia as in fig. 11. Claspers long and narrow. Seen from ventral view, they appear to have a rather long, rectangular basal portion tapering to a fairly sharp point; the sclerotized points on either side of the mesal ridge appear almost in line from this aspect. Tenth tergite with a dorsal semisclerotized portion composed of two flat plates obliquely truncate at apex and almost

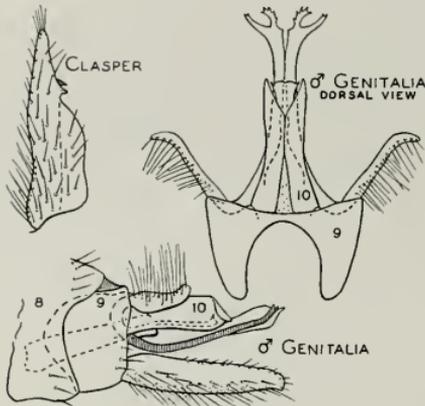


Fig. 11.—*Agapetus pinatus*

touching on the meson; and with a ventral portion consisting of two long, sclerotized rods fused at the base with this dorsal portion and extending considerably beyond it, their apices abruptly turned dorso-laterad and divided into two lobes visible from the dorsal aspect. The lateral one of these apical lobes is divided into two small points, the mesal one clavate with several small, spiny processes. Cerci long, curved outward near apex and having a cluster of long setae along their dorso-lateral margin. The cerci and the ventral rods of the tenth tergite seem to be fused with each other and with the remainder of the tenth tergite at their base. Oedagus simple, composed of a basal tube in which articulates a slender sclerotized rod.

**Holotype, male.**—Elkmont, Tennessee: June 12, 1935, H. H. Ross.

#### *Agapetus debilis* new species

This species is readily distinguished from other members of the group by the long and bidigitate claspers combined with the short tenth tergite.

**MALE.**—Length 6 mm. Body dark brown; the raised areas of the head and thorax, most of the anterior aspect of the head and legs below coxae straw color (except spurs, which are dark brown). Wings uniformly dark brown, the veins darker than the membrane.

General characteristics as for genus except as follows: Front wings with

radial crossvein oblique but with vein  $R_{2+3}$  hardly at all angled at that point; base without a large specialized area such as in *Glossosoma*. Legs with tibial spurs very long, all of them simple, their count being 2-4-4. Fifth sternite of abdomen without the usual complicated platelike appendage but with a raised area on each side connected by a raised line which runs transversely across the segment about one-third the distance from the apex. Sternites 6 and 7 with only small raised processes ending in a small point at apex.

Genitalia as in fig. 12. Ninth segment cylindrical. Tenth tergite divided on meson for almost its entire length. Seen from lateral view, it appears wide at base, gradually tapering to a narrow, depressed, blunt apex; seen from above, the apices seem to diverge slightly from the main axis of the segment. Claspers very long, projecting three-fourths of

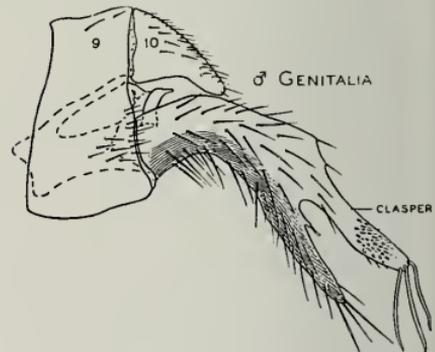


Fig. 12.—*Agapetus debilis*

their length beyond the remainder of the genitalia; the basal portion, or "handle" (comprising .6 of the entire length), is bowed, increasing in depth beyond the middle of the arc. Beyond this "handle" the clasper is divided into two long, fingerlike processes, both of them almost straight, the upper one slightly fusiform, the lower one tapering slightly from base to apex, each one surmounted by a group of setae, the setae on the dorsal process modified into flat spindles. The entire clasper is covered with scattered setae, those on the "handle" longest; it is concave mesally and turned in so that the ventral margin is considerably mesad of the

dorsal margin. Oedagus and its assemblage very small, composed of short, needlelike processes articulating as a group with the tenth tergite and claspers.

**Holotype, male.**—Logan Canyon, Utah; June 27, 1937, W. P. Nye.

This species brings up some interesting questions in relation to the genera of the Glossosomatinae. It is placed here in *Agapetus* but lacks the lateral plate on the fifth segment, which condition should exclude it from *Agapetus*. On the other hand, the straight tibial spur excludes it from *Mytrophora* and the lack of a callosity on the front wing wing excludes it from *Glossosoma*. The venation, especially the oblique radial crossvein, is somewhat suggestive of *Mytrophora*. Here, then, we have a species set off from almost every known genus in the subfamily by the lack of a specialized development of the male. It may well be that a new genus should be erected for this. At present I am placing it in *Agapetus* on the basis of general resemblance of genitalia. I believe, however, that this species should be set off as a distinct subgenus. Perhaps, when the females are associated with more species in this group, we shall find it necessary to express many of the groups as subgenera and not genera.

#### *Anagapetus* new subgenus

Differs from *Agapetus s. st.* in the following characters in the male: Lateral platelike structures on the fifth abdominal sternite represented only by small callous elevations which do not have an internal lamellate structure. No sternites with long, fingerlike mesal projections. Front wing with the radial crossvein diagonal, joining  $R_{2+3}$  just basad of the fork of this vein. Other characters typical of the genotype.

**Genotype.** — *Agapetus debilis* new species (by original designation).

#### *Glossosoma excita* new species

This species is distinguished from all others in the genus by the claspers, which are very wide at the base and taper to an apex that appears narrow and up-turned when viewed from the lateral

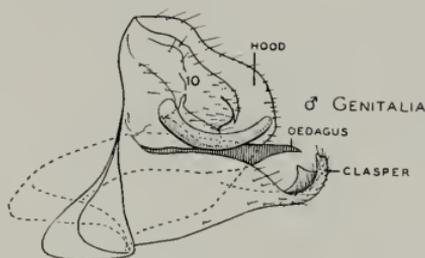


Fig. 13.—*Glossosoma excita*

aspect and truncate when seen from the ventral.

**MALE.**—Length 7 mm. Color and general structure almost exactly as described for *velona* (below), the diagnostic characters occurring chiefly in the genitalia.

Genitalia as in fig. 13. Genital parts in repose shielded by lateral extensions of the ninth segment. Clasper very broad at base, ventral margin slightly sinuate, the dorsal margin arcuate, the clasper narrowing abruptly about two-thirds the distance from the base and turned up at its extreme apex; the ventral margin angled meso-dorsad so that the clasper has a wide mesal shelf with its meso-apical corner sharply angled; only the apex of the clasper has setae, these relatively short. Tenth tergite stocky, the dorsal margin declivous, the dorsal part of the apex forming a sharp, curved process, the portion beneath this rounded; from the extreme lateral portion of this region there arises a pair of cylindrical, tusk-shaped processes which bear no setae; mesad of these are a pair of fingerlike processes only half as long as the lateral ones and sparsely covered with setae. Oedagus long and simple, its apex narrowed and pointed, articulating by two ribbonlike structures which extend from the extreme base of the oedagus to near the lateral corner of the claspers.

**Holotype, male.**—Pringle Falls, Oregon; May 26, 1935, N. F. Canova.

#### *Glossosoma velona* new species

Although this species is closely related to the *parvulum* group, it is readily distinguished by the shorter cerci and claspers.

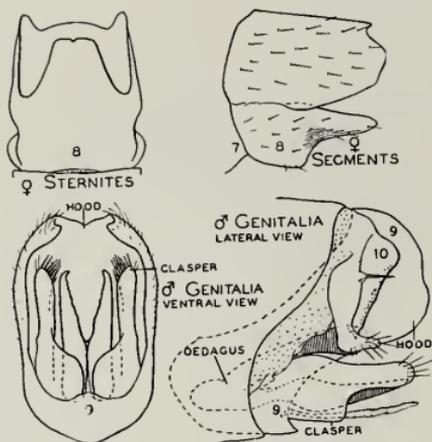


Fig. 14.—*Glossosoma velona*

**MALE.**—Length 6.5 mm. Head, including palpi and scape, dark brown, remainder of antennae straw color. Thorax and abdomen a slightly lighter shade of brown than the head. Legs straw color, the coxae and femora frequently suffused with brown. Wings brown, the portion below the stigma slightly darker than the rest, the veins in this region also darker than the others.

General structure typical for genus as follows: Antennae slightly shorter than wing, broadest at base and tapering greatly to apex. Ocelli well separated from eye, postocellar region with two pairs of setiferous warts. Legs with a spur count of 2-4-4. The spurs on the front tibiae very short, on the middle and hind tibiae very long. Venation typical for genus. Sixth sternite with a broad, flat ligula arising on meson; seventh sternite with a small, stubby process on the meson.

Genitalia as in fig. 14. The entire assemblage in repose enclosed by a hood-like extension of the ninth segment. Claspers with basal half broad, apical half suddenly narrowed, the apex slightly clavate and provided with a mesal brush of stout setae. Tenth tergite held at right angles to longitudinal body axis, divided into two lobes; each of these has the apical portion sharply pointed and bears a lateral enlargement which is probably the cercus; this appendage has a large tooth at its base and is

abruptly angled at its apex, the apex arising free from the segment. Oedagus with a large mesal rod articulating with the tenth tergite at one end and with the remainder of the oedagus at the other; from near the base of this structure arise two stout, sclerotized processes which appear almost fused at their base but are distinct and taper toward the slender and sharp apex.

**FEMALE.**—Length 7 mm. Similar in color and general characteristics to the male, differing chiefly in that the mid-tibiae and tarsi are enlarged and flattened. Genitalia as in fig. 14. Sixth sternite with a raised meso-apical process.

Eighth sternite produced at the base into a humplike keel, the apex flattened. Eighth tergite hoodlike, only slightly incised dorsally; remainder of genitalia a simple extrusible tube with thin, sclerotized supporting rods attached to base of clasper.

**Holotype, male.**—Centralia, Washington: July 26, 1936, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MONTANA.—Ennis: July 8, 1936, along Madison River, H. H. Ross, 7 ♂, 3 ♀.

OREGON.—Arlington: July 29, 1936, along Columbia River, H. H. Ross, 1 ♀.

WASHINGTON.—Same data as for holotype, 1 ♀.

### *Glossosoma verdona* new species

The absence of hoodlike projections of the ninth segment groups this species with *penitum* Banks. It differs from *penitum*, however, in the ventral portion of the claspers and the subquadrate tenth tergite.

**MALE.**—Length 7.5 mm. Color and general characteristics exactly as described for *velona*. The distinguishing

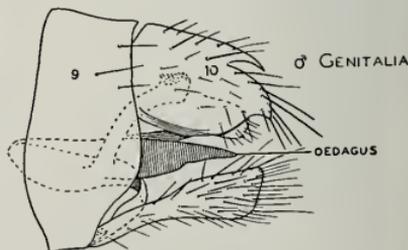


Fig. 15.—*Glossosoma verdona*

characteristics occur only in the genital apparatus.

Genitalia as in fig. 15. Claspers fairly long, basal half narrow, apical half considerably widened, the apical margin practically truncate, seen from either the lateral or ventral aspects; the apical half clothed with long setae and having a mesal lobe abundantly provided with setae. Tenth tergite almost as deep as long; the meso-apical corner is produced into a sharp, curved point; the ventral portion ends in a very broad, curved point and within this is a flaplike lobe; the entire structure is sparsely covered with setae, those on the apical margin being very long. Oedagus anchored at the base by two ribbonlike, sclerotized bands which are fashioned laterally near the base of the claspers; the apical portion of the oedagus is composed of two tapering, sclerotized rods; from the central portion of the oedagus arises an erect process with its apex enlarged into a knoblike structure which is densely covered with short, straight setae.

**Holotype, male.**—Pinedale, Wyoming: July 6, 1936, along Green River north of town, H. H. Ross.

**Paratypes.**—UTAH.—Big Cottonwood Canyon: April 24, 1937, G. K. Knowlton & F. C. Harmston, 5♂.

WYOMING.—Same data as for holotype, 2♂.

The five paratypes from Utah differ from the others in being uniformly darker in color, and in having the dorsomesal point of the tenth tergite of the male reduced or absent. The extreme similarity of all other points of the genitalia leaves no doubt, however, that the two series are the same species.

#### *Paragapetus celsus* new species

This species is most closely related to *nearcticus* Banks, but differs in lacking a long, palmate dorsal process on the tenth tergite.

**MALE.**—Length 4 mm. Color, including wings, legs and other appendages, uniformly blackish brown.

General structure: Antennae about 24-segmented, two-thirds length of forewing. Maxillary palpi stocky, 5-segmented, first two segments short, third subequal in length to first two together, fourth slightly shorter than

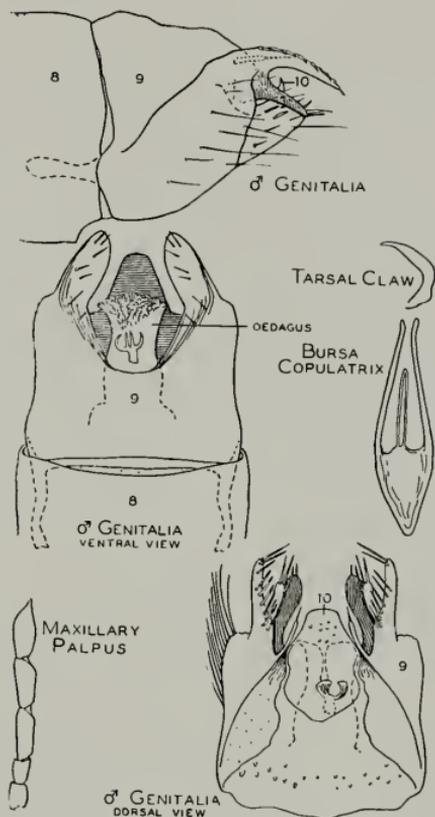


Fig. 16.—*Paragapetus celsus*

third, fifth slightly shorter than fourth, pointed at apex, fig. 16. Ocelli present, the median one situated between antennal sockets, the lateral pair midway between antennal sockets and posterior margin of head. Tibial spurs 2-4-4, none modified. Tarsal claws curved, fig. 16, all of them similar in shape. Wings with typical, simple, Rhyacophilid venation; front wing with  $R_5$  and M having two symmetrical dichotomies;  $Sc_1$  and basal abscissa of  $Sc_2$  variable. Abdomen has a sclerotized thickening just before apex on sternites 5-7; that on the seventh has a small, pointed thickening on meson.

Genitalia as in fig. 16. Most of the parts seem fused at the base with the genital capsule. The lateral margin is prolonged dorso-apically into a forked

process; the upper prong of the fork bears a row of stout, fairly long setae on its dorsal margin, and a long, fingerlike process branches from its base, which may be seen dorsally; the lower branch is shorter, with only a few setae, and is situated almost directly beneath the upper. The ventral margin is produced apically into a pair of lateral lobes bearing scattered setae on their inner margin toward apex. Tenth tergite rounded and slightly upturned at apex. Oedagus submembranous, short and thick, with a sclerotized area on its ventral surface; the apex membranous.

**FEMALE.**—Length 4.5 mm. Similar in color and general structure to male. Abdomen simple in structure. Segments 1–7 normal, remainder retracted into abdomen to form an extensible tube. Bursa copulatrix as in fig. 16.

**Holotype, male.**—Newfound Gap, North Carolina: June 13, 1935, along Little Pigeon River, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—NORTH CAROLINA.—Same data as for holotype, 54♂, 10♀.

### Protoptila Banks

On the basis of their small size and long fringe of hair on the anal margin of the wings, the small insects belonging to this genus would key out to the Hydroptilidae. Certain other characters, however, such as the immature stages, lack of setation on the abdomen and the structure of the male and female genitalia, present conclusive evidence that the genus belongs in the Glossosomatinae of the family Rhyacophilidae. The adults of *Protoptila* may be keyed out from the Hydroptilidae on the basis of always having ocelli which are distant from the eye.

### *Protoptila jeanae* new species

This and the following three species differ from previously described members of the genus in lacking a produced, furcate apical sternite.

**MALE.**—Length 3.5 mm. Head and dorsum of body brown; antennae white with apical eight segments blackish brown; palpi, legs and venter whitish; tibial spurs brown; wings brown with a

narrow, white transverse band two-thirds distance from base.

**General structure:** Head robust and ovoid, with a pair of caudal warts, three prominent ocelli and a pair of larger warts between the lateral ocelli. Maxillary palpi five segmented; the first and second segments subequal and together subequal to the third; the third, fourth and fifth subequal; the entire palpus short and stocky. Antennae filiform, the two basal segments thicker than the rest. Tibial spurs 0–3. Abdomen membranous with only few setae except on genitalia.

Genitalia as in fig. 17. Ninth tergite incised on margin, the lateral lobes pointed, fig. 17. Superior appendages with heavy setae along margins, apex surmounted by a rounded, sclerotized process. Claspers sinuate in lateral view, with no setae, the apex roughened and dark. Between these two pairs of appendages are exerted two narrow and pointed processes, and within the body can be seen an erect, somewhat hook-shaped appendage associated with the oedagus.

**FEMALE.**—Size and general structure as in male. Apex of abdomen as in fig. 17, the ultimate segment rounded, the apex bearing a pair of fingerlike processes, the surface covered with fine setae pointing basad. Penultimate segment broad and short, with two lateral slits, under which may be seen the broad, roughened bursa copulatrix.

**Holotype, male.**—Sevierville, Tennessee: June 11, 1935, J. A. & H. H. Ross.

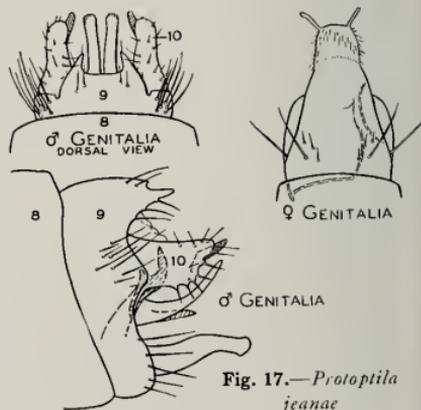


Fig. 17.—*Protoptila jeanae*

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—KENTUCKY.—Livingston: June 16, 1935, along Rockcastle River, J. A. & H. H. Ross, 1♀.

NORTH CAROLINA.—Cherokee: June 14, 1935, J. A. & H. H. Ross, 21♂, 3♀.

TENNESSEE.—Same data as for holotype, 9♂, 3♀.

**Protophila erotica** new species

In characters of tibial spurs and venation, this species belongs to the *maculata* group but differs in lacking a

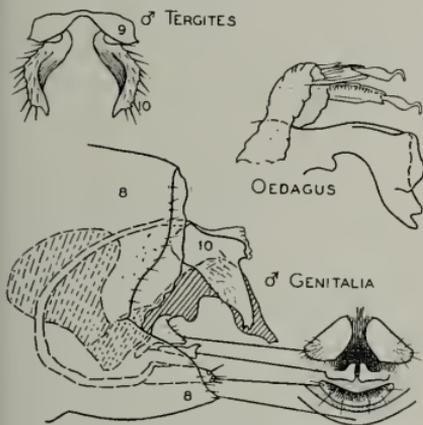


Fig. 18.—*Protophila erotica*

conspicuous and large ventral plate in the male.

**MALE.**—Length 3.0 mm. Color and general structure typical for genus. Middle and hind tibiae have four spurs of about equal length. Hind wings excavated along the anterior margin beyond the middle of the wing.

Genitalia as in fig. 18. Tenth tergite divided into two lateral arms which together appear in somewhat the shape of a horseshoe. Ventral plate small, short and narrow, with a few apical setae. What appear to be the claspers are short, stubby processes angled at the apex and closely attached at the base to a plate bearing a paired mesal process which protrudes slightly beyond the claspers. Oedagus large, consisting of a large knoblike portion within the body cavity and an exterior portion. This consists of a central piece, which is

angled and widened near its middle and tapers to its apex; arising from its base are two membranous arms, each bearing an elongate hook sheathed with membrane around the base.

**FEMALE.**—Similar in size, color and general structure to male.

**Holotype, male.**—Parco, Wyoming: July 5, 1936, along North Platte River, H. H. & J. A. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Momence: May 26, 1936, along Kankakee River, H. H. Ross, 124♂; Aug. 21, 1936, Ross & Burks, 6♂.

WISCONSIN.—Chetek: June 5, 1936, Frison & Ross, 1♂, 3♀. Merrill: July 1, 1933, along Wisconsin River, Frison & Mohr, 1♂. Spooner: June 5, 1936, along Namekagon River, Frison & Ross, 1♂.

WYOMING.—Madison Junction, Yellowstone National Park: July 8, 1936, H. H. Ross, along Gibbon River, 5♂. Parco: Same data as for holotype, 8♂.

**Protophila cantha** new species

Differs from other members of the genus in combining the characters of a single preapical spur on the hind tibiae with an incised hind wing, and in details of the genitalia.

**MALE.**—Length 3.0 mm. Color and general structure typical for genus. Head with only one pair of warts, situated close to the posterior margin. Hind wing with anterior margin incised beyond middle, the wing therefore saberlike. Middle and hind tibiae with three short spurs, the single preapical

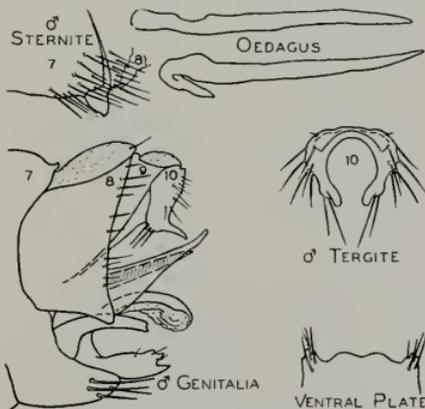


Fig. 19.—*Protophila cantha*

spur being the same size as the two apical ones.

Genitalia as in fig. 19. Tenth tergite horseshoelike, the apices appearing sharp and stout when seen from the side. Ventral plate bilobed in the center, the lateral angles having three small points. Claspers short, the apex of each blunt. Oedagus contained in a hoodlike structure which is somewhat triangular and extends the full width of the genital capsule. Oedagus a simple, heavy, sclerotized rod sharply bent at the base. Below the oedagus is a curved mesal process with a sclerotized dorsal portion and a membranous ventral border.

**Holotype, male.**—Parco, Wyoming: Aug. 1, 1936, along North Platt River, H. H. Ross.

**Paratypes.**—IDAHO.—Caldwell: July 30, 1936, H. H. Ross, along Boise River, 1♂.

MARYLAND.—Plummer's Island: June 24, 1902, H. S. Barber, 8♂.

WYOMING.—Same data as for holotype, 1♂.

### *Protoptila thoracica* new species

Distinguished from other members of the genus by the enlarged scutal lobes and details of the genitalia.

**MALE.**—Length 3.0 mm. Color and

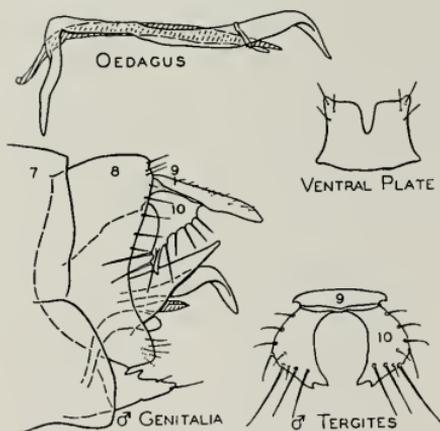


Fig. 20.—*Protoptila thoracica*

general characteristics same as for genus. Lateral portions of mesoscutum greatly swollen, each lobe as large as head. Spur count 0-4-4. Hind wing with anterior margin only slightly incised beyond middle.

Genitalia as in fig. 20. Apical tergite

long, rectangular and overhanging genitalia. Tenth tergite long, forming a broad horseshoe bearing several large setae. Ventral plate short, deeply cleft on meson. Oedagus consists of two rods, a short, sinuate one and a longer one with the base bent at a right angle and the apex flattened and curved; the two rods are apparently bound together near the apex with two fine, sclerotized bands. A broad, triangular sheath surrounds these externally. The claspers and other ventral sclerites are reduced and consolidated almost beyond differentiation. From them a pair of curved organs arise, much as in *cantha*.

**Holotype, male.**—Boulder, Wyoming: July 6, 1936, along tributary of Big Piney River, H. H. Ross.

### Family HYDROPTILIDAE

#### *Agraylea saltesea* new species

Externally this species differs from *multipunctata* Curtis in having the light spots on the wings smaller and in greater contrast with the dark background. Structurally the two species differ in the conical process on the seventh sternite and in the shape of the claspers, which in this new species have a smaller mesal point and a much larger lateral expanse, fig. 21.

**MALE.**—Length 5.5 mm. Color of head, body and appendages dark brown, the basal segments of the antennae and most of the legs below the coxae yellowish brown, the pubescence on these parts tawny yellow. Wings uniformly dark brown with several cream colored spots as follows: a large one below stigma, a large one on the middle of the caudal margin, a small one at apex of discal cell and about eight small ones each situated at the apex of one of the apical cells.

General structure, including venation, ocelli and tibial spurs, as for genus. Seventh sternite with a short, smooth conical process on meson of apical margin. Genitalia as in fig. 21. Claspers somewhat auriculate, the caudo-mesal angle produced into a short, sharp process, the lateral portion wide, the entire surface clothed with relatively abundant setae. Above and closely associated with the claspers is a pair of

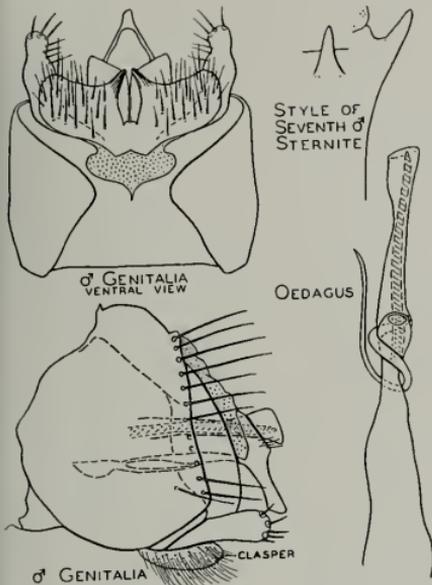


Fig. 21.—*Agraylea salteesa*

sinuate appendages (probably cerci) bearing a number of well separated setae at their apex; these extend considerably beyond the claspers. Above these and below the oedagus is a sclerotized rod which (seen from lateral view) appears bent downward at almost a right angle; this has practically no setae on it and forms a sheath for the oedagus. Oedagus with the basal portion shorter than the apical portion; its margins irregular and sinuate and gradually tapering to the neck; apical portion somewhat bulbous at base, then gradually tapering to a constriction and beyond this expanding again into a cuplike structure; within this is a sclerotized rod running through a circular opening which is above the neck; opposite this opening there originates a spiral appendage which circles the oedagus completely and then runs toward its apex.

**Holotype, male.**—Salte, Montana: July 7, 1936, H. H. Ross.

***Stactobia Brustia* new species**

This species differs from the genotype in lacking well-defined cerci and in the crook-shaped apex of the oedagus.

**MALE.**—Similar in size, color and

general characteristics, such as spur count, position of ocelli, etc., to genotype. Genitalia as in fig. 22. Tenth tergite consists of a large membranous hood, indistinctly divided transversely and bearing a few small setae scattered along this division and two large ones near the ventro-basal corner. Ventral plate heavy, bearing three whiskerlike brushes of setae, although their bases are not segregated into patches; the apex of the plate is turned up. Oedagus long and slender, its apex hooked. The internal support of the genitalia is long, consisting of two long, ventro-lateral rods with a wide, sclerotized arch forming a dorsal bridge between them. The ends of this support join the sides of the ventral plate. This plate is provided with sclerotized supports.

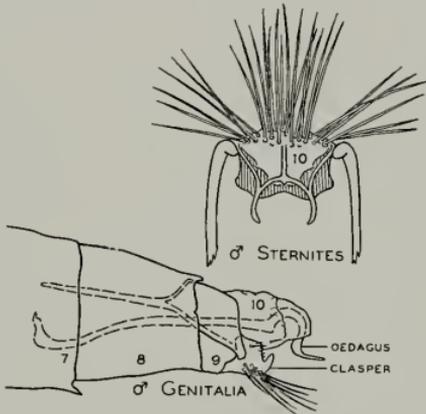


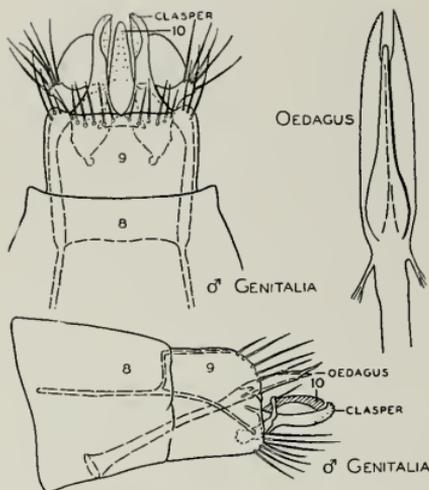
Fig. 22.—*Stactobia Brustia*

**Holotype, male.**—Parco, Wyoming: July 5, 1936, along North Platte River, H. H. Ross.

***Stactobia delira* new species**

This species may be separated from its congeners by the long claspers and the unique, spicate mesal process above them, fig. 23.

**MALE.**—Length 3 mm. Color of head and thorax golden brown. Abdomen pallid with the characteristic dark dorsal pattern. Antennae and legs pallid, almost colorless. Wings gray, the close hairs forming a dark gray background crossed transversely by two light bands situated respectively

Fig. 23.—*Stactobia delira*

one-third and two-thirds the distance from the base to the apex of the wing.

General structure same as for genus. Genitalia as in fig. 23. Claspers long and slender, hooked dorsad at extreme tip, with only a few minute setae on apical portion. Above these is a pair of short, hooklike appendages (probably cerci) produced laterally into a thumblike process bearing a dense cluster of long setae. Above and between the base of the claspers is a stout, curved tenth tergite which is spicate, from ventral view. The internal skeleton of the genitalia is similar in most respects to that of *brustia*, consisting of two long ventral arms with a curved, platelike roof over the apical portion. Oedagus is fairly long and straight, the basal end flute-shaped, the apex divided into a pair of submembranous lateral lobes and a sclerotized mesal process through which the true penis runs; below this apical structure is a pair of threadlike muscle attachments.

**Holotype, male.**—Spooner, Wisconsin: June 5, 1936, along Namakagon River, Frison & Ross.

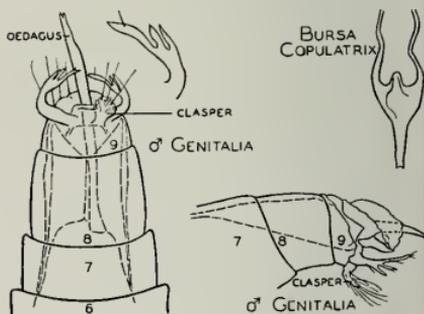
**Paratypes.**—WISCONSIN.—Same data as for holotype, 7♂.

#### *Stactobia palmata* new species

The male is set off from other members of the genus by the digitate processes above the claspers.

**MALE.**—Length and general characteristics as in the two preceding species. Color similar to species of *Hydroptila*, the species in life appearing a salt-and-pepper combination of light and dark grays because of the irregular pattern of these colors on the head, thorax and wings.

Abdomen and genitalia as in fig. 24. Sternites without mesal processes. Claspers curved, short, directed ventrally and with abundant setae on apical portion. Above them arise a pair of trifurcate processes whose bases curve so that the handlike apices almost meet on the meson below the oedagus. Just below the oedagus is a short transverse plate. Oedagus long and slender, without armature, but slightly narrowed at apex. Above it there seem to be only copious folds of membrane. The tenth tergite is entirely membranous. The internal, sclerotized portion of the genitalia is long and bridgelike,

Fig. 24.—*Stactobia palmata*

forming a broad, shallow structure under the dorsal surface of the abdomen.

**FEMALE.**—Size, color and general structure same as in male. Abdomen typical of the family, with the terminal segments forming a long extensible tube braced along the lateral margins by internal, sclerotized rods. Bursa copulatrix similar in general structure to that of *Hydroptila*, but differing in outline, fig. 24.

**Holotype, male.**—Merrill, Wisconsin: June 18, 1934, along Wisconsin River, Frison & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Kankakee: June

6, 1935, along Kankakee River, Ross & Mohr, 2♂.

KENTUCKY.—Livingston: June 16, 1935, along Rockcastle River, H. H. Ross, 2♂, 1♀.

TENNESSEE.—Gatlinburg: June 12, 1935, along Little Pigeon River, H. H. Ross, 14♂, 7♀.

WISCONSIN.—Same data as for holotype, 8♂, 30♀.

**Oxyethira aeola** new species

The arcuate dorsal plate of the male and the approximate internal arms of the female genitalia distinguish this species from all others described in the genus.

MALE.—Size, color and general characteristics as described for members of the genus.

Genitalia as in fig. 25. Seventh sternite with a large, pointed process on the meson. Eighth segment produced into wide lateral lobes which are deeply incised dorsally. Tenth tergite arcuate, angling ventrad and extending just beyond the other parts. Ventral plate truncate. Claspers broad but short, their extreme apex conical. Above them arise a pair of smooth, sinuate appendages composed of one segment and tipped with a long, slender seta. Oedagus composed of an outer sheath, tubular at base, the sclerotized portion narrowing at apex to a thin mesal strip bearing dorsally an extensive membranous area which overlaps the sclerotized strip laterally; within this outer structure is a long, sinuate, slender, sclerotized rod, probably representing the true functional penis.

FEMALE.—Similar in size, color and general characteristics to the male. Genitalia resembling other species of the genus in general pattern, fig. 25. Eighth sternite emarginate on meson. The ninth sternite is represented by an ovoid, sclerotized area, bearing a pair of internal dorsal arms which project into the eighth segment. The bursa copulatrix is small and vasiform, connected with the ninth sternite by a membranous fold.

Holotype, male.—Vancouver, British Columbia: July 20, 1936, along Seymour Creek, H. H. Ross.

Allotype, female.—Same data as for holotype.

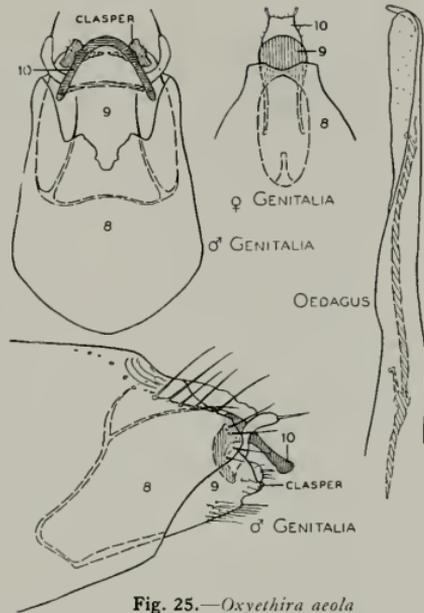


Fig. 25.—*Oxyethira aeola*

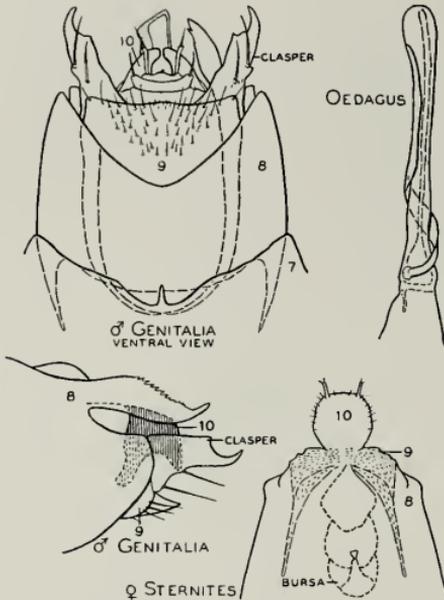
Paratype.—BRITISH COLUMBIA.—Same data as for holotype, 1♂.

**Oxyethira serrata** new species

Differs from described members of the genus in the serrate dorso-lateral processes and other characters of the genitalia.

MALE.—Length 2.8 mm. Color and general characteristics apparently identical with other members of the genus.

Genitalia as in fig. 26. Seventh sternite has a simple median process on apical margin. Apical margin of eighth sternite deeply and angularly incised. Dorso-lateral processes have lower margin curved, upper margin serrate, tapering to a smooth, upturned tip. Ventro-lateral processes, probably the true claspers, with dorsal margin straight, ventral margin concave and setate, the apex deeply excavated to form an apical, upturned hook. Situated alongside the meson and above the claspers is a stout process, the tenth tergite, forming a blunt hook. Below this are two small, semimembranous lobes, each bearing a stylelike process on its caudo-lateral angle. Oedagus has basal tube

Fig. 26.—*Oxyethira serrata*

short, apical portion long, with tip mostly membranous and blunt; spiral process ribbonlike, encircling tube once.

**FEMALE.**—Size, color and general characteristics same as in male. Genital characters as in fig. 26.

**Holotype, male.**—Fox Lake, Illinois: July 15, 1935, at light in town, DeLong & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Antioch: July 7, 1932, Frison & Metcalf, 4♂, 32♀; May 27, 1936, along Channel Lake, H. H. Ross, 15♂, 5♀. Fox Lake: Same data as for holotype, 175♂, 250♀; May 28, 1936, H. H. Ross, 64♂, 1♀; June 10, 1936, Ross & Burks, 1♂. Johnsbury: May 28, 1936, along Fox River, H. H. Ross, 85♂, 15♀.

MICHIGAN.—Houghton Lake: June 15–18, 1935, T. H. Frison, 47♂, 200♀.

WISCONSIN.—Spooner: June 5–6, 1936, along Namakagon River, Frison & Ross, 2♂.

### *Oxyethira verna* new species

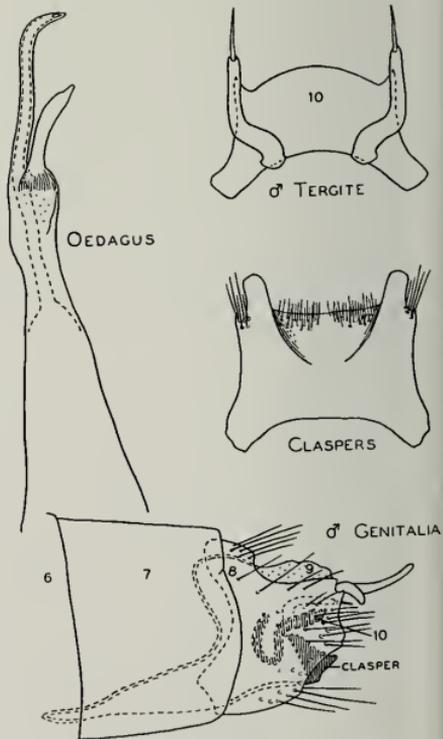
This species is readily distinguished from all other North American species of the genus by the peculiar shape of the oedagus, fig. 27, which has a slender curved tip and a digitate tooth at the point of constriction of the oedagus.

**MALE.**—Length 2.7 mm. Color of

head dark brown, of body light brown. Wings mottled with a salt-and-pepper mixture of cream and brown spots, without conspicuous striping or spot arrangement.

General characteristics as for genus, including spur count, position of ocelli and the narrowed apex of the forewing. Abdomen without conspicuous processes on the sixth to eighth sternites. Eighth sternite deeply incised on the dorsum and incised for one-third its length on the venter, so that this segment is represented chiefly by two lateral areas which flank the genital capsule. These lateral plates have the dorsal margin slightly sinuate, the apical corner with a circular emargination forming a sharp corner on both the dorsal and caudal margins; the caudal margin is slightly emarginate and shelves off into a diagonal caudo-ventral portion which joins the ventral margin.

Genitalia as in fig. 27. The endoskele-

Fig. 27.—*Oxyethira verna*

ton of the genital capsule forms a short, round dorsal lobe and a very long, slender and pointed ventral lobe which extends normally to the sixth segment. Claspers short and stocky, fused on the meson, the lateral portions produced into a pair of prominent lobes separated by a concave mesal portion. Tenth tergite with base sinuate and apex forming a flat plate; the apical margin arcuate except for the sharp corners of the lateral angle; from the base of this arise a pair of semimembranous smooth appendages which have a sinuate base and are tipped with a long seta. Oedagus with the basal portion wide and gradually tapering to the neck; the apical portion is broad at the base but tapers suddenly to form a filamentous rod which is curved at the extreme apex; at the point of constriction there is a large sclerotized digitate process which is half the length of the filamentous portion of the oedagus.

**Holotype, male.**—Spring Grove, Illinois: June 12, 1936, Ross & Burks.

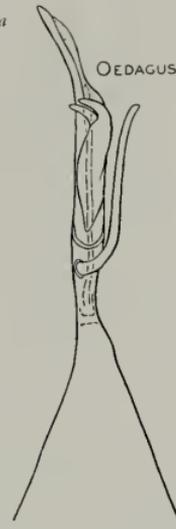
#### *Neotrichia falca* new species

Closely related to *collata* Morton, but differentiated on the basis of a shorter basal tube on the oedagus and other details of hooks and processes on the apical portion of the oedagus.

**MALE.**—Size 2.5 mm. Color a salt-and-pepper mixture of cream and brown spotting over the entire body and wings. General characteristics typical for genus; diagnostic characters apparently restricted to genitalia.

Genitalia as in fig. 28. Tenth tergite membranous, having lateral faces which make a distinct angle with the dorsal face, and a deep cleft on the meson. Below this is a pair of membranous lobes lying beside the oedagus, each lobe surmounted by a bristle. Claspers blade-like, short and stocky, set with fairly numerous setae. Ventral plate divided into two halves, each short and heavily sclerotized; each having apex sinuate and a heavy ventral projection near the middle of the mesal side. Oedagus with basal portion of tube

Fig. 28.—*Neotrichia falca*



widely flared, about a third as long as narrow portion; apical portion consists of (1) a narrow stem with (2) a pair of stout, dark hooks set in a dorsal excavation and (3) a stout process arising dorsally from below this and extending almost to apex of hooks. These dark hooks seem to be set in place quite rigidly with no articulation other than connective membrane.

**Holotype, male.**—Muncie, Illinois: Sept. 20, 1935, along Stony Creek, Frison & Mohr.

#### *Neotrichia vibrans* new species

The curiously shaped oedagus, fig. 29, differentiates the male of this species from all others in the genus. Reliable characters for separating the females have not yet been discovered.

**MALE.**—Size 2 mm. Head and its appendages, thorax and legs pale yellow; the front tibiae covered with black setae; antennae covered with black hair, except apical four segments, which are white. Abdomen gray. Wings covered with patches of black, brown and white, typical for genus.

General characteristics same as for genus. Eighth sternite with a rounded mesal projection on apical margin. Genitalia as in fig. 29, bearing three sets of paired appendages: a dorsal pair, *d*, diverging and angling ventrad, thin, pointed at apex and without setae; a middle pair, *m*, short, stocky at base with the apex curved meso-ventrad and armed with one or two small setae; and a ventral pair, the claspers, somewhat irregular in shape, pointing caudad, slightly concave on their inner margin, and beset with sparse, fine setae. Between the bases of the claspers is a pair of ringlike areas, whose mesal margin

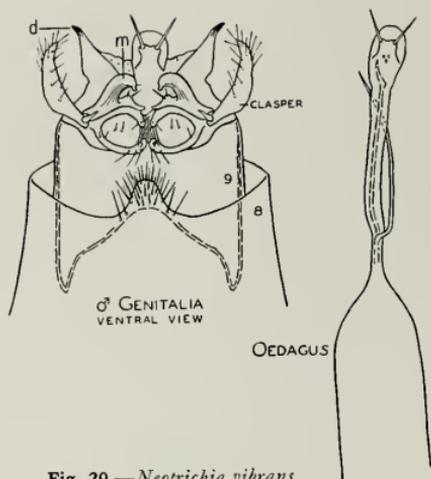


Fig. 29.—*Neotrichia vibrans*

bears small raised portions. Oedagus with a very wide basal cylinder which tapers to a narrow neck; the apical portion is not much thicker than the neck and is slightly enlarged at apex into an ovoid structure bearing two long setae; the neck gives rise to a long, thin filament which curves around the apical portion.

**Holotype, male.**—Oakwood, Illinois: Sept. 7, 1936, along Middle Fork River, DeLong & Ross.

#### *Polytrichia shawnee* new species

Resembles very closely *tarsalis* (Hagen), but differs in the shape of the genitalia, fig. 30.

**MALE.**—Length 3 mm. In general, color brown. Head and antennae almost entirely dark brown; thorax and abdomen mottled brown and whitish. Legs luteous with spurs. Mid and hind tarsi and most of hind tibiae blackish. Wings blackish brown, with a narrow, whitish band just before middle; a white spot on the costal and anal margins two-thirds distance from base, and a white spot at extreme apex.

General structure same as for genus. Ocelli large; antennae filiform, long and slender, reaching apex of abdomen. Apical tibial spurs short and stout. Preapical spur on mid tibiae short and stout; shorter one on hind tibiae the same length; longer one twice that length.

Genitalia as in fig. 30. Claspers almost identical with those of *tarsalis*; the two slightly different, armed within with stout, short, dentiform setae. Oedagus long, slender and enlarged at apex, without armature. Dorsal aspect bears pair of complex appendages; the right one has a long, thin process before middle, is curled in clockspring fashion near apex and ends in a stout tooth set off by a basal suture; the left one bears near base a very long process, beyond this a mesal lobe terminating in a densely sclerotized point, and narrows at its apex to an upturned point.

**FEMALE.**—Similar in size, color and general structure to male. External genital structure similar to that of most members of the family; bursa copulatrix long and slender.

**Holotype, male.**—Herod, Illinois: May 29, 1935, Ross & Mohr.

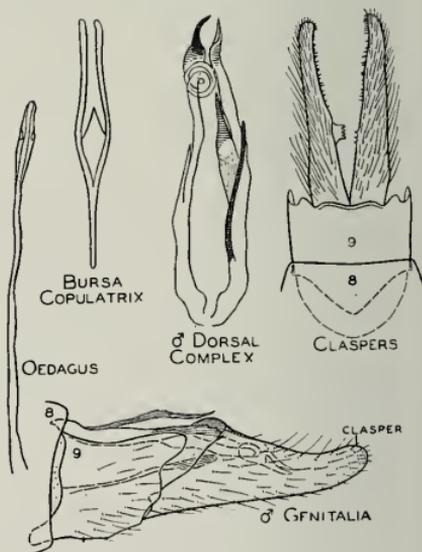


Fig. 30.—*Polytrichia shawnee*

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Same data as for holotype, 11 ♂, 6 ♀.

#### *Polytrichia stylata* new species

Indistinguishable from *shawnee* except for the dorsal aggregate of stylets on the genitalia, fig. 31. The diagnostic

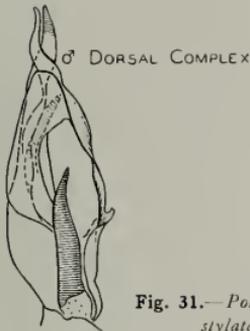


Fig. 31.—*Polytrichia stylata*

characters are as follows: Left process with a small tooth near base, its apex produced into a sinuate, narrow stylet; right process stouter, partially hidden under the "plate" of the left process, the apex pigmented and crossing beneath apex of left process; the right process has a strong tooth arising under the "plate"; at the base of the two processes is a large, dark tooth slightly sinuate at its apex. Reliable characters for separating the females have not yet been unearthed.

**Holotype, male.**—Farson, Wyoming: July 6, 1936, along Little Sandy Creek, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MONTANA.—Ennis: July 8, 1936, along Madison River, H. H. Ross, 1♂.

OKLAHOMA.—Turner Falls State Park: June 2, 1937, along Honey Creek, H. H. Ross, 14♂.

WYOMING.—Same data as for holotype, 1♂, 1♀.

***Polytrichia oregona* new species**

Belonging to the section of the genus containing *confusa* Morton, this species differs from Morton's illustrations in the long mesal process of the left clasper and other details in the shape of the clasper.

**MALE.**—Length 3.25 mm. Color and general structure typical for genus, as described for *shawnee*. Genitalia as in fig. 32. Eighth segment sclerotized much more than sixth or seventh, the dorsal margin almost completely divided by a V-shaped fissure. Dorsal assemblage of parts composed of a stout left and a lighter right sclerotized rod; these are separated at the base and converge to the apex where they are joined by a membranous fold; at the

base arise three sclerotized points which curve dorsad, the one toward the apex being the longest. Claspers asymmetrical; left one, seen from lateral view, appears sinuate, near the middle with a long ventral projection which curves slightly mesad, and at the apex with a short, sclerotized point which also curves mesad; right clasper sinuate, shaped like the left but with no trace of the ventral process. Seen from the ventral aspect, each clasper has a cluster of black spines near the middle, those on the left clasper situated on the mesal side, those on the right clasper situated on the ventro-mesal corner. Oedagus simple, as illustrated for *shawnee*.

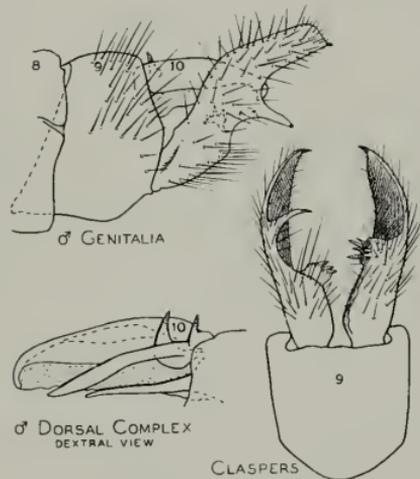


Fig. 32.—*Polytrichia oregona*

**Holotype, male.**—La Grande, Oregon: July 30, 1936, along Grande Ronde River, H. H. Ross.

***Polytrichia spinosa* new species**

Close to *confusa* and *oregona*, this species differs from the latter in having a black spine pointing mesad in place of the long process on the left clasper and from the former in having the dorsal assemblage of the genitalia short, not reaching beyond the cluster of spines on the right clasper.

**MALE.**—Length 2.25 mm. Color and general structure as described for *shawnee*. Genitalia as in fig. 33, and similar in general to the description given for

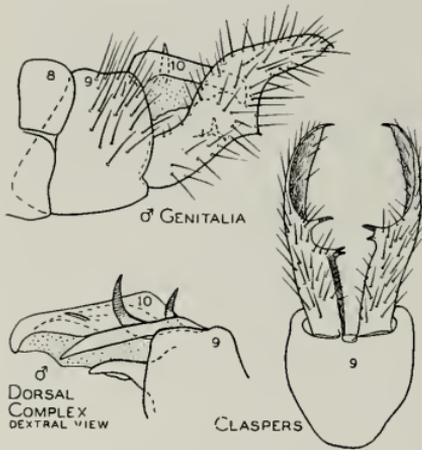


Fig. 33.—*Polytrichia spinosa*

*oregona*, with the following differences: Eighth segment with the dorsal fissure much wider so that the two parts of the dorsum are well separated. Dorsal assemblage of genitalia shorter, the individual sclerotized rods proportionately shorter and stouter; best seen from a lateral view. Left clasper sinuate, the apex with a sclerotized spine pointing mesad, with a fairly long spine on the ventral corner and with a cluster of two black spines just basad of this on the mesal face; right clasper sinuate, with a small cluster of three spines on the mesal face near the ventral corner. Oedagus same as for *shawnee*.

**Holotype, male.**—Turner Falls State Park, Oklahoma: June 2, 1937, along Honey Creek, H. H. Ross.

**Paratype.**—OKLAHOMA.—Same data as for holotype, 1 ♂.

#### *Polytrichia xena* new species

This species is distinguishable from others in the genus on the basis of the short mesal process of the genitalia, which has no complicated armature.

**MALE.**—Length 2.5 mm. Color whitish; areas on periphery of head, all mesonotum, metanotum except scutellum, upper portion of pleurae and dorsum of abdomen brown. Wings dark gray with a light transverse band just before middle; legs whitish, the front tibiae and tarsi clothed with dark setae. General structure same as in *shawnee*.

Genitalia as in fig. 34. Genital capsule wide and long but shallow. Ninth segment twice as long ventrally as dorsally, the dorsal margin cut in on meson so that the segment forms merely a narrow bridge mesally. Tenth tergite triangular, apparently fused with the other appendages of the genitalia aside from the claspers and oedagus. This entire process is short; the base is semi-sclerotized; the right side of the apex is mostly membranous and the left side covered with a sclerotized shield; a small dorsal tooth lies just below extreme apex; the basal third is striate, with irregular creases radiating from the meson. Claspers as long as genital capsule, slightly upturned with the base oblique and the apex bluntly pointed; the inner margin is convex and bears two brushes of stout, dark setae, one at the apex and the other just basad of it; the rest of the clasper is covered with long, scattered setae. Oedagus very simple, as illustrated for *shawnee*, consisting of a narrow filament with the extreme apex more heavily sclerotized than the rest.

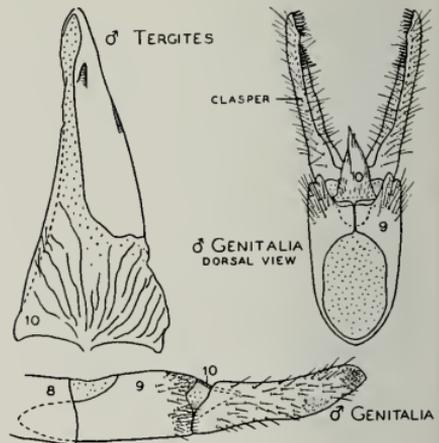


Fig. 34.—*Polytrichia xena*

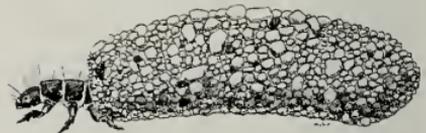


Fig. 35.—Case and larva of *Polytrichia xena*

**Holotype, male.**—Herod, Illinois: May 13, 1937, along Gibbons Creek, Frison & Ross.

**Paratypes.**—ILLINOIS.—Same data as for holotype, 3♂.

The larva in its purselike case, fig. 35, is one of the commonest "micros" found in the rocky streams of the Ozarkian uplift in southern Illinois.

### *Hydroptila vala* new species

This species differs from already described members of the genus in the oedagus, fig. 36, with its coiled middle process and upturned end.

**MALE.**—Length 3.3 mm. Body brown, with palpi, legs and venter whitish; patches of white setae on front of head and some small areas on wings.

General structure typical for genus. Antennae long, slender and filiform. Tibial spurs thick and long. Seventh sternite with a long, slender process of almost uniform thickness, thickly clothed with setae and as long as the longer apical spur on the hind tibia.

Genitalia as in fig. 36. Tenth tergite apparently forming two lateral plates separated by a mesal membranous area. Lateral plate small and with apex angulate. From the mesal side at the base of the lateral plates arise a pair of semi-membranous appendages, *a*, which are straight to the apex of the claspers and then abruptly hook upward and backward over the dorsal plate. Claspers flattened transversely, curving downward, their lateral margin having some large and some small setae. Oedagus long, the tubular portion subequal in length to the portion beyond the spiral spur; spiral spur encircling tube two and one-half times; free tip not very long; apical portion slender and of uniform thickness; apex upturned but without armature.

**FEMALE.**—Similar in size, color and general structure to male. Has the elongate and tubular ovipositor typical of the genus. Eighth sternite terminated by an arcuate lobe bearing six long setae; the middle of the segment, bearing an urnshaped mesal area, shown in fig. 36. Bursa copulatrix with closed end elongate.

**Holotype, male.**—Herod, Illinois: May 29, 1935, Ross & Mohr.

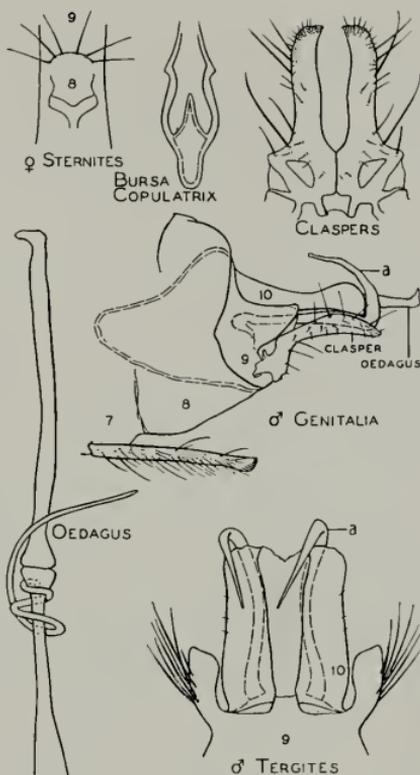


Fig. 36.—*Hydroptila vala*

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Same data as for holotype, 15♂, 18♀.

### *Hydroptila armata* new species

Closely allied to *vala*, but differs in details of the genitalia as given below.

**MALE.**—Similar in size, color and general structure to *vala*. Eighth segment with a long, sinuate process at apex.

Genitalia as in fig. 37. Tenth tergite membranous, narrowed toward apex, with a slight incision on meson, and the two caudolateral angles produced into slender, sclerotized processes. Lateral plate long, narrow and upturned at end. From within this at base arises a pair of long, upturned and semimembranous hooks, *a*. The left one is longer than

the right. Claspers long, narrow at base and thickened toward apex; extreme tip upturned and heavily sclerotized. Entire clasper studded with small setae; a few large ones on dorsal margin. Oedagus fairly simple; basal portion long; apical portion of almost uniform thickness; apex with a stout transverse tooth; spiral process encircling tube twice.

**FEMALE.**—Similar in color and general characteristics to male. Eighth sternite with a crescentic apical lobe bearing six long and diverging setae; eighth tergite with a sclerotized apical portion forming a pair of lateral lobes bearing several setae, the lobes connected with a sclerotized bridge and not conspicuously extended.

**Holotype, male.**—Winamac, Indiana: May 24, 1937, drainage ditch west of town, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Fox Lake: July 15, 1935, DeLong & Ross, 2♂. Moccasin: Aug. 21, 1936, Ross & Burks, 1♂; May 24, 1937, H. H. Ross, 7♂. Oakwood: Sept. 20, 1935, along Salt Fork River, DeLong & Ross, 1♂. Spring Grove: June 12, 1936, Ross & Burks, 1♂. Wilmington: July 1, 1935, DeLong & Ross, 2♂.

INDIANA.—Kankakee State Game Preserve: May 24, 1937, along Kankakee River, H. H. Ross, 1♂. Winamac: May 24, 1937, drainage ditch west of town, H. H. Ross, 5♂, 9♀.

MICHIGAN.—Batavia: May 19, 1936, along

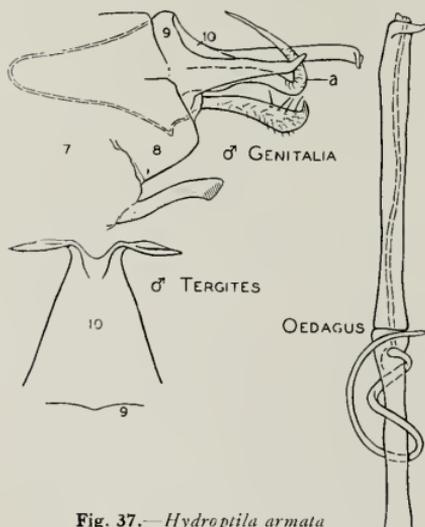


Fig. 37.—*Hydroptila armata*

Swan Creek, Frison & Ross, 1♂. Clinton: May 19, 1936, along Raisin River, Frison & Ross, 1♂. Goodrich: May 30, 1936, along Thread River, Frison & Ross, 1♂.

WISCONSIN.—Spooner: June 5, 1936, along Namakagon River, Frison & Ross, 1♂.

### *Hydroptila amoena* new species

Similar in many respects to *hamata* Morton, but has a more slender process on the seventh segment, longer and more

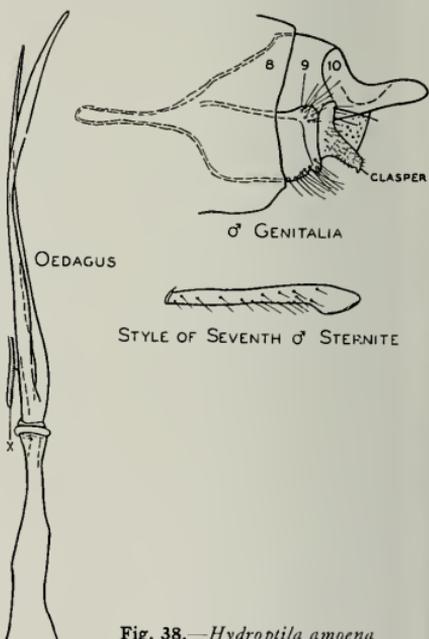


Fig. 38.—*Hydroptila amoena*

deeply cleft tenth tergite, oedagus not curved sharply at tip, as well as other differences.

**MALE.**—Length 3 mm. Color and general structure same as for *vala*. Seventh sternite has a long, slender process with its extreme apex curved out, enlarged and roughened.

Genitalia as in fig. 38. Tenth tergite long, mesal portion depressed and incised at apex, lateral portions at first glance appearing separate and clasper-like. Remainder of external parts difficult to determine from the standpoint of homology, but as illustrated in fig. 38. Claspers short, stout and pyramidal, the extreme apex forming a short, blunt tooth; both claspers ap-

pressed on meson. Oedagus with basal tube less than two-thirds length of apical portion; spiral process short, circling only halfway around the tube; the tube divided immediately beyond this point, the two tubes thus formed progressing side by side to their apex where they may separate; one of them becomes smaller toward the apex and finally terminates as a narrow filament; the other narrows, then widens again and finally narrows to a small tip. Beside the oedagus a small rodlike structure, *x*, has been observed, which is apparently associated with the oedagus but which has not been oriented with certainty.

**Holotype, male.**—Herod, Illinois: May 29, 1935, Ross & Mohr.

**Paratypes.**—ILLINOIS.—Herod: April 19, 1937, along Gibbons Creek, Ross & Mohr, 1 ♂.

OKLAHOMA.—Turner Falls State Park: June 2, 1937, along Honey Creek, H. H. Ross, 20 ♂.

**Hydroptila tortosa** new species

This species is a member of the *hamata* complex but differs from the other species of that group in the peculiar oedagus, fig. 39.

**MALE.**—Length 2.5 mm. Color and

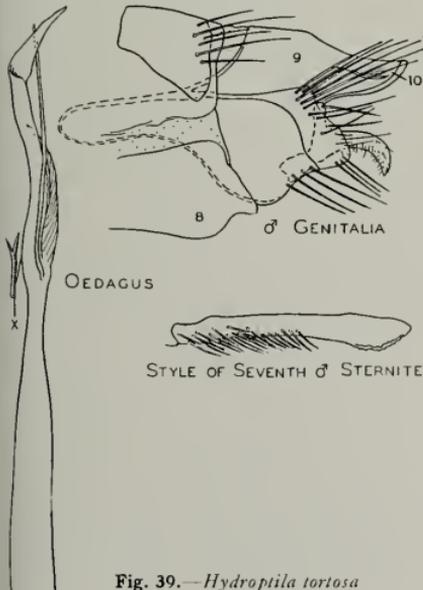


Fig. 39.—*Hydroptila tortosa*

general structure same as for *amoena* except for the legs, which have the femora and tibiae dark brown. Seventh sternite has a long, slender process clothed at base with long setae, the apex enlarged but laterally compressed and having the ventral margin serrate.

Genitalia as in fig. 39. Basal arm of ninth segment short, no longer than segment itself. Tenth tergite pointed, as seen from lateral view; divided into two ovate lobes, as seen from the dorsal view, without setae. Claspers saber-like, curved meso-ventral and almost touching on the meson; thickness uniform for most of length, apex pointed, ventral half with minute setae. Oedagus very long, the basal portion about equal in length to the apical portion which has a heavy, sinuate central stem, the apex of which is twisted and flattened. Two slender filamentous processes arise near base but do not extend so far as the central stem; at the base of the apical portion is the detached, sclerotized rod found also in *amoena*.

**Holotype, male.**—Luray, Virginia: Sept. 28, 1936, T. H. Frison.

**Hydroptila virgata** new species

Resembles *hamata* Morton very closely but differs from it in the tapered projection of the seventh sternite, fig. 40, the absence of a long style beside the oedagus and other characters of the genitalia.

**MALE.**—Size 3.25 mm. Color and general structure as in *vala*. Seventh sternite with a process three-quarters the length of the longer apical spur of the hind tibiae; this process tapered at base and flattened and turned out at apex, normally so densely clothed with wide setae that the shape is obscured. Eighth sternite with an apical mesal protuberance which appears angulate as seen ventrally.

Genitalia as in fig. 40. Lateral lobe of ninth segment small, outcurved and pointed at apex. At the base of the lateral lobe arises a short, tubular process, *p*, bearing a very long seta at apex. Tenth tergite with apex membranous, the tip upturned and set off with a transverse crease; basal portion large and rounded, the ventro-apical region

having a patch of short setae. Claspers sinuate, short and small, with apex rounded on end and coming to a blunt point dorsally. Oedagus with basal tube subequal in length to apical portion beyond spiral; apical portion cylindrical, tapering gradually to region near apex, where it forms a complete S-shaped curve, at the base of which is a stubby and membranous protuberance; spiral process slender, curved around base of tube almost twice and finally continuing beside it for half its length.

**FEMALE.**—Size, color and general structure same as in male. Bursa copulatrix with the apex shorter and stockier than in *vala*. Penultimate segment without ventral ornamentation.

**Holotype, male.**—Herod, Illinois: May 29, 1935, Ross & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Eichorn: May 29, 1935, along Hicks Branch, Ross & Mohr, 1♂.

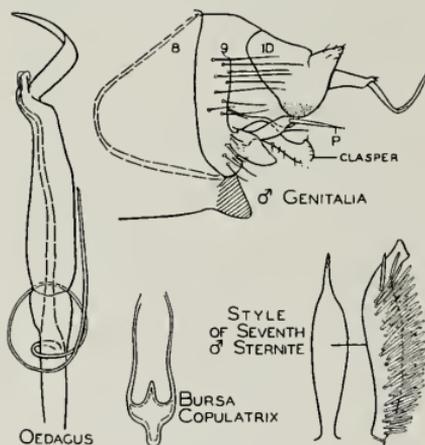


Fig. 40.—*Hydroptila virgata*

Herod: Same data as for holotype, 44♂, 160♀; May 10, 1935, C. O. Mohr, 1♂; May 13, 1937, Frison & Ross, 13♂.

#### *Hydroptila dentata* new species

This species is most closely related to the *delineata* group but differs from all hitherto described species in the lateral, spurlike setae of the eighth segment.

**MALE.**—Length 2.3 mm. Color and general structure identical with preceding species. Eighth segment pro-

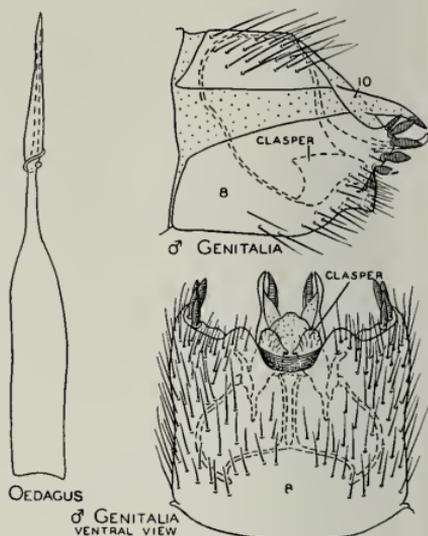


Fig. 41.—*Hydroptila dentata*

duced into a pair of lateral processes, each armed at apex with four or five stout, fingerlike setae; the ventral portion of the segment is emarginate on the meson and produced into a lateral hump on each side.

Genitalia as in fig. 41. Claspers small, apex rounded and produced into a sharp process on the meson, not extending beyond the lateral lobes of the eighth sternite. Tenth tergite semi-membranous and cleft down the meson, the lateral lobes each tapering to a threadlike apex which is recurved to form a bladlike process on each side. Oedagus short, the basal portion very wide compared to the threadlike apical portion. The base of the apical portion is marked by a slender filament which encircles the oedagus at this point.

**Holotype, male.**—Luray, Virginia: Sept. 28, 1936, T. H. Frison.

**Paratypes.**—VIRGINIA.—Same data as for holotype, 2♂.

#### *Hydroptila grandiosa* new species

This species approaches *delineata* Morton very closely in most respects but differs markedly from it in the peglike setae at the apex of the lateral margin of the eighth segment and in the heavily sclerotized, curved appendages of the

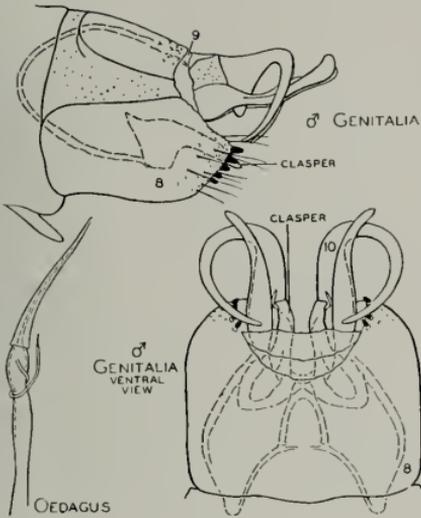


Fig. 42.—*Hydroptila grandiosa*

genitalia, fig. 42. The latter separate it from *dentata* also.

**MALE.**—Length 3 mm. Color and general appearance as for other members of the genus. Seventh sternite with a bluntly pointed mesal spur, short and more or less inconspicuous. Eighth sternite incised at apex, each lateral portion produced into a stout lobe bearing four or five peglike setae at the apex. Eighth tergite small and more or less quadrate; does not extend as far caudad as the sternite.

Genitalia as in fig. 42. Claspers small, narrow at apex and broadening out at base; extreme tip obliquely truncate, with a slight notch and tooth on lateral corner. Above the claspers are two long, sinuate processes which are divergent toward apex. The tenth tergite is reduced to a small triangular sclerite which is pointed at apex. Articulating with it are a pair of large, heavily sclerotized hooks with a very wide base and long curved tips. The dorsal corner of the base of each hook is closely connected with the apex of the dorsal plate, and the ventral corner is closely associated with the sinuate processes below it. Oedagus small compared to the remainder of the genital capsule, the portion beyond the constriction slender

and gradually tapering to apex; tube slightly bulbous below constriction, the spiral rod making a complete revolution around it and lying along and over the apical portion to form a somewhat 8-shaped pattern.

**Holotype, male.**—Oakwood, Illinois: Sept. 20, 1935, along Salt Fork River, DeLong & Ross.

**Paratypes.**—ILLINOIS.—Momence: May 24, 1937, along Kankakee River, H. H. Ross, 2♂. Oakwood: July 18, 1933, along Salt Fork River, Ross & Mohr, 2♂.

INDIANA.—DeLong: May 24, 1937, along Tippecanoe River, H. H. Ross, 13♂. Knox: May 24, 1937, along Yellow River, H. H. Ross, 2♂.

**Hydroptila ajax** new species

A close ally of *albicornis* Hagen, differing in details of genitalia, notably the different claspers and long, stout spiral process of the oedagus.

**MALE.**—Length 2.5 mm. Color and general structure typical for genus.

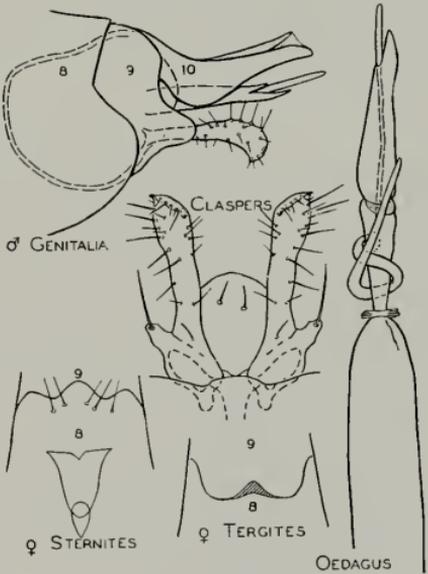


Fig. 43.—*Hydroptila ajax*

Seventh sternite with only a short, pointed mesal process.

Genitalia as in fig. 43. Lateral lobe of ninth segment short and rounded. Tenth tergite entire, but with a pair of membranous areas dividing it distinctly

into one mesal and two lateral lobes. Claspers turned down at end, with a pair of dark areas at tip; lateral margin armed with about six long setae grouped near apex and having smaller setae scattered over entire area; footlike base only slightly produced laterad and not conspicuously large. Oedagus almost straight; basal portion regularly tubular and fully twice length of apical portion; apical portion round, gently tapering and with the penis projecting as a thin rod; articulation with constricted portion apparent but not so well developed as in *albicornis*; spiral process stout, encircling tube one and one-half times.

**FEMALE.**—Similar in color and general structure to male. Diagnostic characteristics, fig. 43, as follows: eighth sternite with a mesal, triangular sclerite which is much longer than wide; dorsal margin of eighth segment with incision humped in middle and ventral margin sinuate with two or three pairs of setae below the emargination.

**Holotype, male.**—Oakwood, Illinois: July 18, 1933, along Salt Fork River, Ross & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Muncie: June 27, 1932, H. H. Ross, at light, 10♂, 12♀; July 18, 1933, Ross & Mohr, 1♂; Sept. 18, 1935, De Long & Ross, 1♂. Oakwood: July 18, 1933, Ross & Mohr, 184♂, 24♀; July 18, 1933, along Middle Fork Vermilion River, Ross & Mohr, 7♂; Sept. 20, 1935, DeLong & Ross, 4♂.

IDAHO.—Bear River Narrows: Aug. 8, 1937, G. F. Knowlton, 12♂, 16♀.

OREGON.—LaGrande: July 30, 1936, along Grande Ronde River, H. H. Ross, 1♂, 1♀.

WASHINGTON.—Centralia: July 26, 1936, H. H. Ross, 5♂, 1♀.

WYOMING.—Farson: July 6, 1936, along Little Sandy Creek, H. H. Ross, 7♂, 4♀.

### *Hydroptila scolops* new species

In many respects this species is intermediate between *albicornis* and *ajax*, but differs from both in the shape of the claspers and oedagus.

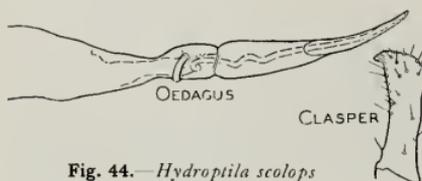


Fig. 44.—*Hydroptila scolops*

**MALE.**—Indistinguishable in size, color and general structure from *ajax*. Genitalia, fig. 44, also very similar to these, the only tangible differences being in the claspers and oedagus. Claspers slightly curved ventro-laterad, the apico-lateral corner produced into a rounded, corneous projection; apical and lateral margins set with several small setae; a smaller number of setae on the ventral face; the baso-lateral seta not on a lateral projection. Oedagus with basal portion short and flaring, constricted before robust portion bearing spiral; apical portion tapering to a thin, curved apex, one side cut away for nearly half its length to form a trough in which lies the apex of the rodlike penis; spiral process short, not encircling tube, its apex very slender and lying close to tube.

**Holotype, male.**—Shawneetown, Illinois: May 11, 1935, at light, C. O. Mohr.

### *Hydroptila melia* new species

This species is closest to members of the *albicornis* group but differs from them in the lengthened claspers and ninth and tenth tergites.

**MALE.**—Length 3 mm. Color and general structure same as for genus. Seventh sternite with a small, pointed mesal process. Eighth segment only moderately incised ventrally.

Genital capsule as in fig. 45, its invaginated portion rounded and arcuate in such a fashion that there is little asymmetry in the dorsal and ventral halves. Ninth tergite slightly produced into a pair of small lobes on the meson, excavated on either side of these. Tenth tergite produced into two long, sclerotized and sharp lateral processes. These two lobes have their lateral margins slightly diverging from the base; their mesal margins almost meet at the base and between them is a pair of membranous folds which partially cover the mesal angle; from the side these lateral pieces appear relatively shallow, deepest near base and tapering to a sharp apical point; both are attached at base by membrane to an orbicular, sclerotized mesal plate connected with the ninth tergite. Claspers long, slightly widened toward apex, the apical two-thirds covered with small scattered setae, the

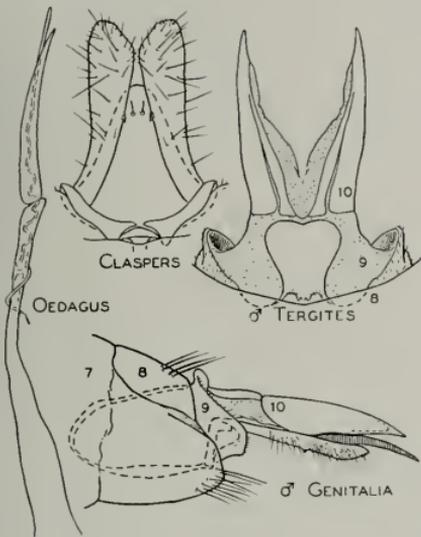


Fig. 45.—*Hydroptila melia*

mesal margin with a slightly produced, darkly sclerotized point in the middle; the transverse footlike portion of the base of the clasper is concealed within the last segment. Oedagus very long; portion below neck no longer than portion beyond neck, widening gradually to a moderately bulbous base; neck very narrow, not at all bulbous, with only a faint and thin spiral rod which encircles the basal portion of the neck; apical portion of oedagus saber-shaped and thin, the terminal opening long because of the extreme obliqueness of the apex.

**Holotype, male.**—Turner Falls State Park, Oklahoma: June 2, 1937, along Honey Creek, H. H. Ross.

**Paratypes.**—OKLAHOMA.—Same data as for holotype, 36♂.

***Hydroptila arctia* new species**

Although similar in a large number of respects to *consimilis* Morton, the attenuated claspers identify this new species at once.

**MALE.**—Length 2.5 mm. Color and general structure same as for other members of the genus. Seventh sternite with only a short, pointed mesal process.

Genitalia as in fig. 46. Genital capsule extending only a short distance into the

abdomen, the basal lobe produced strongly ventrad. Lateral portion of ninth segment produced into a fairly long upturned process which is wide at the base and narrow at the apex, and has a dorsal cushion of stout setae at its base; below this the segment is slightly bilobed to form a pair of convex areas bearing numbers of setae. Tenth tergite markedly flares toward apex, the lateral areas having sclerotized plates which are wide on their basal half and taper on the flared portion to a point; their mesal portion consists of wide membranous lobes which are separated by a narrow cleft down the meson. Claspers broad at base, the apical portion rapidly tapering to an elongate, narrow structure having a few scattered setae on the mesal and lateral surfaces and a few minute ones over the entire surface at extreme apex; the apical lateral angle turns out slightly and forms a small sclerotized point; the mesal margins of the two claspers diverge slightly and have no sclerotized armature. From the lateral aspect the claspers appear quite

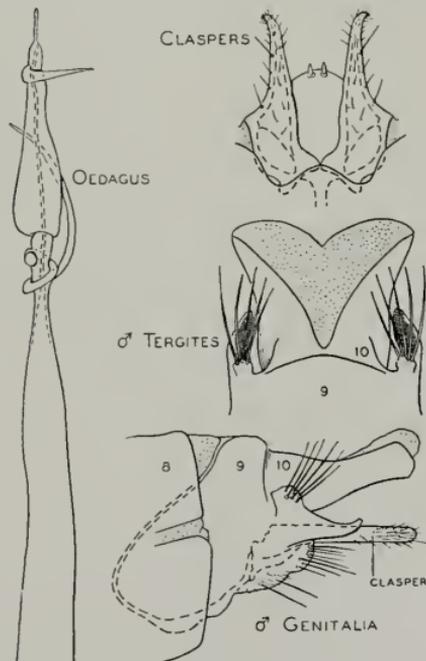


Fig. 46.—*Hydroptila arctia*

regularly filiform with sides parallel and apex rounded.

Oedagus with a long, slightly sinuate, otherwise regular, basal tube which is twice as long as the portion beyond the constriction. Middle "neck" slender, slightly enlarged into a small, bulbous process, at which point the apical portion of the oedagus articulates; apical portion with its greatest diameter near base, from there narrowing evenly to transverse spine, beyond which it continues for a short distance as a narrow membranous tube. The transverse spine is sharp and as long as the "neck." The spinal process encircles the "neck" one and one-half times, its apex angling forward and passing across the vasiform apex.

**Holotype, male.**—Bear River Narrows, Idaho: Aug. 8, 1937, G. F. Knowlton.

### *Hydroptila angusta* new species

Very similar to *consimilis* Morton but differs from it in having the head of the oedagus long and slender with a small tooth at the apex. In *consimilis* this apical process is much longer in proportion to the length of the head of the oedagus.

**MALE.**—Length 2.75 mm. Color and general characteristics same as for other members of the genus. Seventh sternite with only a short, pointed mesal process.

Genitalia, as in fig. 47, similar in almost all respects to those of *consimilis* figured by Betten (1934). Tenth tergite wide, deeply and angularly cleft for half its length, with only the extreme lateral margins sclerotized. Claspers rounded at apex and reaching almost as far caudad as the claspers; it bears a pair of short, erect spines just below the middle. Oedagus slender; basal tube long, narrowed to a creased area just below spiral process; portion beyond constriction with bulbous base, soon tapering into a long, slender apical portion surmounted near apex by a short oblique process; spiral process of neck stout, encircling tube one and a half times, its apex angling away from the

tube. Penis a slender tube, typical of genus, the basal portion semimembranous, the apical portion sclerotized.

**FEMALE.**—Size, color and general structure same as for male. Genital characters of importance, fig. 47, as follows: Eighth sternite near apex with a trapezoidal structure; apex of eighth segment of tube with a square cleft on

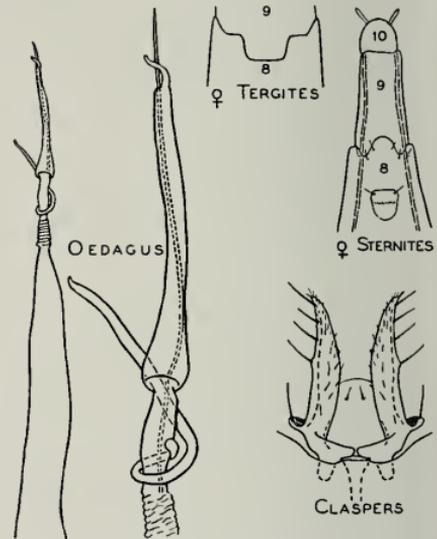


Fig. 47.—*Hydroptila angusta*

the dorsum and with a rounded lobe bearing six paired setae on the venter.

**Holotype, male.**—Muncie, Illinois: Sept. 18, 1935, along Stony Creek, DeLong & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Charleston: Aug. 15, 1933, Embarrass River, Ross & Mohr, 6♂. Danville: Sept. 20, 1935, Frison & Mohr, 1♂. Homer Park: Aug. 5, 1931, H. H. Ross, 1♂; Oct. 16, 1932, Ross & Mohr, 9♂. Kankakee: Aug. 1, 1933, along Kankakee River, Ross & Mohr, 146♂; June 6, 1935, Ross & Mohr, 1♂; July 21, 1935, Ross and Mohr, 1♂; July 22, 1935, DeLong and Ross, 3♂. Mokence: May 24, 1937, H. H. Ross, 1♂. Muncie: June 27, 1932, H. H. Ross, 5♂, 8♀; June 27, 1932, at light, H. H. Ross, 4♂, 8♀; Sept. 18, 1935, DeLong & Ross, 21♂; Sept. 20, 1935, Frison & Mohr, 13♂. Oakwood: July 18, 1933, along Middle Fork Vermillion River, Ross & Mohr, 65♂; July 18, 1933, Ross & Mohr, 140♂, 90♀; Sept. 20, 1935, DeLong & Ross, 80♂. Putnam: July 11, 1933, Lake Senachwine, C. O. Mohr, 4♂. Rock Island: June 24, 1931, C. O. Mohr, 3♂. Wilmington:

May 12, 1935, Frison & Ross, 1♂; June 6, 1935, Ross & Mohr, 1♂; July 1, 1935, DeLong & Ross, 36♂.

### *Hydroptila protera* new species

This species is distinguished from all others in the genus by the combination of the twisted, bladelike apex of the oedagus and the narrow and converging claspers, fig. 48.

MALE.—Length 3 mm. Color and general structure typical for genus. Seventh sternite with only a small, pointed mesal process.

Genitalia as in fig. 48. Genital capsule with the basal portion rounded at base and not produced far into the abdomen.

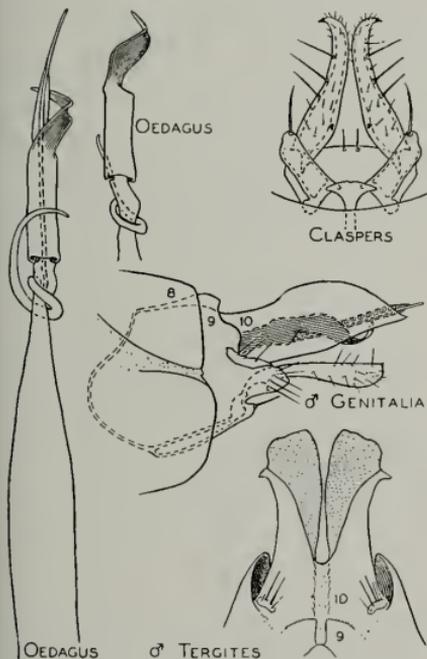


Fig. 48.—*Hydroptila protera*

The apico-lateral margins of the ninth segment bear a small setiferous sclerite at the base of the tenth tergite, and just ventrad of this sclerite are produced into a short lobe bearing a few long setae. Tenth tergite long and deep, deeply incised down meson into two halves; these angle considerably laterad; the basal portion of each half is almost

entirely sclerotized, the sclerotized portion narrowing off abruptly beyond middle into a narrow arm which ends in a small point directed laterad; the mesal portion of the apex of each half consists of a large membranous lobe, the lobes of the two sides almost touching near the middle. Claspers with a distinct and almost quadrate base, the apical portion arising from the lateral half of the base, slightly swollen just beyond base, thence narrowing and ending in outcurved points; from the lateral aspect the claspers appear to have a straight dorsal margin and an evenly sinuate ventral one; the lateral margin has a few long setae supplemented by scattered shorter ones. The ventral plate is very short and armed with a pair of fairly long setae near apex. Oedagus with basal tube slightly more than twice as long as portion beyond constriction; neck small, slightly twisted and slightly bulbous, narrowed where it articulates with the apical portion; apical portion with basal two-thirds almost cylindrical, apex forming a stout, twisted blade. The spinal process, which encircles the neck one and one-half times, is quite stout.

**Holotype, male.**—Turner Falls State Park, Oklahoma: June 2, 1937, along Honey Creek, H. H. Ross.

**Paratypes.**—OKLAHOMA.—Same data as for holotype, 8♂.

### *Hydroptila argosa* new species

This species differs from all hitherto described members of the genus in the curved condition of the entire apex of the oedagus, fig. 49.

MALE.—Length 2.5 mm. Color and general structure typical of genus. Seventh sternite with only a short, pointed mesal process.

Genitalia, fig. 49, relatively simple, without long or recurved lateral processes. Tenth tergite entire, evenly rounded at apex, entirely membranous and with a small, triangular digitate process on meson near apex. Claspers fairly long, narrow, triangular and markedly diverging, beset with short, fine setae. Above them is a submembranous flap bearing two setae near its apex. Oedagus with a long basal portion surmounted by a narrow neck and

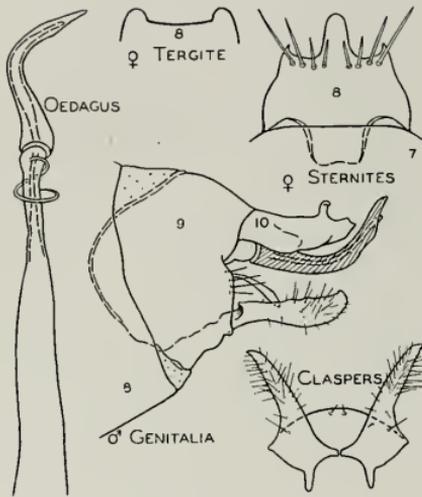


Fig. 49.—*Hydroptila argosa*

small bulbous portion; the apical portion fits on this bulb and is curved almost into a quadrant in one plane; the neck is provided with a thin spiral process encircling the neck one and one-half times.

**FEMALE.**—Slightly larger than the male; similar to it in color and general structure. Diagnostic characters occur on the eighth segment, fig. 49. Apex of eighth tergite almost transverse, slightly produced at sides. Apex of eighth sternite with a long, round, smooth mesal projection, with a semicircle of eight large setae just basad of the apical margin. Seventh sternite with a wide internal process which is slightly emarginate at apex. Bursa copulatrix similar to some other members of the genus.

**Holotype, male.**—Parco, Wyoming: Aug. 1, 1936, along North Platte River, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—WYOMING.—Same data as for holotype, 167♂, 131♀.

**IDAHO.**—Bear River Narrows: Aug. 8, 1937, G. F. Knowlton, 5♂, 14♀.

### *Hydroptila xera* new species

Distinguished from previously described members of the genus by the long, slender oedagus and the long, out-curved claspers, fig. 50.

**MALE.**—Size 2.5 mm. Color and general structure typical for genus. Seventh sternite with a meso-apical process about half the length of the segment and pointed at apex; without flattened setae.

Genitalia as in fig. 50. Tenth tergite semimembranous, deeply incised on meson, the lateral portions of the apex diverging. Claspers sinuate and slender, with a small quadrate base; medium-sized setae along stem and a cluster of minute setae at apex. Above the claspers is a pair of smooth sclerotized appendages which are wide apart at base and meet at apex. Oedagus very long and slender, the bulbous portion set off from the base by a constriction; the extreme apex curved, the apex of the protrusible penis straight. No spiral process has been detected, perhaps because of extreme translucency.

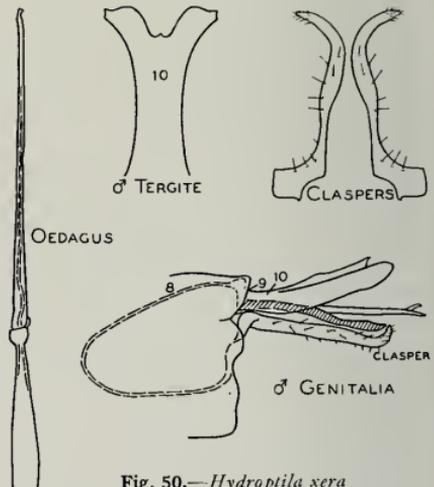


Fig. 50.—*Hydroptila xera*

**Holotype, male.**—Caldwell, Idaho: July 30, 1936, along Boise River, H. H. Ross.

**Paratypes.**—IDAHO.—Bear River Narrows: Aug. 8, 1937, G. F. Knowlton, 2♂.

## Family PHILOPOTAMIDAE

### *Philopotamus dorcus* new species

This species differs from the other nearctic members of the genus in the spatulate terminal segment of the claspers and the appendagelike lateral branches of the apical tergite.

**MALE.**—Length 8.5 mm. Body black, covered with gray hairs. Legs and antennae yellowish brown, covered with dark brown hairs. Front wing membrane gray, irrorate over the entire surface with whitish areas, the gray portion covered mostly with blackish hairs, the white areas with whitish or cream-colored hairs; these white areas form a row of conspicuous spots around the edge of the apical half of the wing. Hind wing uniformly gray, covered with black hairs.

General characteristics of antennae, ocelli, venation and spur count same as for genus. Genitalia as in fig. 51. Seventh, eighth and ninth sternites without mesal processes. Ninth tergite pointed on meson. Tenth tergite set off from ninth by a deep excavation, the tergite cleft practically to the base, forming a pair of foliaceous appendages well separated on the meson. Claspers with the two segments subequal in length, the apical segment slightly constricted near base and expanded at apex. Cerci more than two-thirds length of apical segment of claspers. Oedagus assemblage composed of a pair of slender rods housed in a more or less triangular sheath which is wide at base and short.

**FEMALE.**—Length 11 mm. Color and general structure as in male with the following differences: membrane of front wings darker, the pattern therefore having greater contrast; terminal abdominal segments tubular.

**Holotype, male.**—Burke, Idaho: July 19, 1935, K. F. Richardson.

**Allotype, female.**—Same data as for holotype.

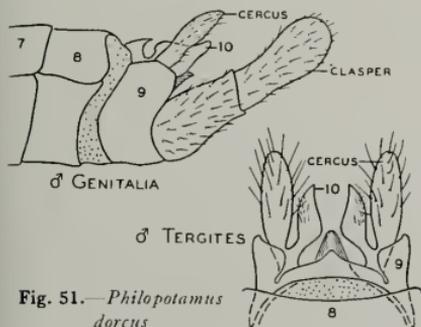


Fig. 51.—*Philopotamus dorcus*

**Paratype.**—BRITISH COLUMBIA.—Vancouver: July 15, 1936, along Capilano River, H. H. Ross, 1 ♂.

***Dolophilus shawnee* new species**

Closely resembling *major* Banks and *gabriella* Banks, this species differs from the former in having only a short dorso-mesal process on the tenth tergite, and



Fig. 52.—*Dolophilus shawnee*

from the latter in having only a short mesal process on the eighth abdominal sternite.

**MALE.**—Length 7 mm. Color of head, body and legs varying shades of brown; antennae annulate with tawny and dark brown; wings uniformly gray. In unrubbed specimens, fig. 52, the head and prothorax are covered with tufts of thick, tawny hair, and the wings with fine, short, black setae which give them a purplish shade.

General structure same as for genus,

with the following differences: Seventh sternite with a broad, triangular process one-half length of sternite, eighth sternite only slightly produced. Genitalia as in fig. 53. Claspers long, basal segment large, scarcely longer than wide, apical segment almost twice as long as basal segment, four times as long as wide and with a brush of short, stout setae within

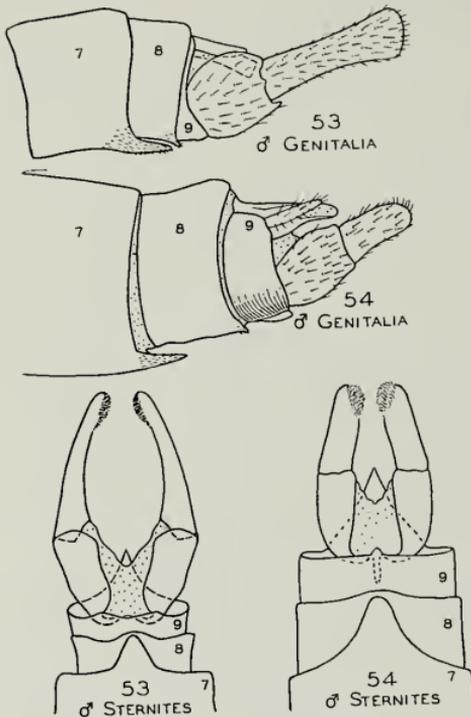


Fig. 53.—*Dolophilus shawnee*

Fig. 54.—*Dolophilus occideus*

apex. Tenth tergite produced into a sharp, triangular process with a pair of narrow cerci almost as long as the process.

**FEMALE.**—Similar in size, color and general structure to male. Abdomen terminated by a tubiform ovipositor typical for genus, without conspicuous sclerotized appendages.

**Holotype, male.**—Herod, Illinois: May 26, 1936, reared from Gibbons Creek, Mohr & Burks.

**Allotype, female.**—Herod, Illinois: May 29, 1936, along Gibbons Creek, Ross & Mohr.

**Paratypes.**—ILLINOIS.—Same data as for allotype, 5♂, 7♀.

### *Dolophilus occideus* new species

This species differs from most members of the genus in the short ventral processes of the seventh and especially the eighth sternites. From *shawnee*, to which it is most closely related, it differs in the short apical segment of the claspers.

**MALE.**—Length 7.5 mm. Color as described for *shawnee*. The specimen is rubbed to such an extent that the condition of pubescence cannot be given. General structure same as for genus. Diagnostic characters found only in the apex of the abdomen and genitalia.

Abdomen and genitalia as in fig. 54. Seventh sternite produced into a very broad mesal lobe which is rounded at apex. Eighth sternite sinuate, slightly produced on meson. Ninth tergite with a mesal T-like protuberance running almost the entire length of the segment and projecting slightly beyond the apical margin. Tenth tergite produced into a long, triangular process. Cerci lanceolate, shorter than the mesal projection; claspers with basal segment only slightly longer than apical one, robust and covered with scattered setae; apical segment short, slightly wider at base than apex, with scattered setae on the outer side and with a band of short, dense setae just within the apex.

**Holotype, male.**—Lincoln County, Oregon: May 3, 1936, along Yew Creek in Alsea Mountains, R. E. Rieder.

### *Chimarrha utahensis* new species

This is the first species of this genus to be recorded from the Rocky Mountain region of North America. It differs radically from the other known North American species in the shape of the clasper and in the shape of the tenth tergite.

**MALE.**—Length 6.5 mm. Color entirely black, the pubescence a mixture of black and gray hairs. General structure: Head robust, the postero-dorsal portion expanded, the eyes small and set close to the base of the mandibles. Ocelli very small and inconspicuous.

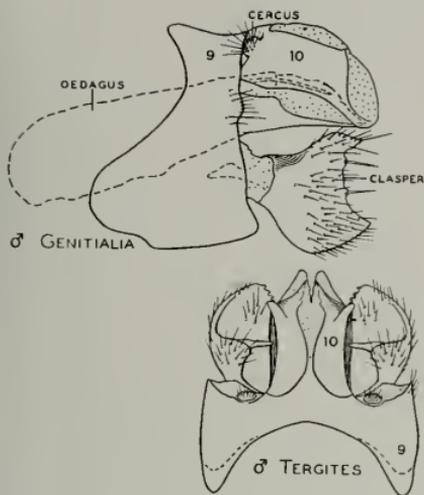


Fig. 55.—*Chimarra utahensis*

Antennae filiform. Maxillary palpi long and relatively thick. Venation and spurs on tibiae typical for genus.

Genitalia as in fig. 55. Claspers with base narrow, apex expanded, the dorsal and ventral corners appearing sharply differentiated when seen from a lateral view, the apical margin (seen from above or below) serrate; the apico-dorsal margin with a fingerlike mesal process. Convex outer surface with moderately thick setae, the apical margin with one or two heavier ones; the hollowed-out inner face has only a few setae. Tenth tergite relatively simple, composed of a pair of sclerotized plates which are somewhat quadrangular, with the postero-ventral corner attenuated; the apico-dorsal portion has a thumblike projection which is not conspicuous from the lateral view. At the base of the tenth tergite is a round, biscuit-shaped cercus set with long, thin setae.

**Holotype, male.**—Gandy, Utah: Sept. 26, 1936, C. J. Sorenson.

Family **POLYCENTROPIDAE**

**Holocentropus glacialis** new species

A close relative of *grellus* Milne, differing in the rhomboidal clasper in having a shorter but wider meso-dorsal flap. In *grellus*, fig. 56, the caudo-ventral portion of the clasper is produced into

a thin point but in *glacialis* no such segregation is evident.

**MALE.**—Length 8 mm. Body and appendages light brown, with abundant tawny hair covering the entire head and body. Front wings with a checkered pattern of light brown and cream which is most noticeably contrasting along the apical margin of the wing; hind wings uniformly light brown. General structure typical for genus, including wing venation, tibial spurs, etc.

Genitalia as in fig. 57. Ninth tergite short and semimembranous. Below its base arise two pairs of processes, a sclerotized, thin, curved dorsal pair (probably the tenth tergite, which follows the line of the oedagus), and a shorter, stout, submembranous ventral pair (the cerci), which lies beside the oedagus and is clothed with long, scattered setae. These two pairs are connected at the base. Claspers with a fairly narrow base, in general somewhat rhomboidal in shape; the lateral face is evenly convex with a deep crease not far above the ventral margin; the dorsal margin is produced into a large flap which is long and wide; its mesal margin is more or less straight, its anterior and posterior margins oblique; the inner

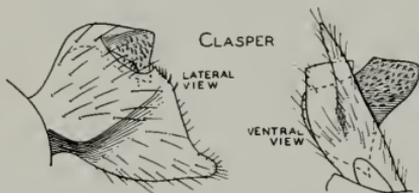


Fig. 56.—*Holocentropus grellus*

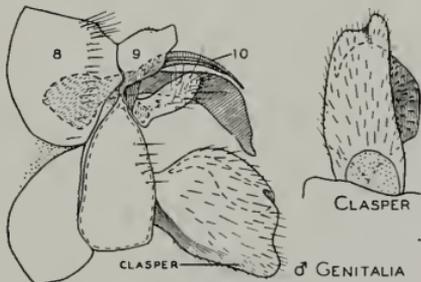


Fig. 57.—*Holocentropus glacialis*

face is studded with triangular spines; the apical margin of the clasper is sinuate, forming a low dorsal lobe and a broad, rounded ventral projection. Oedagus somewhat arcuate, the extreme base bulbous, the apical portion fusiform and tapering to a pointed apex; from the ventral aspect this apical projection appears short and thumblike.

**Holotype, male.**—Antioch, Illinois: June 11, 1936, beside Channel Lake, Ross & Burks.

**Paratypes.**—ILLINOIS.—Antioch: Same data as for holotype, 2♂; July 1, 1931, Frison, Betten & Ross, 16♂; July 7, 1932, at light, Frison & Metcalf, 1♂. Fox Lake: July 1, 1931, Frison, Betten & Ross, 15♂; June 30, 1935, DeLong & Ross, 3♂; May 28, 1936, in weeds, H. H. Ross, 16♂.

WISCONSIN.—Lake Delavan: Sept. 5, 1892, C. A. Hart, no. 18799, 1♂; Sept. 7, 1892, C. A. Hart, no. 18810, 1♂.

### *Holocentropus melanae* new species

Closely related to *flavus*, this genus differs in the lateral projection of the clasper in addition to other details of the genitalia.

**MALE.**—Length 7.5 mm. Dorsum brown; antennae, venter and legs straw

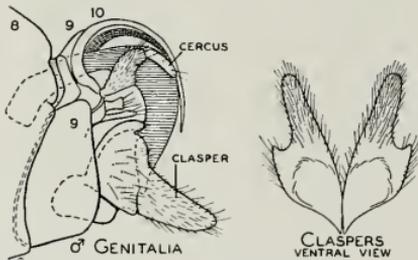


Fig. 58.—*Holocentropus melanae*

color. Forewings almost uniformly brown with a few light patches around stigma and crossveins; hind wings lighter, unicolorous. General structure typical for genus, including setation and wing venation. Diagnostic characteristics apparently restricted to genitalia.

Genitalia as in fig. 58. Ninth tergite weakly developed and submembranous. From the base of it arise two pairs of processes: (1) a pair of long, slender, setaceous filaments, probably representing the tenth tergite, which follow a semicircular course that straightens out at their extremity; (2) a pair of shorter,

two-segmented cerci which have the basal segment stocky, angulate laterally, densely clothed with setae, the apical segment shorter than the basal, submembranous and with only a few scattered setae. Ventro-mesad of the base of these processes are two short projections sticking straight out, with their apices bearing numerous setae. Claspers broad at base, with a mesal fold at the base which from lateral view appears only as a hump; they have a large lateral projection near the base which appears like a pointed flange when seen from ventral view. Between these two projections the remainder of the clasper narrows off rapidly; its apical portion is slender, appearing somewhat angled when seen from the lateral view but fingerlike and seemingly rounded when seen from ventral view. Oedagus somewhat semicircular, the basal portion round, slightly sinuate, the middle slightly enlarged and the apex decidedly pointed.

**Holotype, male.**—Montmorency County, Michigan: July 3, 1935, along east branch of Black River, J. W. Leonard.

### *Cernotina* new genus

This genus is a very interesting connecting link between the two groups Polycentropidae and Psychomiidae. It combines the venation and spur count of the groups considered typical of the latter family with the habitus, structure of mouthparts and general organization of genitalia of the Polycentropidae. There seems little doubt but that these two groups should be placed together in a single family.

**CHARACTERISTICS.**—Head without any ocelli, antennae not longer than length of body. Maxillary palpi, fig. 61, with first segment short and angular; second short with a distinct meso-ventral lobe which is as long as the width of the segment; third segment longer than first two together and slightly longer than fourth; third and fourth widest just above apex; fifth segment subequal to third and fourth together, indistinctly multisegmented. Forewing, fig. 61, between four and five times as long as wide,  $R_{2+3}$  not divided,  $M_{1+2}$  not divided; hind wing, fig. 61, narrow, the apex rounded. The branches of  $R_5$  and

M much reduced. Tibial spur count 2-4-4, the front tibia without a preapical spur.

**Genotype.**—*Cernotina calcea* new species (original designation).

This genus differs from previously described genera of the Polycentropinae in lacking the preapical spur of the front tibia and in having a narrow condition of the hind wing; from hitherto described genera of the Psychomiinae it differs in the lobate second segment of the maxillary palpus.

**Cernotina calcea** new species

**MALE.**—Length 5 mm. Head, body and appendages straw color; the wings, tibiae and tarsi darkened with brown hairs; the abdomen purplish above. General characteristics as described above for genus.

Genitalia as in fig. 59. Tenth tergite bifid at apex, the two processes long, narrow and pointed, covered with thin setae. Cerci consist of a wide, somewhat bulbous base, a long, slender apical process and three large, heavy, pointed spines set one above the other on the mesal side. Claspers extend as far as the cerci, the apex circularly incised, the mesal side produced into a thin, vertical plate, the pair almost touching on the meson. Oedagus tubular, apparently opening between the mesal angles of the dorsal appendages.

**FEMALE.**—Length 6 mm. Color and

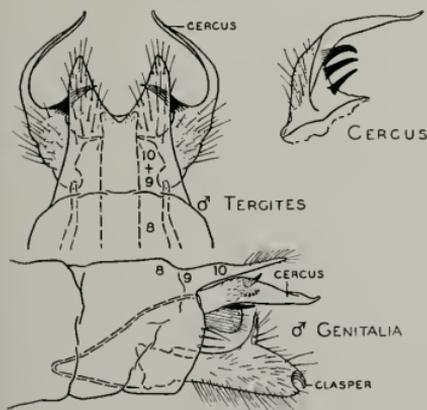


Fig. 59.—*Cernotina calcea*

general structure similar to those of male. Genitalic segments forming a conical structure with no apparent development of diagnostic parts.

**Holotype, male.**—Kankakee, Illinois: July 21, 1935, along Kankakee River, Ross & Mohr.

**Allotype, female.**—Kankakee, Illinois: Aug. 1, 1933, along Kankakee River, Ross & Mohr.

**Paratypes.**—ILLINOIS.—Oakwood: July 18, 1933, along Salt Fork River, Ross & Mohr, 1 ♂.

OKLAHOMA.—Turner Falls State Park: June 2, 1937, along Honey Creek, H. H. Ross, 36 ♂.

**Cernotina oklahoma** new species

This species differs from *calcea* in the short cerci without mesal armature, fig. 60.

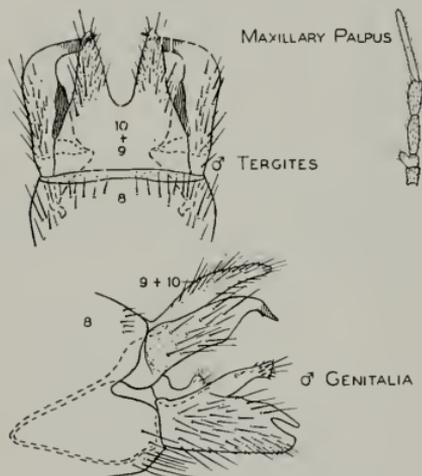


Fig. 60.—*Cernotina oklahoma*

**MALE.**—Size, color and general characteristics same as for the genotype. Diagnostic characters present only in the genitalia.

Genitalia as in fig. 60. Tenth tergite incised as with *calcea*; the lateral lobes separated slightly more at their apex and more nearly triangular in shape. Cerci not projecting beyond lobes of tenth tergite; they are broad at the base and angle sharply mesad at the apex, the apical portion much more slender than the basal, and its distal corner produced into a short, narrow, fingerlike process. At the base of the each cercus is an angulate ventro-mesal lobe bearing at its apex a group of setae.

Claspers have a short, oblique dorsal lobe bearing on its mesal surface at the apex conspicuous, well-separated setae; the main body of the clasper is bifid at the apex, the dorsal process narrow and fingerlike, the ventral portion wide and obtusely angled at the apex. The tenth tergite, basal portion of cerci and main body of clasper are clothed with long, scattered setae.

**Holotype, male.**—Turner Falls State Park, Oklahoma: June 2, 1937, along Honey Creek, H. H. Ross.

**Paratypes.**—OKLAHOMA.—Same data as for holotype, 57♂.

In the collection from Turner Falls State Park containing males of the three species here described in this genus, 50 females were represented. No characters have yet been found to segregate these into groups corresponding with the three species indicated by the male genitalia.

#### *Cernotina spicata* new species

Differs from *calcea* in lacking the mesal teeth of the cerci and the larger dorsal lobe of the claspers.

**MALE.**—Size, color and general struc-

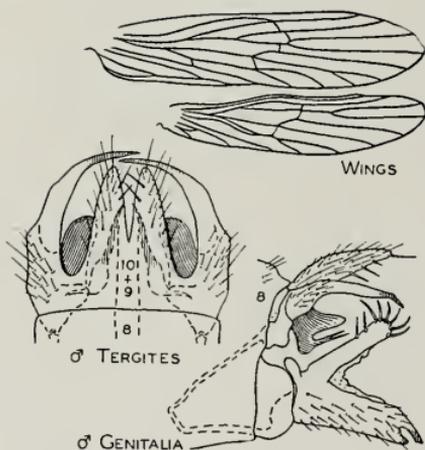


Fig. 61.—*Cernotina spicata*

ture same as for the genotype. Diagnostic differences occur only in the genitalia.

Genitalia as in fig. 61. Tenth tergite divided into two narrow, acute lobes. Cerci with a long, slender dorsal process curving mesad, the two overlapping

slightly, and a sclerotized ventral lobe. From the mesal portion of the base of each cercus a stout, spurlike process arises, extending caudad beyond the ventral lobe. Claspers have a large dorsal lobe surmounted by a cluster of large, curved setae; the main ventral portion slightly concave beneath; the apex deeply incised to form a narrow, oblique and almost truncate upper process and a lower, shorter and more pointed one.

**Holotype, male.**—Turner Falls State Park, Oklahoma: June 2, 1937, along Honey Creek, H. H. Ross.

**Paratypes.**—MICHIGAN.—Montmorency County: July 3, 1935, along east branch of Black River, J. W. Leonard, 2♂.

OKLAHOMA.—Same data as for holotype, 8♂.

#### *Psychomyiella nomada* new species

In many respects this species is intermediate between *Psychomyia* and *Psychomyiella*. It has the hind wing with  $R_{2+3}$  distinct and  $M_1$  separating from  $M_2$  as in the former. In common with the latter, it possesses a hind wing having the apex tapered and male genitalia having the dorsal plate fused with the dorsal appendages. This species differs from all the other species of these two genera in lacking a flaplike, sclerotized plate at the base of the female genitalia. The mixture of characters suggests the possibility that *Psychomyia* and *Psychomyiella* might better be regarded as subgenera rather than genera.

The long cerci separate this species from related nearctic members of the group.

**MALE.**—Length 5.7 mm. Color various shades of light brown, in life the entire insect appearing pale, yellowish brown.

General characteristics same as for genus, with the following exceptions: hind wing with  $R_{2+3}$  distinct from  $R_1$  and separated from it by a crossvein;  $M$  with both  $M_1$  and  $M_2$  present.

Genitalia as in fig. 62. Tenth tergite cleft, its lateral processes each fused with a cercus to form a pair of long, stout, upturned processes; the portion made up of cercus bears long setae, the portion composed of tenth tergite is

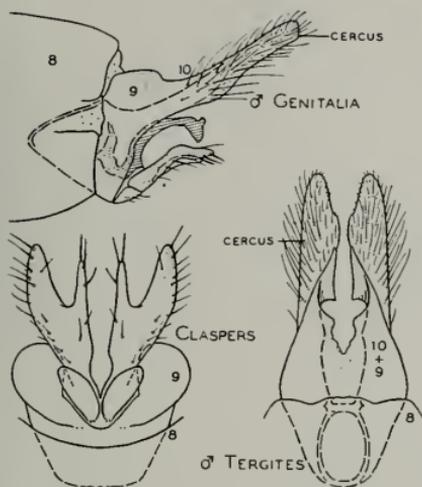


Fig. 62.—*Psychomyiella nomada*

covered with microtrichiae. Claspers, about half length of dorsal processes, divided at apex into a shining, slender inner lobe and a wider outer lobe set with microtrichiae. Over the base of the claspers lies a pair of ovoid plates. These are situated in the mesal emargination of the ventral plate. Oedagus fairly stout, round and forming a semi-circular arc terminated by a small knob which is surmounted by a small, truncate process.

**FEMALE.**—Size 6 mm. Color and general structure same as for male. Differs from female of *flavida* in lacking the sclerotized flap at the base of the genitalia.

**Holotype, male.**—Cherokee, North Carolina: June 14, 1935, along branch of Little Tennessee River, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—NORTH CAROLINA.—Same data as for holotype, 10♂, 6♀.

***Psychomyiella lumina* new species**

This species is very close to *nomada* but differs in the elongate claspers and other details of the genitalia.

**MALE.**—Length 6.5 mm. Body and legs brown. Head and thorax darker than the abdomen. Wings light brown with veins darker. General characteristics same as in *nomada*.

Genitalia as in fig. 63. Tenth tergite cleft, the lateral extensions long and pointed, fused only at base with the preanal cerci. These are long and angled, with long setae on the sides and over the entire apical half; their mesal margin bears an area of stout, dense setae. The apices of the tenth tergite and cerci are not fused. Claspers long, narrow and slightly flattened dorso-ventrally. Seen from the ventral side, they appear slightly pointed at apex toward the meson and have a pair of padlike areas slender covering their base. Oedagus slender and hook-

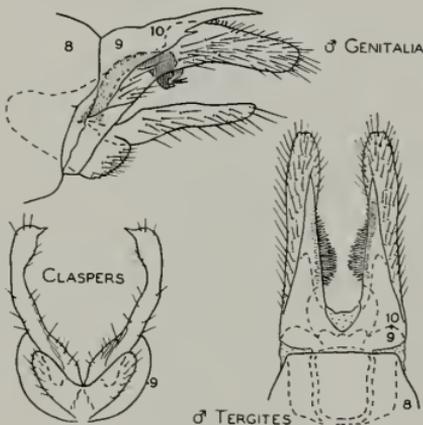


Fig. 63.—*Psychomyiella lumina*

shaped, the extreme apex bulbous and provided with small spiny processes.

**Holotype, male.**—Pringle Falls, Oregon: May 26, 1935, N. F. Canova.

**Paratypes.**—OREGON.—Same data as for holotype, 2♂.

**Family HYDROPSYCHIDAE**

***Hydropsyche simulans* new species**

Very similar to *bidens*, but differs in the convex dorsal hump at the base of the head of the oedagus.

**MALE.**—Length 13 mm. Head and body various shades of brown, clothed with variously colored patches of hairs. Front wings mottled with cream, gray and brown, in addition to patches of light and dark colored setae; the effect is the somewhat patterned mottling shown in fig. 64. Hind wings uniformly gray.

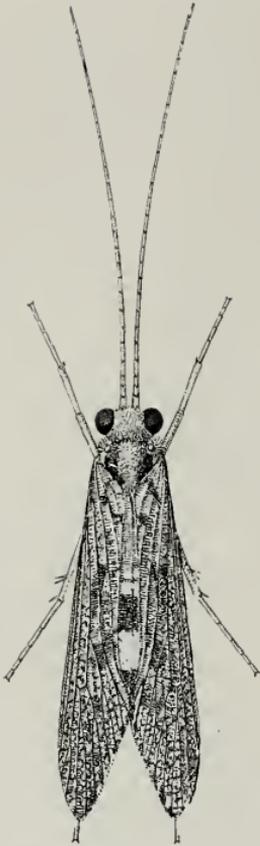


Fig. 64.—*Hydropsyche simulans*

General structure typical for genus. The eyes are slightly larger than those of *cornuta* but smaller than those of *frisoni*. Genitalia as in fig. 65. Very similar to *cornuta*, differing only in the following points: Tenth tergite not declivous, but flat and almost truncate at apex, the lateral lobes separated by only a small notch; claspers inclined to be fusiform, with the base and apex narrowed; apex of oedagus flared only slightly, with the mesal plates narrow at the base, long and curved ventrad, their ventral margins not approximate; where the base of the oedagus joins the apical portion it forms a convex hump.

FEMALE.—Length 14 mm. Color and general structure same as for male, except for the smaller eyes. Genitalia

apparently identical with those of *cornuta* (see p. 141).

**Holotype, male.**—Mount Carmel, Illinois: Sept. 11, 1937, along Wabash River, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Alton: September 6, 1932, along Mississippi River, Frison & Mohr, 1♂; June 26, 1934, DeLong & Ross, 35♂. Freeport: June 28, 1935, DeLong & Ross, 1♂. Havana: May 14, 1934, H. H. Ross, 1♂; April 15, 1935, along Quiver Creek, Ross & Mohr, 1♂; April 25, 1935, along Quiver Creek, Ross & Mohr, 4♂; April 29, 1937, Ross & Mohr, 5♂, 4♀. Homer Park: July 6, 1927, at light, Frison & Glasgow, 1♂. Kankakee: June 12, 1931, Frison & Mohr, 1♂; June 6, 1935, Ross & Mohr, 7♂, 2♀. Lawrenceville: Sept. 7, 1933, Ross & Mohr, 1♂. Mount Carmel: June 25, 1936, DeLong & Ross, 46♂; Sept. 11, 1937, Ross, 10♂, 4♀. Oakwood: July 18, 1933, at Salt Fork River, Ross & Mohr, 1♂; Sept. 20, 1935, DeLong & Ross, 1♂. Olney: Aug. 20, 1902, E. G. Titus, no. 33630, 1♂. Rockford: June 12, 1931, Frison & Mohr, 8♂; May 30, 1936, H. H. Ross, 2♂. Rock Island: June 21, 1928, 1♂; May 3, 1931, H. H. Ross, 1♂; May 6, 1931, Ross & Mohr, 1♂; May 16, 1931, Ross & Mohr, 1♂; June 5, 1935, Ross & Mohr, 1♂. Rockton: July 2, 1931, Frison, Betten & Ross, 1♂. Savanna: July 30, 1892, Hart, Forbes, Shiga & McElfresh, no. 18547, 1♂; June 29, 1935, DeLong & Ross, 1♂, 1♀. Shawneetown: May 27, 1928, at light, Frison, 2♂; May 28, 1935, Ross & Mohr, 2♂, 6♀. Sterling: May 21, 1925, at light, D. H. Thompson, 1♂. Wilmington: May 12, 1935, Frison & Ross, 1♂; May 17, 1935, along Kankakee River, H. H. Ross, 1♂.

INDIANA.—Petersburg: June 4, 1936, along

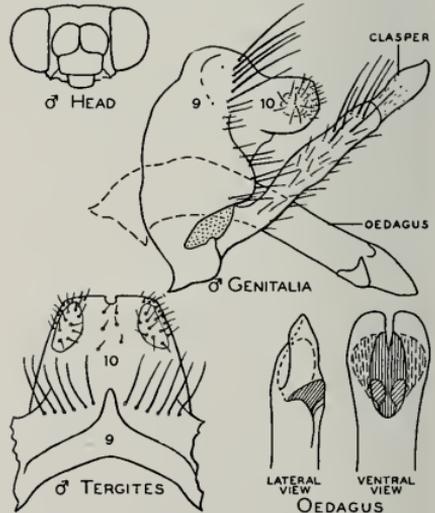


Fig. 65.—*Hydropsyche simulans*

White River, Mohr & Burks, 2♂, 1♀. Portersville: June 3, 1936, along East Fork River, Mohr & Burks, 6♂. Shoals: Sept. 10, 1936, along White River, Ross & Burks, 1♂.

IOWA.—Ottumwa: August 2, 1936, H. H. Ross, 8♂.

WISCONSIN.—The Dells: June 5, 1936, along Wisconsin River, Frison & Ross, 15♂.

**Hydropsyche cornuta** new species

Closely allied to *scalaris* and *simulans*, differing in the wide mesal plates of the oedagus and other small details of the genitalia.

MALE.—Length 12 mm. Color as described for *simulans*, but with slightly

lateral lobes more or less pointed and each having small setae on the mesal and apical regions; lateral portions with a pair of setiferous warts on each side bearing scattered, long setae. Seen from the side, the tenth segment appears declivous and pointed at apex. Clasper sinuate; apical segment hooked upward at apex. Oedagus curved at base, middle portion cylindrical, apex slightly upturned and pointed; mesal plates wide and low, close together on the ventral side; ventral cavity orbicular, the lateral processes of the apex widest near apex and almost touching along the meson.

FEMALE.—Length 13 mm. Similar to male in color and general structure, differing in antigenetic characters of genitalia. Eighth tergite without a brush of strong setae. Eighth sternite divided into two lateral lobes, the mesal incision only half the length of the segment. Mesal angle of lobes of eighth sternite slightly produced, the hump so formed having longer and denser setae than nearby margins of lobe. Characters have not yet been found to differentiate the females of this species from those of *simulans*, *bidens*, etc.

Holotype, male.—Hamilton, Illinois: Aug. 30, 1931, Ross & Mohr.

Allotype, female.—Same data as for holotype and collected *in coitu* with it.

Paratypes.—ILLINOIS.—Alton: June 26, 1934, DeLong & Ross, 22♂. Dixon: June 27, 1935, DeLong & Ross, 42♂, 5♀. East Dubuque: July 22, 1927, Frison & Glasgow, 3♂. Elizabethtown: June 22, 1927, at light, Frison & Glasgow, 1♂; June 27, 1931, Frison, Betten & Ross, 1♂; June 25, 1932, Ross, Dozier & Park, 5♂, 2♀. Florence: June 7, 1928, Frison, 1♂. Golconda: Sept. 4, 1924, T. H. Frison, 1♂. Hamilton: June 22, 1928, at light, Frison, Hottes & Ross, 44♂, 1♀; June 3, 1930, Frison & Ross, 1♂, 1♀; Aug. 30, 1931, Ross & Mohr, 122♂, 274♀, 8 mating pairs. Harrisburg: June 15, 1934, at light, DeLong & Ross, 10♂, 4♀. Havana: May 9, 1931, Ross & Mohr, 1♂; Aug. 30, 1931, H. H. Ross, 2♂; May 14, 1934, H. H. Ross, 17♂, 26♀. Herod: June 9, 1936, T. H. Frison, 1♂, 1♀. Homer Park: May 11, 1927, along Salt Fork River, 1♂; July 6, 1927, at light, Frison & Glasgow, 1♂. Kankakee: June 6, 1935, Ross & Mohr, 1♂. Keithsburg: 1932, 2♂. Mount Carmel: June 25, 1936, DeLong & Ross, 3♂. Oakwood: April 24, 1925, T. H. Frison, 1♂. Oregon: June 30, 1935, at Castle Rock, DeLong & Ross 3♂; May 29, 1936, H. H. Ross, 6♂. Putnam: July 11, 1933, at light, Lake Senachwine, Mohr, 1♂. Rockford: May 30, 1935, H. H. Ross, 24♂; May 30, 1936, H. H. Ross,

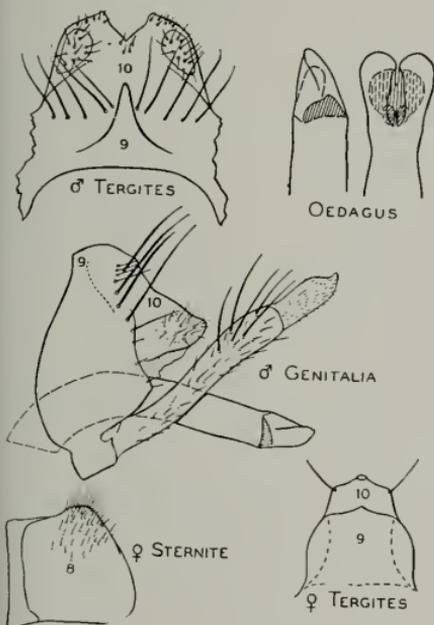


Fig. 66.—*Hydropsyche cornuta*

less contrast in the pattern. General structure same as for this species also, with the exception of the eyes, which are smaller, being only half as wide as the distance between them.

Genitalia as in fig. 66. Suture separating ninth and tenth terga present at the sides only. Median ridge of ninth tergum short and narrow, with a row of long setae just below it on each side. Tenth tergum wide, with a wide V-shaped incision on the meson, the

15♂; June 4, 1936, at light, Frison & Ross, 1♂. Rock Island: May 12, 1928, at Electric Station, 5♂; July 23, 1928, at light, Frison & Hottes, 3♂; May 6, 1931, Ross & Mohr, 4♂; May 10, 1931, Ross & Mohr, 8♂; June 24, 1931, C. O. Mohr, 8♂; May 11, 1934, Ross & Mohr, 35♂; June 5, 1935, Ross & Mohr, 54♂, 26♀. Rosiclare: July 5, 1935, Frison & Mohr, 1♂. Savanna: July 20, 1892, along railroad, Forbes & McElfresh, no. 18504, 1♂; July 23, 1892, along Mississippi River, Hart & Forbes, no. 18518, 1♂; July 26, 1892, Mississippi River, Hart, Shiga, Forbes & McElfresh, no. 18532, 1♂; July 30, 1892, Hart & Forbes, no. 18547 and no. 18549, 2♂; June 29, 1935, DeLong & Ross, 23♂. Shawneetown: May 27, 1928, at light, Frison, 1♂. St. Joseph: July 29, 1919, 1♂. Sterling: May 21-22, 1925, at light, D. H. Thompson, 6♂, 10♀. Urbana, 1♂.

MICHIGAN.—Berrien Springs: Sept. 17, 1936, Ross & Burks, 29♂, 45♀. Grand Rapids: May 23, 1936, Frison & Ross, 1♂.

WISCONSIN.—The Dells: June 5, 1936, along Wisconsin River, Frison & Ross, 1♂.

### *Hydropsyche bidens* new species

A close relative of *cornuta*, differing in the conformation of the apex of the oedagus.

MALE.—Length 10 mm. Similar in color, general structure and genitalia to *cornuta* with the following differences:

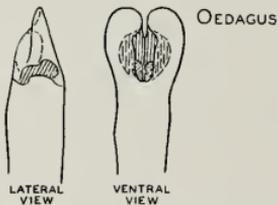


Fig. 67.—*Hydropsyche bidens*

Form usually more slender; tenth tergite slightly upturned at apex; apex of oedagus, fig. 67, with lateral arms pointed, narrowly V-shaped and aligned with the horizontal axis of the oedagus; the dorsal portion between them depressed at apex.

FEMALE.—Length 11 mm. Color, general structure and genitalia apparently identical with *cornuta*.

**Holotype, male.**—Apple River Canyon State Park, Illinois: Aug. 22, 1935, DeLong & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Alton: June 26, 1934, DeLong & Ross, 121♂. Apple River

Canyon State Park: Aug. 22, 1935, DeLong & Ross, 2♂. Carmi: April 24, 1935, on bridge across Wabash River, T. H. Frison, 2♂; May 28, 1935, Ross & Mohr, 7♂, 23♀. Charleston: June 11, 1931, at light, H. H. Ross, 10♂; Aug. 15, 1933, Embarrass River, Ross & Mohr, 1♂. Danville: Sept. 20, 1935, Frison & Mohr, 1♂. Dixon: June 27, 1935, DeLong & Ross, 2♂. East Dubuque: June 15, 1932, Frison & Mohr, 1♂. Elizabethtown: June 27, 1931, Betten, Frison & Ross, 1♂. Freeport: June 28, 1935, DeLong & Ross, 1♂. Fulton: June 20, 1927, Frison & Glasgow, 1♂. Havana: July 20, 1927, at light, Frison & Glasgow, 1♂, 1♀; Aug. 30, 1931, Ross & Mohr, 3♂; May 9, 1934, Ross & Mohr, 1♂; May 14, 1934, H. H. Ross, 1♂. Hardin: June 25, 1931, Frison, Betten & Ross, 8♂. Homer Park: Aug. 10, 1925, T. H. Frison, 1♂; June 30, 1927, at light, Frison & Glasgow, 2♂, 1♀; July 6, 1927, at light, Frison & Glasgow, 4♂; July 11, 1927, at light, Frison & Glasgow, 2♂. Kampsville: June 25, 1931, Frison, Betten & Ross, 6♂. Kankakee: June 12, 1931, Frison & Mohr, 6♂; June 6, 1935, Ross & Mohr, 3♂. Keithsburg: 1932, 4♂. Momence: June 4, 1932, Frison & Mohr, 1♂; May 26, 1936, along Kankakee River, H. H. Ross, 6♂. Mount Carmel: June 25, 1936, DeLong & Ross, 4♂. Oakwood: July 6, 1927, at light, Glasgow & Frison, 4♂; Sept. 20, 1935, DeLong & Ross, 3♂. Pike: May 26, 1906, 1♂. Quincy: June 9, 1932, Ross & Mohr, 2♂. Rockford: June 12, 1931, Frison & Mohr, 2♂; May 30, 1936, H. H. Ross, 4♂; June 4, 1936, at light; Frison & Ross, 1♂. Rock Island: June 23, 1928, Frison & Hottes, 1♂; May 3, 1931, H. H. Ross, 1♂; May 16, 1931, 2♂; June 24, 1931, C. O. Mohr, 3♂; May 11, 1934, Ross & Mohr, 3♂; May 11, 1935, Ross & Mohr, 1♂; June 5, 1935, Ross & Mohr, 27♂. Savanna: July 20, 1892, Forbes & McElfresh, no. 18504, 1♂; July 20, 1927, at light, Frison & Glasgow, 1♂, 1♀; June 29, 1935, DeLong & Ross, 12♂. Urbana: June 17, 1887, Hart, no. 12096, 1♂.

INDIANA.—Petersburg: June 3, 1936, White River, Mohr & Burks, 1♂, 2♀. Rogers: Sept. 8, 1936, Ross & Burks, 1♂. Shoals: Sept. 10, 1936, along White River, Ross & Burks, 1♂.

IOWA.—Ottumwa: Aug. 2, 1936, H. H. Ross, 6♂.

MICHIGAN.—Grand Rapids: May 23, 1936, Frison & Ross, 1♂.

WISCONSIN.—The Dells: June 5, 1936, along Wisconsin River, Frison & Ross, 3♂.

### *Hydropsyche frisoni* new species

Similar in size and color to *scalaris*, but differs in having larger eyes and in the more upturned apex of the oedagus, fig. 68, in which the lateral plates are below the level of the mesal portion.

MALE.—Length 12 mm. Body dark brown, covered with tawny hair; wings with an irregular mottling of tawny and

brown, the latter color darkest along the cubital veins; the entire surface of the wing beset with patches of whitish hairs, the assemblage of colors giving the wing a salt-and-pepper effect.

General structure similar to *simulans*. Eyes large, each about one-third the size of the entire head.

Genitalia, as in fig. 68. Suture separating ninth and tenth terga apparently

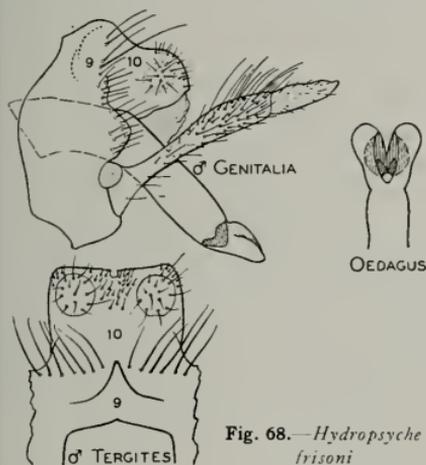


Fig. 68.—*Hydropsyche frisoni*

obsolete. Median ridge short and pointed, a row of long setae below it on each side. Apex of tenth tergite wide and truncate with a narrow mesal notch; mesal and lateral areas of apex with clusters of small setae; each of lateral portions with a large raised wart bearing about a dozen scattered, long setae. Seen from lateral view the tenth tergite appears short and declivous at the apex. Claspers narrow at base, widening toward apex; the apical segment is slightly sinuate, with the tip upturned. Oedagus angled at base, the middle portion cylindrical and the apical portion upturned at a slight angle to it. Apex with lateral processes flared, dividing the ventral cavity with a wide incision; the plates appear narrow and triangular, seen from the ventral view.

FEMALE.—Similar in size, color and general structure to male. The eyes are small, and the genitalia appear to be identical with those of *cornuta*.

Holotype, male.—Oakwood, Illinois; April

24, 1925, along Salt Fork River, T. H. Frison.

Allotype, female.—Same data as for holotype.

Paratypes.—ILLINOIS.—Danville, July 18, 1933, along Middle Fork Vermilion River, Ross & Mohr, 1♂. Homer Park: July 11, 1927, at light, T. H. F. & R. D. G., 1♂. Muncie: July 27, 1927, T. H. Frison, 2♂. Oakwood: Same data as for holotype, 5♂; July 6, 1927, at light, T. H. F. & R. D. G., 5♂; July 18, 1933, Ross & Mohr, 2♂; Aug. 25, 1936, H. H. Ross, 1♂.

MICHIGAN.—Crawford County: May 2, 1936, along north branch of AuSable River, J. W. Leonard, 2♂.

### Hydropsyche arinale new species

This species resembles several others in the *scalaris* group in general structure of genitalia but differs from them in the moniliform apex of the oedagus.

MALE.—Length 9 mm. Color and general characteristics same as in preceding species.

Genitalia as in fig. 69. Suture dividing ninth and tenth terga apparently obsolete. Median ridge of ninth tergite short and pointed. Tenth tergite with a wide incision on meson; apical margins and mesal area with a few short setae; on each side of the meson at apex is an elliptical membranous area bearing medium-long setae. Claspers with first segment thicker beyond middle; apical segment with tip slightly



Fig. 69.—*Hydropsyche arinale*

upturned. Oedagus curved at base, narrowed at middle and swollen at apex; when oedagus is seen from above or below, an extra constriction is visible below the apex. Apical portion with lateral arms remote at apex; ventral cavity not covered below, but entirely covered above by mesal extensions of the lateral arms which overlap slightly at apex and are incised to form a small

opening just below it; mesal plates appearing slightly hooked dorsally.

**Holotype, male.**—Oregon, Illinois: July 18, 1927, at light, T. H. Frison & R. D. Glasgow.

**Paratypes.**—ILLINOIS.—Algonquin: Sept. 5, 1904, 1♂. Oregon: Same data as for holotype, 1♂. Richmond: May 28, 1936, H. H. Ross, 1♂.

### *Hydropsyche valanis* new species

Similar in size of body and eyes to *aerata* but differs in its deeper brown color, its rounded ninth and tenth

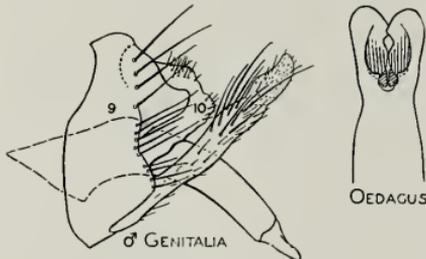


Fig. 70.—*Hydropsyche valanis*

segments, more nearly flat apex of oedagus and other genital characters.

**MALE.**—Size and general structure similar to *cornuta*. Color tawny or cream, with irregular flecking of light brown over the entire surface of the wings. Antennae with diagonal black lines on the basal seven segments of the flagellum. Legs light tawny. Eyes large, as wide as the distance between them.

Genitalia as in fig. 70. Ninth and tenth abdominal terga separated by a well-marked suture. Ninth tergite with median hump rounded at apex and with a line of four or five long setae below it on each side; apical margin of segment emerginate on meson, forming a pair of lateral, angulate projections. Tenth tergite semimembranous, divided by a mesal incision into two wide lobes, each with scattered, short setae along its margin. Claspers sinuate, the apical segment slightly hooked at tip; the basal segment with scattered, short setae over its entire surface and in addition an area near apex bearing many extremely long setae; apical segment covered with fine setae. Oedagus angled at base; middle portion cylindri-

cal, narrowing slightly at apex; apical portion flattened dorso-ventrally, the lateral processes meeting on the meson at tip and leaving only a small hole between them.

**Holotype, male.**—Rockton, Illinois: July 2, 1931, along Rock River, Frison, Betten & Ross.

**Paratypes.**—ILLINOIS.—Kankakee: July 21, 1935, Ross & Mohr, 1♂. Rock Island: June 23, 1928, Frison & Hottes, 1♂. Rockton: Same data as for holotype, 7♂.

INDIANA.—Peru: May 18, 1936, at light, Frison & Ross, 1♂.

IOWA.—Ottumwa: Aug. 2, 1936, H. H. Ross, 1♂.

WISCONSIN.—Merrill: July 1, 1933, along Wisconsin River, Frison & Mohr, 1♂.

### *Hydropsyche aerata* new species

Closely allied to *valanis* but differs in the white and brown pattern of the wings and body, the narrower apex of the oedagus and the upturned tenth tergite.

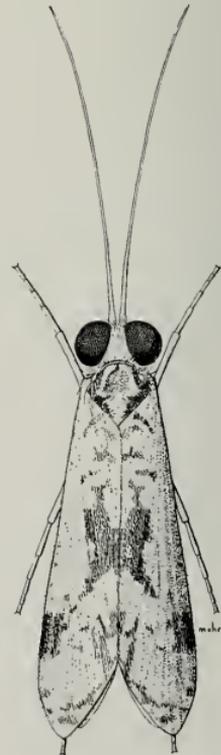


Fig. 71.—*Hydropsyche aerata*

MALE.—Length 9 mm. Color markings as in fig. 71. Head and thorax dark brown; abdomen light brown, covered with white hair; antennae and legs white; wings white with definite brown markings which form a broad, saddle-shaped mark on the meson just beyond the middle and a rectangular spot on the anterior margin near apex; in addition to these, there are a few indistinct, lighter markings in the anal and cubital region near the base of the wing and sparse mottling over the apical fourth of the wing.

Form slender. Eyes very large, fig. 71, together forming two-thirds of the head. Malar space narrow, no longer than the width of the flagellum.

Genitalia as in fig. 72. Ninth tergite humped, forming a high, pointed mesal ridge, just below which is a row of long setae. Tenth tergite long and narrow, the apex divided by a short incision into a pair of semispatulate lobes; on each lateral margin is a slightly elevated, oval region bearing distinct, scattered setae. Lateral lobe considerably produced, with eight to twelve long setae on its caudal margin. Claspers with apical segment rounded at tip, slightly elliptic and covered with short setae; basal segment with basal half narrow, apical half abruptly wider, the latter with an area bearing several long setae, the entire segment bearing sparse, shorter setae. Oedagus with base angled, middle portion narrowed and apical portion wider; extreme apex considerably flattened and widened, in-

than male; similar to light females of *phalerata* and *hageni*, with which *aerata* usually occurs. Structure identical with that of *cornuta*.

**Holotype, male.**—Aurora, Illinois: July 17, 1927, at light, T. H. F. & R. D. G.

**Allotype, female.**—Kankakee, Illinois: Aug. 8, 1935, Ross & DeLong.

**Paratypes.**—ILLINOIS.—Kankakee: Aug. 1, 1933, along Kankakee River, Ross & Mohr, 1♂; May 26, 1935, Ross & Mohr, cage no. 3, 1♂; June 6, 1935, Ross & Mohr, 78♂, 42♀; July 21, 1935, Ross & Mohr, 23♂; Aug. 8, 1935, Ross & DeLong, 1♂. Mومence: May 26, 1936, along Kankakee River, Ross, 1♂; Aug. 4, 1936, Frison & Burks, 4♂; Aug. 21, 1936, Ross & Burks, 1♂. Mount Carmel: July 3, 1906, 1♂. Wilmington: May 12, 1935, Frison & Ross, 10♂, 7♀; May 17, 1935, along Kankakee River, H. H. Ross, 37♂, 10♀; June 6, 1935, Ross & Mohr, 7♂; July 1, 1935, De Long & Ross, 1♂; Aug. 20, 1935, DeLong & Ross, 2♂.

INDIANA.—Shoals: Sept. 10, 1936, White River, Ross & Burks, 61♂, 2♀.

**Hydropsyche leonardi** new species

This species is very closely related to *hageni* Banks but differs in the shorter and thicker apical projection of the

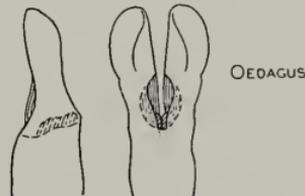


Fig. 73. *Hydropsyche leonardi*

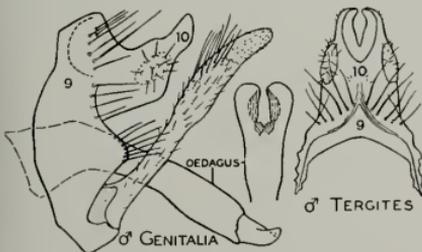


Fig. 72.—*Hydropsyche aerata*

cised on meson to form a circular area almost surrounded by a pair of rounded processes.

FEMALE.—Length 10 mm. Darker

oedagus beyond the ventro-mesal cavity.

MALE.—Length 12 mm. Color identical with that of *cornuta*. General structure as described for *cornuta* except for the eyes, which are as large as those in *simulans*.

Genitalia as in fig. 73. Ninth and tenth tergites almost identical with those illustrated for *cornuta*, the apex of the tenth tergite not upturned and only slightly emarginate on the meson. Claspers with basal segment slightly sinuate and slightly enlarged at apex; apical segment twice as wide as greatest length, the dorso-apical angle concave, the extreme ventro-apical corner pointed and slightly hooked. Oedagus

with base angled as in *simulans*. Apex of oedagus shaped much like a duck's bill, long, wide, narrowed at base and expanded at apex; the lateral processes extending beyond the mesal cavity, slightly more than the full length of the cavity; seen from the side, with the apex appearing only obtusely angled, the portion adjacent to the mesal cavity narrowed, giving it a spatulate appearance; mesal cavity with a wide opening ventrally, and the dorsal side with a fairly narrow, parallel-sided opening; mesal plates small, seemingly very low seen from side view, closely appressed on the meson.

**Holotype, male.**—Lovells, Crawford County, Michigan: May 2, 1936, along north branch Au Sable River, two miles above town, J. W. Leonard.

**Paratype.**—MICHIGAN.—Same data as for holotype, 1♂.

#### *Hydropsyche dicantha* new species

The swollen oedagus and large spines on the tenth tergite distinguish this species from all other members of the genus.

**MALE.**—Length 8.5 mm. Color various shades of brown. Head and dorsal portion of thorax almost black, covered with a mixture of white and tawny, bushy pubescence; antennae yellowish brown, the eight basal segments of the flagellum with a dorsal, dark brown V; legs and ventral portion of abdomen yellowish brown, the tarsi with sparse, short, black setae. Wings for the most part brown with small light areas over the entire surface and with a larger light area just before the apex of the anal cells; pubescence of wings generally tawny, cream colored over the light areas of the membrane.

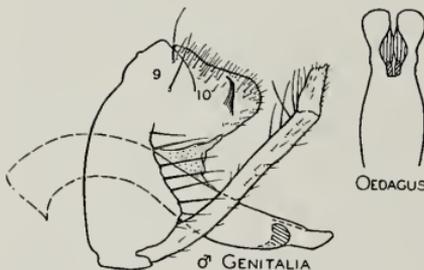


Fig. 74.—*Hydropsyche dicantha*

General structure same as for genus. Seen from front, eyes appear twice as high as wide; longer than the distance between them at base as 4:3; markedly converging at base.

Genitalia as in fig. 74. Tenth tergite deeply and narrowly incised on the meson, the two lobes thus formed rounded at the apex and having a dorsally directed spine arising near the latero-ventral margin; claspers long and extremely slender, the basal segment very little expanded at apex and five times the length of the apical segment. Oedagus sigmoidal, markedly swollen before apex, the apical portion having slender lateral arms which are slightly depressed dorsally; meso-ventral cavity almost completely open ventrally, the dorsal margins meeting on the meson; mesal plates somewhat orbicular, not very prominent seen from the ventral aspect.

**Holotype, male.**—Swansea, Ontario: Aug. 15, 1934, H. S. Parish.

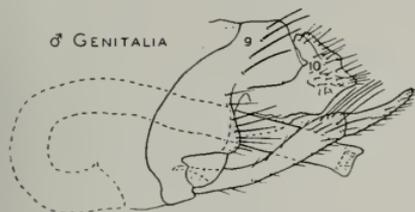
This species was identified as *venularis* Banks by Betten. *Venularis*, however, although a member of the *scalaris* group, is very different from this species.

#### *Hydropsyche betteni* new species

This species is close to *depravata* Hagen, differing from it in the truncate apex and abruptly curved base of the oedagus, fig. 75.

**MALE.**—Length 12 mm. Color: Head yellowish brown with dark brown mottling on the dorsum; antennae dark brown with a black V mark on the seven basal segments of the flagellum; thorax dark brown, the mesonotum almost black; the legs concolorous with thorax at base, gradually merging into a yellowish brown toward apex; wings dark gray with whitish areas scattered over the entire surface, the gray portion of the wing covered with blackish pubescence, the lighter spots covered with whitish pubescence.

General structure typical of genus. Genitalia as in fig. 75. Claspers with basal segment narrow at base and widened at apex; the apical segment, half the length of basal segment, gradually tapering from base to apex, curved

Fig. 75.—*Hydropsyche betteni*

mesad, the extreme apex blunt. Tenth tergite cleft on meson to its base, the two lobes with the dorsal margin incised just above apex, the apical dorsal corner angular, the apical margin truncate and slightly declivous. Oedagus long, the basal portion turned abruptly and forming a complete half circle, the remainder almost straight and cylindrical; the extreme apex almost truncate except for two small, ovate dorsal lobes.

**FEMALE.**—Length 13 mm. Similar in color and general structure to the male. Genitalia as in fig. 75. Eighth tergite with apical ventral corner produced ventrad, with a brush of ventrally directed setae. Eighth sternite cleft for only two-thirds its length, the lateral lobes highest near lateral margin and with scattered setae at apex. Ninth and tenth tergites form a round structure divided down the meson by a furrow.

**Holotype, male.**—Richmond, Illinois: May 28, 1936, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Clinton: May 21, 1935, at Weldon Springs, Frison & Ross, 2♂, 3♀. Havana: April 25, 1935, along Quiver Creek, Ross & Mohr, 3♂. McHenry: May 28, 1936, two miles north of town, H. H. Ross, 1♂. Richmond: Same data as for holotype, 3♀. St. Anne: July 20, 1934, Frison, DeLong & Ross, 1♂. White Pines State Park: May 30, 1936, H. H. Ross, 5♂.

INDIANA.—Rome City: May 19, 1936, Frison & Ross, 9♂, 6♀.

This species was identified as *incommoda* Hagen by Betten (1934). Hagen's species, however, is a close relative of *scalaris* and *simulans*.

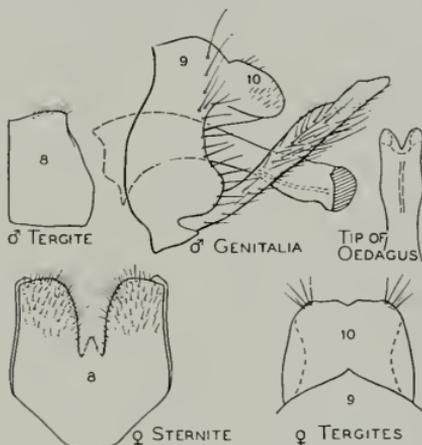
#### *Hydropsyche cuanis* new species

Similar in general structure to *depravata* Hagen but differing markedly in the incised apex of the oedagus.

**MALE.**—Length 10 mm. Body black, covered with light brown pubescence; eyes reddish; antennae annulate with light and darker brown; legs beyond coxae yellowish; wings fairly dark, mottled with shades of brown and without a definite pattern.

Antennae slender. Eyes large, two-thirds as wide as the distance separating them, the inner margins diverging ventrad. Malar space subequal in length to width of flagellum.

Genitalia as in fig. 76. Tenth tergum with a narrow mesal impression, dividing the apical portion of the sclerite into

Fig. 76.—*Hydropsyche cuanis*

two wide and almost truncate parts. Ninth tergite humped, separated from the tenth tergite by a definite crease. Claspers narrowing just beyond base, then gradually enlarging to region near joint; apical portion of uniform thickness except at apex, which is obtusely pointed because of the obliqueness of the dorsal portion; basal segment of clasper with long setae, apical segment with close, fine setae and with a few additional longer ones on the ventral side. Oedagus broad and curved at base, narrowed in middle and swollen at apex; extreme apex with a pair of liplike lobes pointing dorsoventrad, separated by a fairly sharp cleft.

**FEMALE.**—Length 11 mm. Color and general structure as for male. Eighth tergite with an inconspicuous row of

small setae along lateral half of apical margin, fig. 76. Eighth sternite with two lateral lobes, the mesal incision reaching only halfway to base of segment; meso-apical portion of these lobes almost evenly rounded, with an even fringe of slender setae over a wide margin.

**Holotype, male.**—Wilmington, Illinois: May 17, 1937, on Kankakee River, Ross & Burks.

**Allotype, female.**—Collected *in coitu* with holotype.

**Paratypes.**—ILLINOIS.—Mörence: June 4, 1932, Frison & Mohr, 4♂; Aug. 1, 1935, Ross & Burks, 1♂; May 26, 1936, Ross, 1♂; July 14, 1936, B. D. Burks, 1♂; Aug. 3, 1936, C. O. Mohr, 1♂; Aug. 4, 1936, Frison & Burks, 53♂. Spring Grove: May 14, 1936, Ross & Mohr, 3♂, 1♀; June 12, 1936, Ross & Burks, 5♂, 1♀. Wilmington: May 12, 1935, Frison & Ross, 130♂, 142♀; May 17, 1935, H. H. Ross, 136♂, 22♀; May 27, 1935, Ross & Mohr, 24♂, 50♀; June 6, 1935, Ross & Mohr, 31♂, 7♀; May 17, 1937, Ross & Burks, 142♂, 65♀.

MICHIGAN.—Bronson: May 19, 1936, along Prairie River, Frison & Ross, 3♂, 3♀. Goodrich: May 20, 1936, along Thread River, Frison & Ross, 6♂.

### *Hydropsyche piatrix* new species

Although closely related to *vexa*, this species differs in the short processes of the tenth tergite and the lack of spines at the apex of the lateral appendages of the oedagus.

**MALE.**—Length 8 mm. Head, thorax and abdomen various shades of brown; legs straw color; antennae alternate bands of straw color and brown; wings with membrane almost clear and with a mottled, irrorate pattern of setae resulting in a salt-and-pepper brown mixture typical of the *alternans* group.

General structure typical for genus. Genitalia as in fig. 77. Tenth tergite with a round, raised portion before apex

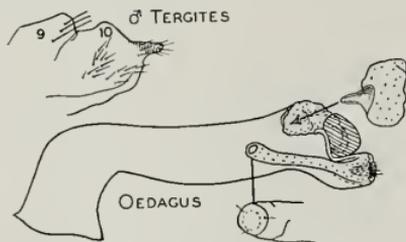


Fig. 77.—*Hydropsyche piatrix*

and with a pair of short, stubby lateral processes. Oedagus with base sharply angled and slightly constricted at the angulation, then gradually increasing in size to apex. The dorsal sclerotized plates are large and fit into the abrupt angle at the apex of the oedagus. Behind this is a pair of short membranous lobes, each bearing at its end a short, buttonlike sclerotized spine. The terminal projection of the oedagus is angled down more than usual and bears a single invaginated cluster of spines and a pair of thin, membranous lateral appendages which reach one-third of the way to the base of the oedagus; these appendages have no spines at their apex but instead a circular opening around which are several small setae.

**Holotype, male.**—Greer, Missouri: March 28, 1937, at spring near town, T. H. Frison.

**Paratypes.**—ARKANSAS.—Mammoth Springs: June 6, 1937, H. H. Ross, 2♂.

### *Hydropsyche vexa* new species

This species differs from *piatrix* in having spines in the apex of the dorso-lateral arms of the oedagus and from others in having only short and very

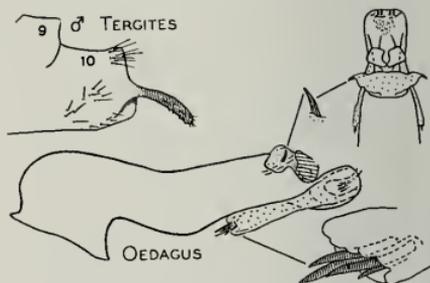


Fig. 78.—*Hydropsyche vexa*

slender spines on the dorso-lateral arms of the oedagus.

**MALE.**—Length 9 mm. Color and general structure and characteristics exactly as in *piatrix*. Genitalia as in fig. 78. Tenth tergite fairly long with a relatively sharp angle at its apex, and with a pair of long, slender lateral processes. Oedagus with the basal portion wide and low and a distinct thickening near middle; dorso-lateral appendages membranous, each tipped with a short, slender spine; apex of oedagus with a

single invaginated group of spines and with a pair of stout, membranous appendages which have a group of spines at their apex.

**Holotype, male.**—Bloomer, Wisconsin: June 5, 1936, Frison & Ross.

**Paratypes.**—WISCONSIN.—Same data as for holotype, 2♂.

***Hydropsyche bronta* new species**

Although close to *morosa* Hagen, this species differs markedly in the very long spur at the end of the lateral appendage, fig. 79.

**MALE.**—Length 11 mm. Color same as described for *piatrix*. General structure typical of genus. Diagnostic characters, apparently, present only in the genitalia.

Genitalia as in fig. 79. Ninth and tenth tergites with prominent hump;

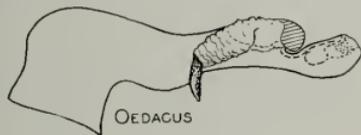


Fig. 79.—*Hydropsyche bronta*

tenth tergite with a pair of short, finger-like apical processes. Apical segment of claspers conical, the base about one-third as wide as the length of the segment, the apex very narrow and pointed. Oedagus with base broad and at right angles to remainder. Horizontal portion swollen beyond basal angle, the apical half little more than half as thick. Mesal plates ovate. Behind these arise a pair of long, membranous processes, at the end of which is situated a long spur which projects beneath the ventral margin of the oedagus. This spur is held at right angles to the oedagus; its surface is armed with spinelike teeth, and its apex is curved slightly caudad. Apical portion of oedagus knoblike, with one mesal and two lateral membranous pockets; the lateral pockets provided with two to four very small sclerotized spicules; mesal pocket having at the most a few weak, unsclerotized spicules; the spicules of the lateral pockets are completely sessile.

**FEMALE.**—Length 12 mm. Color and

general structure same as for male; genitalia apparently indistinguishable from other species of *alternans* group (see *sparna*, p. 150).

**Holotype, male.**—Bronson, Michigan: May 19, 1936, along Prairie River, Frison & Ross.

**Allotype, female.**—Same date as for holotype.

**Paratypes.**—ILLINOIS.—Apple River Canyon, Aug. 22, 1935, DeLong & Ross, 3♂. Havana: April 25, 1925, along Quiver Creek, Ross & Mohr, 1♂. Oregon: Aug. 23, 1935, DeLong & Ross, 2♂. White Pine State Park: May 30, 1936, H. H. Ross, 7♂, 3♀.

MICHIGAN.—Big Rapids: May 22, 1936, along Muskegon River, Frison & Ross, 1♂. Bronson: Same data as for holotype, 12♂.

NEW YORK.—Ithaca: Aug. 1, 1934, C. Betten, 1♂.

WISCONSIN.—Bloomer: June 5, 1936, Frison & Ross, 5♂. Trout Lake: Aug. 13, 1936, D. M. DeLong, 1♂.

***Hydropsyche cheilonis* new species**

This is a close relative of the species described above. The points of difference in the genitalia are described below.

**MALE.**—Similar in size, color and general characteristics to *bronta*. Genitalia as in fig. 80. Horizontal part of oedagus not markedly constricted just below mesal plates; the apical bulb



Fig. 80.—*Hydropsyche cheilonis*

short and stout, with four pockets (two meso-dorsal and two lateral) each bearing a group of at least six relatively long and heavily sclerotized spicules; the lateral pockets are exerted so that these lateral groups of spicules are slightly stalked. The membranous appendages behind the mesal plates are short, and the spur at the end of these is narrower and more nearly round in cross section than is that of *bronta*; this spur has a distinct constriction just beyond its base, and the apex is pointed.

**FEMALE.**—This is indistinguishable from that of *bronta* and other females of this group.

**Holotype, male.**—Oakwood, Illinois: July

18, 1933, along Salt Fork River, Ross & Mohr.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Muncie: May 4, 1936, Ross & Burks, 1♂. Oakwood: Same data as for holotype, 2♂, 6♀; Sept. 20, 1935, DeLong & Ross, 7♂, 9♀; July 18, 1933, along middle fork Vermilion River, Ross & Mohr, 1♂.

INDIANA.—Knox: May 24, 1937, along Yellow River, H. H. Ross, 1♂.

### *Hydropsyche sparna* new species

Belonging to the *chlorotica* group, this species differs from hitherto described members in the long, membranous appendages of the oedagus which bear a sclerotized lateral process shaped like a collar button, fig. 81.

**MALE.**—Length 11 mm. Color and general structure same as in *piatrix*, the

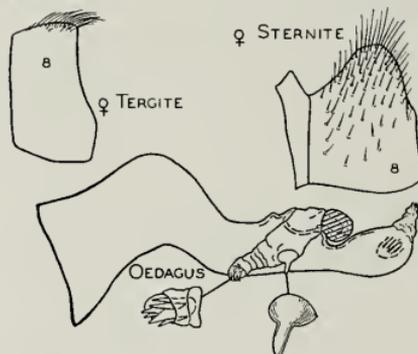


Fig. 81.—*Hydropsyche sparna*

differences occurring in the male genitalia.

Genitalia as in fig. 81. Ninth and tenth tergites humplike but not excessively so. Apical process of tenth tergite short, slightly thickened in middle and tapering off to a rounded apex; bilaterally compressed, arcuate and converging at tip when seen from above. Oedagus with basal portion sharply S-shaped, the extreme base wide. Dorsal plates ovoid. Basad of these extend a pair of membranous appendages with the apex terminating in a group of colorless, flattened spines and with a collar buttonlike spine on the ventro-lateral margin near middle. Extreme apex of oedagus bulbous with three eversible pockets of spines, one mesal and two lateral.

**FEMALE.**—Length 12 mm. Color and general structure same as for male. Lateral corner of eighth tergite similar to *cuanis* but with a longer fringe of setae. Eighth sternite incised on the meson for only one-half its length, as is typical of the genus, but with the apical lobes much more prominent than in either *cornuta* or *cuanis*.

**Holotype, male.**—Lovells, Michigan: May 22, 1936, along Au Sable River, Frison & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MICHIGAN.—Lovells: Same data as for holotype, 9♂, 9♀.

NEW YORK.—Ithaca: Sept. 1, 2♂; May 20, 1♂; May 26, 4♀; Aug. 1, 1924, 39♂; June 23, 1937, D. T. Ries, 1♂.

TENNESSEE.—Gatlinburg: May 28, 1934, along fork of Little Pigeon River, T. H. Frison, 1♂.

This species was recorded as *H. phalerata* Hagen by Betten, 1934. An examination of Hagen's type shows that true *phalerata* is not the one described here.

### *Hydropsyche centra* new species

This species is close to *cockerelli* but differs in having longer lateral appendages of the tenth tergum and a longer postero-lateral spur on the oedagus, fig. 82.

**MALE.**—Length 9 mm. Color and general structure same as for *piatrix* and other members of *alternans* group. Genitalia as in fig. 82. Tenth tergite with an angulate crest, its lateral appendages long, thickened in middle

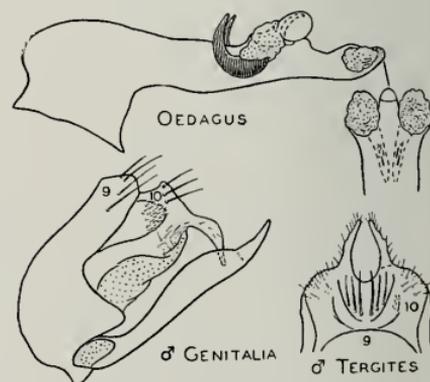


Fig. 82.—*Hydropsyche centra*

and tapered at apex, close together at base and converging toward apex. Claspers with apical segment long and tapering. Oedagus with a very large lateral spur which is upcurved and sharp. Apex of oedagus rounded, with a mesal and two lateral patches of very short, almost indiscernible rods.

**FEMALE.**—Size, color and general structure as in male. At present indistinguishable from females of other closely related species.

**Holotype, male.**—Centralia, Washington: July 26, 1936, at light, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

***Hydropsyche tana* new species**

Closely related to *oslari* Banks, but is distinguished by the high crest of the tenth tergite and the short apical segment of the clasper.

**MALE.**—Size 8.5 mm. Color and general structure same as for *centra* and other members of *alternans* group. Genitalia as in fig. 83. Tenth tergite with a high, spurlike crest, its lateral appendages short, stout and curved ventrad, narrow and close together as seen from the dorsal aspect. Claspers with relatively short apical segment. Oedagus with a short, pointed lateral spur; the dorsal plates longer than deep,

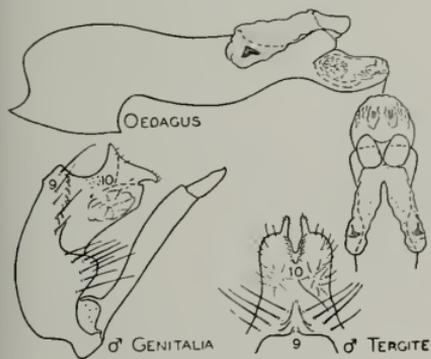


Fig. 83.—*Hydropsyche tana*

overhanging apex of oedagus; the latter is rounded at tip, with two pockets of fairly long rods.

**FEMALE.**—Size, color and general structure same as in male. No distinguishing characters found to separate

it from females of other species in the group.

**Holotype, male.**—Harrison, Montana: July 8, 1936, along creek, H. H. Ross.

**Allotype, female.**—Same date as for holotype.

**Paratypes.**—MONTANA.—Same data as for holotype, 9♂, 2♀.

***Cheumatopsyche aphanta* new species**

This species is closely related to *gracilis* Banks but is readily distinguished from it by the shorter and

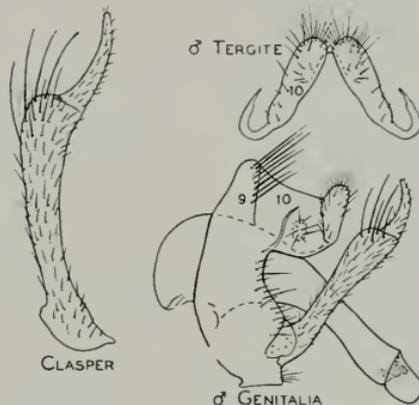


Fig. 84.—*Cheumatopsyche aphanta*

stockier basal segment of the claspers, the shorter and deeper tenth tergite and the ovate, oblique lobes at the apex of the tenth tergite.

**MALE.**—Length 7 mm. Color dark brown with the following exceptions: antennae yellowish brown, the six basal segments of the flagellum with a dark dorsal V mark, the apical portion slightly darker; prosternum, most of the legs and the venter of the abdomen straw color; each wing with indistinct grayish spots scattered over most of its area, in addition to a large gray spot on the anal margin near apex and a smaller but conspicuous spot near apex of stigmal region. General structure, including warts on the head, venation and spur count of legs, typical for genus. Diagnostic characters apparently restricted to genitalia.

Genitalia as in fig. 84. Tenth tergite almost as deep as long, and having a

lateral lobe covered with about ten long, scattered setae; apex developed into two lateral processes which are situated obliquely in reference to the anal aspect and are somewhat ovate, wider near the lobe; clothed with fine setae which are most abundant at the apex. Claspers with basal segment not quite three times length of apical segment, enlarged at apex and with a cluster of long setae on the lateral angle near apex; apical segment long and slender, tapering gradually from base to apex, clothed with short, fine setae. Oedagus with base considerably enlarged, and with the apico-lateral plates short.

**FEMALE.**—Similar in length, color and general structure to male. To date no definite characters have been found to separate the females of this genus except average size and color, so that their determination is largely a matter of association.

**Holotype, male.**—Oakwood, Illinois: June 14, 1935, C. O. Mohr.

**Allotype, female.**—Oregon, Illinois: Aug. 23, 1935, Ross & DeLong.

**Paratypes.**—ILLINOIS.—Apple River Canyon: Aug. 22, 1935, Ross & DeLong, 7♂; June 29, 1935, DeLong & Ross, 7♂. Chemung: May 28, 1936, Piscasaw Creek, H. H. Ross, 2♂. Muncie: Sept. 7, 1931, at light, H. H. Ross, 5♂, 1♀. Oakwood: June 14, 1935, C. O. Mohr, 52♂; Sept. 20, 1935, DeLong & Ross, 13♂. Oregon: Same data as for allotype, 41♂.

### *Cheumatopsyche campyla* new species

This species forms an intermediate step between the *gracilis* group and *lasia*, which in turn is intermediate between *campyla* and *speciosa*. *Campyla* differs from the *gracilis* group in having the apical processes of the tenth tergite tapering from base to apex and forming a narrow tip, fig. 85. From *lasia* it differs in that these processes are straight and not deeply emarginate near base, fig. 85.

**MALE.**—Length 10 mm. Color of head and thorax blackish, remainder of body and appendages light brown, the legs and antennae shading to straw color toward apex. Flagellum with five or six basal segments having a distinct, dorsal V mark. Each front wing finely irrorate with light brown and cream

color, and with a large light spot on anal margin near apex. Hind wings uniformly light brown. General structure same as for genus.

Genitalia as in fig. 85. Tenth tergite slightly longer than deep with a lateral submembranous knob bearing long, scattered setae and with the apex produced into a pair of lateral processes which extend considerably above the level of the segment. These processes, seen from caudal view, are wide at base, gradually narrowed to the apex and curved, sometimes the lateral margin having a small but noticeable emargination; processes are clothed with setae which fringe the lateral margin and form a rather thick crown at the apex. Claspers with basal segment three times length of second; slender and somewhat knobbed just above apex and with the usual type of pubescence; apical segment broad at base, tapering to a slender and slightly sinuate apex. Oedagus with basal portion not greatly enlarged compared to other members of the genus; the lateral lobes short and ovate.

**FEMALE.**—Similar in length, color and general characteristics to male.

**Holotype, male.**—Momence, Illinois: May 26, 1936, along Kankakee River, H. H. Ross.

**Allotype, female.**—Same data as for holotype. Collected in *coitu* with it.

**Paratypes.**—ILLINOIS.—Algonquin: W. A. Nason, 1♂, 1♀. Carmi: April 24, 1935, on bridge across Little Wabash River, T. H.

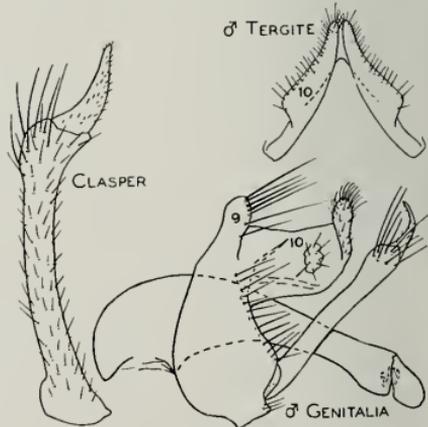


Fig. 85.—*Cheumatopsyche campyla*

Frison, 9♂, 7♀; May 28, 1935, Ross & Mohr, 6♂. Dixon: June 27, 1935, DeLong & Ross, 21♂. East Dubuque: July 22, 1927, Frison & Glasgow, sweepings, 3♂, 1♀. Florence: Oct. 11, 1931, Mohr, 1♂. Harrisburg: June 15, 1934, at light, DeLong & Ross, 1♂. Havana: June 20, 1936, at light, C. O. Mohr, 4♂, 4♀. Kankakee: Aug. 1, 1933, along Kankakee River, Ross & Mohr, 1♂; July 21, 1935, Ross & Mohr, 19♂. Moccasin: May 26, 1936, Ross, 2 mating pairs; Aug. 3, 1936, along Kankakee River, C. O. Mohr, 1♂, 1♀. Mount Carmel: June 23, 1927, Frison & Glasgow, 1♂. Oakwood: June 14, 1935, C. O. Mohr, 1♂; Sept. 20, 1935, DeLong & Ross, 15♂. Oregon: June 27, 1928, Frison, Hottes & Ross, mating pair; Aug. 23, 1935, DeLong & Ross, 2♂; May 29, 1936, H. H. Ross, 2♂, 2♀. Rockford: May 30, 1936, H. H. Ross, 12♂, 15♀; June 4, 1936, at light, Frison & Ross, 1♂. Rock Island: May 6, 1931, Ross & Mohr, 1♂. Savanna: June 29, 1935, DeLong & Ross, 4♂. Springfield: July 9, 1931, Frison, 1♂. Spring Grove: May 10, 1935, Frison & Ross, 2♂, 3♀. Wilmington: May 12, 1935, Frison & Ross, 1♂; May 17, 1935, along Kankakee River, H. H. Ross, 45♂; July 1, 1935, DeLong & Ross, 10♂; May 17, 1937, along Kankakee River, Ross & Burks, 9♂.

INDIANA.—Peru: May 18, 1936, at light, Frison & Ross, 3♂, 15♀. Shoals: June 26, 1936, along White River, Ross & DeLong, 4♂, 2♀; Sept. 10, 1936, along White River, Ross & Burks, 19♂, 16♀.

IOWA.—Lewiston: July 10, 1936, altitude 550 feet, 2♂.

MICHIGAN.—Berrien Springs: Sept. 17, 1936, Ross & Burks, 1♂, 5♀. Grand Rapids: May 13, 1936, Frison & Ross, 5♂, 1♀. Jonesville: May 19, 1936, Frison & Ross, 2♂. Omer: May 21, 1936, along Rifle River, Frison & Ross, 4♂, 6♀.

MONTANA.—Flathead Lake: Aug. 26, 1891, S. A. Forbes, no. 27108, 1♂.

OHIO.—Gibraltar Island, Put in Bay: May 25, 1937, DeLong & Smith, 4♂, 4♀.

ONTARIO.—Niagara Falls: June 10, 1937, Ries & Davis, 9♂.

OREGON.—Arlington: July 29, 1936, along Columbia River, H. H. Ross, 43♂, 51♀. La Grande: July 30, 1936, along Grande Ronde River, H. H. Ross, 11♂.

WISCONSIN.—The Dells: June 5, 1936, along Wisconsin River, Frison & Ross, 9♂, 2♀. Edgerton: June 5, 1936, Frison & Ross, 2♂, 2♀.

WYOMING.—Boulder: July 6, 1936, tributary Pine Branch River, H. H. Ross, 1♂. Pinedale: July 6, 1936, along Green River north of town, H. H. Ross, 1♂, 14♀.

### *Cheumatopsyche enonis* new species

Probably one of the most generalized in the genus, this species differs from the *sordida* complex in having the apical segment of the claspers pointed and triangular; it differs from other nearctic

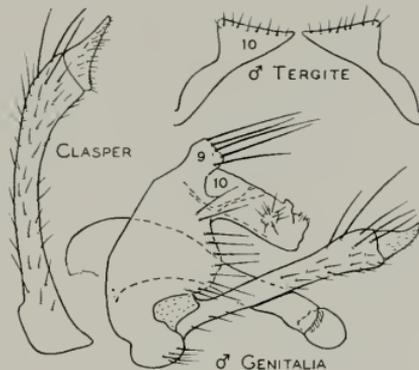


Fig. 86.—*Cheumatopsyche enonis*

members of the genus in having a short apical segment of the claspers and in lacking conspicuous lateral processes at the apex of the tenth tergite, fig. 86.

MALE.—Length 6 mm. Body light brown, with the venter and legs grading into straw color and the wings having a definite mottling of lighter brown than the body. General structure same as for genus.

Genitalia as in fig. 86. Tenth tergite long and shallow, almost three times as long as deep, the usual lateral tuberculate processes bearing long, slender setae. The apex of the segment is divided into two lateral processes which are erect along the transverse line; they do not extend above the level of the segment and, because of their small size, they are inconspicuous. Claspers with basal segment four times length of apical, enlarged at apex with setation as in preceding species; apical segment somewhat triangular with both the lateral and mesal margins convex, the baso-mesal corner produced into an angle, the entire segment covered with minute setae which are longer on the mesal margin. Oedagus with basal portion enlarged very little, the lateral lobes at the apex appear more or less globular seen from lateral view.

**Holotype, male.**—Parco, Wyoming: July 5, 1936, along North Platte River near town, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—WYOMING.—Parco: July 5, 1936, along North Platte River near town, H. H. Ross, 28♂, 27♀; Aug. 1, 1936, along North

Platte River, H. H. Ross, 6♂, 4♀. Rock Springs: July 5, 1936, at light, H. H. Ross, 44♂, 18♀.

### *Cheumatopsyche gyra* new species

This species is closely related to *gracilis*, from which it differs in the more bulbous oedagus and the caudal appendages of the tenth tergite, which

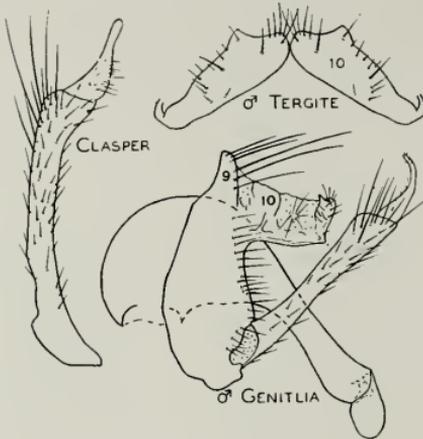


Fig. 87.—*Cheumatopsyche gyra*

have a sharp tooth on the dorso-lateral corner and which meet to form a much wider angle.

MALE.—Length 7 mm. Color dark brown with the following exceptions: Apical half of legs shading to a light brown, the body and wings with a few very distinct, light spots, the spot on the anal margin near apex being very much reduced in size and no larger than any of the other spots. Antennae, unlike *aphanta*, uniformly brown with only a slight indication of the dorsal V mark on the basal segments of the flagellum. General structure as for genus.

Genitalia as in fig. 87. Tenth tergite almost twice as long as deep, with a lateral tuberculate hump bearing several long, slender setae; apex divided into a pair of lateral plates almost touching dorsally and forming a wide angle. Viewed from the caudal aspect, these plates have both inner and outer margins slightly sinuate, the lateral margin produced dorsally into a sharp, angular projection so that the dorsal margin of the process is concave. These plates

bear scattered setae; a slight concentration of setae is found on the dorso-mesal portion. Claspers with basal segment slightly more than three times length of apical segment; apex slightly enlarged, clothed with scattered setae and having the usual cluster of long setae on the lateral side at apex; apical segment with the lateral margin evenly concave, the mesal margin sinuate, which results in the base being wide and tapering to a narrow constriction, above which the remainder of the segment widens very slightly. The entire segment is sparsely studded with minute setae, a few longer ones occurring along the mesal margin. Oedagus with basal portion more bulbous than in *aphanta* and with a narrower constriction upon the lobe. The lateral lobes at the apex are longer than in *aphanta*.

Holotype, male.—Cherokee, North Carolina: June 14, 1935, H. H. Ross.

### *Cheumatopsyche lasia* new species

In general appearance this species is similar to *campyla* but differs from it in the bent condition of the lateral processes at the apex of the tenth tergite, fig. 88.

MALE.—Length 7 mm. Color similar to *campyla* except that the irrorate

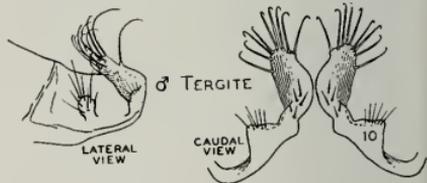


Fig. 88.—*Cheumatopsyche lasia*

pattern of the front wings is finer and slightly more markedly contrasting. General structure typical for genus.

Genitalia very similar in most particulars to *campyla*, the oedagus, claspers and general proportions being almost identical with those in fig. 85. Tenth tergite, fig. 88, slightly longer than deep, the apex produced into two lateral lobes. The base of each lobe is at right angles to the axis of the segment, but the apical half is bent back at a 45-degree angle and hides part of the apex

of the tergite. Seen from caudal view, these processes have an angular lateral projection near base, which bears a few short setae. This projection merges with the apical portion, which is somewhat ovate and which has a crown of about ten long setae that curve dorsal and then caudad. These setae are more conspicuous from a lateral view.

**FEMALE.**—Size, color and general structure same as for male, with the usual antigeny.

**Holotype, male.**—Davis, Oklahoma: June 2, 1937, along Washita River, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Dixon: June 27, 1935, DeLong & Ross, 2♂. White Pine State Park: May 30, 1936, H. H. Ross, 1♂.

IOWA.—Ottumwa: Aug. 2, 1936, H. H. Ross, 11♂, 3♀.

OKLAHOMA.—Same data as for holotype, 242♂, 96♀.

### *Cheumatopsyche oxa* new species

This species is closely related to *petiti* but differs from it on the basis of the much longer apical segment of the claspers, the more bulbous oedagus and the shape of the processes at the end of the tenth tergite.

**MALE.**—Length 8 mm. Color indistinguishable from that of *gyra*, the wings having only inconspicuous light areas so that they appear almost uniformly brown. General structure typical for genus.

Genitalia as in fig. 89. Tenth tergite scarcely longer than deep, the apex produced into two lateral processes appearing slightly constricted in middle, seen from caudal view. These processes are clothed with scattered setae that are more abundant at the apex. The lateral aspect of the tenth tergite has the usual knoblike projection, which bears long, scattered setae. Claspers long, the apical segment slender, two-thirds as long as the basal segment; the basal segment bears the usual setation but is scarcely thickened at the apex; the apical segment is clothed with minute setae scattered sparsely over its entire surface and also a few longer setae along the mesal margin. Oedagus bulbous, very similar in proportions to that of *aphanta*, fig. 84.

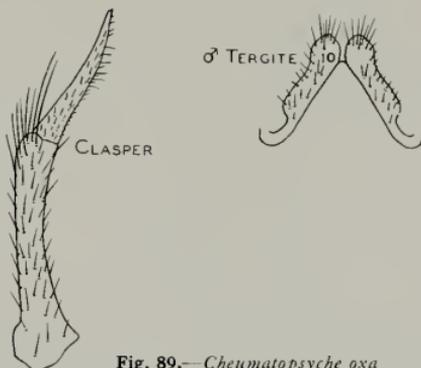


Fig. 89.—*Cheumatopsyche oxa*

**FEMALE.**—Similar in length, color and general characteristics to male. Differing in the usual antigenetic characters of genitalia.

**Holotype, male.**—Columbia City, Indiana: May 19, 1936, along Eel River near town, Frison & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—INDIANA.—Same data as for holotype, 4♂.

MICHIGAN.—Bronson: May 19, 1936, along Prairie River, Frison & Ross, 3♂, 5♀.

### Family LEPTOCERIDAE

#### *Athripsodes alagus* new species

Closely resembling *tarsipunctatus* Vohries, this species differs from it in having the cerci and tenth tergite shorter, the ventral spines of the tenth tergite almost as long as the tergite itself and the oedagus more robust.

**MALE.**—Length 12 mm. Color reddish brown except as follows: antennae straw color, each segment having a narrow, dark apical band; in addition, apical half of antennae covered with dark brown scales and basal half covered with almost white scales; wings with membrane rather dark brown, bearing very small, round areas of lighter brown scattered over the entire surface; membranous area whitish; legs beyond coxae straw color. General structure typical for genus; size of eyes same as given for *ophioderus* (see p. 157).

Genitalia as in fig. 90. Tenth tergite seen from above appears vasiform; seen from the side shallow at base and enlarged at extreme apex; a pair of heavily

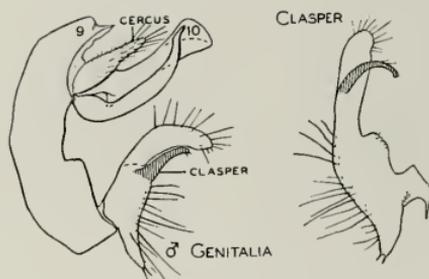


Fig. 90.—*Athripsodes alagnus*

sclerotized lateral arms arise at the extreme base, progressing for a distance parallel with the rest of the tergite; moderately upturned near apex and with the end truncate. Cerci short, as wide as long and deeply incised laterally near apex to form a narrow apical projection on the mesal side. Claspers with the basal portion projecting into a long, pointed process, the apical lobe submembranous, fusiform and markedly curved caudad; the sclerotized process curved, either slightly truncate or rounded at apex. The basal portion of each clasper has a baso-mesal projection which is truncate, with a basal thread and a semitruncate or semiangulate smaller projection just above this on the meson. Oedagus short and deep with a small lateral flange and with the apex pointed. Of the internal structures, the most conspicuous is a pair of heavily sclerotized spines which are more than half the length of the oedagus, bulbous at base and pointed at apex.

**Holotype, male.**—Fox Lake, Illinois; July 1, 1931, Frison, Betten & Ross.

**Paratypes.**—ILLINOIS.—Antioch: July 7, 1932, Frison & Metcalf, 2♂. Fox Lake: Same data as for holotype, 7♂. Fulton: July 20, 1927, Frison & Glasgow, 5♂. Homer Park: July 6, 1927, at light, Frison & Glasgow, 1♂. McHenry: June 30, 1931, Frison, Betten & Ross, 1♂.

WISCONSIN.—Little St. Germaine Lake: Aug. 12, 1936, D. M. DeLong, 2♂.

#### *Athripsodes cophus* new species

This species is similar in general habits to *submaculus* Walker and *erraticus* Milne but differs from both in the flange-like structures at the base of the tenth tergite, in addition to other characters of the genitalia.

**MALE.**—Length 14 mm. Color of head, thorax, dorsum and venter of abdomen, and most of legs blackish brown to black, antennae slightly darker brown than head; apices of tibiae and all but apical segment of tarsi light brown; wing membrane pale yellowish brown, most of veins darker shades of brown. Pubescence of head a mixture of white and black hairs, that of thorax black and that of the remainder including the wings brown. General characteristics same as for genus. Eyes small; seen from dorsal view, separated by slightly more than twice longest dorsal length. Venation and spur count same as for genus.

Genitalia as in fig. 91. Tenth tergite with a large base from which protrude (1) a narrow, mesal prolongation flared

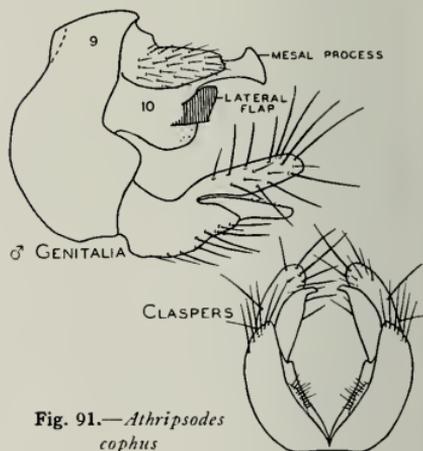


Fig. 91.—*Athripsodes cophus*

at the apex and with the apical margin arcuate; (2) a pair of short, flaplike plates below the base of the mesal projection. Cerci short, bluntly angled at apex. Clasper with base bulbous, without rows of heavy setae or mesal flaps; only the mesal margin armed with a patch of short setae; apical lobe finger-like, semimembranous, with about fifteen long, slender setae scattered over its surface; at the base of this lobe is the sclerotized lateral appendage which is almost as long and wide as the apical lobe and has the apex pointed and slightly hooked. Oedagus anchored firmly within the genital capsule, com-

posed of a tonguelike ventral flap which is thin and spatulate in outline, a middle submembranous and extrusible lobe and a dorsal pair of pointed, sclerotized rods which also are extrusible.

**Holotype, male.**—Pinedale, Wyoming: July 6, 1936, Green River north of the town, H. H. Ross.

**Paratypes.**—WYOMING.—Same data as for holotype, 2♂.

I have compared this species with *Athripsodes nigronervosus* Retzius, of Europe, with which it is very similar in size and general appearance, but the genitalia of the two species are very different.

#### *Athripsodes ophioderus* new species

Close to the *punctatus* group, this species differs from the members of that group in the necklike tenth tergite with its ovate apical enlargement.

**MALE.**—Length 10 mm. Color of head, body and appendages reddish brown, with the following exceptions: antennae almost straw color, each segment with a very narrow, dark brown ring at apex; wings with three whitish spots, one just in front of and the other just beyond the stigmal area of the costal margin, the third on the anal margin near apex. Setation of body and appendages a mixture of brown and blackish hairs.

General structure, including wing venation and setation, typical for genus. Eyes small, seen from lateral view appearing slightly longer than high; seen from above, the two seem separated by three times the distance of their greatest dorsal length.

Genitalia as in fig. 92. Ninth tergite produced dorsally into a narrow point. Tenth tergite somewhat S-shaped, divided into three distinct regions: (1) a robust basal part bearing at its apex a pair of short dorsal spurs and a pair of disto-ventral humps with a cluster of short, stout setae; (2) a slightly curved necklike portion which is slightly excavated beneath, the dorsum convex transversely and twice as wide as deep; and (3) a bulbous apical portion which is rounded apically, no wider than the "neck" but enlarged ventrally. Cerci short and wide, the apico-lateral margin incised. Claspers with the basal portion

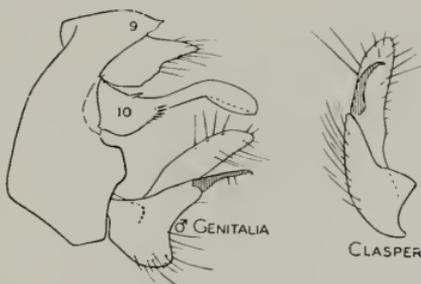


Fig. 92.—*Athripsodes ophioderus*

somewhat triangular, the ventro-mesal corner produced into a right angle plate; mesal margin immediately behind this plate with a small flange bearing a few small setae; apical lobe fingerlike and semimembranous, with about fifteen long setae scattered over its surface; at the base of this lobe is the sclerotized lateral appendage which is only one-half the greatest length of the apical lobe, moderately stout at base, curved and tapering evenly to a slender point. Oedagus with a spatulate ventral plate and a pair of stout, upcurved dorsal spines; between these and the ventral plate a semisclerotized process somewhat fingerlike but indefinite in outline for most of its length. Oedagus withdrawn into a small socket joined internally with the tenth segment.

**Holotype, male.**—Elizabethtown, Illinois: June 22, 1927, at light, Frison & Glasgow.

**Paratype.**—ILLINOIS.—Same data as for holotype, 1♂.

#### *Triaenodes taenia* new species

This species resembles *dentata* Banks in the general pattern of the genitalia but differs in the longer lateral process and the small, short mesal process of the claspers and the shorter and wider sclerotized bands which arise from the base of the claspers, fig. 93.

**MALE.**—Length 10 mm. Head, body, mouthparts and legs almost straw color and covered with long, yellowish pubescence. Wings tawny, covered with long and fairly dense pubescence which forms a tawny background with poorly defined darker areas covering the basal third of the costal region and the apical fourth of the front wing. Antennae cream color with a narrow brown ring

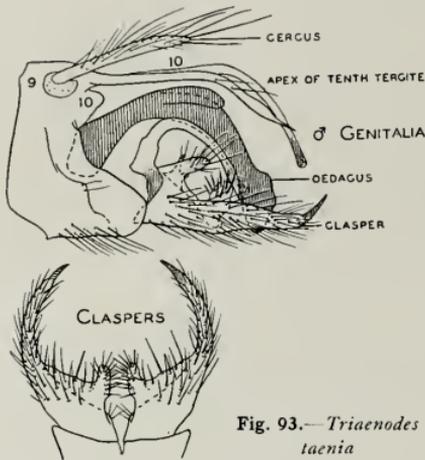


Fig. 93.—*Triaenodes taenia*

at the apex of each segment; these rings diminish in darkness from base to apex until at the tip of the antennae they are scarcely perceptible.

General structure typical for subgenus *Triaenodes*. The basal segment of the antennae is furnished with an ellipsoid, scalelike plate which runs the entire length of the dorso-mesal margin. Wing venation, mouthparts and legs same as for subgenus.

Genitalia as in fig. 93. Tenth tergite cleft, divided into two long, ribbonlike processes which curve ventrad near the middle and follow the outline of the oedagus; the right process is longer than the left and curves to the left at its extreme apex; the left is shorter but curves as much to the right as the right does to the left. Cerci long and fingerlike, clothed with long setae. Claspers with (1) a long arcuate lateral arm whose tip is smooth and sclerotized, the remainder of the arm set with abundant setae; (2) a small mesal projection which is subdivided into two almost equal lobes separated at the base by a distance equal to their length, one basal, the other apical, only the latter visible from a ventral view, both clothed with setae, those on the apical lobe shorter and much stouter; and (3) a curved, almost saberlike process originating from the base of the clasper and following the contours of the oedagus, curving downward and reaching only half the distance to apex of clasper. Oedagus arcuate, semi-

membranous, with a conspicuous dorsal lobe near middle and with the apex somewhat enlarged.

**Holotype, male.**—Gatlinburg, Tennessee: June 12, 1935, along Little Pigeon River, H. H. Ross.

### *Triaenodes tridonta* new species

Related to the more primitive members of the genus, this species differs from them in the tridentate tenth tergite, fig. 94.

**MALE.**—Length 10 mm. Head and body chestnut brown, the antennae annulate with narrow bands of brown and wider bands of cream color. Mouth parts and legs shading to straw color; wings uniformly brown, covered with brown pubescence.

Belongs to the subgenus *Triaenodes*, having a scale on the dorso-mesal surface of the basal antennal segment; the scale having a round base, more or less parallel sides and a tapering, rounded apex. Maxillary palpi long and very bushy. Venation and spurs typical for genus.

Genitalia as in fig. 94. Ninth segment very short dorsally and long ventrally. Tenth tergite longer than the claspers or the preanal appendages. The base is somewhat cylindrical, gradually widening to a tridentate apex, the two lateral arms long and sharp, the mesal one short and sharp; the entire structure twisted so that the tridentate condition is not conspicuous from a dorsal view.

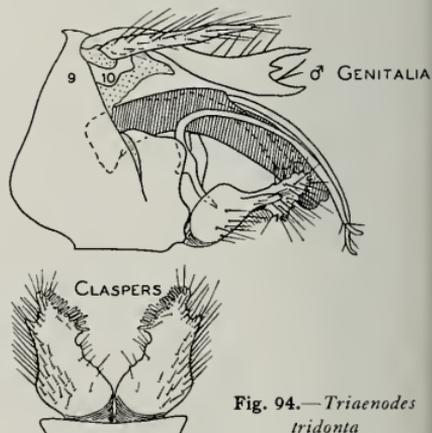


Fig. 94.—*Triaenodes tridonta*

Cerci shorter than tenth tergite, narrow, pointed and clothed with long setae. Claspers short, the base enlarged and bulbous, especially when seen from the side, the apical portion divided into a short, sharp lateral angle and a wider mesal lobe. The lateral half of the clasper is provided with abundant long setae, and the oblique apical margin of the mesal lobe bears a dense row of short, peglike setae. From the base of the clasper arises a long, sclerotized, filamentous process which curves near the base and thence follows the direction of the oedagus; the apical portion of this process is slightly fusiform with the apex narrowed and slightly upturned. The processes of each side are similar in general outline. Oedagus arcuate, the basal portion tubular and the apical portion composed in part of semimembranous folds which are difficult to distinguish.

**Holotype, male.**—Pushmataha County, Oklahoma: May 28, 1934, C. A. Soeler.

#### *Trienodes perna* new species

A close relative of *helo* Milne, this species differs in the constricted claspers and the much stronger asymmetry of the ribbonlike processes which arise at their base.

**MALE.**—Length 9 mm. Color of head, body, antennae, mouthparts and legs same as for *tridentia*. Wings with a fairly well defined pattern as follows: Front wing basad of cord with a nearly parallel-sided, dark brown stripe occupying about one-half of the width of the wing, set off from the anal margin by a narrow, tawny border and from the costal region by a tawny border which is narrow at the base and gradually increases in width to the cord; the area beyond the cord is dark brown, unicolorous with the dark streak on the basal part of the wing, except for the small continuation of the tawny costal part, which tapers off beyond the stigma, and indications of tawny shading along the extreme distal edge of the wing. General structure typical of the subgenus *Trienodes* with respect to the antennal scale, wing venation, etc.

Genitalia as in fig. 95. Ninth segment very short dorsally, ventral half to-

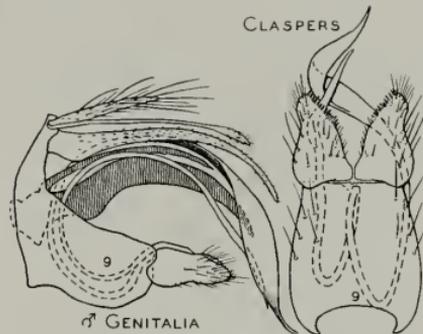


Fig. 95.—*Trienodes perna*

gether with the tenth sternite forming a long, deep projection which is longer than and twice as deep as the claspers. Tenth tergite very slender, slightly clavate at extreme apex. From immediately below the tergite protrudes a semimembranous "tongue" which is broad at base and soon tapers to a whip-like apex. Both the tenth tergite and the "tongue" project almost as far posteriorly as the apex of the claspers. Cerci half length of tenth tergite, narrow, finger-like and clothed with long setae. Claspers somewhat triangular, the lateral margin indented so that the basolateral corner is somewhat bulbous; the meso-apical margin oblique and with a dense row of short, peglike setae; the ventro-mesal lobe is not developed but is represented only by a low ridge directly dorsad of the area bearing the peglike setae. From the base of the claspers arise the usual ribbonlike bands. They are very long and form an almost complete circle, ending below and beyond the apex of the claspers; the right band has the apical half greatly widened and turned, and has a sharply pointed tip; the left band is slender throughout, slightly thickened a short distance before the apex, scarcely twisted and has a sharp point. Oedagus branched near base, the dorsal branch forming a narrow, tonguelike structure underneath the larger similar structure that arises from under the tenth tergite; the ventral branch bulbous at extreme base, thence arcuate and tapering to a narrow apex.

**FEMALE.**—Similar in size, color and general characteristics to male, differing chiefly as follows: venter of abdomen

with third and fourth sternites dark brown; fifth, sixth and seventh gradually becoming lighter toward apex; scale at base of first antennal segment absent; external genitalia typical for the genus, provided with a hollowed-out, clasperlike pair of appendages which hide the ovipositor tube.

**Holotype, male.**—Eichorn, Illinois: June 13, 1934, along Hick's Branch, DeLong & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratype.**—ILLINOIS.—Same data as for holotype, 19.

### *Oecetis eddlestoni* new species

This species is intermediate between *avara* Banks and *scala* Milne, differing from the former in the long processes of the tenth tergite and from the latter in the reniform claspers, fig. 96.

**MALE.**—Length 10 mm. Color various shades of brown; the flagellum straw color with a dark apical ring on each segment; the palpi dark brown; the wings fairly dark brown with fine, light dots scattered over the membrane, the cord and cubital veins darker than the rest; the abdomen pale with a dark dorso-mesal line down each segment.

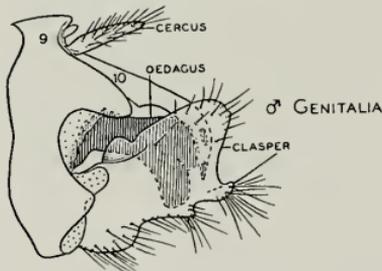


Fig. 96.—*Oecetis eddlestoni*

General characteristics same as for genus. Antennae thrice length of body. Protibiae with only one apical spur. The three "crossveins" forming the cord staggered ladderlike, none interstitial with each other, the posterior one interstitial with  $Cu_{1a}+M_{3+4}$ .

Genitalia as in fig. 96. Ninth segment with a long, thumblike caudal projection closer to dorsal margin than to ventral. Tenth tergite with a small, sub-

membranous mesal projection at extreme base and with the apex produced into a pair of long, flat, sclerotized arms curving ventrad at base and armed with two spines, one at apex and one just beyond arch of curved portion. Cerci lanceolate, short and covered with sparse but long setae. Claspers rectangular-reniform in general outline, the apical margin with one emargination and the ventral one with two, each emargination bordered by blunt lobes; the apico-ventral lobe curved mesad, slightly longer than the others, although this is not apparent from the lateral aspect; each lobe is surmounted by a tuft of setae, those on the dorsal lobe more scattered, shorter and slightly stouter than the others. Oedagus suddenly constricted just above base, the apical portion swollen and bilobed, the ventral lobe hanging much lower than the dorsal one.

**Holotype, male.**—Sayre, Pennsylvania: July 29, 1937, along Susquehanna River, J. H. Eddleston.

The similarity of this species to both the subgenus *Oecetodes* Ulmer and *Quaria* Milne in regard to wing venation and general characteristics, as well as its intermediate position between the two in regard to genitalia, necessitates the sinking of the subgenus *Quaria* under *Oecetodes*.

### *Leptocerus oligius* new species

This species is very close to *guttata* (Banks) from which it differs in the shape of the tenth tergite, which in *oligius* is broad at base and suddenly narrowed to form a pair of filaments. In *guttata* these processes are long and gradually tapering for their entire length. This is the species illustrated by Betten (1934, plate 36, fig. 10, and plate 37, fig. 1) as *Setodes* sp. 1 from Ogdensburg and Buffalo, New York.

**MALE.**—Length 8 mm. Body creamy; some sutures and veins light brown; eyes black.

General structure same as for genotype; eyes large, occupying most of the lateral view of head capsule, the dorsal length two-thirds the shortest distance between them. Basal segment of each antenna swollen; one and one-half times

as long as wide and no longer than the third antennal segment. Spur formula 0-2-2. Front wings slender, pointed at apex, radial sector three-branched,

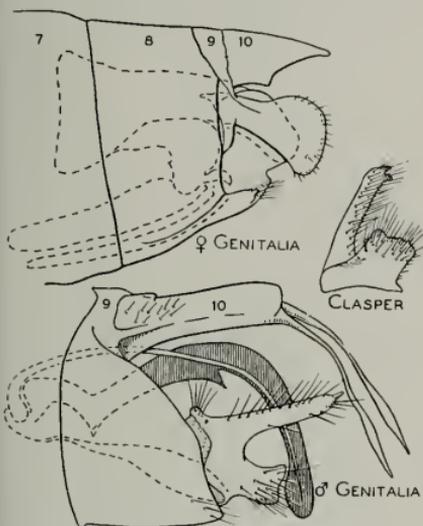


Fig. 97.—*Leptocerus oliginus*

media two-branched; hind wings also narrow and pointed, with  $Cu_1$  branched.

Genitalia as in fig. 97. Tenth tergite divided into two processes whose basal two-fifths are broad and contiguous on meson; the apical three-fifths narrow, slender filaments slightly thickened and sinuate before apex, the constriction occurring abruptly. Claspers divided into a ventro-mesal, quadrate lobe slightly emarginate at the apex, and a long, fingerlike, dorso-lateral lobe with a pair of toothlike processes at apex. From the baso-mesal angle of each clasper arises a sclerotized plate joining the base of the oedagus. The entire clasper is clothed with long, fine setae. Oedagus arcuate with basal portion sclerotized and with a sharp ventral process near the height of its arc, the apical portion semimembranous; from each side at base arises a sclerotized filament which curves back to the base of the ninth segment, then curves up and follows oedagus to its apex, the two processes being similar.

FEMALE.—Similar in size, color and

general structure to male, differing in characters of the genitalia, fig. 97. Ninth tergite cylindrical and heavily sclerotized. Tenth tergite carinate on meson, broad at base, the apical half tapering to a triangular and pointed apex. Below this on each side is a spatulate, clasperlike process constricted at the base; between these is a moundlike structure formed of two lateral plates open above and fused ventrally. The sternal plate is somewhat produced, its apical margin forming one mesal and two lateral pointed projections. A pair of invaginated, spindlelike structures lie just above the venter and extend halfway into the eighth segment.

**Holotype, male.**—Wilmington, Illinois: Aug. 20, 1934, along Kankakee River, DeLong & Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—ILLINOIS.—Same data as for holotype, 2♀.

Family **PHRYGANEIDAE**

***Agrypnia dextra* new species**

Similar to *glacialis*, differing in the apex of the tenth tergite, which has only a single pair of lateral styles, the two being distinctly asymmetrical, the right one the longer and the left one the shorter, fig. 98.

**MALE.**—Length 19 mm. Light brown to straw color, the pubescence straw color; the eyes are slightly darker.

General structure identical with other members of the genus *Agrypnia s. st.*

Genitalia as in fig. 98. Ninth segment with the ventral half cylindrical, the dorsal half narrowed and forming a short collar across meson; this collar bears tufts of long setae at the apex. Tenth tergite twice as long as wide, the ventral

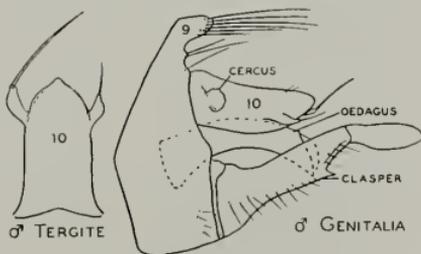


Fig. 98.—*Agrypnia dextra*

margin evenly arcuate, the dorsal margin slightly concave and the apex narrowed to a blunt point; just before the apex there arises a pair of submembranous styles which are both slightly fusiform, the right one longer than the left and bearing at its apex a very long, stout seta; the left style is shorter, bears a short seta only one-third the length of seta of the right style, and is not narrowed at apex; near the base of the tergite is a small, submembranous and flaplike preanal appendage. Claspers arcuate and converging apically; from a lateral view the basal segment appears over twice as long as the apical segment and bears an angular projection two-thirds the distance from base (this projection is on the mesal margin and is better seen from the ventral aspect). The apical segment is almost lanceolate and bears tufts of spines pointing basad. Oedagus tubular and evenly but not greatly arcuate; the apical margin oblique, forming a pointed ventro-mesal end.

**Holotype, male.**—Riverdale, Idaho: May 10, 1935, C. F. Smith & G. F. Knowlton.

**Paratype.**—IDAHO.—Same data as for holotype, 1♂.

### Family LIMNEPHILIDAE

#### *Apatelia aenicta* new species

This species is a very close relative of *A. wallengreni* but differs in the longer mesal process of the ninth tergite and the apical widening of the cerci.

**MALE.**—Length 10 mm. Color of body and appendages black with the following exceptions: apical segments of antennae brownish, sutures of venter, apical and upper portion of femora, most of tibiae and basal portion of tarsi reddish brown; wing membrane dark gray, venation dark brown. The body and wings are clothed with tawny hair.

General characteristics same as for genus in regard to setation and shape of head and thorax. Spur count of tibiae 1-2-4, the spurs relatively short, very sharp and yellow. Front wing with stigmal area half as deep as long, tapered in relation to the remaining surface of the wing and set off sharply at the base by an oblique, weakly sclerotized but convex crossvein. Remainder of venation typical for genus.

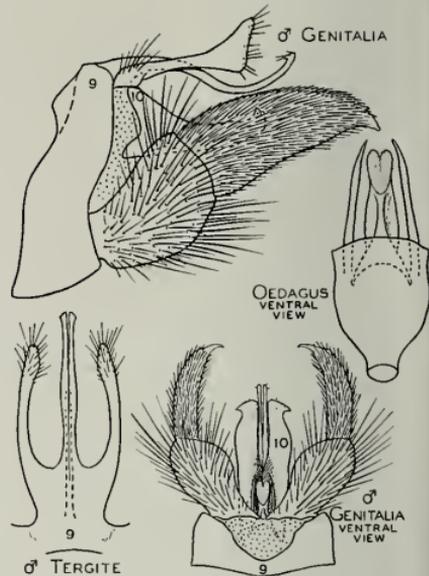


Fig. 99.—*Apatelia aenicta*

Genitalia as in fig. 99. Ninth segment cylindrical, narrow and slightly sinuate from lateral view. Set in the mesal notch is a three pronged appendage composed of a slender, sinuate mesal rod and a pair of lateral rods greatly expanded at the apex in the vertical plane; these lateral appendages are considerably shorter than the mesal rod; each has at its base and apex a tuft of scattered setae. Tenth tergite long and wide, deep at its base but excavated dorsally to form a shallow apical portion which is upturned at the tip; seen from a ventral view the lateral margins of the tenth tergite appear slightly sinuate, then incised near tip to form a relatively sharp lateral point. Claspers very large, the basal segment covered with thick, long setae, the apical segment covered with shorter and denser setae; basal segment shorter than apical segment, only slightly longer than wide; apical segment narrower than basal segment, tapering gradually to a sclerotized and curved point free from setae. Oedagus consists of a large, vasiform base from which extrude a pair of long, sclerotized rods lying one on each side of the apical portion of the oedagus, which is surmounted by a bilobed, cushionlike pad.

**FEMALE.**—Similar to male in size, color and general structure, differing from male in genitalia. Diagnostic characters have not yet been worked out for females of this genus, but the tapered and wide stigmal area will separate this female from most of its congeners.

**Holotype, male.**—Churchill, Manitoba: July 2, 1936, H. E. McClure.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MANITOBA.—Same data as for holotype, 1♂; same place as for holotype, July 5, 1936, 1♂, 2♀.

***Carborius lyratus* new species**

This species, fig. 100, differs from *punctatissimus* (Walker), fig. 101, in the short genal spine and different shape of the oedagus and claspers, fig. 100.

**MALE.**—Length 16 mm. Head and thorax light brown; the abdomen, antennae, mouthparts and legs straw color (except the spines on the legs, which are black); the wings light brown, minutely flecked with pale areas over the entire membrane.

General structure, including legs and

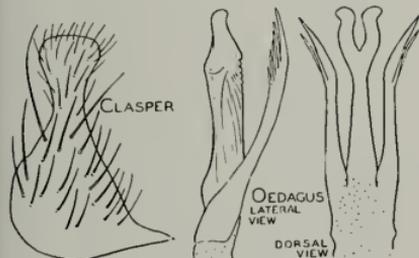


Fig. 100.—*Carborius lyratus*

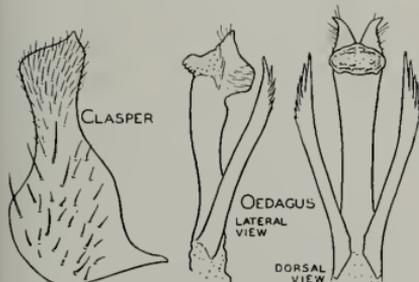


Fig. 101.—*Carborius punctatissimus*

wing venation, same as for genus. Head with a small genal projection, which is only a third as long as that in the genotype. A large macrochaeta present behind each lateral ocellus. Basitarsi without black spines on ventral side.

Genitalia as in fig. 100. Eighth tergite with apical margin only finely setate, and produced into a mesal process which is slightly wider than long, is shallowly emarginate at apex and has sharp corners and well delineated margins. Ninth and tenth tergites much reduced, represented by a pair of mesal, thumblike processes pointing dorsad, these flanked by a pair of cerci laid back flat against the tergite; caudad of these is a triangular, sclerotized plate, the narrowed apex rounded, the widening base invaginated into the body cavity and articulating with the base of the oedagus. Claspers with a wide, quadrate base, beyond which the clasper narrows and then widens just before apex. Oedagus extrusible; apical portion consisting of a pair of heavy, sclerotized, sinuate rods each bearing four or five stout appressed spines near apex and a central oedagus tube which is slightly dumb-bell-shaped and is surmounted by a lyre-shaped division of the apex.

**Holotype, male.**—Oakwood, Illinois: Sept. 20, 1935, DeLong & Ross.

**Paratype.**—PENNSYLVANIA.—Columbia Crossroads: July 7, 1931, R. M. Leonard, 1♂.

***Glyphopsyche ormiæ* new species**

Close to *ullus* Milne, this species differs in the smaller pads on the eighth tergite and the smaller, thinner and less bulbous apices of the tenth tergite.

**MALE.**—Length 19 mm. Color tawny to yellowish brown except for the following: some black spines and setae (especially those on the legs); a pale, silvery stripe on the front wing down the radial cell and continuing in a straight line through cell  $R_5$  almost to margin of wing; and an almost entirely colorless hind wing.

General structure typical for genus, the form very slender. Shape and setation of head and thorax, and venation of wings, typical for genus. Tibiae with the spur count 1-2-1, the lone spur on the hind tibiae long, sharp and sinuate.

Genitalia as in fig. 102. Eighth tergite with a pair of convex apical pads densely clothed with short, fine, brown setae. Ninth and tenth tergites narrowed on

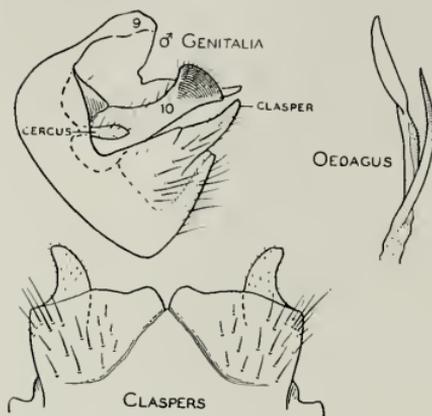


Fig. 102.—*Glyphopsyche ormiae*

meson, mostly submembranous except for the lateral processes of the tenth tergite; these are heavily sclerotized, enlarged and deeply concave at apex to form a pair of spurlike lobes. Cerci very small, situated at base of tenth tergite. Claspers not readily differentiated from apical sternite; they have a broad base with the lateral angle produced into a pointed, fingerlike process curved laterad; the extreme base of the clasper is armed with scattered, long setae; it is set off from the apical sternite by a V-shaped mesal suture which becomes obsolete toward the lateral margin. Oedagus with a pair of sclerotized lateral arms lying beside the central portion; the central portion is divided into two long, submembranous lobes at extreme apex and is provided with a long, narrow cushion of minute spines from the base of these lobes to the base of the sclerite.

**Holotype, male.**—Smithfield, Utah: Oct. 20, 1936, H. F. Thornley.

**Paratypes.**—UTAH.—Smithfield: Same data as for holotype, 1 ♂. Logan: Nov. 3, 1934, C. F. Smith, 1 ♂.

#### *Limnephilus acnestus* new species

In color and general appearance this species resembles many species hitherto placed in *Colpotaulius*. It differs from

them in the combination of small tenth tergite, large cerci and spiny lateral arms of the oedagus.

**MALE.**—Length 9 mm. Head and body various shades of brown. Wings with a pale, tawny brown color irregularly peppered with darker brown spots, brown sections of veins and dark brown setae. Legs uniformly tawny to light brown, the spurs and setae concolorous, the spines conspicuously black.

General characteristics same as for genus. Dorsum of head with scattered, appressed setae and long, black bristles; the wart in front of the lateral ocellus bears three, and there is one bristle which arises mesad and slightly caudad of the ocellus. Pronotum collarlike, with a fossa between the two halves. Mesonotum slightly flattened, the scutal warts long and bearing a linear row of very long, black bristles arched caudad. Front wings bearing long and erect setae along the veins; the wing is somewhat abbreviated so that the apical cells are short, giving the wing a chopped-off appearance. Front tibia with apical spur,

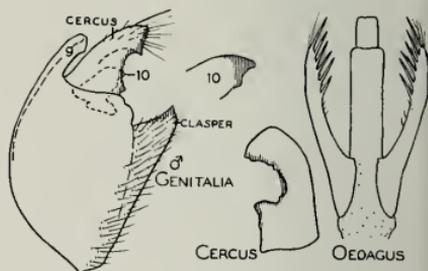


Fig. 103.—*Limnephilus acnestus*

which is very wide at base, triangular and flattened. Front basitarsus subequal in length to next segment of tarsus. Eighth tergite with a long mesal projection overhanging the genitalia; this projection bears a cushion of short, black bristles.

Genitalia as in fig. 103. Ninth segment wide in the middle, suddenly constricted to a very narrow dorsal bridge. Lateral lobes of tenth tergite small and low, the apex of each lobe curved and emarginate to form a pair of low humps. Cerci large, the base broad, the central mesal portion incised so that the apex is

somewhat hoodlike. Claspers broad, their apex forming a sharp, sclerotized point which does not extend above base of cerci; they are covered with moderately long setae and set off from the ninth segment by an obsolescent suture. Apical portion of oedagus tubular, the extreme apex forming a short, narrowed cylinder; lateral arms stout, tapering to a somewhat pointed apex which bears on its dorso-mesal corner a row of six or seven stout spines interspersed with thinner setae.

**Holotype, male.**—Inyo County, California: May, 1922, O. C. Poling.

### *Limnephilus keratus* new species

In general appearance this species comes closest to members of the *Anabolina* group but differs from all species previously described in having the two horns arise from the base of the tenth tergite.

**MALE.**—Length 17 mm. Color of head, body and appendages various shades of reddish brown. The spines on the tibiae and tarsi are black. Wings a fairly uniform salt-and-pepper mixture of dark brown and straw-colored dots; the brown markings are thickest just below radius 1, cubitus 1 and the anal veins.

General structure same as for subgenus *Anabolina*. Head with one or two bristles mesad and slightly caudad of lateral ocellus, the base of the bristles arising from a wide calyx. The wart in front of the ocellus bears two or three large and a few small bristles. Pronotum with the two warts forming a collar bisected by a fossa on the meson. Mesonotum with scutal warts only moderately long and bearing two large, black bristles and about eight small, pale ones, all arching caudad. Tibiae with spur formula 1-3-4, all the spurs long, pale and pointed. Front basitarsus elongate, one and one-half times the length of the next segment. Front wings wide with the apex evenly rounded. Eighth segment cylindrical with no patches of bristles or produced lobes.

Genitalia as in fig. 104. Ninth segment cylindrical, widened dorsally to form a projection over part of the genital appendages. Just below the apex of the

ninth and above the base of the tenth tergite is a very heavily sclerotized structure divided almost to base to form a pair of slightly diverging horns which curve ventrad slightly. Lobes of the tenth tergite composed of deep, thin

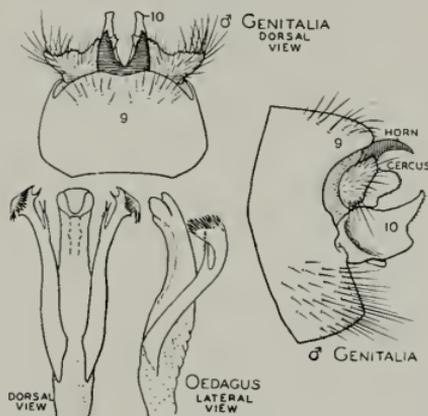


Fig. 104.—*Limnephilus keratus*

plates sunken in the middle to form a wide basal portion situated in the transverse plane and a produced and up-pointed apical portion in the longitudinal plane; the apex is indented to form an upturned and a shorter, blunter ventral angle, the dorsal point being armed with a few minute setae. Cerci situated between the base of the lobes of the tenth tergite and the pronged structure; their base is small but their entire base is small but their entire dorsal, lateral and mesal margins are expanded into an earlike structure whose edges are heavily sclerotized, irregularly serrate and armed with long setae. Claspers greatly reduced and scarcely differentiated from ninth segment, with no dorsal projection of any description. Apical portion of oedagus wide at base, which is semimembranous with a sclerotized fork embedded in the dorsal margin; lateral arms stout, the apex divided into a narrow, pointed dorso-mesal spike beset with a few small spines and an apical, foliaceous and in-curved "palm." This "palm" bears a small projection on each lateral margin just before apex and a picketlike row of setae along the apical margin.

**Holotype, male.**—Thunder Bay, Ontario: July 1, 1937, H. S. Parish.

***Limnephilus merinthus* new species**

This species is most closely related to the *kincaidi* group but differs in the short and uniformly sclerotized lateral arms of the oedagus.

**MALE.**—Length 8.5 mm. Head and body dark brown to black, the warts reddish brown. Antennae and legs reddish brown suffused slightly with dark brown; the spines of the tibiae and tarsi black. Wings light brown to tawny with irregular, darker brown markings between radial sector and cubitus 1.

General structure typical of the subgenus *Anabolina*. Head long, with a

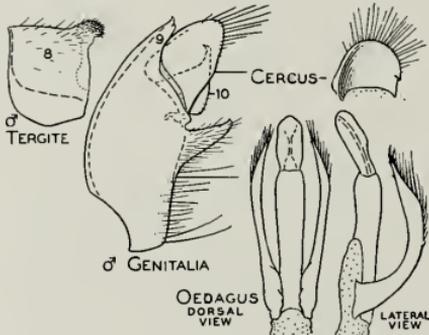


Fig. 105.—*Limnephilus merinthus*

large bristle mesad and slightly caudad of each lateral ocellus, the wart in front of lateral ocellus with one or two large and several small bristles. Pronotum collarlike, the two dorsal warts separated by a fossa. Mesonotum flat, the scutal warts long and wide, containing an abundance of long and short bristles arched caudad. Venation same as for subgenus, the wings somewhat abbreviated so that the apical cells are short. Front basitarsus short and stocky, slightly shorter than succeeding segment. Tibial spur formula 1-3-4, the spur on the front leg black, smooth and angled sharply at extreme apex, the other tibial spurs long, sharp and yellow. Eighth tergite produced on the meson to form an apical lobe extending over genitalia in repose.

Genitalia as in fig. 105. Ninth seg-

ment narrowed to a collar dorsally. Lobes of tenth tergite thin, platelike and with a rounded ventral angle but with the dorsal segment produced into an erect projection recurved at extreme apex. Cerci appear semiovate as seen from lateral view, the apex rounded; seen from the caudal view they appear somewhat auriculate and close together on the meson; the mesal margin is armed with a single stout spur; the apical surface of the cercus is fringed with scattered, long setae. Clasper projecting caudad considerably, its apex turned up slightly, the surface covered with a scattering of medium length setae. Oedagus with apical portion short, the mesal tube cylindrical with a more slender terminal portion; lateral arms entirely sclerotized. Dorsal margin practically smooth; extreme apex divided into two or three heavy spines, the ventral margin having a fringe of setae longest at the apex and gradually diminishing in length toward the base.

**FEMALE.**—Similar in size, color and general structure to male, differing in the longer front basitarsus, genitalia and other antigenetic characters.

**Holotype, male.**—Churchill, Manitoba: July 17, 1936, H. E. McClure.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MANITOBA.—Same data as for holotype, 3♂; same place as for holotype, July 10 and July 20, 1936, 2♂.

***Limnephilus taloga* new species**

This species belongs to the section *Colpotautilus* and bears a marked resemblance in the genitalia to *spinatus* Banks. It differs from this species markedly in the shape of the cerci and in the setation of lateral arms of oedagus.

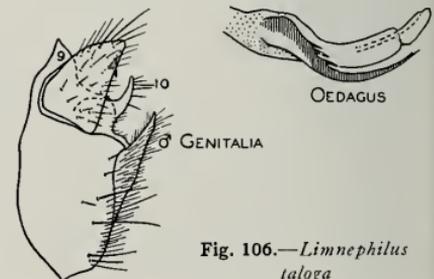


Fig. 106.—*Limnephilus taloga*

**MALE.**—Length 12 mm. Body various shades of brown; the dorsum mottled with dark and light shades; the venter, including the legs, straw color; wings with the membrane straw color, no pattern, the venation a mixture of straw color and brown. Most of the long setae on the head and thorax black, the remainder tawny; the spines on the legs black, the spurs brown; the setae on the veins of the wings black, the remainder of the wing vestiture dark brown to black.

General characteristics typical of the genus *Limnephilus*. The lateral ocellus has a wart just in front of it bearing two very long, black macrochaetae and has one small and one large macrochaeta just meso-caudad of ocellus. Scutal wart of the mesonotum very long, the anterior setae the shorter, the posterior ones the longer, all curved caudad. Front femur with a band of black spinulae beneath; the tibia with a companion band of black spinulae; the basitarsus short, flared at apex and only one-third the length of the succeeding segment. Wing venation typical for genus, the veins supplied with regularly placed and abundant long setae, more erect and markedly longer than the hairs of the membrane.

Genitalia as in fig. 106. Eighth without cushions of setae and with only two or three sparse rows of setae across the segment. Tenth tergite with the median area low and inconspicuous; the lateral processes broad at base, narrowed and up-turned at the apex to form almost needlelike structures which appear divergent when seen from a caudal view. Cerci almost twice as high as width at base, both margins evenly curved, the mesal aspect with a single long, sharp spinous process near the dorso-caudal angle; seen from above, the cerci are separated at their base for a distance almost equal to their length. Claspers long and pointed, set off at the base by a faint suture. Apical extensile portion of oedagus with the central portion typical of genus, the lateral arms diagnostic, having the base broad and armed with three strong dorsal spines, the apical portion narrowed gradually to a sharp point which may have a slight division near its apex. All parts of the genital

capsule are yellowish with the exception of the following: the setae, the lateral processes of the tenth tergite and the mesal spines of the cerci, which are black; the lateral arms of the oedagus, which are a darker brown than the remainder of the structure.

**FEMALE.**—Length 13.5 mm. Similar in color and general structure to male, except for the usual antigeny. No characters have been discovered which will separate the females of the closely related form of this genus.

**Holotype, male.**—Taloga, Oklahoma: June 6, 1937, Standish & Kaiser.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—OKLAHOMA.—Taloga: Same data as for holotype, 1♀.

UTAH.—Indian Writings (near Logan): Sept. 11, 1937, San Rafael Road, at light, W. P. Nye, 1♂, 1♀.

***Limnephilus thorus* new species**

Closely related to *externus* Hagen, this species differs in the larger clasper, the sharper dorsal angle of the cerci and the less ornamented lateral arms of the oedagus.

**MALE.**—Length 18 mm. Body brown with the eyes black and the wings shaded

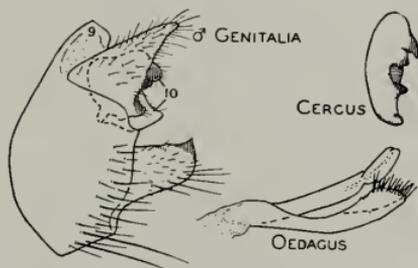


Fig. 107.—*Limnephilus thorus*

ing to yellowish; there is no pattern on the wings except a slight shading from light to dark at various places.

General structure: Macrochaetae of head inconspicuous because they are fairly short and the same color as the head. Front tarsus with basal segments one-quarter longer than second, neither the tarsus nor tibia with areas of black spines underneath. Wings extending beyond apex of abdomen, three and

three-fourths times as long as wide; venation typical for genus. Eighth tergite with patch of black setae at apex.

Genitalia as in fig. 107, with appendages short. Ninth segment reduced to a narrow collar on the dorsum. Tenth tergite short and stocky, its apical margin produced into a dorsal knob and a ventral point which juts out beyond the base of the cerci. Cerci triangular, the apex angular; the caudal margin with two projections on ventral portion visible from the side and with four toothlike processes visible from caudal view. Clasper short and stocky, its extreme apex turned up into a small, sharp dorsal point. The setae on the entire genital capsule are scattered. The apico-dorsal knob of the tenth tergite and the apical, mesal, toothlike processes of the cerci are heavily sclerotized. Oedagus with central portion tubular, the extreme apex constricted at its base; lateral arms as long as the mesal portion, wider at base than in middle and slightly enlarged in apex; the mesal margin of the apex is armed with a row of short setae.

**Holotype, male.**—Blue Creek, Utah: Aug. 28, 1934, C. F. Smith.

### *Neophylax oligius* new species

This species resembles *autumnus* Vorhies in size and general appearance, but differs from it in the genitalia of the male, in particular the claspers with their short, sharp mesal point and unrecurved lateral corner, fig. 108.

**MALE.**—Length 11 mm. Body, antennae and legs light brown, the pubescence light brown and the spines on the legs dark brown to black; front wings with the ground color brown, darker

than the body, and with lighter brown areas forming an irrorate pattern on the distal two-thirds of the wing and a narrow band covering most of the area caudad of vein  $Cu_2$ ; hind wings uniform color, lighter than front wings.

General characteristics typical for genus, with diagnostic characters apparently restricted to the genitalia of the male. Wing venation, ocelli and legs normal; the head with the small wart just behind lateral ocelli.

Genitalia as in fig. 108. Tenth tergite long, divided into a dorsal, robust branch rounded at apex and a ventral branch which is slender and slightly truncate at apex. Apparent ninth sternite with an apico-dorsal lobe which appears triangular viewed laterally, straplike viewed caudally, and which joins the oedagus assemblage on the meson; the remainder of the sternite is hemicylindrical. Clasper short, produced into a short, sclerotized mesal point and an erect lateral point which is apparent chiefly from the side; the entire clasper, except the mesal point, is covered with scattered setae. Between the claspers is a pair of small, sclerotized, quadrate plates which are striate. The internal portion of the oedagus is tubular; from this juts a smaller, tapering tube.

**FEMALE.**—Length 12 mm. Color and general structure same as in male. The female genitalia are very simple and to date no good morphological differences have been discovered which will separate the females of this genus.

**Holotype, male.**—Merriweather, Michigan: Aug. 23, 1937, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—MICHIGAN.—Merriweather: Same data as for holotype, 3♂, 3♀. Honor: Aug. 24, 1936, in Platte River, C. O. Mohr, 1♂, 1♀, taken from cocoon.

WISCONSIN.—Sayner: Aug. 25, 1937, in Plum Creek, H. H. Ross, 3♂, 1♀, taken from cocoon.

### *Neophylax ayanus* new species

This species is distinguished from previously described members of the genus by its somber coloring and the elongate claspers.

**MALE.**—Length 11 mm. Head, body and wings dark brown, the wings in-

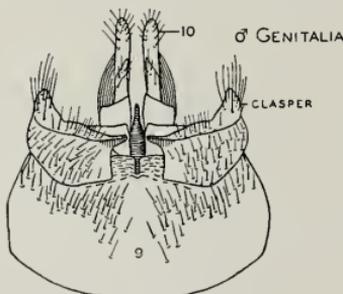


Fig. 108.—*Neophylax oligius*

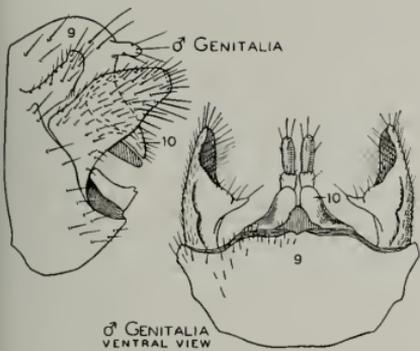


Fig. 109.—*Neophylax ayanus*

conspicuously flecked with luteous markings in the membrane which are somewhat obscured by the tawny hair that covers the entire wing. Antennae and legs pale yellow, the spines of the tibiae and tarsi black.

General structure as described for preceding species.

Genitalia as in fig. 109. Tenth tergite with the basal portion rounded and humplike, the apex attenuated into a beaklike structure following the line of the oedagus; the apparent cerci form a pair of clavate knobs above the base of the beak. Claspers twice as long as wide, the lateral margin convex, the inner margin concave and with a cuplike mesal process arising near middle; the margins and lateral surface are covered with a scattering of long and medium length setae. Apical portion of oedagus beaklike, extending under the beak of the tenth tergite. Ninth sternite with the apical margin produced to form a pair of wide mesal lobes, surmounted by a pointed projection on the meson; this mesal projection is the hump in the center of a caudo-mesal sclerite set at right angles to the ninth sternite.

**FEMALE.**—Similar in size, color and general structure to male. The characters of the female genitalia have not yet been worked out in this genus, so that for the present the female can be distinguished only by the color.

**Holotype, male.**—Louisville, Kentucky: Oct. 8, 1937, Bear Grass Creek, Ross & Burks.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—KENTUCKY.—Same data as for holotype, 6♂, 3♀.

INDIANA.—Cataract: Sept. 24, 1937, Mill Creek near Cataract Falls, Frison & Ross, 1♂, 1♀.

***Neophylax stolon* new species**

A close relative of *ayanus*, this species differs from it in the narrow projection of the ninth sternite and in the twisted condition of the clasper.

**MALE.**—Similar in size, color and general structure to *ayanus*. Genitalia, fig. 110, similar in general to *ayanus* but with the following differences: Beak of tenth tergite and that of oedagus more slender and slightly longer, seen from lateral view. Claspers slightly shorter, with the dorsal margin evenly convex and with the apical portion twisted so that only a triangle at the base is in full lateral view; the oblique apical portion forms a hoodlike apex; from ventral view the clasper appears concave; it has a shelflike plate across it two-thirds the distance from the base; the apical margins of the clasper bear several long setae, the basal portion shorter setae.

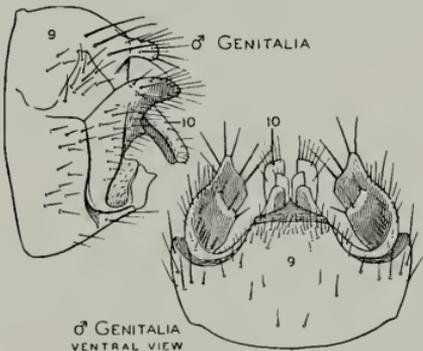


Fig. 110.—*Neophylax stolon*

Ninth sternite excavated on the sides to form a prolonged mesal lobe, at the apex of which is a heavily sclerotized, declivous plate ending in a sharp mesal point.

**Holotype, male.**—Monterey, Virginia: Sept. 28, 1936, T. H. Frison.

***Platycentropus plectrus* new species**

This species is easily distinguished from *indistinctus* Walker by the lateral, hornlike angles of the ninth tergite.

**MALE.**—Length 16.5 mm. Dorsum of head and body dark brown to blackish

with the warts brownish yellow; entire venter, antennae, legs and mouthparts yellow; the spines on the tibiae and tarsi black. Wings almost entirely brownish yellow with the following darker marks: a light brown streak running from base

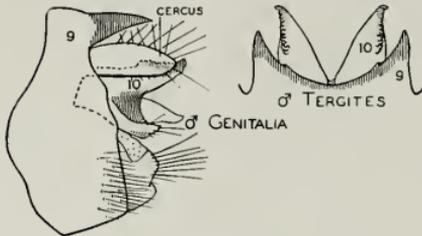


Fig. 111.—*Platycentropus plectrus*

of media along stem of media,  $M_{3+4}$  and cubitus 1, a lighter brown band in the postanal field and a dark brown band filling all but the central portion of cell  $R_5$ .

Structure typical for genus. Head with a long bristle mesad and slightly caudad of lateral ocellus. Mesonotum with scutal wart triangular, the anterior portion forming a sharp angle and the wart bearing only medium sized, luteous bristles. Front basitarsus long and slender, almost twice length of next segment. Tibial spur formula 1-3-3. Eighth tergite simple, without prolongations or patches of small bristles.

Male genitalia as in fig. 111. Ninth tergite mostly cylindrical but with the dorsum flattened slightly, produced laterally and incised dorsally to form a pair of dark, heavily sclerotized, sharp projections which overhang the genitalia. Lobes of tenth tergite with a broad base and a platelike mesal extension; this latter has the apico-ventral margin rounded, the apex up-turned and the apico-dorsal margin slightly raised, moderately serrate and very heavily sclerotized; the basal portion of the lobe is furnished with a few short bristles. Cerci obovate, the dorsal margin evenly convex and bearing numerous long setae. Claspers small, distinctly set off from the ninth segment and with a cushion of long setae on the small knob which forms the apex. Oedagus with the apical portion consisting of a very large central tube and a pair of much shorter

lateral arms which are flat, thin and with the apex divided into a number of small, uneven points.

**Holotype, male.**—Honor, Michigan: Sept. 16, 1936, along Platte River, Ross & Burks.

**Paratype.**—WISCONSIN.—Prairie du Lac, 1 ♂ (Museum of Comparative Zoology collection).

## Family SERICOSTOMATIDAE

### *Notidobia pele* new species

Running closest to *assimilis* Banks, this species differs from it in having no hook at the apex of the clasper; instead it has a plate situated on the mesal margin.

**MALE.**—Length 12 mm. Color light brown mixed with irregular areas of a lighter shade; the costal and apical cells

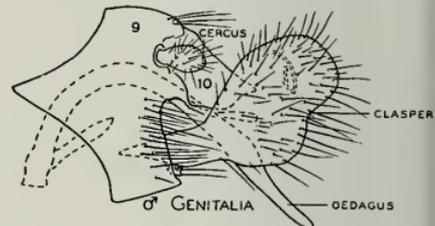


Fig. 112.—*Notidobia pele*

of the wings even paler except for a narrow area adjacent to the veins.

Structure typical for genus. Eyes set with dark setae. First antennal segment very short, as wide at base as length. Eyes large, separated anteriorly for a distance equal to the greatest dorsal length of the eyes. Maxillary palpi very short and closely appressed to face, the

apical segment short and submembranous, the first and second very closely united, twice as long as the third and with a membranous mesal filament extending almost the entire length of the combined two segments. Spur formula 2-2-4.

Genitalia as in fig. 112. Sternites without processes. Ninth segment with lateral pointed extensions reaching into the eighth segment. Tenth tergite appearing somewhat triangular viewed from above, narrowed to a subacute tip which is slightly depressed as seen from side; from the baso-lateral corners extend a pair of slender semisclerotized styles which reach almost to the apex of the tergite. Cerci short, obovate and flaplike, covered with sparse setae. Claspers with base quite narrow, apical portion enlarged and reniform, the disto-ventral margin emarginate, the mesal margin with a long, clavate process extending up from base and a small, platelike projection at right angles to the clasper, one-fourth the distance from the apex; in addition, the dorsal margin near middle has a short, blunt mesal projection. The lateral aspect of the clasper, except at base, is covered with a scattering of long and very coarse setae. Oedagus bowed, the extreme base slightly enlarged and with a fingerlike process, the apical portion slightly enlarged and then excavated dorsally to form a narrowed and very slightly upturned apex.

**Holotype, male.**—Smokemont, North Carolina: June 14, 1935, H. H. ROSS.

**Paratype.**—NORTH CAROLINA.—Same data as for holotype, 1 ♂.

**Goerita** new genus

This genus differs from the Brachycentrinae in having four spurs on the hind tibiae; from the Lepidostomatinae in having the spurs short and grouped close together toward the apex of the tibia; from the Helicopsychinae in having the hind wings broad at base; from the Sericostomatinae in having the eyes smooth and not hairy. From the Goerinae, to which it is most closely related, this genus can be distinguished by the maxillary palpus of the male, which has a quadrate second segment, and by the high crown of the head in the female, fig. 113.

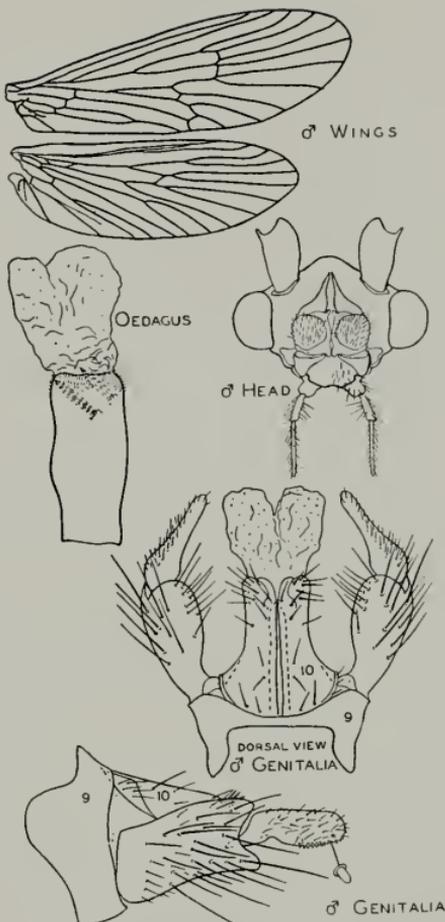


Fig. 113.—*Goerita semata*

Characteristics: Maxillary palpi of male three-segmented, the first segment widening to apex, the second quadrate, the third membranous and tapering to a thin filament; the two palpi held up together in front of the face to form a short mask. First antennal segment only as long as greatest length of eye; cylindrical. Eyes small, separated by almost twice their length in both sexes. Wing formation typical for generalized members of the subfamily. Both eyes ovate, relatively broad at base and blunt at apex, with most of the hypothetical veins and crossveins present. Male claspers distinctly two-segmented.

**Genotype.**—*Goerita semata* new species (original designation).

***Goerita semata* new species**

**MALE.**—Length 6 mm. Body light brown; the membranous areas white; the dorsum of the abdomen purple; the first antennal segment and legs below coxae straw color; the wings uniformly light brown with light brown pubescence. General structure as given for genus.

Genitalia as in fig. 113. Abdomen without ventral ornamentation. Ninth segment very narrow dorsally, forming across the meson a thin, sclerotized bridge. Tenth tergite formed of a pair of fairly wide lateral plates, practically touching on meson, wide and arcuate at base, the apical half with sides subparallel, the apex divided into two rounded lobes, the lateral lobe slightly overlapping the mesal lobe; the entire structure with only scattered long setae clustered chiefly at apex and along meson. Claspers, viewed from above, with basal segment swollen at apex and apical segment swollen at base. Seen from the lateral view, the basal segment appears almost rectangular; it appears slightly concave when viewed ventrally. It is incised at the apex to form a hollow bearing the apical segment, which is constricted just beyond base to form an apical, sausagelike portion having on its ventral surface a row of rounded, fat, peglike setae. Oedagus tubular, with an apical fringe of very fine setae; in prepared specimens there protrudes from the apex a large, membranous fold and within the oedagus can be seen two stout spines.

**FEMALE.**—Similar in size, color and general structure to male, except for antigeny. Maxillary palpi longer than width of front between eyes. Eighth sternite crescentic; ninth forming a concave sinuate pad fitting within the crescent. For purposes of diagnosis the shape of the head is most important.

**Holotype, male.**—Newfound Gap, North Carolina: June 13, 1935, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—NORTH CAROLINA.—Same data as for holotype, 14♂, 4♀.

***Goera stylata* new species**

This species is readily distinguished from others in the genus by the distomesal processes of the claspers and the extremely long styles of the tenth tergite.

**MALE.**—Length 9 mm. Color a medium dark shade of brown, with the following exceptions: membranous areas white; warts, labial palpi and legs beyond femora straw color; maxillary

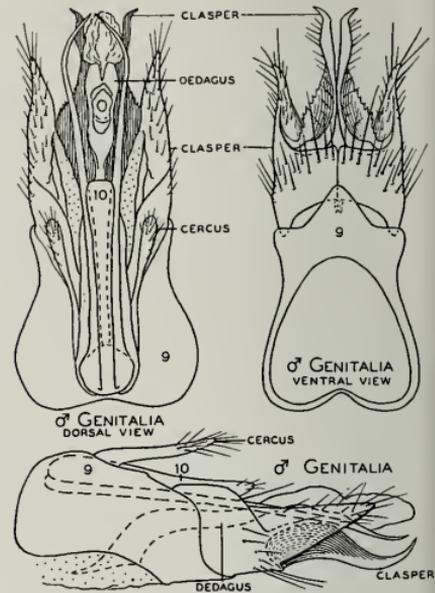


Fig. 114.—*Goera stylata*

palpi white with a black line along the ventro-mesal edge; pubescence brown throughout. General structure typical for genus.

Genitalia as in fig. 114. Sternites 6 and 7 with a row of six or seven erect yellow spines, those on the sixth sternite slightly longer. Ninth segment seen from lateral view appears twisted into an oblique position, the ventral margin pushed twice its own length caudad of the dorsal margin. Tenth tergite, arising far back in a fold of the ninth, consists of a narrow central style reaching midway to apex of genitalia and a

pair of long, sclerotized styles which arise under and laterad of the central style and proceed as far caudad as the rest of the genital capsule; these sclerotized styles diverge slightly from near the base to almost the apex but at this latter point curve mesad and almost touch at extreme apex. Cerci long and slender, clavate, bearing at their apex a cluster of scattered setae and reaching not quite so far caudad as the middle lobe of the tenth tergite. Claspers complicated, the basal portion embracing a large proportion of the segment, the two claspers truncate and approximate on the venter; the apex is divided into two lobes, a triangular, lateral lobe set with long, scattered setae and a very heavy, dark, sclerotized mesal lobe which is sigmoidal from lateral view, broad at base and tapering to apex, and which from a ventral view curves into meson, where it touches the mesal processes of the other clasper. The two processes proceed distad with only slight divergences until close to the apex, where they are angled laterad to form a short point. The dorsal margin of the mesal process is produced into a thin, serrate ledge. Oedagus with the basal portion tubular and sinuate, constricted just beyond middle and expanded into an apical bulb which is three times as long as wide, is constricted in the middle and bears at the apex an ovate mass of membranous folds.

**Holotype, male.**—Lovells, Michigan: May 24, 1936, north branch Au Sable River near town, J. W. Leonard.

***Theliopsyche epilone* new species**

Closely related to *parva* Banks, this species differs from it in the longer process of the clasper, fig. 115.

**MALE.**—Length 6 mm. Body dark brown with the membranous areas and legs below coxae lighter brown to straw color. Pubescence dark brown.

General structure: Maxillary palpi cylindrical, the apical segment slightly longer than the preapical and clothed with abundant, very long setae, the ventral setae forming a fairly thick brush. First antennal segment long and cylindrical, slightly longer than half width of head. Wing venation and spur count typical for genus.

Genitalia as in fig. 115. Seventh sternite with a broad, ligulate mesal tongue, typical of genus. Ninth segment oblique, the apico-ventral margin truncate with a slight incision on the meson

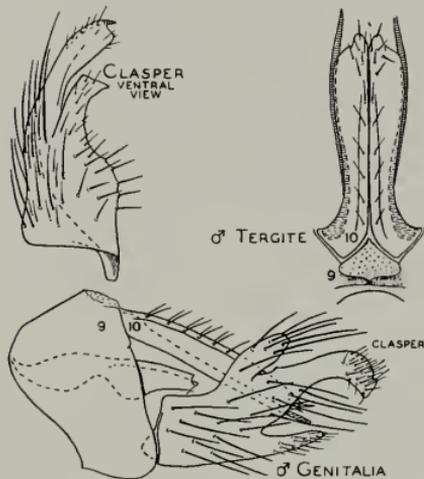


Fig. 115.—*Theliopsyche epilone*

and situated very much caudad of the dorsal portion of the segment. Tenth tergite long, set into a mesal angulation of the ninth, consisting of (1) a pair of long, sclerotized, sinuate rods which arise at the baso-lateral corner of the tergite and follow the outline of the mesal sclerite and (2) a mesal pair of wider, thinner plates which are appressed on the meson to form a rooflike structure, which end on a rounded lateral corner and a short, round mesal projection and which bear scattered setae along meson. Claspers with a wide base, produced into three apical processes: (1) a short, truncate ventral one which curves mesad and which has the mesal corner pointed (2) a short, thumblike dorsal one which is about the same length as the ventral one and (3) a lateral one, representing the body of the clasper, which curves mesad and ends in a very short, sharp spur; the base of the clasper is covered with a scattering of long setae, as is the dorsal lobe also, but the lateral and ventral lobes bear only a few short setae on the apical half. Oedagus submembranous; situated beneath rooflike tenth tergite.

**Holotype, male.**—Newfound Gap, North Carolina: June 13, 1935, along Little Pigeon River, H. H. Ross.

**Paratypes.**—NORTH CAROLINA.—Same data as for holotype, 3♂.

### *Aopsyche* new subgenus

This subgenus is very closely related to *Theliopsyche* as evidenced by the similar type of distinctive genitalia and the tongue-like process on the seventh sternite. It differs from that genus, however, in the different shape of the maxillary palpi, fig. 116, and the peculiar venation featuring a very wide subcostal cell and crowded branches of radial sector.

Characteristics: Structure typical of Lepidostomatinae. First antennal segment almost as long as width of head. Maxillary palpi long, the second segment slender at base, widened toward apex, and the inner apical side bearing a brush of dense, dark setae; apical segment slender, tapering to apex, bearing only a few long setae on inner side. Front wing without scales; venation as in fig. 116. Costa thick to juncture with subcosta, which is close to costa and faint; subcostal cell wide; branches of radial sector crowded together and close to  $R_1$ ; media with three branches. Hind wing with costa and subcosta indistinguishable, radius with four branches, media with two and cubitus 1 with two; all are weak except the strong veins  $R_1$  and  $Cu_1$ . Spurs 2-4-4. Seventh sternite of abdomen with a tongue-like projection extending from the incised apical margin. Eighth sternite reduced to a narrow, sclerotized band.

**Genotype.**—*Theliopsyche corona* new species (original designation).

### *Theliopsyche corona* new species

**MALE.**—Length 6 mm. Color blackish brown with the wings and legs lighter than the other parts. General structure given under description of the genus.

Genitalia as in fig. 116. Tenth tergite consists of a pair of raised plates, each of which gives rise to a lateral, elongate, spinous process extending almost to the apex of the claspers. Claspers consisting of several parts: a broad base, a large dorsal knob which is more or less thumb-

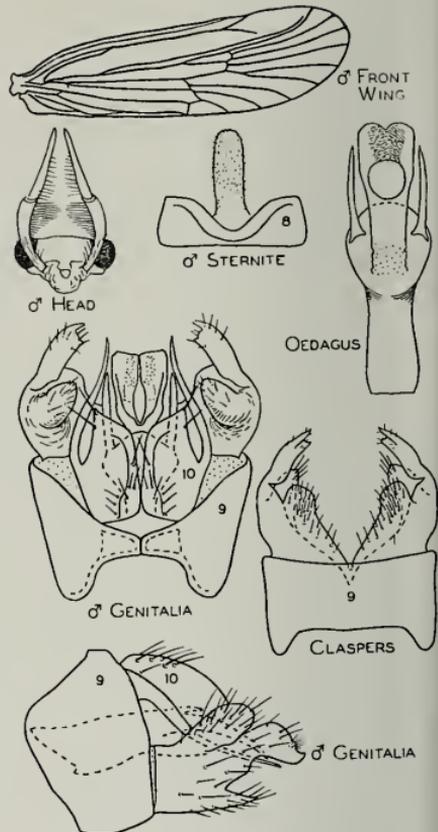


Fig. 116.—*Theliopsyche corona*

shaped, a ventral projection which is slightly truncate at apex and a lateral, fingerlike appendage which bears a small outer tooth at extreme apex, flanked by several small setae. Oedagus large, composed of a tubular base which merges into an oval area bearing a pair of lateral, spinous processes and a submembranous, mesal appendage; this latter has a circular opening on the ventral side, above which the oedagus is divided along the meson.

**Holotype, male.**—Gatlinburg, Tennessee: May 27, 1934, along branch of Little Pigeon River, T. H. Frison.

### *Lepidostoma Rambur*

A study of the females of the Lepidostomatinae shows that many of the genera, such as *Lepidostoma*, *Nosopus*

and *Olemira*, are set apart as genera only on secondary sexual characters. A detailed study of the genitalia shows that, in many cases, past divisions have cut across phylogenetic lines. It seems advisable at the present time to group the species of this complex under the one genus *Lepidostoma*. There is no doubt but that a great deal of investigation will be needed to establish even a semi-permanent generic organization of the subfamily, and it seems to me that until this takes recognition of the females it will not be at all satisfactory.

**Lepidostoma knowltoni** new species

This species is closest to the *togatum* group but differs in the combination of unreflexed costa in the front wing with a very twisted and abnormal first antennal segment, fig. 117.

MALE.—Length 10 mm. Body light brown with the eyes, first antennal segment and dorsum of thorax darker brown.

General structure: Basal antennal segments contorted, excavated and twisted as in fig. 117, bearing at the base a short dorsal process pointed dorso-mesad, beyond this another similar one on the mesal margin pointing mesad and between these on the ventral margin another process which is pointed and continues as a thick brush of stout setae, the entire structure curving meso-dorsad and ending on a level with the dorsal margin of the segment. Beyond this the segment is dorso-ventrally com-

pressed, then widened again at apex. Maxillary palpi with a stout brush of scales issuing from the apex; in both specimens examined this brush is opened up to form an almost globular mass which hides the structure of the palpus. Legs and wings normal for genus. Both wings with a sparse scattering of scales over most of the wing but without the costal margin reflexed.

Genitalia as in fig. 117. Ninth tergite produced caudad on meson, merging imperceptibly with the tenth tergite. Tenth tergite represented by two rather distinct parts: (1) a pair of dorsal, mesally appressed lobes with a scattering of fine setae and (2) a pair of lateral appendages joined at their base to the dorsal pair, converging toward the tip and angled dorsad at the tip; the basal portion is fairly stocky, clothed with numerous long setae; the apical portion is smooth and more heavily sclerotized; this pair of processes is almost twice the length of the dorsal pair. Claspers fairly long and narrow, the base with a long, thin and clavate dorsal appendage and a short, wide, hooklike process on the ventro-mesal edge (seen from ventral view). The apex is abruptly tapered to a triangular point, beneath which is a short, smooth projection. The entire ventral aspect of the clasper bears a dense mat of long setae. Oedagus is tubular and forms a semicircular arc.

Holotype, male.—Clinton, Utah: June 21, 1936, G. F. Knowlton.

Paratype.—UTAH.—Same data as for holotype, 1 ♂.

**Lepidostoma pleca** new species

Closely related to *bryanti*, this species differs in the depressed and pointed apex of the tenth tergite and the bristle-filled cavities on the first antennal segment.

MALE.—Length 9 mm. Color dark brown with the following exceptions: pubescence on maxillary palpi mostly white; bristles on the first antennal segment a mixture of black, brown and white; legs below coxae light brown; wing membrane almost colorless with a sparse covering of light brown hair and irregular patches of black scales on front wing and a fairly thick, uniform scattering of black scales on the hind wing.

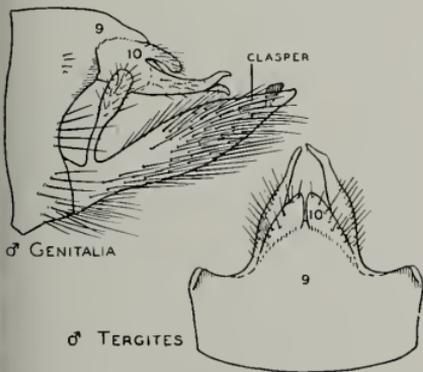


Fig. 117.—*Lepidostoma knowltoni*

General structure as follows: Maxillary palpi with apical segment long and cleft, clothed ventrally with long, whitish hair and dorsally with a long brush of long, slender scales. First antennal segment twisted and compressed, the lateral margin deeply excavated for almost its entire length, the cavity so formed filled with a dense brush of

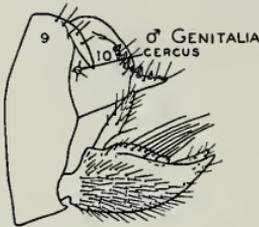


Fig. 118.—*Lepidostoma pleca*

bristles; ventro-mesal margin produced into an arcuate, flat appendage, usually hidden by a lateral brush of bristles. Tibial spurs numbering 2-4-4. Wing venation typical of group, the costal margin reflexed at base for one-tenth the distance to stigmal region, the pocket thus formed filled with scales.

Genitalia as in fig. 118. Ninth segment annular, its meso-dorsal margin indented to receive the tenth tergite. Tenth tergite divided down the meson for its entire length but with an open V fissure for only half its length; the resultant lobes broad at base with the ventral margin almost straight and the dorsal margin S-shaped, resulting in a quadrantlike base and a narrow fingerlike apex; the apical half of this S-shaped upper margin set with a row of irregular, toothlike spines. Clasper extends one-third its length beyond apex of tenth tergite. From the meso-dorsal angle of the base arises a fingerlike process which proceeds at a wide angle to the clasper. Near the base is a second small, fingerlike process appressed to the dorsal margin, and near the apex is a third flat process which (from lateral view) seems to lie behind and to extend slightly dorsad of the pointed apex of the clasper. From a ventral view the clasper appears arcuate, with both mesal and lateral margins evenly curved. Oedagus tubular and arcuate with a pair of dorsal, fingerlike processes arising

near base and following contour of oedagus almost to apex.

**Holotype, male.**—Ingles Creek (near Bluett Pass), Washington: July 10, 1936, H. H. Ross.

### *Lepidostoma quercina* new species

This species is close to *podager* McL. but differs in having the front legs normal. In *podager*, the first segment of the tarsus is abnormally developed and dilated, twice the length of the tibia.

**MALE.**—Length 10 mm. Body brown with the eyes almost black, the membranous areas white, the venter of the abdomen and legs below coxae lighter brown than the sclerotized portions of the head and thorax; wings light brown, the veins slightly darker than the membrane, surface covered with brown setae but without patches of white scales.

General structure: Basal segment of antenna subequal in length to greatest length of eye, only slightly swollen.

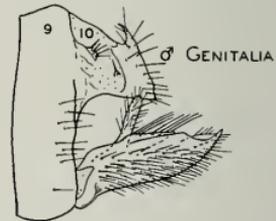


Fig. 119.—*Lepidostoma quercina*

Maxillary palpi short, the apical segment slightly expanded and covered with a dense brush of white setae. Front basitarsus one-fourth shorter than front tibia and not quite twice length of second tarsal segment. Spur formula of tibiae 2-4-4, the spurs long, straight and pointed. Front wing obovate, the front margin not reflexed and the venation typical of the genus. Cells C, Sc and R<sub>1</sub> subequal in width. Hind wing typical for genus.

Genitalia as in fig. 119. Ninth tergite annular. Tenth tergite with base submembranous and apex divided into two sclerotized lateral plates. Seen from the lateral view, each of these appears to have a fairly straight ventral margin, a slightly irregular, oblique caudal margin; the dorsal angle produced into a long, sharp, recurved point and the lateral

margin near base having a pointed hump that bears a seta, this hump being more conspicuous from the dorsal aspect. Basad of this is a small, shelflike projection (probably the cercus) bearing several conspicuous setae. Claspers extending considerably beyond apex of tenth tergite. From the main body of each clasper arise three, straight, fingerlike processes: a short one arising just within apex and extending not quite to apex; a meso-dorsal one arising about one-third distance from base and running in the same longitudinal plane as the clasper and from a lateral view having the dorsal margin just visible above the dorsal margin of the clasper; and a third arising on the mesal margin near base and diverging dorsally at close to a right angle to the body of the clasper. The body of the clasper itself has a convex ventral margin; the dorsal margin is excavated near apex to form an apical point; from ventral view the clasper appears arcuate, the two claspers converging toward apex. Oedagus tubular and bearing two dorsal plates which lie above it; these plates are very thin, wide at base, tapering gradually to a sharp point, and follow the outline of the oedagus.

**Holotype, male.**—Corvallis, Oregon: April 2, 1935, Oak Creek.

The male genitalia of this species are practically exact for *Nosopus podager* McL. but the legs and mouthparts are quite normal. Considering the close relationship of these two, expressed by similarity in male genitalia, it is obvious that the genus *Nosopus* is not really a distinct unit from many species which I am placing in *Lepidostoma*.

#### *Lepidostoma strophis* new species

This species is closest in most respects to *modesta*, differing in the short tenth tergite and other details of the genitalia, fig. 120.

**MALE.**—Length 8 mm. Color similar to *quercina*. General structure also similar to *quercina* with the following differences: maxillary palpi held close together for their entire length, forming a spatulate mask which when held up to face reaches to the apex of the first antennal segment.

Genitalia as in fig. 120. Ninth segment annular. Tenth tergite divided as far as its length by a wide V-shaped cleft, the apical process thus formed appearing triangular from dorsal aspect and arcuate dorsally from a lateral aspect; the extreme apex is slightly produced into a short stub which diverges slightly laterad and bears a cluster of small setae. The area basad of this stubby apex bears only a few scattered

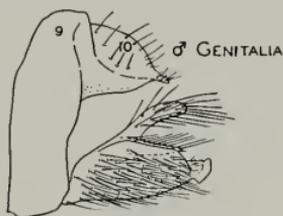


Fig. 120.—*Lepidostoma strophis*

setae. Claspers extend somewhat beyond apex of tenth tergite; they are broadest near middle and the apex is surmounted by a thin, spatulate plate which bears no conspicuous setae; near the base of the clasper there arise two dorsal processes, one is fusiform and thumblike and curves dorso-caudad, the other is pointed and runs along partly hidden for its entire length by the latero-dorsal edge of the clasper. Each clasper has its ventral margin so densely clothed with setae that they form a brush.

**Holotype, male.**—Beulah, Michigan: Sept. 16, 1936, Ross & Burks.

**Paratypes.**—BRITISH COLUMBIA.—Cultus Lake: June 5, 1927, H. H. Ross, 2♂.

MICHIGAN.—Same data as for holotype, 1♂.

#### *Amiocentrus* new subgenus

Characteristics: Venation as in *Brachycentrus*, with the apex of vein radius<sub>1</sub> bowed in the front wing. Maxillary palpi, fig. 121, very short, failing to reach the ventral margin of the antenna, the first and second segments sufficiently coalesced to obscure completely the dividing suture; the apical segment very short and pointed at the apex, the outer face of the entire palpus clothed with long, shaggy hair. Tibial spur count 2-2-2; structure otherwise typical of *Brachycentrus*.

**Genotype.**—*Brachycentrus aspilus* new species (by original designation).

***Brachycentrus aspilus* new species**

**MALE.**—Length 9 mm. Color mostly dark brown with the sutures and membranous areas whitish, the legs upon the femora light brown to straw color, the wing membrane light brown, the vena-

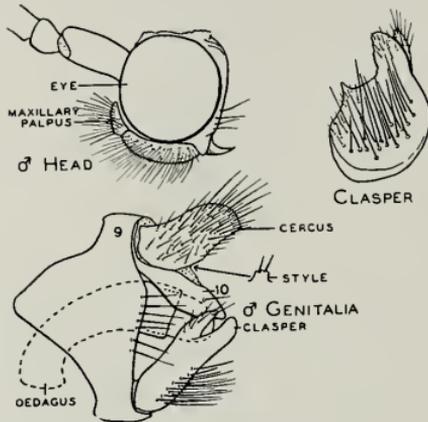


Fig. 121.—*Brachycentrus aspilus*

tion darker. General structure as described for subgenus.

Genitalia as in fig. 121. Ninth segment very narrow dorsally and ventrally, but with large lateral expansions which underlie the eighth segment. Tenth tergite membranous with the lateral margins and apex sclerotized, divided down the meson from apex to base of scleriosis; just basad of this point are a pair of small, flabby tubercles bearing two to three setae. Cerci short, with all corners rounded, the short mesal margin closely appressed, the dorsal surface clothed with a mixture of long and short setae. Claspers with a broad basal portion and a pair of lateral lobes; seen from ventral view the base appears ovate with a meso-apical, sharp point, the disc bearing a pad of long, dense setae, the ventral lobe sclerotized with only a few minute setae and the dorsal lobe membranous with a scattering of medium setae. Oedagus arcuate, tubular. The apical fifth rounded and semi-membranous.

**FEMALE.**—Size, color and general structure similar to those of male except for antigeny. Genitalia apparently identical with other members of the genus.

**Holotype, male.**—Pinedale, Wyoming: July 6, 1936, along Green River north of town, H. H. Ross.

**Allotype, female.**—Logan, Utah: July 31, 1937, at light, K. Nyc.

**Paratypes.**—MONTANA.—Ennis: July 8, 1936, along Madison River, H. H. Ross, 1♂.

UTAH.—Same data as for allotype, 1♂, 1♀.

This species resembles many forms of *Brachycentrus s. st.* in the approximate cerci, shape of the oedagus and the short maxillary palpi. On the basis of key characters, notably tibial spurs, the species would key out to *Micrasema* but this similarity is only superficial.

***Micrasema wataga* new species**

Closely related to both *rusticum* (Hagen) and *charonis* Banks, this species differs from both in the long pair of setiferous tubercles on the tenth tergite (these are very short and stubby in both previously described species) and in the arrangement of setae along the edge of the apical lobes of the tenth tergite (these setae form a small, round cluster in both previously described species).

**MALE.**—Length 6 mm. Color dark brown, the eyes black, the membranous areas white and the entire body covered with brown hair. General structure, including venation and spur count, typical for genus. Maxillary palpi three-segmented, long and hairy, and extended in front and considerably above dorsal

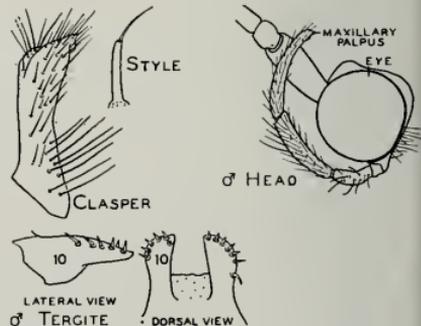


Fig. 122.—*Micrasema wataga*

margin of head, the second and third segments subequal in length. Tibial spurs short and not much longer than some of spurlike setae elsewhere on the tibiae. Venter of abdomen with abundant long setae but without mesal processes.

Genitalia as in fig. 122. Tenth tergite represented most conspicuously by two lateral, sclerotized plates connected at base by membranous folds; these plates appear pointed as seen from lateral view and bear a row of stout setae along the edge; from dorsal view they appear as in fig. 122, their mesal margins subparallel, their lateral margins rounded. At the base of these lateral processes and just caudad of the cerci are two long, narrow, submembranous filaments, bearing at their apex a single long setae. Cerci short and somewhat auriculate, held in a somewhat vertical position and covered with long, scattered setae. Claspers narrowed in middle, the apex creased to form two small, irregular lobes; the entire clasper covered with long, scattered setae, those near the base longest. Oedagus elongate, appearing egg-shaped seen from above and arcuate seen from the side; identical with that of *charonis*.

**FEMALE.**—Length 7.5 mm. Color and general structure same as for male except for antigeny. Abdomen with only sternites 2-7 rectangular, these covered with scattered setae clustered more abundantly near apex. Beyond this the abdomen presents the usual structure for the subfamily.

**Holotype, male.**—Elkmont, Tennessee: June 12, 1935, H. H. Ross.

**Allotype, female.**—Same data as for holotype.

**Paratypes.**—NEW YORK.—Enfield Glen: Aug. 13, 1928, A. R. Park, 1♂.

NORTH CAROLINA.—Smokemont: May 28, 1934, along Oconoluttee River, T. H. Frison, 2♂.

TENNESSEE.—Same data as for holotype, 5♂.

### *Helicopsyche limnella* new species

This species differs from previously described members of the genus from North America in the longer scape and the pointed corner of the male claspers.

**MALE.**—Length 5.5 mm. Body almost uniformly brown; wings and abdomen the same color; the flagellum

and apical segments of the legs straw color; the membranous portions white. The pubescence is almost entirely dark brown.

General characters as for genus, with the maxillary palpi three-segmented, the second and third subequal and long; spur formula 2-2-4 and venation as illustrated for the genus. Scape one and one-half times depth of head; robust; the inner margin concave and bearing a dense cluster of long, thin setae. Fore tibiae and tarsi covered

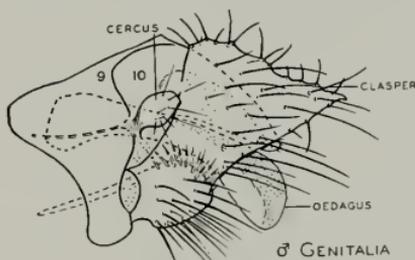


Fig. 123.—*Helicopsyche limnella*

with scales, mid and hind tibiae and tarsi with rows of small, black spinulae.

Genitalia as in fig. 123. Sixth sternite with a mesal, spatulate projection which is as long as the segment. Tenth tergite reduced to a narrow, submembranous flap extending between the claspers and above the oedagus. Cerci small, reduced to small knobs bearing scattered setae at apex. Each clasper, seen from the side, appears small at base and flared at apex, the caudoventral corner produced into a slender point curving mesad; from a ventral view each clasper appears to have a small basal lobe situated mesad and crowned with a tuft of short setae; from this base the clasper curves gracefully to the apex. Oedagus bulbous at base and apex, these two portions connected by a narrow tube.

**FEMALE.**—Length 6 mm. Color and general structure same as for male with the following exceptions: Maxillary palpi five-segmented and the scape of the antennae small. Genitalia indistinguishable from those of other members of the genus, displaying the usual brush of unkempt, black setae on the fourth, fifth and sixth sternites.

**Holotype, male.**—McFadden Springs, Arkansas: June 5, 1937, H. H. Ross.

**Allotype, female.**—Mountain Pine, Arkansas: June 5, 1937, H. H. Ross.

**Paratypes.**—ARKANSAS.—McFadden Springs: Same data as for holotype, 2♂. Mountain Pine: Same data as for allotype, 6♂, 2♀.

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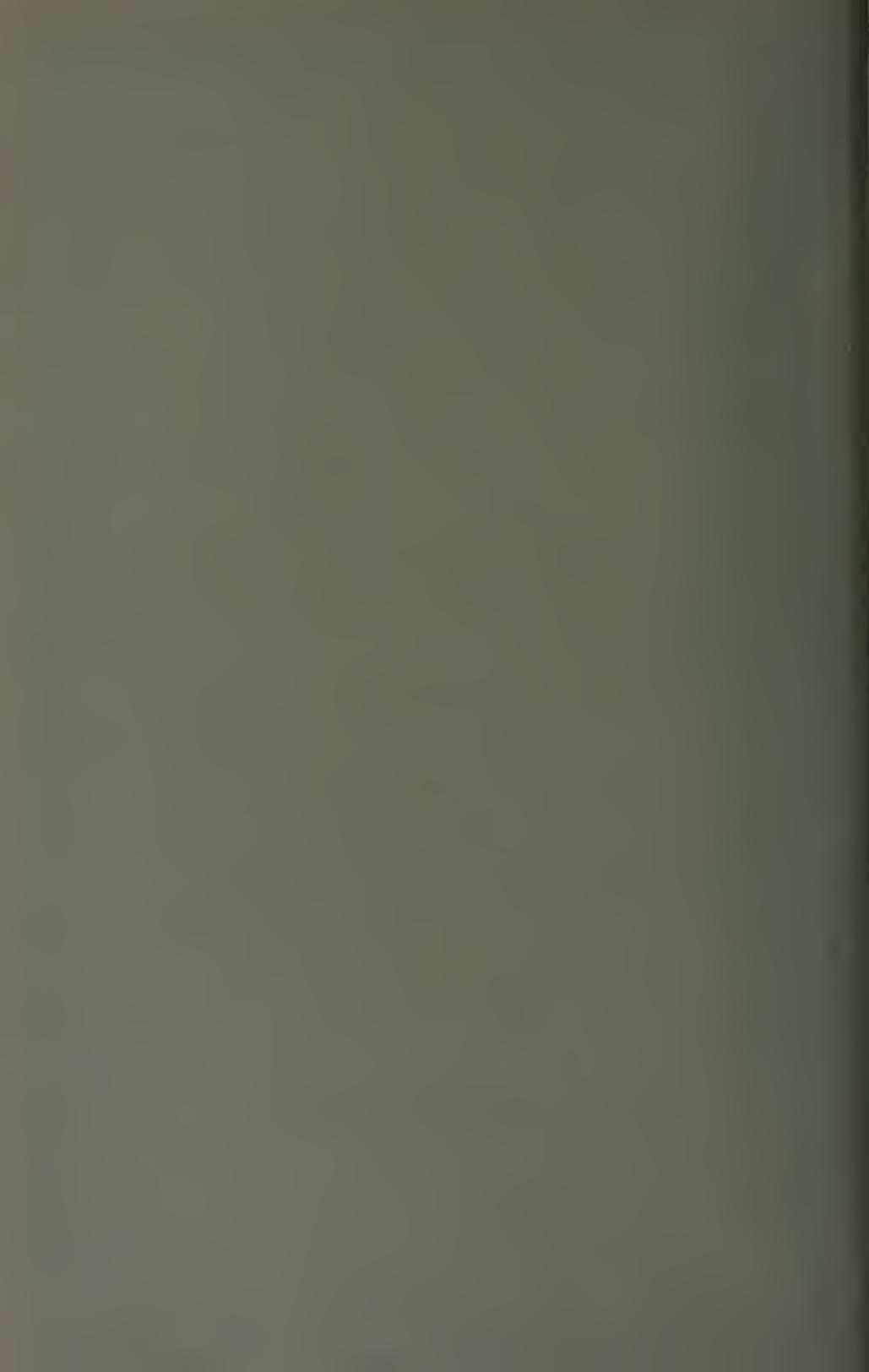
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*This paper is a contribution from the Section of Game Research and Management*

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Young of the ring-necked pheasant, a desirable upland game bird important in Illinois.



Adult male of the prairie chicken, an upland game bird once common in the state.



Adult of the muskrat, most numerous and valuable of the Illinois fur-bearers.

## Preliminary Studies

On Parasites of Upland Game Birds  
And Fur-Bearing Mammals in Illinois

W. HENRY LEIGH

THE following is a brief report on studies of the parasites of Illinois upland game birds and fur-bearing mammals. It was undertaken by the author during graduate study at the University of Illinois as a project of the Section of Game Research and Management of the Illinois Natural History Survey.

Because it was not possible to continue the study following completion of graduate work, it has seemed advisable to present what has been learned in a preliminary way about the parasite fauna of such important upland game birds as the prairie chicken, pheasant and quail, and of such fur-bearers as the raccoon, muskrat, opossum, red fox, skunk and mink.

While it obviously is not to be regarded as giving a satisfactory picture of host-parasite relations of the animals mentioned, the information embodied by this paper constitutes most of that available concerning these relationships in Illinois, and is to be viewed only as an explorative attempt to evaluate the possibilities for further productive and more intensive work to determine what part parasites play in the economy of nature as it concerns these animals in Illinois.

Sincere appreciation is extended to all those who assisted in this work, especially to Dr. R. E. Yeatter and Dr. D. H. Thompson of the Illinois Natural History Survey and Dr. H. J. Van Cleave of the University of Illinois, who cooperated with the author in many ways. Gratitude is felt for the fine cooperation of the Illinois State Department of Conservation and of the various farmers' and sportsmen's clubs throughout the state, too numerous to

mention individually, in the collection of animals for study.

This paper is divided into two parts, the first dealing with a brief discussion of some parasites of three upland game birds of the state, the second reporting what was learned about parasites of the miscellaneous fur-bearing mammals that were collected by or sent to the Illinois Natural History Survey during the time of the author's connection with this organization.

## UPLAND GAME BIRDS

At the time this report was written, no significant information was available concerning the parasites of the ring-necked pheasant, *Phasianus colchicus torquatus*, Gmelin; bobwhite quail, *Colinus virginianus virginianus* (Linnaeus); and greater prairie chicken, *Tympanuchus cupido americanus* (Reichenbach) in Illinois. Much had been learned and written about parasites of the pheasant and quail in other parts of the country, and game farms had contributed considerably to a knowledge of the parasites to which these birds are susceptible, but information concerning parasites of the prairie chicken was almost totally lacking throughout its entire range.

Because, at the time the present study was being made, the Section of Game Research and Management of the Illinois Natural History Survey was conducting a general ecological investigation of the protected prairie chicken in central Illinois, this bird received careful consideration, and the information concerning it is more nearly complete than that for the pheasant and quail in that in the prairie chicken

study the birds were fully autopsied, whereas in the pheasant and quail investigations only the viscera were examined.

During 1935 and in the early summer of 1936, dead young prairie chickens were found in unusually large numbers by Survey investigators on a study area in Jasper County, and others were reported in the vicinity by farmers. The present study was undertaken to determine the possible role of parasites as a cause of these deaths.

Because of the relative scarcity of the prairie chicken over the state as a whole and the desirability of making collections without significantly reducing breeding stock in the limited areas where birds were fairly abundant, and because of the low rate of survival of young in the drought summer of 1936, only a few birds were collected. Fourteen young and 14 adult prairie chickens were taken, most of them shot on the wing in Jasper and Richland counties during the summers of 1936 and 1937. Most of the birds were autopsied in field headquarters soon after collection. Examination comprised a search for external parasites or abnormalities, observations on the intact internal organs and, finally, separate examination of component parts of the viscera for helminth parasites or gross pathological change. When possible, blood smears were made and intestines and ceca examined for protozoan parasites.

Three species of cestodes, comprising two genera and one new species, two species of nematodes, one species of acanthocephalon, one species of louse and an undetermined species of mite constitute the list of parasites realized from this study of the prairie chicken.

The source of material for the quail and pheasant studies was the farmer and sportsman hunters of the state. To avoid sacrifice of the edible portions of the birds, the cooperating farmers and sportsmen were instructed to preserve only the viscera of quail and pheasants that were killed during the hunting season of 1936. One hundred forty-one quail were collected from 15 counties and 41 pheasants from 5 counties; the majority of the latter came from Livingston County.

The quail harbored four species of nematodes and two species of cestodes. The relatively few pheasants examined had only one species of helminth, a nematode. Since, in most instances, the respiratory tract was

not preserved, this study does not supply information concerning the presence or absence of parasites of that tract.

The following discussion treats individually the hosts and their parasites. At the close of the discussion a list is given showing the parasites found in each host species.

## The Greater Prairie Chicken

### *Tympanuchus cupido americanus*

#### Cestodes

Tapeworms were by far the most important and abundant of the parasites found in the prairie chicken. They were found in 10 of the 14 young birds but in none of the 14 adults. The genera *Railletina* and *Choanotaenia* were represented. Those cestodes belonging to the genus *Railletina* were found to comprise a new species, which will be described elsewhere. This new species appeared in 9 of the 14 young birds and, since it differs distinctly from described species of poultry cestodes of the same genus, may be indigenous to the prairie chicken in this area. In four cases, the infestations were so intense as completely to occlude the lumen of the small intestine for most of its length. Infestations varied from 3 to 52 specimens but, because of size variation, numbers mean little. Seven specimens in one host filled the intestine as completely as did 52 smaller specimens in another host. The genus *Choanotaenia* was represented by seven specimens in two hosts. Two species were present, but neither could be identified with published descriptions of members of the genus.

#### Nematodes

*Seurocyrnea colini* (Cram), inhabiting the proventricular wall at its junction with the gizzard and using the cockroach, *Blattella germanica* (Linnaeus), as an intermediate host (Cram 1931), was taken in seven young and seven adult prairie chickens. Infestations ranged from 1 to 35 worms per individual, averaging 12.4 worms per infested young and 5.1 worms per adult bird. There is no indication that *S. colini* is ever responsible for a severe pathological condition of its hosts. It was originally described from quail in the southeastern states and has been reported

from the turkey in Georgia and from sharp-tailed grouse in Wisconsin and Montana; Gross (1930) in Wisconsin gave the first report of its occurrence in the prairie chicken.

*Heterakis gallinae* (Gmelin), the common cecal worm of poultry, was found in 11 of the 28 young and adult prairie chickens. No intermediate host is required for this parasite, the infestation being acquired when the birds eat over infested ground. Infestation ranged from 1 to 30 individuals per infested host and averaged 11.5 worms for the adult, 2.4 worms for the young birds. The presence of *Heterakis* in moderate numbers is not of serious consequence, although large numbers may cause unthriftiness. Barger & Card (1935) state, "The irritation caused by these small worms in the ceca often leads to a general unthriftiness, and in young chicks death may result from heavy infestation."

*Heterakis gallinae* has been reported from a number of wild birds and is common in quail, pheasant and domestic poultry. Its presence in wild game birds is indicative of their contact with domestic poultry. Game birds that range over ground occupied by domestic fowl are in danger of falling prey to fatal diseases of poultry, especially blackhead, a serious protozoan disease of domestic turkeys that may be contracted through eating the eggs of *H. gallinae* containing viable blackhead organisms. Gross (1930) reports *H. gallinae* in 50 per cent of the prairie chickens examined in Wisconsin and in association with a case of blackhead.

### Acanthocephala

The thorny-headed worm has never before been reported from the prairie chicken. The two occurrences of *Mediorhynchus papillosus*, described by Van Cleave (1916), in this collection are undoubtedly accidental infestations. A single male worm was found in each of two young birds taken on the same area. Its presence in such limited numbers cannot be considered as important.

### Lice

*Menopon monostaechum* Kellogg, identified by R. O. Malcomson of the University of Illinois, was taken from only

four young prairie chickens, and the infestations were light in all cases, 36 being the heaviest infestation encountered. This is a new host record for this species of louse. Gross (1930) states that the louse parasitizing a large number of the prairie chickens of Wisconsin belongs to the genus *Chapinia*. In the numbers observed, lice are not significant. However, their presence is a potential threat to the health of the host, since under circumstances suitable to the parasites their numbers could quickly grow to serious proportions.

### Mites

Two light infestations on young prairie chickens constitute the only records of mites during this study. The mites were not identified.

### Protozoa

Blood smears were made of the majority of the prairie chickens collected. These were examined by Dr. R. R. Kudo of the University of Illinois and by the author, but they showed no indications of blood parasites of any kind. Smears of intestinal and cecal scrapings were negative for coccidia or other protozoa.

It is believed that one case of blackhead, caused by the protozoan *Histomonas meleagris* (Smith), was encountered. An adult male bird in an extremely emaciated and weakened condition was easily caught by a bird dog in use on the study area. It died before examination was possible. While it had the clinical symptoms of typical blackhead, the causative organism could not be definitely demonstrated, possibly because of the death of the host. As Gross (1930) had similarly found in Wisconsin, the infected bird was heavily parasitized with the cecal worm *Heterakis gallinae*. The Illinois bird was caught on an area where domestic turkeys known to have died of blackhead ranged widely.

### The Bobwhite Quail

*Colinus virginianus virginianus*

### Cestodes

Cestodes were taken from bobwhite quail in only two instances, once in Bond and once in Christian County. They were

identified as *Rhabdometra odiosa* (Leidy) and *Hymenolepis (Hymenolepis)* sp. The infestations were light.

### Nematodes

Three species of cecal nematodes appeared in the quail collections, *Heterakis bonasae* Cram, *H. gallinae* (Gmelin) and *Subulura strongylina* (Rudolphi).

*Heterakis bonasae*, a characteristic parasite of quail in the southeastern states, was found only in Alexander County, at the southern tip of the state, in 18 of the 20 hosts. Only a single specimen of *H. gallinae* was noted from this county. While the percentage of *H. gallinae* may be higher than is here indicated, there is no doubt that *H. bonasae* highly predominates in this area. It seems reasonable to believe that the extreme southern part of the state may be the normal northern limit for this characteristic southern parasite.

*Heterakis gallinae*, found in 12 of the 15 counties from which quail were collected, takes the place of *H. bonasae* in the central and northern parts of the state as a dominant parasite. Its range is indicated in fig. 1. It is a common parasite of domestic poultry and would be expected to be found in wild birds frequenting areas ranged by poultry.

*Subulura strongylina* occurred in quail in only four centrally located counties, Bond, Sangamon, Montgomery and Christian. *Heterakis gallinae* existed in three of the four counties and in multiple infestations with *S. strongylina*. The latter species is a common parasite of domestic and wild birds in South America and was reported by Stoddard (1932) from quail in North Carolina. The pathogenicity of this parasite is unknown, but it is probably similar to that of *H. gallinae*. Fifty-one, or 36 per cent, of the 141 quail examined were infested with cecal worms of one or more of the above-mentioned species; 110 was the heaviest infestation encountered and 15 the average number for infested hosts.

*Seurocyrnea colini* (Cram), the proventricular worm, a common parasite of quail in the southeastern states, occurred in 21, or 15 per cent of the 141 quail, 18 of the infestations occurring in 20 quail from Alexander County at the southern tip of the state. It also was taken from Living-

ston, Sangamon and Jasper counties, where collections were few in number. Twenty-two specimens represented the heaviest infestation recorded. Infested hosts averaged 8 worms. No pathological condition has been attributed to this parasite.

Madison and Crawford counties had no parasites recorded for the three quail representing these areas. Obviously the number of birds from these counties is too small to be significant.

### The Ring-Necked Pheasant

*Phasianus colchicus torquatus*

### Nematodes

*Heterakis gallinae* (Gmelin) was the only parasite encountered in the pheasant. Nineteen of 41 birds, 46 per cent, harbored this cecal worm in varying degrees of infestation. The heaviest single infestation was 60 worms; the average infestation for parasitized birds was 18 worms. Although this parasite occurred in pheasants taken from five counties, fig. 2, 36 of the 41 birds examined came from Livingston County.

### Conclusions

#### Prairie Chicken

It is not possible to draw any definite conclusions as to the role that parasites play in prairie chicken mortality in the area studied. The data obtained from 28 prairie chickens do not indicate that protozoan, arthropod and helminth parasites are responsible for any widespread loss of life in south-central Illinois. However, this study has been primarily limited to prairie chickens vigorous enough to be on the wing when shot and does not take into account birds which may have been too ill to flush. Neither does it determine the cause of death of the young prairie chickens whose remains were found by the Survey investigators or reported by others.

It seems reasonable to believe that some prairie chicken loss may occur from cestode infestation, inasmuch as considerable loss in domestic turkeys and other poultry is known to occur occasionally from this cause in south-central Illinois. Because cestodes of a previously undescribed species of *Raillietina* occurred in 10 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.

References in the literature to *Raillietina* in wild birds for the most part do not give any indication of pathogenicity. Gross (1930) reported finding heavy infestations of cestodes of the genus *Raillietina* in sharp-tailed grouse and in one prairie chicken but made no mention of the age or condition of the hosts. Simon (1937) described *Raillietina* (*Skrjabinia*) *centro-*

or only cause of death of 25 young quail raised by bantam foster parents. Passage of food stopped, the intestinal lining sloughed off and some birds exhibited locomotor



Fig. 1.—Range of helminths of quail in Illinois, as indicated by parasites found on 141 birds collected in hunting season of 1936.

*cerci* from the sage grouse in Wyoming but gave no indication of degree of infestation, age or condition of host.

Jones (Stoddard 1932) gave some evidence of the pathogenicity of this genus of cestodes by reporting that *Raillietina tetragona* was observed to be the principal



Fig. 2.—Range of helminths of ring-necked pheasants in Illinois, as indicated by parasites found on 41 birds collected in 1936.

difficulties. Jones also observed that *Raillietina cesticillus* caused less serious damage, but the vitality of the infested quail was greatly reduced.

The pathogenic effects of cestodes in poultry are well known, and it seems reasonable to believe that the effects on wild gallinaceous birds might be similar, at least in young birds heavily infested. Cestodes of the genus *Raillietina* are common in poultry. Buckley *et al.* (1933) state, "Loss of weight, loss of appetite, a general condition of droopiness or unthriftiness, intestinal catarrh and diarrhea are the conditions most frequently found associated with the presence of tapeworms. Young fowls are most seriously affected. Occa-

sionally lameness and paralysis have been associated with heavy infestations with certain tapeworms." Barger & Card (1935) state that "It has also been fairly well established that the worms (cestodes) produce substances during their growth which are harmful when absorbed by the fowl. In heavy infestations the bowel may be practically occluded, and the normal movement of intestinal contents greatly disturbed."

Although it cannot be definitely stated at this time that the high incidence and heavy infestations with cestodes of a genus known to be pathogenic for other gallinaceous birds constitute a serious mortality factor in young prairie chickens, it is reasonable to think that the minimum effect of such intense parasitism in birds 4 to 8 weeks old would be a reduction in vitality which would open the way to secondary infections and render the birds more susceptible to predation or unfavorable environmental factors. Finding no cestodes in adult hosts would seem to indicate that the prairie chicken is susceptible to the new species of *Raillietina* during only the first few weeks of life.

The nematodes in the indicated numbers cannot be regarded as dangerous, although *Heterakis gallinae* as a carrier of blackhead is a potential threat. External parasites, acanthocephala and parasitic protozoa do not seem, on the basis of autopsies performed on a small number of birds, to be important factors in prairie chicken mortality in the area studied.

## Quail

The results of this study indicate that the quail of Illinois are not so heavily infested with the diversity of helminth parasites as are the quail of the southeastern states. Stoddard (1932) for the latter area reports 16 species of nematodes and 5 species of cestodes from quail. Additional data are necessary before the effects of parasites on Illinois quail can be determined.

## Pheasant

The data available on the parasites of Illinois pheasants are not sufficient to enable the drawing of conclusions about them at this time.

## Limitations of the Study

Because these observations on the prairie chicken, pheasant and quail embrace only a part of the year and do not cover all parts of the state, they do not indicate conclusively that helminth parasites are not an important consideration in the welfare of their hosts. The study needs to be extended to other seasons of the year, with particular attention given to the young birds, because mortality from parasitic infestations is most severe during the early weeks of life. Ideally, the studies should be made on the entire, freshly killed birds. Preserved viscera are only partially satisfactory for this type of study.

## Host Parasite List

The numerals following the names of parasites below indicate the number of hosts in which the parasites were found. The letter preceding the name of each parasite may be identified from the following key: C, cestode; N, nematode; A, acanthocephalon; L, louse.

### Greater Prairie Chicken, *Tympanuchus cupido americanus* (Reichenbach) (28 examined)

C	<i>Raillietina</i> ( <i>Skrjabinia</i> ) sp. (undescribed).....	9
C	<i>Choanotaenia</i> spp. (undescribed)....	2
N	<i>Scurocyrnea colini</i> .....	14
N	<i>Heterakis gallinae</i> .....	11
A	<i>Mediorhynchus papillosus</i> .....	2
L	<i>Menopon monostachum</i> .....	4
	Mites (unidentified).....	2

### Bobwhite Quail, *Colinus virginianus virginianus* (Linnaeus) (141 examined)

C	<i>Rhabdometra odiosa</i> .....	1
C	<i>Hymenolepis</i> ( <i>Hymenolepis</i> ) sp.....	1
N	<i>Heterakis bonasae</i> .....	18
N	<i>Heterakis gallinae</i> .....	31
N	<i>Subulura strongylina</i> .....	11
N	<i>Scurocyrnea colini</i> .....	21

### Ring-Necked Pheasant, *Phasianus colchicus torquatus* Gmelin (41 examined)

N	<i>Heterakis gallinae</i> .....	19
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## FUR-BEARING MAMMALS

In order to acquire a general knowledge of the diversity and prevalence of the helminth parasites of fur-bearing mammals in

Illinois, as opportunity afforded, the writer obtained and examined viscera of these animals taken by hunters. Sixteen opossums, 12 red foxes, 6 raccoons, 5 mink, 8 muskrats and 1 skunk, a total of 48 furbearers, comprise this incidental collection made during the hunting seasons of 1935-36 and 1936-37. Because this problem cannot be continued by the writer, the following information is made available.

All the helminths were identified to genus and, when the condition of the material justified it, to species. Seven species of trematodes, representing as many genera, 3 genera and species of cestodes, and 8 genera and species of nematodes, comprising a total of 18 genera and species, were found in the 48 host individuals. In view of the small number of hosts and host species, these results are surprising, and they suggest the desirability of further development of this problem in Illinois.

Pathogenicity of the helminth parasites identified is not discussed, since the condition of much of the material received did not warrant such observations. A study of the literature offers little information on pathogenicity of the parasites found in the hosts studied. So this report, because of the preliminary nature of the observations, consists of miscellaneous remarks on incidence and degree of infestation, morphology, distribution and host records. Parasites are listed by host at the close of the discussion.

## Trematodes

### *Amphimerus pseudofelineus* (Ward)

Biliary ducts of liver and gall bladder of opossum, *Didelphis virginiana*. Tuscola, Ill.

Occurred in two opossums from the same area. Liver ducts packed with 300 to 400 of the flukes. This is the first record of this species from the opossum. Stiles & Baker (1935) list only the domestic cat, *Felis catus domestica*, and the coyote, *Canis latrans*, as hosts. Wallace & Penner (1939) have recently described a similar trematode, *Opisthorchis tonkai*, from the bile ducts and gall bladder of the muskrat.

### *Brachylaemus opisthotrias* (Lutz)

Intestine of opossum, *Didelphis virginiana*. Greenup, Olney, Tuscola and Urbana, Ill.

These forms measure 2 to 4 mm. in length and largely conform to Lutz's (1895) description of Brazilian trema-

todes from *Didelphis aurita*, but lack the spines. In this last respect, they agree with those described by Chandler (1932) in Texas. Because the spines are likely to slough off following the death of the host and its parasites, this characteristic has limited diagnostic value. These trematodes are much larger than the forms which Dickerson (1930) described as *Harmostomum opisthotrias* var. *virginianum*. Occurred in 5 of 16 hosts. Heaviest infestation was 115 worms. Average for infested hosts was 28 worms.

### *Catatropis filamentis* Barker

Small intestine of muskrat, *Ondatra zibethica*. Sellers, Ill.

Only one specimen. Conforms to Barker's (1915) description except that the three rows of papillae are not observable.

### *Echinostoma revolutum* (Froelich)

Intestine of muskrat, *Ondatra zibethica*. Sellers, Ill.

Intestine of opossum, *Didelphis virginiana*. St. Joseph, Ill.

Beaver (1937) has reduced the members of the genus *Echinostoma* by absolute synonymy of eight species and has expressed doubt concerning the validity of seven more species. *E. armigerum* and *E. coalitum* are direct synonyms of *E. revolutum*, and *E. callawayensis* is of doubtful validity (Barker 1915). All three species were described from the muskrat. So the echinostomes under consideration are assigned to *E. revolutum*. Beaver states that *E. revolutum* "would probably occur in almost any bird or mammal whose feeding habits are similar to the so-called 'natural hosts.'" Dikmans (1931) reports *Echinostoma* sp. in opossums in Louisiana. There were 8 worms in 1 of the 16 opossums and 1 worm in 1 of the 8 muskrats in the present investigation.

### *Echinoparyphium* sp.

Small intestine of red fox, *Fulpes fulva*. Bath, Ill.

Two specimens taken from 1 of 12 hosts were not in condition for accurate specific determination. No record has been found of a previous occurrence of this genus in foxes.

### *Diplostomum variabile* (Chandler)

Small intestine of opossum, *Didelphis virginiana*. Urbana and Tuscola, Ill.

First record of its occurrence since described by Chandler (1932) in Texas opossums. Great variation in size, shape and degree of division between fore and

hind bodies, reported by Chandler, observed in these forms, although none was observed to lack the glandular organs lateral to the pharynx. Because of the constancy of the glandular organs it is not likely that *Diplostomum variable* could be confused with a similar species, *Neodiplostomum lucidum*, which La Rue & Bosma (1927) described from *Didelphis virginiana*. *Diplostomum variable* was found in 2 of the 16 opossums. One hundred fifty-six worms constituted the heaviest infestation.

*Rhopalias macrocanthus* Chandler

Small intestine of opossum, *Didelphis virginiana*. Urbana, Ill.

Only one specimen. Conforms to Chandler's (1932) description of Texas forms.

### Cestodes

*Hymenolepis (Weinlandia)* sp.

Small intestine of opossum, *Didelphis virginiana*. Urbana, Ill.

Hooks were gone from rostellum; so specific determination could not be made. As far as can be ascertained this genus has been reported only once from marsupials, from *Peremeles macrura* in Australia (Imperial Bureau of Agricultural Parasitology 1933). There were 3 specimens in 1 of the 16 hosts.

*Ochroristica mephitis* Skinker

Small intestine of skunk, *Mephitis mephitis*. Urbana, Ill.

Described by Skinker (1935) from *Mephitis elongata* in Georgia. Specimens from *M. mephitis* in Illinois conform to Skinker's description. Sixteen specimens were found in the only skunk collected.

*Ochroristica* sp.

Small intestine of raccoon, *Procyon lotor*. Tuscola, Ill.

Small intestine of opossum, *Didelphis virginiana*. Champaign County, Ill.

Specific identification could not be made due to immaturity of the specimens. Three specimens were taken from 1 of the 16 opossums and 75 were taken from 1 of the 6 raccoons.

*Taenia pisiformis* (Bloch)

Intestine of red fox, *Vulpes fulva*. Bath, Arcola and Dwight, Ill.

This species has been reported from the European fox, *Vulpes vulpes*, but not from the American fox, *Vulpes fulva*. Reported from species of *Felis*, *Canis* and *Procyon*. Because of immaturity of the specimens, identification was made on scolex characters alone; so the determination is ques-

tionable. Six of 12 foxes were infested. The maximum infestation was seven helminths.

### Nematodes

*Ascaris* sp.

Small intestine of raccoon, *Procyon lotor*. Tuscola and Urbana, Ill.

These ascarids were taken from four of the six raccoons examined. Morphologically they do not differ significantly from *Ascaris lumbricoides*. The genus *Ascaris* has not previously been reported from the raccoon. *Ascaris* did not occur in other mammals collected. Maximum infestation was 71 helminths; for infested hosts, 27 helminths.

*Arthrocephalus* sp.

Small intestine of raccoon, *Procyon lotor*. Tuscola and Havana, Ill.

This genus of nematodes has not previously been reported for *Procyon lotor*, but Vaz (1935) has redescribed *Arthrocephalus maxillaris* (Molin) from *Procyon cancrivorus* in South America. Since the form under consideration shows capsule characters not figured by Vaz, it is not assigned to *A. maxillaris*. Other characters conform to Vaz's description. Two of the six hosts were infested. Each had approximately 100 specimens.

*Ancylostoma caninum* (Ercolani)

Small intestine of red fox, *Vulpes fulva*. Havana, Ill.

Only one specimen. A common and widely distributed hookworm of dogs and cats. Has often been reported from European foxes, but no previous specific record has been found of its occurrence in *Vulpes fulva* in North America.

*Cruzia tentaculata* (Rudolphi)

Intestine and cecum of opossum, *Didelphis virginiana*. Havana, Tuscola and Greenup, Ill.

Has been recorded for South American *Didelphis*, and for *D. virginiana* in Pennsylvania, Texas and Louisiana (Chandler 1932, Dikmans 1931). Four of 16 hosts were infested. The heaviest infestation was 120 specimens; 44 was the average per infested host.

*Trichuris* sp.

Large intestine of red fox, *Vulpes fulva*. Bath, Ill.

Possibly *Trichuris vulpis* (Froelich) but, because of the absence of males, specific identification was not made. It is the only valid species listed for foxes in Stiles

& Baker (1935). Two specimens were found in 1 of the 12 hosts.

*Toxocara canis* (Werner) = *Belascaris marginata* (Rudolphi)

Small intestine of red fox, *Vulpes fulva*. Bath, Havana, Arcola, Manville and Dwight, Ill.

Occurred in all 12 foxes examined. A common parasite of various species of *Felis*, *Canis* and *Vulpes*. This common ascarid of dogs is one of the most frequent parasites of foxes and may cause serious trouble in young puppies. Heaviest infestation was 30 specimens; the average was 12 specimens per host.

*Physaloptera turgida* (Rudolphi)

Stomach and intestine of opossum, *Didelphis virginiana*. Urbana, Tuscola, St. Joseph, Greenup, Danville and Olney, Ill.

Stomach and intestine of raccoon, *Procyon lotor*. Tuscola, Ill.

Stomach and intestine of skunk, *Mephitis mephitis*. Urbana, Ill.

This nematode seems to be a common and cosmopolitan parasite of the opossum. Members of this genus from the raccoon and skunk did not differ noticeably from those from the opossum; hence, they are assigned to the same species. This is the first record of *Physaloptera turgida* from *Procyon lotor* and *Mephitis mephitis*. Found in 15 of 16 opossums; 49 specimens were the maximum and 18 specimens the average infestation. Sixty-three specimens were in one of six raccoons. Five specimens were found in the only skunk collected.

*Viannia bursobscura* (Dikmans)

Small intestine of opossum, *Didelphis virginiana*. Urbana, Ill.

Sixty small, coiled worms, blood-red when alive, were found in only one opossum; first record of this species since its description by Dikmans (1931).

## Host Parasite List

The numerals following the names of parasites indicate the number of hosts in which the parasites were found. The letter preceding the name of each parasite may be identified from the following key: T, trematode; C, cestode; N, nematode.

### Opossum, *Didelphis virginiana* Kerr (16 examined)

T	<i>Echinostoma revolutum</i> .....	1
T	<i>Brachylarum opisthotrias</i> .....	5
T	<i>Amphimerus pseudofelineus</i> .....	2
T	<i>Diplostomum variabile</i> .....	2
T	<i>Rhopalium macrocanthus</i> .....	1
C	<i>Hymenolepis (Weinlandia) sp.</i> .....	1
C	<i>Oochoristica sp.</i> .....	1
N	<i>Cruzia tentaculata</i> .....	4
N	<i>Viannia bursobscura</i> .....	1
N	<i>Physaloptera turgida</i> .....	15

### Red Fox, *Vulpes fulva* Desmarest (12 examined)

T	<i>Echinoparyphium sp.</i> .....	1
C	<i>Taenia pisiformis</i> (?).....	6
N	<i>Ancylostoma caninum</i> .....	1
N	<i>Toxocara canis</i> .....	12
N	<i>Trichuris sp.</i> .....	1

### Raccoon, *Procyon lotor* (Linnaeus) (6 examined)

C	<i>Oochoristica sp.</i> .....	1
N	<i>Ascaris sp.</i> .....	4
N	<i>Anthrocephalus sp.</i> .....	2
N	<i>Physaloptera turgida</i> .....	1

### Skunk, *Mephitis mephitis* (Schreber) (1 examined)

C	<i>Oochoristica mephitis</i> .....	1
N	<i>Physaloptera turgida</i> .....	1

### Mink, *Mustela vison* Schreber (5 examined)

No helminth parasites found

### Muskrat, *Ondatra zibethica* (Linnaeus) (8 examined)

T	<i>Echinostoma revolutum</i> .....	1
T	<i>Catantropis filamentis</i> .....	1

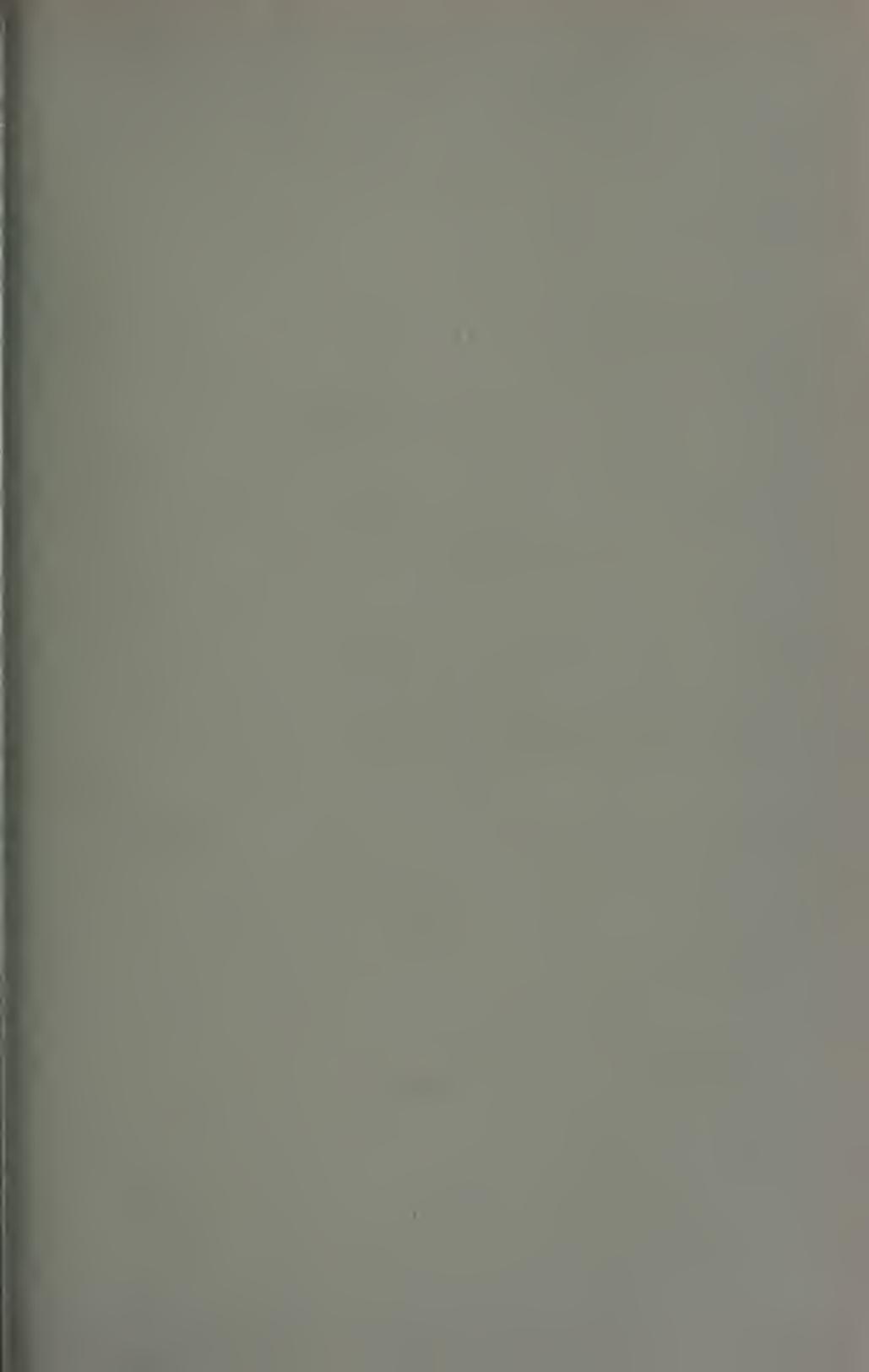
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Volume 21

BULLETIN

Articles 6-7

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**Preliminary Investigation of  
Oak Diseases in Illinois**

J. CEDRIC CARTER

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**A Needle Blight of Austrian Pine**

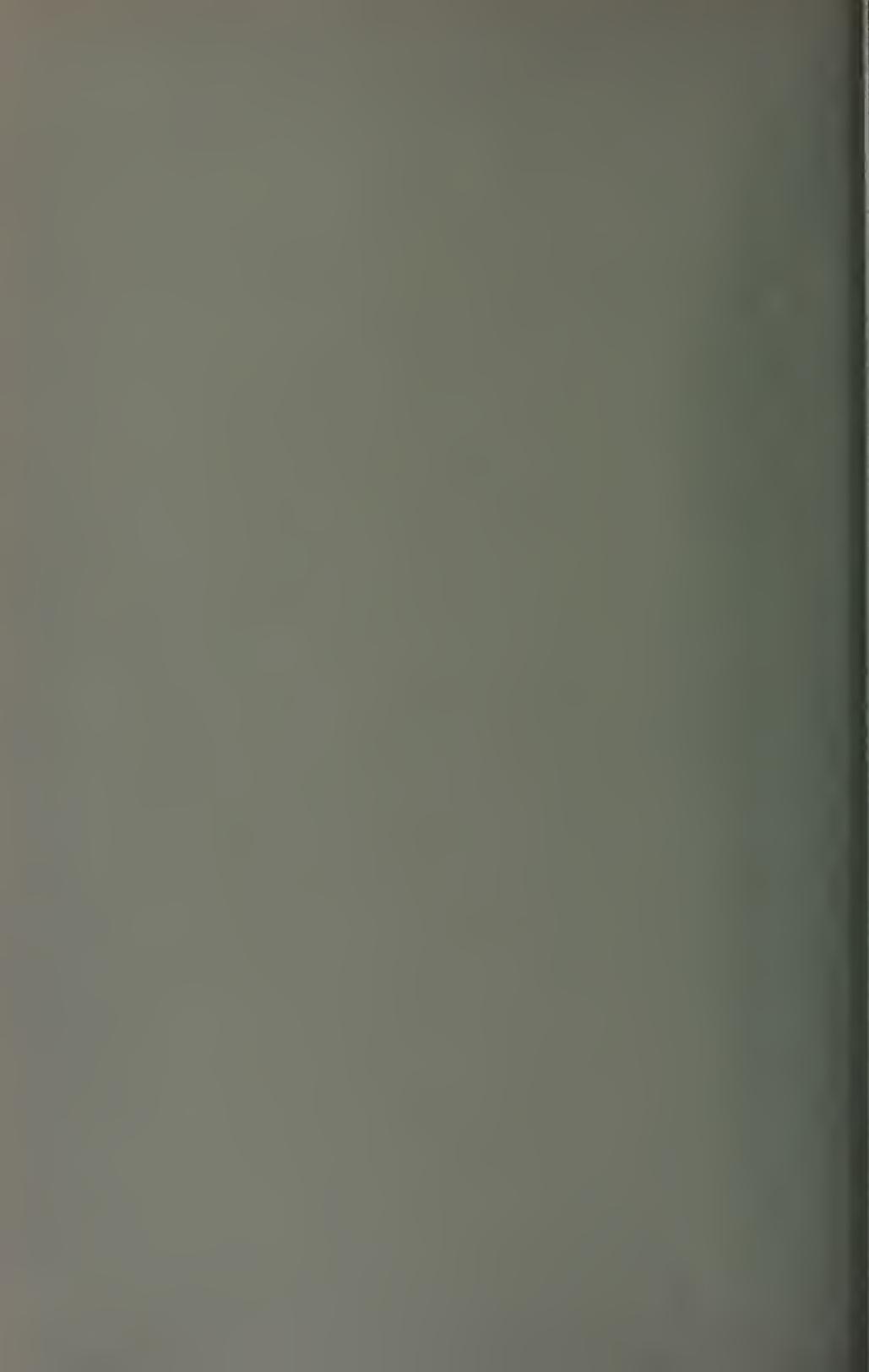
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Volume 21

BULLETIN

Article 6

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# Preliminary Investigation of Oak Diseases in Illinois

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J. CEDRIC CARTER



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The bur oak, *Quercus macrocarpa* Michx., is one of the several species of oak found in Illinois. Because native oaks are numerous throughout the state and have become increasingly popular, diseases of these trees are an important concern to Illinois citizens.

## Preliminary Investigation of Oak Diseases in Illinois

J. CEDRIC CARTER

IN our investigation of tree diseases in Illinois the cases of disease of oak that have been brought to our attention have increased each year since 1934. These cases have consisted mainly of canker and dieback diseases of small to large branches. Species of *Gnomonia*, *Marssonina*, *Phyllosticta* and *Septoria*, some of the fungi that cause leaf diseases, have been studied by other investigators, and control measures have been recommended. Many heart-rot and a few root-rot fungi, namely, species of *Armillaria*, *Fomes*, *Hydnum*, *Polyporus*, *Stereum* and *Ozonium*, have been studied by others in relation to their parasitism of oaks. Only a few twig-blight and twig- and branch-canker producing fungi, principally *Cytospora chrysosperma* (Pers.) Fr., *Diplodia longispora* Cke. & Ell., *Nectria cinnabarina* Fr., *N. galligena* Bres., *N. ditissima* Tul. and *Strumella corynoidea* Sacc. & Wint., have been investigated by other workers.

The diseases of oak studied by the author and the fungi associated with them are described in this paper.

### ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation for the helpful assistance given to him during the course of this work. Through the cooperation of the Forest Preserve District of Cook County and many commercial nurseries in northern Illinois, he collected and studied many specimens of diseased oak material. Robert Everly of the Glencoe Park District, Glencoe, and George R. Pedlow of the Rockford Park District, Rockford, cooperated with the author in the study of the relationship of *Armillaria mellea* (Vahl.) Quél. to the infection of oaks. Much credit is given to G. H. Boewe,

Field Botanist of the Natural History Survey; William Ellsworth Rose, Village Forester, Hinsdale; H. F. Seifert, Chief State Plant Inspector of Illinois, and his assistants, William R. Jack, Glenn L. Pierce and John K. Karlovic; and to many others for their help in collecting diseased oak material. The author is indebted to Dr. Lewis E. Wehmeyer, Associate Professor of Botany at the University of Michigan; Dr. E. F. Guba, Research Professor of Botany at Massachusetts State College; and Dr. H. A. Edson, Principal Pathologist in Charge, Mycology and Disease Survey, U. S. Department of Agriculture, and his associates—Dr. J. A. Stevenson and Dr. W. W. Diehl—for the identification of several of the fungi described in this paper. The photographic illustrations were produced through the willing cooperation of Ray R. Hamm, photographer for the University of Illinois. The examination of exsiccati was made possible by the Department of Botany, University of Illinois. The author is indebted to Dr. L. R. Tehon, Botanist and head of the Section of Applied Botany and Plant Pathology, Natural History Survey, under whose supervision the study was conducted, for suggestions and criticisms during the course of the work.

### REVIEW OF LITERATURE

Internal disturbances of the living parts of oak trees have received very little attention by investigators of tree diseases. The "alcoholic flux" or white slime flux of oak was described by Ludwig (1886) and later reported by Masee (1907) at Kew. Ludwig (1888) also reported brown slime flux of oak 2 years after he had described white slime flux. Slime flux of oak was further discussed by Tubeuf & Smith

(1897), Holtz (1901), Ward (1901), Ogilvie (1924) and Guba (1934). An abnormal discoloration of oak wood, called "brown oak," was described by Groom (1915). He associated *Melanogaster variegatus* Tul. var. *broomianus* Berk., a *Penicillium*-like fungus, with the production of the disease. Davidson (1935) observed that *Fistulina hepatica* (Huds.) Fr. was associated with the type of "brown oak" described by Groom. A recent investigation by Cartwright (1937) established the relationship of *F. hepatica* to the production of "brown oak." A vascular disease of trees, none of them oak, was first reported by Hartley & Crandall (1935). This disease, since called wetwood, was later found in oak by Crandall, Hartley & Davidson (1937), who isolated bacteria from the wood adjacent to the wetwood regions.

A bark disease of oak, called smooth patch, was described by Tehon & Jacks (1933). They found *Aleurodiscus Oakesii* (B. & C.) Cke. associated with smooth patch and believed it to be the cause of the disease. Craighead (1923) previously had attributed this type of injury to the larvae of *Encyclops*, and stated that these larvae have the peculiar habit of mining in the dry, corky outer bark of *Quercus alba* L. and other trees. Bark blotch of oak produced by *Dichaena quercina* Fr. was described by Massee (1910).

A trunk canker of *Quercus rubra* L. was described by Ludvig (1887) and attributed to *Bulgaria inquinans* (Pers.) Fr., considered by him a wound parasite. A basal canker of oak was reported on *Q. Cerris* L., *Q. palustris* Muench. and *Q. rubra* by Hennings (1894), who found *B. polymorpha* (Oeder) Wett. associated with the disease and pointed out that this fungus may attack and kill the bark of old trees. A trunk canker of oak attributed to *Polyporus hispidus* (Bull.) Fr. was described by Sleeth & Bidwell (1937).

Twig and branch cankers of oak have received some attention. Hartig (1894) attributed a Nectria canker in the cortical tissue of oak and other trees to *Nectria ditissima* Tul. Buckhout (1900) reported a disease originating in crotches of black oak (*Quercus tinctoria* Bart.) and pin oak; he attributed it to *N. ditissima*. Zeller & Owens (1922), Ashcroft (1934) and Clinton (1934) reported Nectria

canker on oak and considered the disease to be produced by *N. galligena* Bres. Welch (1934a) reported Nectria canker, as caused by *N. ditissima*, on oak in Connecticut, Massachusetts, New Hampshire and Vermont. Kienholz & Bidwell (1938) listed Nectria canker on black, chestnut, red, scarlet, scrub and white oaks in Connecticut and stated it was caused by *Nectria coccinea* (Pers.) Fr. and other *Nectria* species. Welch (1934b) and Spaulding, Grant & Ayers (1936) pointed out that no hardwoods are immune to attack by *Nectria*. Grant & Spaulding (1939) recently pointed out that the avenues of entrance for the canker-forming species of *Nectria* on oak and other hardwoods in New England are branch stubs, cracks at the axils of branches, and rubbing injuries, as well as other avenues of infection not determined.

Strumella canker on oak, with which *Strumella coryneoidea* Sacc. & Wint. is associated, was found by Anderson (1922) in Illinois in 1919. Strumella canker was also reported on oak by Bidwell & Bramble (1934), Bramble (1934), Clinton (1934), Davis (1935), McKenzie (1937), Kienholz & Bidwell (1938) and others (Anonymous 1934). Heald (1914) and Heald & Studhalter (1914) pointed out that there are two forms of *Strumella* infection. One form produces cankers and the second form causes a diffused type of infection. In this latter type of infection the fungus spreads rapidly in the tree without callus production, and the tree dies quickly. *Cytospora chrysosperma* (Pers.) Fr., the willow canker fungus, was reported by McKenzie (1937) to be the cause of a canker on oak. Two years earlier, *Cytospora* sp. (Humphrey & Wood 1935) was reported to be the cause of canker on oak in New Jersey. A canker on oak described by Hartig (1894) was attributed by him and by Henry (1902) to *Aglaospora taleola* Tul., considered *Diaporthe taleola* (Fr.) Sacc. by Massee (1910) and by Moreillon (1918). Moreillon pointed out that, in Switzerland, twigs up to one-half inch in diameter and 20 inches long were affected with *D. taleola*. A nut rot of red oak was attributed by Orton (1908) to "*Sphaeropsis quercina*" Cke. & Harkn.

Twig blight and canker of chestnut oak, *Quercus prinus* L., is becoming in-

creasingly important. The blight, found occasionally on *Q. alba* as well as on *Q. Prinus*, was reported in 1912 and described in 1914 by Ingram (1912, 1914), who demonstrated that *Diplodia longispora* Cke. & Ell. is the fungus responsible for the disease. Ingram (1914) stated that infection occurs through wounds in the bark and that the fungus, after penetrating the twig, does not extend into the leaves. Small trees are killed outright; large trees are weakened by loss of young branches and die later. This twig blight was reported on *Q. Prinus* and other species of oak by Haensler (1932), Clinton (1934), Davis (1935) and White (1936). In 1935 it was found on *Q. alba* in California, Maryland, Texas and Wisconsin (Edson & Wood 1936). Four years later, it was reported on *Quercus* in Iowa, Massachusetts, Virginia and West Virginia by Waterman (1939). A similar twig blight has been attributed to *Sphaeropsis malorum* Berk. by Rankin (1914) and others (Anonymous 1930, 1931).

*Botryodiplodia Ravenellii* Sacc. was found by Babcock (1915, 1916) to be the cause of twig blight on scarlet oak in the vicinity of Cincinnati, Ohio, and to attack the host through bark wounds. *Dothidea noxia* Ruhl. was reported on oak by Ruhland (1904). He stated that it attacked the living cortex of twigs and branches of oaks, and that it was especially noticeable in young trees. The conidial stage of this fungus he called *Fusicoccum noxium* Ruhl. *D. noxia* has since been reported on American oaks in Europe by Bavendamm (1936). A tumor disease of oaks and hickories in the United States, attributed to a species of *Phomopsis*, was described by Brown (1938). Other fungi, that are mentioned by Boyce (1938) and that appear to be related to canker diseases of oak, are *Stereum rugosum* Pers. and *Fomes ignarius* (L.) Gill in Germany and *F. robustus* Karst. in France.

Ten genera of fungi were reported by Carter (1938) associated with branch diseases of oak: *Bulgaria*, *Coryneum*, *Cytospora*, *Diatrype*, *Phoma*, *Phomachora*,\* *Rhodosticta*, *Sphaeropsis* and *Ustilina*.† From diseased specimens of oak Carter isolated the fungi *Alternaria*, *Armillaria*,

*Coryneum*, *Cytospora*, *Fusarium*, *Penicillium*, *Phoma*, *Phomachora*,\* *Phomopsis* and *Ustilina*.†

Other genera of fungi that are believed to cause twig and branch diseases of oak include *Pseudovalsa* and *Coryneum*. *Pseudovalsa longipes* (Tul.) Sacc. was reported on oak by Henry (1902). Wehmeyer (1926) reported *P. longipes* on twigs of *Q. coccinea* Muench. and studied the cultural life history of this fungus and its imperfect stage, *Coryneum Kunzei* Corda. *P. sigmoidea* (Cke. & Ell.) Sacc., which Wehmeyer believed to be synonymous with *P. longipes*, and an unidentified species of *Coryneum* were reported in Fort Worth, Texas, by Taubenhau & Ezekiel (1932), who suggested that the *Coryneum*, which was causing injury to live oak, might be a stage of *P. sigmoidea*; they found both forms fruiting on the same diseased tree. A stem blight of *Q. virginiana* Mill. in Texas was first reported in 1934 and attributed to *Trabutia erythrospora* (B. & C.) Cke. by Taubenhau (1934, 1935). Death of three pin oaks and one willow-leaf oak on the Kansas State College campus in 1933 and 1934 was associated with *Diatrype stigma* (Hoffm.) Fr. by Lefebvre & Johnston (1935). Atkinson (1897) had previously reported the same fungus on dead oak branches at Auburn, Alabama. *Godroniopsis Quercea* (Schw.) Diehl & Cash was reported by Overholts (1934) on living branches of *Q. coccinea*. *Fistulina hepatica* (Huds.) Fr. was found by Hartig (1894) to be the cause of a reddish-brown wood rot of oak and was suggested by Braid (1924) as a major factor in the production of staghead and hollow tree of oak. Weir (1925) reported that *Endothia gyrosa* (Schw.) Fr. was capable of causing a root disease of *Q. velutina* Lam.

Numerous studies have been made on the relationship of *Armillaria mellea* (Vahl.) Quél. to the decline and death of oaks and other trees. Thomas (1934) reported that the fungus is capable of invading the roots through the sound and healthy periderm by a combination of mechanical and chemical means. Campbell (1934) maintained that the black zone lines produced in the infected roots by this fungus are actually sheets or plates of black strands, which he called pseudo-sclerotia. Rhizomorphs of *A. mellea* are

\**Dothiorella*, as described in this paper.

†*Nummularia*, as described in this paper.

present and often widespread in soils covered by natural oak stands. Numerous control measures have been suggested and recommended, but none of these has proved to be completely satisfactory (Horne 1914, 1915, 1919, Newman 1926, Rankin 1927, Brooks 1928, Owens 1928, Hubert 1931, Kendall 1931, Felt & Rankin 1932, Heald 1937 and Boyce 1938).

The parasitic nature of most of the above fungi has not been proved. A large majority of these fungi, which have been reported on living oak trees, have been associated with cankers on twigs and branches. These twig and branch cankers, in the later stages of their development, frequently result in twig blight or branch dieback.

### METHODS OF STUDY

To study the parasitism of various fungi that might be associated with the diseases of living oaks it was necessary to examine many diseased specimens. Culture tests were made in order to isolate the organism that was present in the diseased tissue of each specimen. Wood pieces for culture tests were taken from diseased living tissue and from diseased dead tissue that had been only recently killed, and isolations were made of those fungi that were sporulating on the dead tissue.

The fungi present in the diseased specimens were isolated in the following manner. A diseased specimen, including the bark, was sterilized in 0.1 per cent mercuric chloride for 1 to 2 minutes, and then thoroughly rinsed in sterile water. After the bark was removed, several slices were cut from the diseased wood with a sterile scalpel. With sterile forceps some of the slices were planted directly on *Difco* corn meal agar in Petri dishes. The others were sterilized individually by being dipped in and out of a 0.1 per cent mercuric chloride solution. Then they were washed in two changes of sterile water and planted on the agar in the Petri dish with the unsterilized slices. A similar procedure was followed in making isolations from diseased bark.

Single-spore plantings were made of the fungi found fruiting in the cankerous tissue. These plantings were made by sterilizing the cankerous tissue, which contained the fungus, in 0.1 per cent mercuric chlo-

ride for 30 to 60 seconds. The fruiting structures were then removed with a sterile scalpel and placed in a large drop of sterile water on a flamed microscope slide. The fruiting structures were crushed, placed in suspension and agitated to liberate the spores. A sterilized bacteriological loop was used to transfer the spores in suspension to agar in Petri dishes. The spores were planted in streaks across the agar. Widely separated spores on the agar, that were visible with the low power of the microscope, could be located and their positions marked. After the spores had started to germinate they were easily removed, with a small amount of the surrounding agar. A sterilized, bacteriological, spatula-tipped wire was used to remove these germinating spores, and they were placed on sterile agar in Petri dishes for further development.

Some histological studies were made of the diseased tissues. Some of the fungi associated with canker and with dieback grew and progressed slowly in the host tissues. It is quite possible that other fungi of secondary importance were present in these diseased tissues. In such cases histological studies would be of very little value. Careful examinations were made of living xylem from which *Dothiorella* and *Coryneum* had been isolated. Cartwright's (1929) method of staining fungal mycelium in wood sections was followed in this investigation.

### INCIDENCE OF OAK DISEASES

Diseases of oaks and other trees have not received so much attention and consideration as have the diseases of field crops, vegetables, fruits and similar economic plants. However, in recent years the importance of tree diseases has been forcefully brought to our attention by the destruction of the American chestnut and by the widespread dying of the American elm. The destruction of trees by disease is an economic and aesthetic loss to the inhabitants of large areas of the United States. Because native oak forests and groves are numerous throughout Illinois, and because oaks for shade and ornamental purposes are receiving more attention than formerly from nurserymen and home owners, diseases of oaks are now an important concern to the people of the state.

In this investigation, diseased trees were found among native, shade, ornamental and nursery plantings of oak, including *Quercus alba* L. (white oak), *Q. bicolor* Willd. (swamp white oak), *Q. borealis maxima* Ashe (red oak), *Q. ellipsoidalis* E. J. Hill (Hill's oak), *Q. imbricaria* Michx. (shingle oak), *Q. macrocarpa* Michx. (bur oak), *Q. marilandica* Muench. (black jack oak), *Q. Muhlenbergii* Engelm. (chinquapin oak), *Q. palustris* Muench. (pin oak), *Q. stellata* Wang. (post oak) and *Q. velutina* Lam. (black oak). Future reference to these oak species will be made by common name. The diseases considered in this investigation are those of the twigs, branches and to some extent the trunks of living trees. The much-studied heart rots and leaf diseases, as well as the root diseases, have received very little attention in the present study. However, it has been necessary to give some consideration to shoestring root rot caused by *Armillaria mellea* (Vahl.) Quéf.

The diseases most frequently observed on the wood of living oak trees in Illinois are known as cankers, dieback and staghead. Although wilts of elm and maple are common, wilt of oak is very unusual. On oaks, the development of cankers as well as the progress of dieback and staghead is very slow. The slow progress of these diseases, which each year spread only a few inches in some cases to a few feet in others, is ideal for the growth and fructification of parasitic fungi. Furthermore, saprophytic fungi may attack and develop on and in the dead and dying tree parts.

It is not uncommon to find that the same fungus is associated constantly with the perennial development of a canker or dieback on an oak branch. The frequency and consistency with which numerous fungi have been associated with the diseases of oaks leave no doubt of their importance in the occurrence, prevalence and spread of the diseases.

The diseases under consideration in this bulletin occur as cankers, dieback and root rot. Cankers are found on twigs and branches of trees of various sizes and on trunks, principally, of small trees. Dieback is found on twigs and branches. Deep wood infections, associated with both canker and dieback diseases, are found mainly on medium to large branches. The

blighting of leaves and twigs, which usually results in twig cankers or dieback, is quite prevalent throughout the state. Often, differentiation between cankers and dieback is difficult because many cankers continue to grow and spread year after year, and frequently branches are entirely encircled by them. After a canker has encircled a branch, subsequent dying may develop as dieback, as in *Dothiorella* canker and dieback. In some cases, when the twig is affected with dieback, the whole twig is killed, and the causal agent continues to grow and to spread into the branch at the base of the twig. From this type of infection a branch canker may develop with the dead twig for the original region of infection, fig. 27. Differentiation between canker and dieback seems to depend more on the physical appearance of the diseased region than on the infectious agent.

In the study of diseased specimens obtained for examination, an attempt was made to associate specific symptoms with a specific fungous parasite. Accomplishment of this purpose was impracticable, because each of several fungi was associated with cankers, dieback and twig blight. The external and internal characters of several cankers may appear to be identical, but the causal organisms associated with these cankers may represent several species of fungi. This situation holds true for dieback and twig blight, as well as for cankers, and makes practically impossible an accurate field diagnosis of the cause of a given branch disease of oak.

Twelve genera of fungi were found fruiting on the cankerous tissues of 80 of the diseased oak specimens that were studied. These genera and the number of specimens infected by each genus are given in table 1.

Of the fungi observed fruiting on the 80 specimens, *Dothiorella* and *Coryneum* were prevalent, as shown in table 1. *Dothiorella* comprised 42.50 per cent and *Coryneum* 21.25 per cent of the specimens. Ten genera, namely, *Cytospora*, *Phoma*, *Diatrype*, *Nummularia*, *Fusicoccum*, *Bulgaria*, *Cylindrosporium*, *Phomopsis*, *Rhodostricta* and *Sphaeropsis*, comprised the remaining 36.25 per cent.

A list of the genera of fungi obtained in culture from 284 specimens of diseased oak and the frequency of the appearance

of each genus may be observed in table 2. Although *Dothiorella* was secured in the fruiting stage from only 6 specimens, a fungus which appeared similar to single-spore cultures of *Dothiorella* but which did

Table 1.—Genera of fungi found fruiting in the cankerous oak tissues of 80 specimens.

GENUS	NUMBER OF SPECIMENS INFECTED	PER CENT OF SPECIMENS INFECTED
<i>Dothiorella</i> .....	34	42.50
<i>Coryneum</i> .....	17	21.25
<i>Cytospora</i> .....	7	8.75
<i>Phoma</i> .....	6	7.50
<i>Diatrype</i> .....	4	5.00
<i>Nummularia</i> .....	4	5.00
<i>Fusicoccum</i> .....	2	2.50
<i>Bulgaria</i> .....	2	2.50
<i>Cylindrosporium</i> .....	1	1.25
<i>Phomopsis</i> .....	1	1.25
<i>Rhodosticta</i> .....	1	1.25
<i>Sphaeropsis</i> .....	1	1.25
Total.....	80	100.00

Table 2.—Genera of fungi obtained in culture from 284 specimens of diseased oak, arranged according to frequency of appearance.

GENUS	FREQUENCY OF APPEARANCE*	PER CENT OF TOTAL APPEARANCES†
<i>Dothiorella</i> type‡...	135	31.11
<i>Alternaria</i> .....	38	8.76
<i>Coryneum</i> .....	29	6.68
<i>Cephalosporium</i> ...	27	6.22
<i>Phoma</i> .....	25	5.76
<i>Coniothyrium</i> .....	17	3.92
<i>Cytospora</i> .....	16	3.69
<i>Phomopsis</i> .....	9	2.07
<i>Dothiorella</i> .....	6	1.38
<i>Penicillium</i> .....	6	1.38
<i>Armillaria</i> .....	4	0.92
<i>Fusicoccum</i> .....	4	0.92
<i>Pyrenochaeta</i> .....	3	0.69
<i>Nigrospora</i> .....	2	0.46
<i>Chaetomium</i> .....	1	0.23
<i>Cunninghamiella</i> ...	1	0.23
<i>Nummularia</i> .....	1	0.23
<i>Pestalotia</i> .....	1	0.23
Bacteria.....	28	6.45
Non-fruiting.....	65	14.98
Negative.....	16	3.69
Total.....	434	100.00

\*The number of specimens from which each genus was cultured out of the total 284 diseased specimens examined. In several instances more than one genus was cultured from a single diseased specimen.

†Per cent of total appearances is calculated on the total frequency of appearance, which is 434.

‡This fungus appears to be identical with *Dothiorella*, below in the table, but did not produce fruiting structures in culture.

not develop fruiting structures was obtained in culture from a total of 135 specimens. This fungus, which is believed to be *Dothiorella*, showed a frequency of appearance of 31.11 per cent and was obtained from 47.54 per cent of the 284 diseased specimens. It was not uncommon to obtain *Dothiorella* and other fungi from the same specimen of diseased wood. The isolation of more than one fungus from a single specimen is pointed out in the discussion of the respective fungi.

*Coryneum* was obtained in culture from 29 different specimens, *Phoma* from 25 specimens, *Coniothyrium* from 17 specimens and *Cytospora* from 16 specimens, table 2. The combined frequency of appearance of these four fungi, *Dothiorella* and *Dothiorella* type represents approximately 53 per cent of the total appearances. The remaining 47 per cent is composed of more than 13 other fungi.

Although *Alternaria* shows a frequency of 38 and *Cephalosporium* a frequency of 27, they are not considered important, as they were obtained from diseased living oak tissue in only a few cases—*Alternaria* in one case and *Cephalosporium* in five cases.

The repeated association of *Dothiorella*, *Coryneum*, *Phoma*, *Cytospora*, *Coniothyrium*, *Phomopsis*, *Fusicoccum*, *Nummularia* and *Diatrype* with diseases of oak indicates that these fungi are important in the occurrence and development of the diseases with which they are associated.

## CANKER AND DIEBACK DISEASES

### *Dothiorella* Canker and Dieback

A *Dothiorella* canker and the resultant dieback are shown on a pin oak specimen in fig. 1. The cankerous bark is dark brown to almost black, collapsed and shrunken. The formation of fissures in old cankers is due to the arresting of tissue development, the drying out, and the splitting that occurs between the dead tissue of the canker and the adjacent living tissue. It is clear from fig. 2 that the stromata of *Dothiorella* develop abundantly in the cankerous bark and that they are erumpent at maturity. Fig. 3 shows the dark brown to black discoloration of the xylem, which occurs beneath the cankerous bark. This discoloration progresses down the branch in the

living tissue from 1 to 10 inches beyond the lower extremity of the cankerous region. The streaks of discoloration in the xylem vary in size. Some streaks are so small as to be just visible, while others are approximately 2 mm. in diameter. In some cases the streaks coalesce and form solid regional discolorations.

*Dothiorella* was associated with branch cankers and dieback of 40 diseased specimens collected throughout Illinois from black, pin, red and white oaks. Indications are that the growth of the fungus is perennial; the cankers continue to progress in their development for several years. Branches that show dieback continue to die year after year until the whole branch is killed. In many instances infection occurs first on twigs and small branches. These infections spread and involve the larger branches when the originally infected part has been killed.

The pycnidia of *Dothiorella* vary in their development from single pycnidia to aggregated pycnidia in a pulvinate stroma. In fig. 4, pycnidial chambers are shown in the vertical section of a stroma. The fruiting structures are laid down in the phellogen-phelloderm tissues of the branch, and their development causes a separation of these tissues accompanied by very little cellular disintegration. Further development to maturity ruptures the overlying phellem and epidermis. These tissues are forced back to form oval to round openings with shielded sides. The erumpent stromata are visible through these openings, as shown in fig. 2.

Mature stromata of *Dothiorella* in the cankerous bark are dark brown to black, sessile, dothideoid, erumpent, 600-1300  $\mu$  in diameter and 400-500  $\mu$  high. The pycnidial walls for the most part fuse to form the stromatic tissue. The pycnidial cavities are globose to ovoid, 145-300  $\mu$  in diameter, and open by individual, circular ostioles 15-30  $\mu$  in diameter. Conidiophores are hyaline, simple, 6-15  $\times$  2.8-3.4  $\mu$ , and papillate. The conidia, shown in fig. 5, are continuous, hyaline, 15-26  $\times$  9-15  $\mu$ , and ovoid. The content of each spore is granular.

A culture of *Dothiorella*, grown from a single-spore isolation on corn meal agar, is shown in fig. 6. The fungus produces an exceedingly sparse mycelial growth with gray aerial hyphae, gray to very light tan

surface hyphae and gray-black to tan sub-surface hyphae. A single germ tube from



Fig. 1.—*Dothiorella* canker and dieback on pin oak. The smooth, sunken, brown to almost black, diseased region, shown at the left of the branch, contains numerous black, erumpent stromata of *Dothiorella*. X  $\frac{3}{4}$ .

each spore pushes out as an evagination of the spore cell wall, and the cell contents pass from the spore into the germ tube.

Spore germination as high as 66 per cent occurs in approximately 10 hours. This high germination percentage is obtained

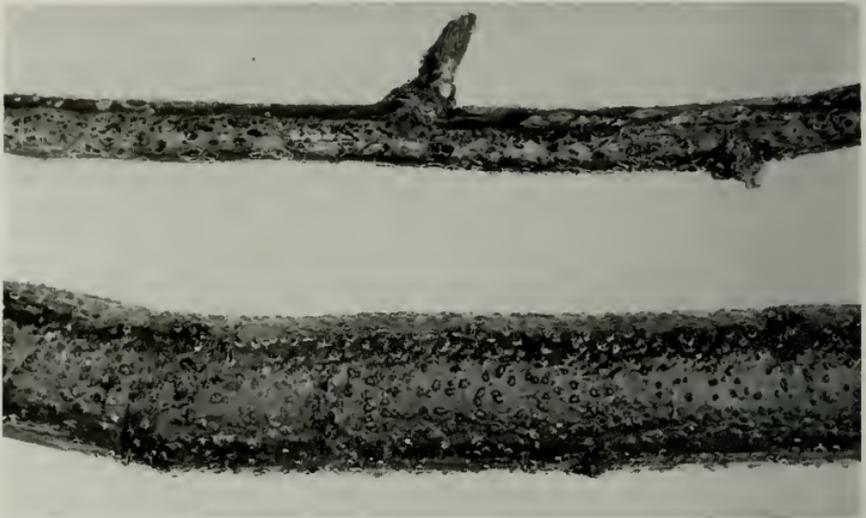


Fig. 2.—*Dothiorella* dieback on red oak. The brown to black, cankerous bark of each branch contains numerous black, erumpent stromata of *Dothiorella*. X 2.

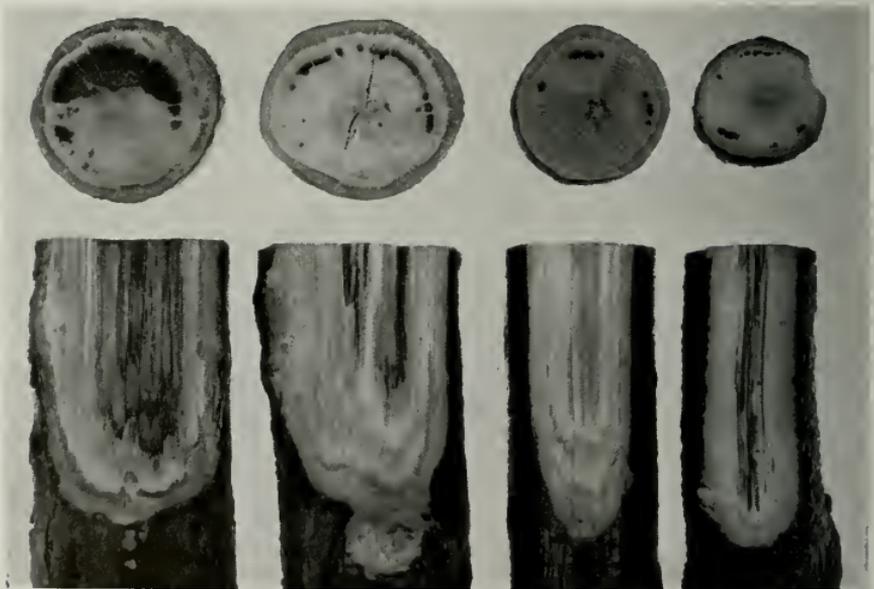


Fig. 3.—Wood discoloration of white oak associated with *Dothiorella* infection. Discoloration of the xylem tissue is characterized by fine to broad streaks that frequently coalesce and appear as solid regional discolorations. X  $1\frac{2}{3}$ .

when the spores are suspended in sterile, distilled water on a microscope slide and when the slide is maintained in a moist atmosphere. Single-spore colonies on corn meal agar produce an average diameter growth of 46 mm. in 8 days, or an average

*Dothiorella* was isolated from five diseased oak specimens affected with twig blight. Two of the five isolations were obtained from black oak: one from discolored living wood of a twig and one from a blighted petiole. Three were obtained



Fig. 4.—A stroma of *Dothiorella*. The black stromatic tissue and pycnidial cavities that contain spores are shown in vertical section. X 50.

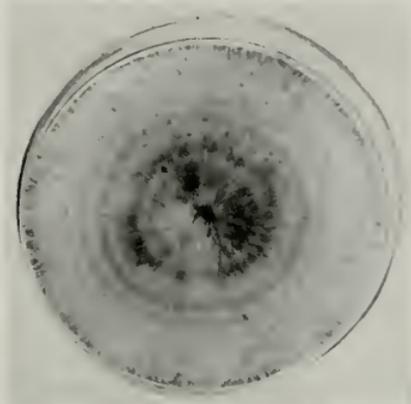


Fig. 6.—Culture of *Dothiorella*. On corn meal agar, this fungus produced gray to tan mycelium without stromata.



Fig. 5.—Spores of *Dothiorella*. The spores are continuous, hyaline and ovoid. X 300.

daily diameter growth of 5.8 mm. Germ tubes reach a length of approximately 188  $\mu$  before any branching occurs.

Cultures of *Dothiorella* grown from single-spore isolations failed to produce fructifications on artificial media or on sterilized wood of white oak. However, fructifications of *Dothiorella* developed on the naturally infected wood pieces that were placed on corn meal agar.

from pin oak: two from blighted petioles of two separate specimens and one from a twig. In the above cultures the fructifications varied from a pycnidium with one chamber to compound pycnidia in a stroma. The fructifications are black, ovoid, ostiolate, pseudoparenchymatous, and 260–530  $\mu$  in diameter. They contain conidia that are 18–25  $\times$  12–17  $\mu$ , hyaline, ovoid and continuous. The conidiophores are hyaline, 12–16  $\times$  2.8–3.4  $\mu$ , papillate and unbranched.

Microscopic examination did not reveal the presence of fungous hyphae in the discolored regions of the xylem, fig. 3. Many of the trachea and parenchyma cells appeared to be partially filled with a granular material, and many of the cell walls were dark and evidently were not stained.

The *Dothiorella* described in this paper was previously called *Phomachora* by Carter (1938). Our material agrees with *Dothiorella quercina* (Cke. & Ell.) Sacc. as represented in Shear's New York Fungi No. 373.

Other fungous cultures from 135 specimens of diseased oak appeared to be identical with *Dothiorella* in every respect ex-

cept that they did not fructify on artificial media, on sterilized oak twigs or on sterilized clover stems. They were isolated from 10 species of oak, namely, black, black jack, bur, chinquapin, pin, post, red, shingle, swamp white and white. They were grown from bark and wood of cankers, some with and some without *Dothiorella* stromata in the bark, from dieback specimens, from blighted petioles and twigs, and from deep wood infections. The deep wood infections were conspicuous because they showed dark brown to black discolored regions, illustrated in fig. 3. Over 50 per cent of the fungi cultured from the deep wood infections were similar in appearance to *Dothiorella*. However, it cannot be conclusively stated that these cultures were *Dothiorella*, since fructifications did not occur.

**INOCULATION TRIALS.**—On March 8, 1937, three white oaks, grown in flower pots in the laboratory, were inoculated with living cultures of *Dothiorella*. The method of inoculation was, in general, that described by Carter (1936) in the inoculation of American elms with *Cytosporina ludibunda* Sacc.

By March 20, 1937, leader tips of two of the three inoculated trees had started to die. By April 23 each of the two dying trees had 3 inches of its leader tip dead. The third tree showed dying back of the leader tip by May 1. All three trees were dead by July 1, 1937; however, at that time no stromata of *Dothiorella* had developed in the dead bark.

Stromata were first observed in the dead bark of one of the above three trees on March 24, 1938, when attempts were made to reisolate *Dothiorella* from each of the three trees. These stromata were brown to black, globose to ovoid, pseudoparenchymatous, dothideoid, 600–800  $\mu$  in diameter and 450–530  $\mu$  high. They contained from one to several pycnidia, and the pycnidial walls, for the most part, formed the stromatic tissue. The pycnidia were immature, and conidia developed in only a few pycnidia. These conidia were hyaline, 18–23  $\times$  12–16  $\mu$ , ovoid, continuous, and had granular contents.

*Dothiorella* was reisolated in pure culture from each of the three inoculated oaks. The reisolated *Dothiorella* did not produce stromata on artificial media. However, it did produce stromata on ster-

ile white oak wood and on sterile clover stems. The oak wood and clover stems were partially submerged in corn meal agar in test tubes. Approximately 6 months were required for the stromata to develop. These stromata were ovoid, black, ostiolate, pseudoparenchymatous, and 775–825  $\times$  625–675  $\mu$ . The pycnidial cavities were 350–670  $\mu$  in diameter, and the conidia were ovoid, hyaline, 18–22  $\times$  12–16  $\mu$ , continuous, and had granular contents. The reisolated *Dothiorella* was identical in appearance with the original isolate.

A second series of inoculations, previously reported by Carter (1940), was made, June 20, 1940, on nine oaks (three each of black, red and white oaks) located in the experimental nursery of the Natural History Survey. *Dothiorella* infection of these trees occurred, and within 3 weeks after the trees were inoculated bark was dying around the inoculated regions. Canker and dieback developed with external and internal symptoms identical to those described above as the characteristic symptoms of *Dothiorella* canker and dieback. Stromata of *Dothiorella* appeared in the infected bark within 7 weeks after inoculation but had not become erumpent by the end of 9 weeks.

*Dothiorella* was reisolated in pure culture from representative trees of each of the three species of oak on August 17, 1940. The reisolated *Dothiorella* was identical with the original isolate.

Adequate check trees were maintained for both the 1937 and the 1940 series of *Dothiorella* inoculations. In no instance was *Dothiorella* cultured from the check trees.

### Coryneum Canker and Dieback

Coryneum cankers develop on twigs and small to large branches of oaks of various sizes, and occasionally on trunks of small oak trees. They are found most frequently on small branches. The diseased tissues of Coryneum canker and dieback are reddish brown; the cankerous region is somewhat sunken and is dotted with erumpent acervuli of the fungus, as may be seen in fig. 7. The borders of the canker are sharply defined by the contrast in color of the healthy and diseased tissue and by the shrinking of the cankerous bark. Inter-



Fig. 7.—*Coryneum* canker and dieback on red oak. The section of a diseased branch pictured here shows black, erumpent acervuli in the reddish-brown, shrunken bark.  $\times 3$ s.



Fig. 8.—Portion of an acervulus of *Coryneum*. Several attached spores and the broken host tissue are shown on the upper portion of the acervulus.  $\times 100$ .

nally the cankerous tissue is light brown, and the discoloration in the xylem does not progress over 2 cm. beyond the external cankered region. From observation it seems quite evident that *Coryneum* grows year after year and that the cankers progress down the branch. Not infrequently a canker encircles a branch and develops into dieback, which may progress to the base of the branch. In a few cases *Coryneum* was associated with twig blight. *Coryneum* canker and dieback was found on pin, red and white oaks. The fungus *Coryneum* was grown from cankerous bark, discolored wood, blighted twigs and living wood adjacent to developing cankers on post, shingle, red, swamp white and white oaks.

The acervulus of *Coryneum* is laid down fundamentally in the phellogen-phellogen region of the bark. Development of a compactly interwoven hyphal mass, the base of the acervulus, causes a separation of the associated tissues that is accompanied by very little cellular disintegration. Further development of the acervulus, especially about the time conidia are pro-



Fig. 9.—Spores of *Coryneum*. Each tip cell and base cell of the tan to olive-brown, curved spores are hyaline.  $\times 230$ .

duced, ruptures the overlying phellem, epidermis and cuticle, forcing these tissues back; the result is a more or less triangular opening through which the black acervulus is visible. A portion of an acervulus in vertical section, with attached conidia, is shown in fig. 8. The erumpent acervuli are dark brown to black, discoid or pulvinate, compact, 1000–1500  $\mu$  in diameter and 260–400  $\mu$  high. Conidia are shown in fig. 9. They are 3- to 6-septate, not constricted at septa; they are curved, clavate or narrow-fusiform, tan to olive brown, 40–80  $\times$  9–18  $\mu$ , with each tip and base cell hyaline. The conidiophores are 15–30  $\times$  3–4  $\mu$ , straight to slightly curved, hyaline to brown and few-septate.

Single spores of *Coryneum* planted on

corn meal agar give rise to slowly spreading, dense mycelial growth. A culture of *Coryneum* is illustrated in fig. 10. The surface and aerial growth is bluish gray with a margin, approximately 1 mm. wide, of white hyphae. The subsurface growth as greenish gray. Sporodochialike, grayish-brown acervuli arise promiscuously over the surface of the older portions of the

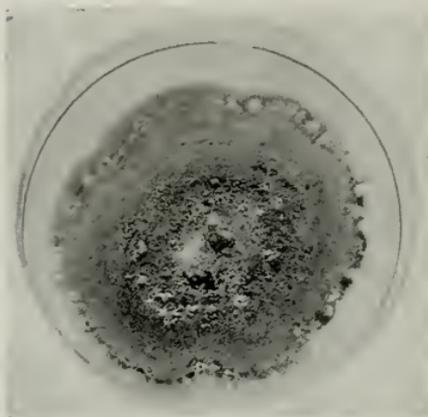


Fig. 10.—Culture of *Coryneum*. The fungus grows slowly and produces gray to tan mycelium on corn meal agar. Acervuli and spores develop on old cultures when the agar becomes dry.

culture. Typical tan to olivaceous-brown conidia arise from the acervuli and are interspersed with aerial hyphae. Growth of colonies from single-spore plantings increased radially about 1.6 mm. each day for a period of 28 days. In culture the acervuli are 1200–1600  $\mu$  longitudinally and 650–675  $\mu$  vertically, and the conidia are 40–90  $\times$  12–19  $\mu$ . In shape and color, acervuli and conidia that developed in culture are similar to those that developed on the branch. *Coryneum* has not only been grown in culture from single-spore transplants but it also has been isolated from cankerous bark and from discolored living sapwood beyond the diseased tissue of cankers.

The identification of this fungus as *Coryneum Kunzei* Corda (Wehmeyer 1926) was verified by Dr. Lewis E. Wehmeyer.

Microscopic examination of branches of red oak infected with *Coryneum* showed no evidence of the fungus in the xylem tissue.

INOCULATION TRIALS.—Three white oaks were inoculated with *Coryneum* on March 8, 1937. The procedure followed is that described on page 204 for the *Dothiorella* inoculation trials.

Two of the three trees showed dying of the leader tips by March 20. A gradual dying back of these two trees progressed rapidly from tip to base, and by April 1 they were dead. Culture tests were not made from these trees until March 24, 1938. *Coryneum* acervuli did not develop in the bark of the dead trees during the period from April 1, 1937, to March 24, 1938, and no fungus was obtained in culture tests from these two trees. The third tree inoculated with *Coryneum* showed no signs of infection by February 1, 1939. Adequate check trees were maintained for this series of *Coryneum* inoculations. In no instances was *Coryneum* cultured from the check trees.

#### Cytospora Canker and Dieback

Cytospora canker and dieback was found on red oaks in the northeastern section of Illinois. Isolations of *Cytospora* were obtained from cankerous bark, diseased wood, blighted petioles and twigs, and discolored living wood adjacent to developing cankers on black, pin, red and white oaks. Cytospora canker and dieback on a black oak branch is shown in fig. 11. The cankerous tissue is sunken and varies from light to dark brown; few to many scattered erumpent stromata appear in the bark. The stromata appear as small, circular, black spots. Stromatic regions appear oval to elongate when two or more stromata fuse. Shrinkage of the cankerous tissue causes the irregular margin of the canker to appear raised. Internally the diseased xylem is light brown above and below the base of the canker; the woody tissue beneath the cankerous bark is discolored and varies from dark brown to almost black. The fungus develops year after year, and the cankers continue to spread down the infected branches. A gradual drying out and dieback of the branches result when they are completely girdled by the cankers.

The stromata are laid down in the cortex just beneath the phelloderm. As the interwoven hyphal mass continues to develop, the outer cortical cells disintegrate, the stromata develop laterally, and the



Fig. 11.—*Cytospora* canker and dieback on black oak. Only a few scattered, erumpent stromata are present in the light to dark brown, sunken, diseased region. The border of this region is made conspicuous by the contrast in color of the living and diseased bark and by the shrunken appearance of the diseased bark. X 1.

periderm and epidermis are ruptured by the time the conidia are mature. An erumpent stroma is shown in vertical section in fig. 12. Stromata are black, val-soid, tubercular, pulvinate, compact, 550–2000  $\mu$  in diameter and 400–600  $\mu$  high,

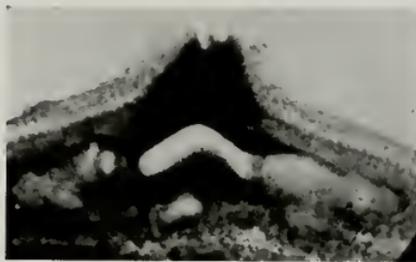


Fig. 12.—Portion of a stroma of *Cytospora*. The erumpent appearance of the stroma is shown in vertical section. The black stromatic tissue with its locules and spores is embedded in the cankerous host tissue. X 55.

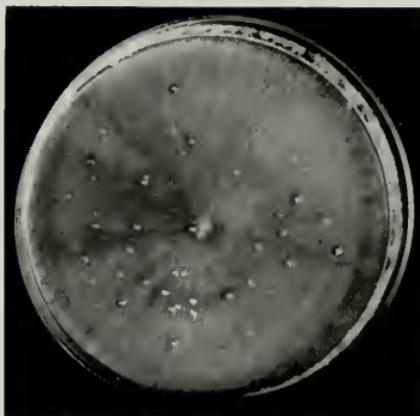


Fig. 13.—Culture of *Cytospora* on corn meal agar. The black stromata are embedded in white to greenish-white tufts of hyphae.

and they are exposed through the ruptured host tissues. The locules are irregularly arranged. The conidia are continuous, hyaline, allantoid, elongate,  $4.5-9 \times 1-4 \mu$ , and they exude from the stromata in cirrhi. Conidiophores are typically simple but occasionally are branched.

A culture of *Cytospora*, grown on corn meal agar, is shown in fig. 13. The fungus, in its early development, appears white

with a very sparse growth of interwoven mycelium. Later a more dense growth of white surface and aerial mycelium develops. Tufts of hyphae appear more or less concentrically or promiscuously interspersed with the mycelium. They are white to greenish white above and green below. In some instances the hyphae adjacent to the developing tufts are light brown. The stromata are black, firm, multilocular, tubercular, 525–1600  $\mu$  in diameter, 600–1500  $\mu$  high and embedded in tufts of hyphae. The conidia produced in culture are  $3-9 \times 1-3.5 \mu$ . Except for greater variability in size, they are identical with the conidia produced in the host tissue. The conidiophores are simple to branched,  $10-15 \times 2-3.5 \mu$ , and hyaline.

This fungus is considered to be *Cytospora intermedia* Sacc. (*Valsa intermedia* Nits.). The pycnidial stage is identical morphologically with that of Jaap's Fungi Selecti No. 621 *Valsa intermedia* Nits. (*Cytospora intermedia* Sacc.).

#### Nummularia Canker and Dieback

Small to large Nummularia cankers were found on branches of red oaks. The cankers extend a few inches to several feet along the branches; dieback results when the branches are completely girdled by the cankers. The cankers appear as sunken diseased regions with small to large stromata located at irregular intervals. The smooth, reddish-brown, cankerous bark and two stromata in a portion of a canker are shown in fig. 14. On old branches the bark turns black and becomes fissured. The fissures are produced by lengthwise and crosswise splitting of the

bark. The borders of the cankers are sharply defined on young branches by a contrast in color between living and cankerous tissues. There is no discolored streaking in the wood; however, the wood appears dried out and light brown.

*Nummularia* stromata produced in the cankerous tissue are shown in fig. 14. These stromata are discoid to linear, subeffuse and rather thick. Immature stromata are covered with a pulverulent, cinereous, conidial hymenium that sloughs off at maturity, when the stromata become black, carbonous, rigid, bare and usually somewhat convex. They are laid down in the phellem immediately under the epidermis, and the epidermis disappears during the early development of the stromata. The periderm, endodermis, pericycle and phloem tissues turn dark brown to black and disintegrate. The cortical tissue is crushed during the development of the stromata.

The stromata vary from 460 to 530  $\mu$  thick. The perithecia, shown in fig. 15, are large, monostichous, globose to ovoid, and immersed in the stroma. They range from 260 to 400  $\mu$  in diameter and from 350 to 370  $\mu$  in height. The height measurement does not include the extended ostioles, which are 135–200  $\mu$  long and 18–30  $\mu$  in diameter. The asci are cylindrical,  $90-125 \times 9-12 \mu$ , pedicellate and 8-spored. The ascospores are arranged obliquely in one row in the ascus and are ellipsoid to fusiform, continuous,  $15-19 \times 9-12 \mu$ , and brown when mature. They are illustrated in fig. 16. The paraphyses are hyaline,  $125-215 \times 4.7-7.8 \mu$ , filiform and somewhat abundant.

This *Nummularia* was determined as



Fig. 14.—Portion of a Nummularia canker on red oak. The gray to blackstromata develop in the smooth, reddish-brown cankerous tissues. X 1½.

*Nummularia clypeus* (Schw.) Cke. by Dr. W. W. Diehl.

Single-spore plantings of *Nummularia clypeus*, from red oak, were made on corn meal agar. Abundant germination of ascospores occurred in 12 hours. The ascospores germinated by sending out, terminally or laterally, one to several germ tubes from each spore. Branching of the



Fig. 15.—Portion of a stroma of *Nummularia* in vertical section. The ovoid perithecia are embedded in the black stromatic tissue, and the black perithecial wall separates readily from the stromatic tissue. X 70.



Fig. 16.—Ascospores of *Nummularia*. The immature ascospores are hyaline to light brown, and the mature ascospores are dark brown to black. Eight ascospores develop in each hyaline ascus. X 200.

germ tubes occurred in 24 hours and after they were 60  $\mu$  long. One colony, which had grown from a single spore, produced in 10 days a growth 80 mm. in diameter. The average growth for several colonies was 36 mm. in diameter, produced in 5 days. Cultures of *N. clypeus* from single-spore plantings on corn meal agar developed a sparse growth of interwoven, gray aerial hyphae. The surface growth was interwoven, gray-tan and more dense than the aerial growth. Spores placed in sterile distilled water gave an average germination of 28 per cent in 17 hours. *N. clypeus* failed to sporulate when grown on artificial media. A culture of this *Nummularia* is shown in fig. 17.

A fungus isolated from 28 specimens of diseased oak appeared to be identical with



Fig. 17.—Culture of *Nummularia* grown from a single-spore isolate. The aerial hyphae are gray, and the surface hyphae are gray to tan. The fungus grows vigorously and spreads rapidly on corn meal agar.

known cultures of *Nummularia clypeus*. This fungus was isolated from discolored wood, stromatic tissue of cankers, cankerous bark and discolored regions of living wood of both red and shingle oak.

#### Diatrype Canker and Dieback

Diatrype cankers were found on medium to small branches of red oak in the northeastern region of Illinois. A young canker is shown in fig. 18 and an old canker in fig. 19. Diatrype canker develops as a light to dark reddish-brown,



Fig. 18.—*Diatrype* canker and dieback on red oak. The diseased tissue is light to dark reddish brown and sunken. The border of the diseased region is raised where living and dead tissues meet. The stromata are irregular, black, crumpled, roughened and fissured. X  $\frac{1}{2}$ .



Fig. 19.—*Diatrype* canker on red oak. Portion of an old canker which shows a large, fissured, mature stroma that has almost covered the whole cankered region. X  $\frac{1}{4}$ .



Fig. 20. Perithecia of *Diatrype*. A vertical section of stromatic tissue which shows the arrangement of perithecia. X 75.



Fig. 21.—Asci and ascospores of *Diatrype*. Each hyaline and clavate ascus contains 8 hyaline, botuliform, 1-celled ascospores. X 320.

sunken region on the branch. The canker is conspicuous because of the contrast between the healthy and the diseased tissues, and it is surrounded by a callus. Dieback develops when the branches are completely girdled by cankers.

The stromata of *Diatrype* develop subepidermally, and they become erumpent at maturity. A portion of a stroma is shown in fig. 20. Stromata are diatrypoid, black and smooth at first, but later they become grayish black, somewhat roughened and fissured. The fissures are produced by vertical and longitudinal splitting of the stromatic tissue. The ovoid, dark, car-

bonous and ostiolate perithecia are shown in fig. 20. Immature perithecia are  $48-53 \mu$  in diameter and  $63-68 \mu$  high. Mature perithecia are globose and  $200-225 \mu$  in diameter without their extruded beaks, which are  $75-85 \mu$  long from the top of the perithecia to the ostioles at the external surface of the stromata. The ostioles are papillate, round, not compressed, and are  $30-40 \mu$  in diameter. The asci, shown in fig. 21, are 8-spored, hyaline,  $30-33.5 \times 4.8-5.2 \mu$ , and somewhat clavate with a tapering base. Each ascus has a pore at its apex. The ascospores are pictured in fig. 21. They are hyaline,  $6.6-9.5 \times 1.6-3.3 \mu$ , botuliform and continuous. Known cultures of *Diatrype* were not secured on artificial media.

Our material agrees with *Diatrype stigma* (Hoffm.) Fr. as represented in Ellis & Everhart's North American Fungi, Second Series, No. 3,529.

#### Phomopsis Canker and Dieback

Phomopsis canker and dieback, identified by isolation of the fungus from the diseased wood, was found on branches of pin, red, swamp white and white oaks. Externally, Phomopsis cankers are reddish brown, elongate, smooth and somewhat shrunken, and they have definite borders where the cankerous and living bark meet. In most of the cankers the diseased xylem tissue varies from light brown to dark brown; and occasionally light to dark brown streaks extend into the adjacent living xylem tissue.

*Phomopsis* was found fruiting in the diseased bark of only one canker and dieback specimen of oak—pin oak. The pycnidia in the diseased bark are black, ovoid to discoid, erumpent,  $200-270 \mu$  high and  $400-470 \mu$  in diameter. They are fundamentally laid down in the phellogen-phellogen region of the bark. Their development causes very little distortion of the underlying cortical tissue, but the overlying phellem and epidermis are ruptured by the enlarging pycnidia. The ruptured tissues form a triangular-shaped shield around the mature pycnidia. The conidia,  $\alpha$ -spores, are hyaline,  $7-10 \times 1.5-3 \mu$ , ellipsoid to fusoid, and continuous.

In culture, *Phomopsis* develops a sparse growth of gray mycelium that spreads rapidly on corn meal agar. Pycnidia are

promiscuously interspersed with the mycelium. The portion of the pycnidium that grows above the agar is gray, and the portion that is embedded in the agar is black.

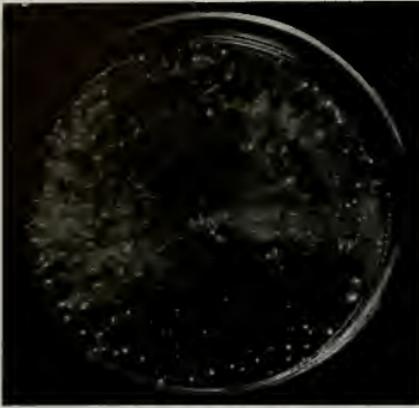


Fig. 22.—Culture of *Phomopsis* on corn meal agar. The gray pycnidia are produced promiscuously and are interspersed with the mycelium.



Fig. 23.—Spores of *Phomopsis*. Both  $\alpha$ - and  $\beta$ -spores are produced on sterilized red oak twigs. The ellipsoid to fusoid, continuous, hyaline  $\alpha$ -spores are produced in greater abundance than are the straight to curved or hamate, filiform, hyaline  $\beta$ -spores. X 300.

A culture of *Phomopsis* on corn meal agar is shown in fig. 22.

*Phomopsis* from the red and swamp white oak branches produced both  $\alpha$ - and  $\beta$ -spores in culture. It was isolated from the discolored, diseased xylem and from the living xylem of cankers that showed fine, light to dark brown streaks. It was cultured not only from cankers but from the black, discolored xylem tissue of a die-back specimen of red oak. One canker

from which *Phomopsis* was cultured had stromata of *Diatrype stigma* on the cankerous tissue.

The pycnidia of the *Phomopsis* that produced both  $\alpha$ - and  $\beta$ -spores are black, globose to ovoid, without ostioles, are subcarbonaceous, and 500–1000  $\mu$  in diameter. The  $\alpha$ - and  $\beta$ -spores are shown in fig. 23. The  $\alpha$ -spores are elliptic to fusoid, 5–10  $\times$  2–4  $\mu$ , hyaline and continuous. The  $\beta$ -spores are straight to curved or hamate, normally 16–30  $\times$  1–2.8  $\mu$ , filiform, hyaline and continuous. In one instance the  $\beta$ -spores measured 28–34  $\times$  3–5  $\mu$ .

Our material from the red and swamp white oak branches agrees with *Phomopsis quercina* (Sacc.) v. Höhn. as represented in Sydow's *Mycotheca germanica* No. 1,122.

*Phomopsis* grown from the branch cankers of pin oak and white oak and also from the blighted petioles of one specimen of red oak produced only  $\alpha$ -spores in culture. The pycnidia are black, 400–500  $\times$  330–450  $\mu$ , globose to ovoid, and pseudoparenchymatous. The conidia are continuous, 4–10  $\times$  2–4  $\mu$ , hyaline, and ellipsoid to fusoid. They are comparable in size to the *Phomopsis* spores produced in the cankerous tissue of the pin oak and also to the  $\alpha$ -spores of *Phomopsis* grown in culture from red and swamp white oak branches.

## CANKER DISEASES

### Phoma Canker

Phoma cankers were found on twigs and on small to large branches of bur, pin, red, shingle and white oaks. The cankers are dark brown to black, somewhat shrunken and roughened, and have definite borders where the cankerous and living tissues meet. In some specimens of diseased oak, dark brown to black streaks of discoloration are present in the living wood beyond the extremities of the cankers. This discoloration is similar to that of the *Dothiorella* cankers shown in fig. 3. Pycnidia develop in the phellogen-phelloderm region. The overlying host tissue is ruptured by the developing pycnidia, which are erumpent at maturity.

Five Phoma cankers—two on twigs, two on small branches and one on the trunk of a small tree—were found on red oak. The pycnidia in these cankers are

black, globoid to slightly ovoid, ostiolate, and 150–200  $\mu$  in diameter. The conidia are hyaline,  $3\text{--}3.5 \times 1\text{--}2.5 \mu$ , oblong to fusoid, and continuous.

From one of the two twig cankers, *Phoma* was obtained in culture; *Cephalosporium* was obtained from the other. *Dothiorella* was obtained from the trunk canker and from one branch canker; *Penicillium* and *Cephalosporium* were obtained from the other branch canker. The *Phoma* from the twig canker, cultured on corn meal agar, produced black, globose pycnidia 80–110  $\mu$  in diameter. The conidia are oblong to fusoid, hyaline,  $3.3\text{--}3.6 \times 2.5\text{--}3.2 \mu$ , and continuous.

*Phoma* was obtained in culture from 22 canker specimens of diseased oak that had no *Phoma* pycnidia in the cankerous tissue. One of these cankers was on bur oak, 2 on pin oak, 12 on red oak, 1 on shingle oak and 6 on white oak. *Phoma* was grown from the living wood that showed dark brown to black streaks in 7 of these 22 specimens and from the cankerous tissue of the remaining specimens.

*Phoma* was the only fungus obtained in culture from 17 of the 22 diseased oak specimens mentioned above. It was obtained in association with other fungi from the remaining 5 specimens. The associated fungi were *Alternaria*, *Cephalosporium* and *Dothiorella*. *Coryneum* was found fruiting on 1 and *Cytospora* on 2 of the 22 specimens.

Cultures of *Phoma* from the above-described sources produced pycnidia on corn meal agar. The pycnidia, illustrated in fig. 24, are black, globoid, pseudoparenchymatous, and 50–200  $\mu$  in diameter. Conidia are hyaline,  $1.5\text{--}4 \times 0.7\text{--}2.5 \mu$ , continuous, and oblong to fusoid. The fungus produces a dense growth of radiate mycelium, which develops slowly. Black pycnidia are interspersed with the mycelium. A culture of *Phoma* is shown in fig. 25. The dense growth of surface hyphae is tan to brown with a 1 mm. marginal growth of white hyphae. The sparse growth of aerial hyphae is white to gray.

All of the pycnidia and conidia of *Phoma* described above are sufficiently similar in size and shape to be regarded as from one species. This species compares more closely with the morphological description of *Phoma aposphaerioides* Briard & Hariot (Saccardo 1892) than with the morpho-

logical descriptions of other species of *Phoma* on *Quercus*.

A second *Phoma* was found fruiting on the blighted petioles of a post oak. This



Fig. 24.—Pycnidia of *Phoma*. Numerous black, globoid, pseudoparenchymatous pycnidia are produced on corn meal agar. X 140.

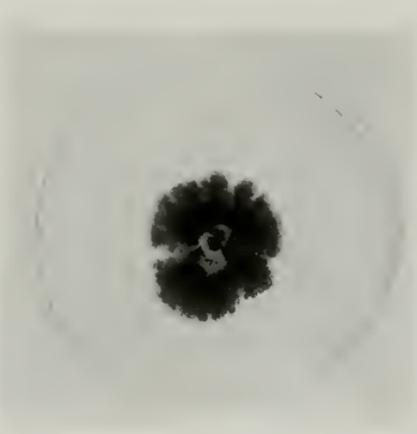


Fig. 25.—Culture of *Phoma* on corn meal agar. Numerous black pycnidia develop in more or less concentric circles.

fungus was grown in culture from these diseased petioles and from blighted petioles of another post oak.

On the petioles, the second *Phoma* produced dark brown to black, ovoid, pseudoparenchymatous pycnidia 350–450  $\mu$  in diameter. The conidia are hyaline,  $6\text{--}8.5 \times 2.8\text{--}3.4 \mu$ , continuous, and ellipsoid to fusoid. On corn meal agar the fungus produced dark brown to black, ovoid, pseudoparenchymatous pycnidia 250–400  $\mu$  in diameter, and conidia that are hyaline,  $6\text{--}9 \times 1.5\text{--}3 \mu$ , and oblong to fusoid.

This *Phoma* was associated with only the blighted petioles of twig blight specimens of oak. In this disease the leaves wilt and then turn brown to reddish brown during the summer (July and

August). The petioles, externally and internally, turn brownish purple, and the twig tips die back 1 to several inches. The bark turns brown and then dries and shrinks tightly around the wood.

This second *Phoma* agrees with the morphological description of *Phoma quercina* (Peck) Sacc. (Saccardo 1884).

### Fusicoccum Canker

Fusicoccum cankers, shown in figs. 26 and 27, are slightly sunken, dark brown to brownish-black areas, with conspicuous borders where the cankerous and living tissues meet. Erumpent stromata develop in the cankerous tissue. Deep fissures, which extend partially to completely across the cankerous bark, are very conspicuous. Dark brown discoloration of the wood beneath the cankerous bark does not extend into the living wood beyond the margin of the canker. *Fusicoccum* was isolated from two cankers on red oak and from brownish-purple, blighted petioles of two diseased oaks (black and post oaks). The brownish-purple discoloration is most apparent at the base of the petioles; it fades to a light brown color where the petioles and the brown leaf blades unite. Abscission layers are formed at the junction of the petioles and twigs, and the leaves are easily removed from the twigs.

Stromata are laid down fundamentally in the phellogen-phelloderm region of the bark. Their development causes very little distortion and crushing of the underlying cortical cells. The overlying phellem and epidermis are ruptured as the stromata enlarge and mature. The mature stromata appear dotlike in the cankerous tissue.

The stromata, 700–1400  $\mu$  in diameter and 250–450  $\mu$  high, are black, ovoid to conoid, erumpent, multilocular and with a sterile central region of pseudoparenchymatous hyphae. A vertical section of a stroma is shown in fig. 28. The conidial cavities are ovoid to elongate and somewhat irregular in outline. Conidia, shown in fig. 29, are hyaline, 6–12  $\times$  2–4  $\mu$ , ellipsoid to fusoid, and continuous. Conidiophores are hyaline to subhyaline, 6–12  $\times$  1.5–3  $\mu$ , and bacillar.

*Fusicoccum* produces white mycelium on corn meal agar. A few promiscuously scattered stromata that are black, 1300–1500  $\mu$  across, ovoid to globoid, and multi-



Fig. 26.—*Fusicoccum* canker on red oak. The shrunken, dark brown to brownish-black, cankerous tissue contains numerous black, ovoid to conoid, erumpent stromata. Numerous fissures extend partially to completely across the cankered region.  $\times 1$ .

locular are interspersed among the hyphae. The pycnidial locules are globoid to ovoid, black, and 650–800  $\mu$  in diameter. The conidia are hyaline, 6–13  $\times$  2.5–4  $\mu$ , con-



Fig. 27.—*Fusicoccum* cankers on red oak. The erumpent stromata and fissures in the shrunk, cankerous bark are conspicuous in the larger canker, which has developed around the base of a twig. The smaller canker, below, has developed from infection through an injury. X 3.



Fig. 28.—Portion of a stroma of *Fusicoccum* from red oak. This vertical section shows the internal cavity of the stroma and the black stromatic tissue that has pushed through the host tissue. X 58.



Fig. 29.—Spores of *Fusicoccum*. The spores are hyaline, ellipsoid to fusoid, and continuous. X 320.

cardo (1899), the material that we studied is *F. Ellisianum* Sacc. & Syd.

#### Sphaeropsis Canker

A portion of the only *Sphaeropsis* canker found on oak, on a red oak twig, is shown in fig. 30. This canker is reddish brown, is promiscuously dotted with *Sphaeropsis* pycnidia and is bounded by a definite border made conspicuous by the contrast between the smooth, reddish-brown, dead bark of the canker and the adjacent, living, dark green bark. The dead wood beneath the cankerous bark is discolored chocolate brown and is bordered by a black region adjacent to the healthy wood. This discoloration in the wood extends down the twig approximately 1 inch beyond the base of the cankerous bark.

tinuous, and they are ellipsoid to fusoid.

Our material agrees with *Fusicoccum quercinum* Ell. & Ev. as represented in North American Fungi, Second Series, No. 3,360. Saccardo (1899) considered *F. quercinum* Ell. & Ev. identical with *F. Ellisianum* Sacc. & Syd. and not with *F. quercinum* Sacc. (Saccardo 1884). Therefore, according to the classification of Sac-

The pycnidia are black, ostiolate, separate to cespitose, globose to ovoid, 650–860  $\mu$  in diameter and 400–600  $\mu$  high. They arise fundamentally in the phellogen-phelloderm region of the bark. The over-

lying phellem and epidermis are broken when the pycnidia mature and become erumpent, and there is very little crushing or disintegration of the underlying tissues. The broken host tissues form oval to cir-



Fig. 30.—Portion of a *Sphaeropsis* canker on red oak. The reddish-brown, smooth, shrunken cankerous tissue contains numerous black, globose to ovoid, erumpent pycnidia. X 1.



Fig. 31.—Spores of *Sphaeropsis*. A cross section of a pycnidium which shows the brown, 1-celled, ovoid to ellipsoid spores and the black pseudoparenchymatous pycnidial tissue. X 150.

cular shields around the erumpent pycnidia. The conidia, shown in the cross section of a pycnidium in fig. 31, are brown,  $15-25 \times 8-11 \mu$ , continuous, and ovoid to ellipsoid. The conidiophores are hyaline, rodlike,  $6-9 \times 1.5-2.5 \mu$ , and the oval ostioles are  $15-25 \mu$  in diameter. This fungus was not grown in culture.

Our material compares closely with the morphological description of *Sphaeropsis quercinum* Cke. & Harkn. (Cooke & Harkness 1884).

### Bulgaria Canker

Apothecia were obtained from Bulgaria cankers on two black oak trees. The cankers were located on the trunks ap-



Fig. 32. Ascospores of *Bulgaria*. Each hyaline, cylindrical, pedicellate ascus contains 4 to 8 brown, ovoid to suboblong, continuous ascospores. X 230.

proximately 2 feet above the soil line. Small and oval to large and irregular areas of the bark had been killed. The cambium under the dead bark was tan to light brown and was water soaked. Black zone lines were present in the underlying xylem tissue. Killing of the cambial region was followed by general decline and finally death of the infected trees.

Several attempts to grow the fungus on artificial media (corn meal agar, potato dextrose agar and acidified potato dextrose agar) from ascospores and from apothecial tissue were unsuccessful. *Aspergillus*, *Cephalosporium*, *Fusarium* and an unidentified fungus were obtained in culture from the apothecial tissue of *Bulgaria*.

The apothecia of *Bulgaria* are black, substipitate to sessile, gelatinous to fleshy,

and cupulate with a wall  $700-1800 \mu$  thick. Asci are hyaline,  $40-60 \times 6-10 \mu$ , cylindrical, pedicellate and 4- to 8-spored. The ascospores, fig. 32, are brown,  $7-15 \times 4-6.5 \mu$ , continuous, and ovoid to ellipsoid or suboblong. Paraphyses are subhyaline to light tan,  $75-110 \times 0.7-1.7 \mu$ , and filiform.

Our material agrees with *Bulgaria inquinans* (Pers.) Fr. as represented in Ellis' North American Fungi No. 448.

## DIEBACK DISEASES

### Coniothyrium Dieback

*Coniothyrium* branch and twig dieback was found on black, bur, pin, red, swamp white and white oaks. The *Coniothyrium* fungus was isolated from diseased bark, blighted twigs and discolored regions in the live wood that extended from the dead wood in specimens of dieback.

In this type of dieback the diseased bark is light reddish brown to dark brown, smooth, slightly raised, and continuous with the surrounding living bark. There are no pycnidia or fissures in the diseased bark. In some cases streaks that are light to dark brown and fine to broad extend from the discolored dead wood beneath the diseased bark into the living wood below the dieback region.

On corn meal agar, the *Coniothyrium* isolated from oak develops dark tan to

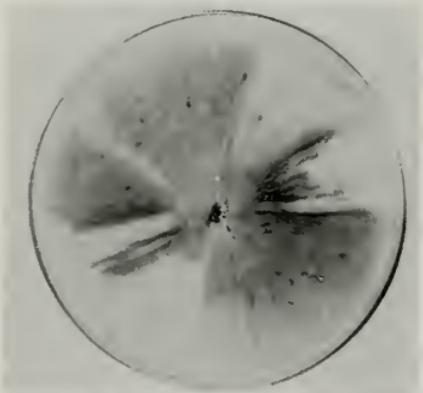


Fig. 33.—Culture of *Coniothyrium* on corn meal agar. The dark brown to black, partially submerged, sphaeroid pycnidia develop in old cultures.

brown mycelium, fig. 33. The mycelium is white when young but becomes tan to brown with age. A dense growth of surface hyphae and a very sparse growth of aerial hyphae develop in culture.

Pycnidia develop as partially submerged, dark brown to black, pseudoparenchyma-

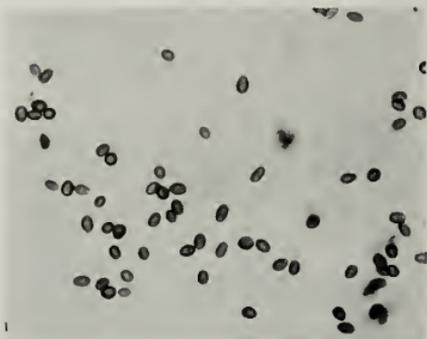


Fig. 34.—Spores of *Coniothyrium*. They are ovoid to subcylindrical, olivaceous and 1-celled. X 430.

tous, spheroidal structures with flattened bases; they are 150–500  $\mu$  in diameter. The conidia, fig. 34, are ovoid to subcylindrical,  $4-7 \times 3-4.5 \mu$ , olivaceous and continuous.

This *Coniothyrium* compares closely with the morphological description of *Coniothyrium truncisedum* Vestergr. (Saccardo 1899).

### *Pyrenochaeta* Dieback

*Pyrenochaeta dieback* was found on pin oak and white oak. The diseased bark is dark brown to brownish black and is shrunken; most of it is smooth. Fungous fructifications are not present in the cancerous tissue. The underlying wood is dark brown to black and has broad streaks of discoloration that extend into the living wood. *Pyrenochaeta* was isolated from discolored living wood of pin oak and white oak about one-half inch below the base of the dieback regions; also from one twig blight specimen of white oak.

On corn meal agar the fungus produces small, globose to ovoid, pseudoparenchymatous, dark brown to black, ostiolate pycnidia, normally 60–100  $\mu$  in diameter, and with setae. The measurement of the

pycnidia of one culture from white oak is 335–535  $\mu$  in diameter and, in a second culture, 100–250  $\mu$  in diameter. Two pycnidia are shown in fig. 35. The ostioles are circular and 8–10  $\mu$  in diameter. The setae, shown in fig. 35, are brown, septate, 10–50  $\times$  2–4  $\mu$ , straight to curved, and tapering toward the apices. Conidia of this *Pyrenochaeta* are very small, hyaline, 1.5–4  $\times$  0.7–3  $\mu$ , fusiform, continuous, and they are ovoid to ellipsoid in shape.



Fig. 35.—Pycnidia and spores of *Pyrenochaeta*. The small, globose to ovoid, dark brown to black pycnidia have septate, straight to curved, tapering, brown setae especially around their ostioles. The spores are minute, hyaline, continuous, fusiform and ovoid to ellipsoid. X 170.



Fig. 36.—Culture of *Pyrenochaeta*. The tan to dark brown mycelium grows slowly and produces a dense mat on corn meal agar.

The mycelium is light to dark brown. A culture is shown in fig. 36. The sparse growth of aerial hyphae is gray to light brown. The dense growth of surface and subsurface hyphae is light to dark brown with a 1 mm. marginal growth of white hyphae.

This *Pyrenochaeta* does not appear to compare morphologically with any of the described species of *Pyrenochaeta*.

#### *Pyrenochaeta minuta* sp. nov.

Mycelium in culture light to dark brown in mass, with sparse, gray to light brown aerial hyphae and abundant light to dark brown surface hyphae; pycnidia scattered, globose to ovoid, sooty brown to black, 60–535  $\mu$ , mostly 60–100  $\mu$ , in diameter; ostioles round, 8–10  $\mu$  in diameter; setae brown, septate, straight to curved, tapering toward apex, 10–50  $\times$  2–4  $\mu$ ; conidia hyaline, minute, fusiform, continuous, ovoid to ellipsoid, 1.5–4  $\times$  0.7–3  $\mu$ .

Mycelio in cultura diluto usque atrato brunneo in massa, hyphis aëris sparsis griseis usque dilutis brunneis, hyphis in superficie mediis abundantibus dilutis usque atratis brunneis, picnidiiis sparsis globosis usque ovoideis fuliginosis usque nigris 60–535  $\mu$  ut plurimum 60–100  $\mu$  diametris cum ostioliis rotundatis 8–10  $\mu$  diametris et setis brunneis septatis rectis usque curvatis ad apicem attenuatis 10–50  $\times$  2–4  $\mu$ , conidiis hyalinis minutis fusiformibus continuis ovoideis usque ellipsoideis 1.5–4  $\times$  0.7–3  $\mu$ .

Type specimen: Pure culture isolated from the cortical parts of an infected branch of *Quercus palustris* Muench., collected by J. C. Carter at Xenia, Clay County, Illinois, October 8, 1937, Ill. Nat. Hist. Surv. Acc. No. 27,082.

Other specimens cultured from branch of *Quercus alba* L. collected by J. C. Carter at Galena, Jo Daviess County, Illinois, October 28, 1937; twig of *Q. alba* collected by J. C. Carter at Lake Forest, Lake County, Illinois, September 25, 1937.

## ROOT ROT

### Armillaria Root Rot

Observations were made in the course of this investigation to determine the cause of staghead, general dieback and the sudden dying of numerous oak trees. These pathologic conditions of oak were observed

in widely scattered sections of Illinois; however, they were noticed especially in the northeastern section of the state. In nearly every instance, staghead and general decline of oak were associated with root disturbances, especially with root rot.

In the stagheaded trees examined, young roots and the white wood of older roots



Fig. 37.—Culture of *Armillaria*. The reddish-brown rhizomorphs are produced in abundance on corn meal agar.

were affected by a white rot. The brown wood of the older roots showed a gradual change from the early to the late stages of rot. In the early stage of rot the brown wood of the older roots becomes lighter brown, but later it gradually changes to gray, which is sometimes mottled. Finally, in the late stage of rot, the wood becomes white, soft and spongy, and in time it crumbles away and leaves a cavity in each infected root. From specimens of this



Fig. 38.—Young sporophores of *Armillaria*. They were found developing in the soil about 1 foot from the base of a bur oak tree and above the infected root. The reddish-brown to black rhizomorphs are attached to the young sporophores. X 1.

white, heart-rot wood as well as from rhizomorphs, *Armillaria mellea* (Vahl.) Quél. was isolated. A culture of *A. mellea* with rhizomorphs that permeate the potato dextrose agar is shown in fig. 37.

In the roots of many of the diseased oaks, rhizomorphs of *Armillaria*, shown with attached sporophores in fig. 38, develop in the cambial region and in root cavities. In the late stage of staghead, the rhizomorphs are frequently found under the bark at the base of the large roots and in the root crotches. Rhizomorphs may enter through wounds in the root crotches at or below the surface of the soil. They are present in the duff at the base of seriously infected trees and frequently are found spreading through the soil for distances of 25 feet or more. In the early stage of staghead, rhizomorphs are associated with the death and rotting of the very small feeding roots. Gradual destruction of these roots reduces the feeding capacity of the root system and limits the amount of foliage that can be supplied with plant food and water. An inadequate supply of plant food and water causes the gradual drying back and dying of the extremities of the branches, and in time the affected trees show staghead. *Armillaria* infection at the base of a large root quickly reduces the amount of food

and water supplied by the root and causes dieback or death of the branches that are supported by the infected root. Infections of this type in several roots cause the relatively sudden death of the tree.

In the soil, rhizomorphs are dark reddish brown to black externally, cylindrical,



Fig. 39.—Sporophores of *Armillaria*. This group of sporophores developed at the base of a dead bur oak root. X  $\frac{3}{4}$ .

little branched, 0.5–3 mm. in diameter, and they contain cream to white hyphal strands. The rhizomorphs that develop in the cambial region of the roots and tree trunks are dark red to reddish brown, flattened, much branched, 0.2–3 mm. broad, and they contain cream to white hyphal strands.

Sporophores of *Armillaria* develop, usually in October in Illinois, on the dead bark of the trunks and the roots of infected trees. Also they may be found on the ground at or near the base of the infected trees and sometimes at distances of several feet from them. A group of immature sporophores taken from the root of an oak may be seen in fig. 39.

## MISCELLANEOUS FUNGI

### *Cylindrosporium*

*Cylindrosporium* was found fruiting in the diseased tissue of one dieback specimen of shingle oak. The fungus was not grown in culture from this specimen nor from any other specimens of diseased oak. However, *Coryneum* was grown in culture from the diseased tissue of this specimen and was most likely the fungus responsible for the dieback. The *Cylindrosporium* evidently developed in the bark after the branch had become infected with *Coryneum*.

The diseased bark of this shingle oak specimen is light to dark brown, slightly shrunken and for the most part smooth; however, where the numerous *Cylindrosporium* acervuli have been produced there



Fig. 40. Acervulus of *Cylindrosporium* on shingle oak. A vertical section of an acervulus which shows the position of the acervulus in relation to the host tissues. X 75.

are blisters. An acervulus is shown in vertical section in fig. 40. Acervuli are dark brown to black, pulvinate and immersed. They become erumpent at maturity and are 530–1100  $\mu$  in diameter and 130–400

$\mu$  high. The acervuli arise fundamentally in the phellogen-phellogen region of the bark and at first cause very little distortion and disintegration of the cortical cells. As they expand in growth and become mature, they rupture the overlying phellogen and epidermis, which form shields around



Fig. 41.—Spores of *Cylindrosporium* attached to a portion of an acervulus. The spores are hyaline, acicular and straight to curved. X 500.

them. The conidia, shown in fig. 41, are hyaline, 20–40  $\times$  1–3  $\mu$ , acicular, 1- to 2-celled, and straight to curved.

This fungus does not appear to compare morphologically with any of the described species of *Cylindrosporium* that have been found on *Quercus*.

### *Cylindrosporium quercinum* sp. nov.

Acervuli scattered, dark brown to black, pulvinate, innate, becoming erumpent, 530–1100  $\mu$  in diameter, 130–400  $\mu$  high, inhabiting an elongated, light to dark brown diseased region of the branch; conidia hyaline, acicular, continuous to 1-septate, straight or slightly curved, 20–40  $\times$  1–3  $\mu$ .

Acervulis sparsis atrobrunneis usque nigris pulvinatis innatis dein erumpentibus 530–1100  $\mu$  diametris 130–400  $\mu$  altis regionem elongatam dilutam usque atratam brunneam aegrotam rami incolentibus, conidiis hyalinis acicularibus continuis vel 1-septatis rectis curvulisve 20–40  $\times$  1–3  $\mu$ .

Type specimen: Collected by G. H. Boewe, Cartter, Marion County, Illinois, on branch of *Quercus imbricaria* Michx., September 17, 1936, Ill. Nat. Hist. Surv. Acc. No. 27,081.

*Rhodosticta*

*Rhodosticta* was found fruiting on a single specimen of dieback, taken from a pin oak growing in a nursery row. The diseased branch, approximately 1 inch in

parenchymatous hyphae that compose the bases of the stromata. The overlying phellem and epidermis are ruptured and forced back to form a collar around the erumpent stromata.

Erumpent stromata are shown in fig. 42.

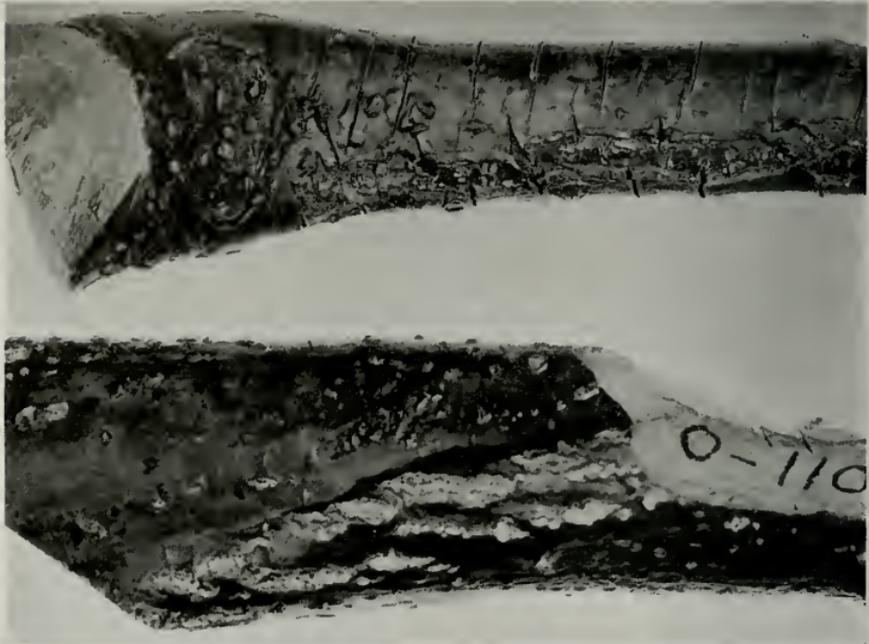


Fig. 42.—Dieback of pin oak with *Rhodosticta* fruiting in the diseased tissue. The central region of the shrunken and smooth diseased bark is pale yellow but it blends into a light brown and then into a dark brown at the border. The scattered, ovoid to irregular, red stromata are present in the discolored, diseased tissue. X 2.

diameter, had become infected through the stub of a lateral.

The color of the diseased bark in the central region is white to pale yellow, blending into a light brown and then into a dark brown toward the margin. A raised region of callus tissue contrasts sharply with the adjacent diseased bark. This contrast marks a definite separation of the living and dead tissues. Light brown discoloration of the dead wood beneath the diseased bark does not extend into the living wood.

Stromata are laid down fundamentally in the phellogen-phelloderm region of the branch. These tissues and the underlying cortex are partially disintegrated and crushed by the development of the pseudo-

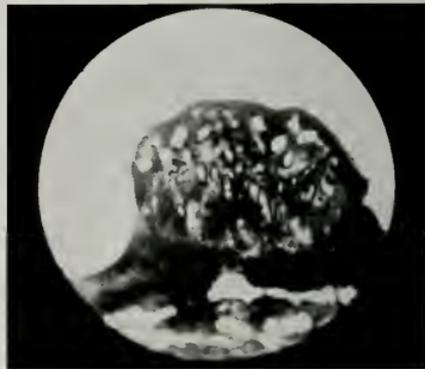


Fig. 43.—Stroma of *Rhodosticta*. A vertical section of a stroma which shows the variable shape and arrangement of the pycnidia. X 29.

They are red, ovoid, with an irregular outer surface, not crustose, 1200–1500  $\mu$  in diameter and 800–1000  $\mu$  high. The pycnidial cavities, visible in the vertical section of the stroma, illustrated in fig. 43, are ovoid to irregular, promiscuously dispersed throughout the stromatic tissue and variable in size. They are of three types: small, oval cavities, 60–65  $\times$  25–35  $\mu$ ; large, oval cavities, 160–180  $\times$  30–40



Fig. 44.—Spores of *Rhodosticta*. The spores are minute, ovoid to ellipsoid, and hyaline to subhyaline. X 860.

$\mu$ ; and long, narrow cavities, 115–135  $\times$  70–85  $\mu$ . The conidia, shown in fig. 44, are hyaline to subhyaline, 2.8–3.5  $\times$  1–2  $\mu$ , and ovoid to ellipsoid. The fungus was not grown in culture.

Our material does not compare with *Rhodosticta Caraganae* Woronichin (Saccardo 1913). The present report is believed to be the first of *Rhodosticta* on *Quercus*.

#### *Rhodosticta quercina* sp. nov.

Stromata scattered, red, tubercular, not crustose, 1200–1500  $\mu$  in diameter, 800–1000  $\mu$  high, inhabiting a light to dark brown diseased region of the branch; pycnidia ovoid to irregular, immersed, 60–180  $\times$  25–85  $\mu$ ; conidia hyaline to subhyaline, ovoid to ellipsoid, 2.8–3.5  $\times$  1–2  $\mu$ .

Stromatibus sparsis rubris tuberculiformibus non crustosis 1200–1500  $\mu$  diametris 800–1000  $\mu$  altis regionem dilutam usque attratam brunneam

aegrotam rami incoentibus, picnidiiis ovoideis usque irregularibus immersis 60–180  $\times$  25–85  $\mu$ , conidiis hyalinis usque subhyalinis ovoideis usque ellipsoideis 2.8–3.5  $\times$  1–2  $\mu$ .

Type specimen: Collected by J. C. Carter, Onarga, Iroquois County, Illinois, October 25, 1935, on branch of *Quercus palustris* Muench., Ill. Nat. Hist. Surv. Acc. No. 27,083.

#### *Cephalosporium*

*Cephalosporium* was obtained in culture from 27 specimens of diseased oaks, black, red, shingle and white. It was isolated from cankerous wood and bark and from discolored living wood of red, shingle and white oaks, and from a living twig of black oak that had blighted leaves. *Cephalosporium* was the only fungus isolated from the living wood below cankers of three specimens of red oak and of one specimen of white oak. In each case the fungus was isolated from discolored, light to dark brown living wood that was taken at points 1 to 3 inches below the cankers. *Cephalosporium* was obtained from most specimens in association with other fungi, including *Alternaria*, *Coniothyrium*, *Coryneum*, *Cytospora*, *Penicillium*, *Pestalotia*, *Phoma* and *Dothiorella*. The only cultures of *Cephalosporium* not associated with other fungi were obtained from discolored dead wood and, as pointed out above, from discolored living wood.

On corn meal agar the surface of old cultures of this *Cephalosporium* appears granular or pulverulent. The appearance is due to the numerous conidia produced. The fungus grows and spreads rapidly over the surface of the agar. Conidiophores, produced on septate, hyaline, branched hyphae, are unbranched, variable in length but approximately 250–300  $\times$  2–3  $\mu$ , hyaline and filiform. Conidia are capitate, hyaline, ellipsoid to ovoid, sessile, 2–3  $\times$  1.5–2  $\mu$  to 7.5–10  $\times$  3–3.5  $\mu$ , most frequently 3–4  $\times$  1.5–2  $\mu$ , and produced acrogenously in globose heads on the conidiophores.

#### *Nigrospora*

*Nigrospora* was isolated from two specimens of diseased oak: one isolate from a blighted twig of post oak and one from a blighted petiole of pin oak. The blighted

twig was brown internally and had blighted leaves with purplish petioles attached. The blighted petiole was shriveled, dead purplish internally and externally, and was attached to a twig that had hyper-



Fig. 45.—Culture of *Nigrospora*. The white to gray, abundant growth of mycelium develops on corn meal agar.



Fig. 46.—Spores of *Nigrospora*. The black, smooth, globose to ovoid spores develop singly on doliform basidia. X 320.

trophied buds. *Nigrospora* was not found fruiting on the diseased wood of any specimens of oak. Both *Nigrospora* and *Coryneum* were cultured from the blighted twig of post oak; *Dothiorella* and *Alter-naria*, as well as *Nigrospora*, were cultured from the blighted petioles of pin oak.

When grown on corn meal agar, the *Nigrospora* discussed here develops a dense surface and aerial growth of hyphae that is white and somewhat powdery. A culture is illustrated in fig. 45. Produced on erect conidiophores, the black, exogenous, smooth, globose to ovoid, acrogenous conidia, shown in fig. 46, develop singly on doliform basidia and are 11.5–22  $\mu$ , most of them approximating 15.5  $\mu$ , in diameter. Sometimes the conidiophores are branched, and several conidia develop on each of the branched conidiophores.

This *Nigrospora* agrees with *Nigrospora sphaerica* (Sacc.) Mason on elm, discussed by Harris (1932). Harris' material was determined by E. W. Mason of the Imperial Mycological Institute.

### *Cunninghamella*

*Cunninghamella* was isolated from a specimen of red oak dieback. The dieback had developed where the branch was broken. The diseased bark was reddish brown, shrunken and cracked crosswise. The xylem tissue under the bark was discolored dark brown to black with fine streaks that extended into the living xylem below the base of the dieback region. Immature fungous fruit bodies were present in the diseased bark. The fungus was obtained in culture not only from dead discolored wood but from living discolored wood taken from an area approximately 1 inch below the base of the dieback region.

This *Cunninghamella* develops a sparse growth of yellowish-tan surface mycelium on corn meal agar. Conidia are borne in abundance on erect, tan conidiophores. Sporangia and sporangioles are lacking. The conidiophores, shown in fig. 47, are continuous with the hyphae and are tan, straight or curved, 75–300  $\times$  4–6  $\mu$ , frequently joined to the hyphae at right angles and apically swollen. The swollen apices of the conidiophores are 9–15  $\mu$  in diameter. Conidia, shown in fig. 47, are globose, 2.9–3.3  $\mu$  in diameter, tan and



Fig. 47.—Spores and conidiophores of *Cunninghamella*. The globose, tan, echinulate spores are produced on erect, tan, apically swollen conidiophores. X 200.

echinulate. The hyphae are coenocytic, hyaline and  $2.8-3.5 \mu$  in diameter.

This is believed to be the first report of a *Cunninghamella* cultured from diseased oak wood; no attempt has been made to secure zygospore production, and the species has not been determined.

### *Pestalotia*

*Pestalotia* was isolated from living tissue of a black oak twig that had blighted leaves attached to it. The twig was not discolored internally, but the leaves were dead and brown, and the petioles were purplish, shriveled and dead. No fungus was fruiting on the twig or on the attached petioles. *Cephalosporium* and *Dothiorella* as well as *Pestalotia* were obtained in culture from the twig.

This *Pestalotia* produces a sparse growth of light to dark tan surface and aerial mycelium on corn meal agar. Scattered acervuli are dark brown to black, ovoid to globose and  $300-400 \mu$  in diameter. The conidia, shown in fig. 48, are clavate, mostly straight, 5-celled, not constricted to slightly constricted at septa,  $20-30 \times 6-9 \mu$ , and with setae (usually 4) on each apical cell. Basal cells of the conidia are hyaline and ellipsoid to conoid. Apical

cells are hyaline and somewhat conoid. The intermediate cells, 3 in each conidium, are brown: the upper 2 dark brown and



Fig. 48.—Spores of *Pestalotia*. The clavate, 5-celled spores have hyaline apical and basal cells, and brown intermediate cells. There are usually 4 setae on the apical cell of each spore. X 200.

the lower 1 light brown to tan. The setae are  $25-40 \times 2.8-3.4 \mu$  and hyaline. The basidia are  $9-12 \times 1-2 \mu$  and hyaline.

This fungus was determined as *Pestalotia clavispora* Atk. (Atkinson 1897). The determination was verified by Dr. E. F. Guba.

### *Chaetomium*

A single isolation of *Chaetomium*, a culture of which is shown in fig. 49, was secured from brownish-black, discolored live wood of white oak. The discolored live



Fig. 49.—Culture of *Chaetomium*. Numerous brownish-black, ovoid, membranous perithecia develop on corn meal agar.

wood was adjacent to the base of a diseased region that showed dieback. Both *Chaetomium* and *Cytospora* were obtained from this specimen of dieback. The living wood from which *Chaetomium* was isolated showed black, discolored streaks that appeared to be identical with the black streaks that are commonly associated with *Dothiorella* infection of oak, as illustrated in fig. 3.

The *Chaetomium* discussed here produces appendaged brownish-black, ovoid, membranous perithecia in abundance on corn meal agar. The perithecia are 375–425  $\mu$  in diameter and 270–300  $\mu$  high. Appendages are dark brown to black, long wavy to spiral (wavy at base and spiral toward top of perithecia) and, above the perithecia, form dense tufts that measure 610–650  $\mu$  in diameter and 400–415  $\mu$  high. The asci are hyaline, ovoid to clavate, 8-spored, 40–50  $\times$  12–14  $\mu$ , and tapering to 6–7  $\mu$  in diameter near the base. Ascospores are olivaceous, 9.3–11  $\times$  7–9  $\mu$ , and lemon shaped.

This *Chaetomium* was identified as *Chaetomium globosum* Kunze by Dr. J. A. Stevenson.

### *Alternaria*

*Alternaria* was frequently obtained in culture from diseased bark and wood and occasionally from blighted petioles of black, bur, chinquapin, pin, post, red, shingle, swamp white and white oaks. Only one isolation of *Alternaria* was obtained from the living wood of a specimen of diseased oak—white oak. This specimen showed fine streaks of black discoloration that extended from a canker into the living wood a few inches up the branch. Large, black, carbonous and immature stromata, characteristic of the stromata of *Nummularia*, were present in the diseased tissue.

The *Alternaria* isolated from oak is similar to the *Alternaria* that is frequently obtained from diseased woody tissues of other hosts. A culture of the *Alternaria* from oak, grown on corn meal agar, is shown in fig. 50. The dense growth of surface and aerial mycelium is dark brown to almost black, and conidia are produced in abundance. The conidia are dark brown to almost black, 9–46  $\times$  6–12  $\mu$ , averaging approximately 21  $\times$  9  $\mu$ , muriform,

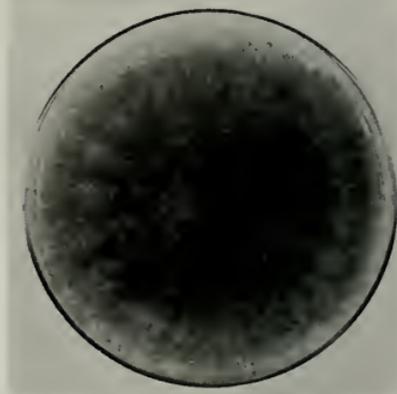


Fig. 50.—Culture of *Alternaria*. This fungus produces a dark brown mycelium that grows rapidly over the surface of corn meal agar.

catenulate, with 1 to 6, usually 3 to 4, transverse septa, and with none to 3, usually 1 to 3, longitudinal septa.

### *Penicillium*

*Penicillium*, fig. 51, was obtained in culture from specimens of diseased living and dead wood of oak, including red, white and an unidentified species. It was obtained from living wood that showed dark brown to black, discolored streaks and from dead wood at the junction of the

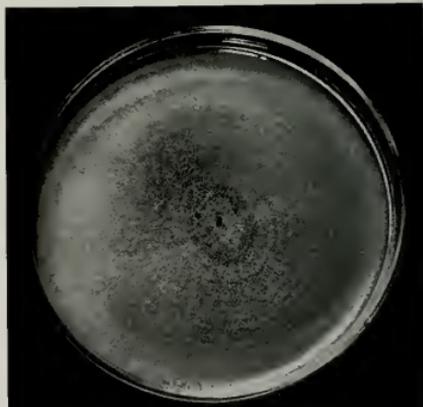


Fig. 51.—Culture of *Penicillium*. The gray to pale green mycelium develops on corn meal agar. Abundant production of spores causes the mycelium to have a granular surface appearance.

living and dead wood of a single dieback specimen of red oak. Scattered, black, erumpent stromata of *Cytospora* were present in the diseased bark of this particular specimen of dieback. The diseased bark was dark brown and was shrunken and attached closely to the underlying brown to black, discolored wood. *Penicillium*, *Cephalosporium* and an unidentified fungus were obtained from a second specimen of diseased red oak. Both *Penicillium* and *Dothiorella* were obtained from a specimen of diseased white oak; *Phoma* and bacteria, as well as *Penicillium*, from the diseased wood of the unidentified species of oak.

The conidia of *Penicillium* are hyaline,  $4.4-4.8 \times 3.4-3.8 \mu$ , ovoid to globose, and catenulate. The light green mycelium develops as concentric circles of sparse and dense growth that spreads rapidly on corn meal agar.

### SUMMARY

In this investigation it was found that in Illinois diseases of oak, namely, cankers, dieback, twig blight and root rot, are important in the decline and death of trees in nursery, shade and ornamental plantings and in native stands. Numerous fungi, of which 22 are described in this paper, were associated with cankers, deep wood infections, dieback and twig blight. Some of the fungi associated with cankers frequently were found fruiting on or were isolated from specimens of dieback and twig blight. It was apparent, in many cases, that canker infections developed into dieback when the infected branches were

completely girdled by the invading fungus.

The fungi associated most consistently with canker and dieback of oak were species of *Dothiorella*, *Coryneum*, *Cytospora*, *Nummularia*, *Diatrype* and *Phomopsis*. Those associated principally with canker diseases were species of *Phoma*, *Fusicoccum*, *Sphaeropsis* and *Bulgaria*. Those associated mainly with dieback diseases were species of *Coniothyrium* and *Pyrenochaeta*. *Dothiorella quercina* (Cke. & Ell.) Sacc. and *Coryneum Kunzei* Corda were the fungi associated most frequently with the diseases of oak. The fungi described in this paper can develop on dead oak wood as saprophytes. Many of them are potential parasites of oak trees, especially when the trees are growing under adverse conditions.

This investigation was made on diseased material of black, black jack, bur, chinquapin, Hill's, pin, post, red, shingle, swamp white and white oak.

Inoculation trials were made with *Dothiorella quercina* and with *Coryneum Kunzei*. Black, red and white oaks inoculated with *D. quercina* became infected and showed canker and dieback symptoms typical of those described as characteristic of *Dothiorella* canker and dieback. *D. quercina* was reisolated in pure culture from the inoculated oaks.

Two of the three white oaks inoculated with *Coryneum Kunzei* died within 1 month after they were inoculated; however, *C. Kunzei* was not reisolated from either of these two oaks. The third white oak inoculated with *C. Kunzei* showed no symptoms of infection at the end of 21 months.

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Volume 21

BULLETIN

Article 7

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# A Needle Blight of Austrian Pine

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Blighted needles of *Pinus nigra* var. *austriaca* with areas of original infection apparent in various parts of the needles. In this, the fall, stage, there often is a droplet of resin near the base of the lesion, and only the entostroma of the fungus is present.

## A Needle Blight of Austrian Pine

ROBERT L. HULBARY\*†

OVER a period of years, blighted needles of ornamental pines have constituted an important part of the diseased evergreen samples received by our laboratory for diagnosis. Needle blight is a well-known and widespread type of pine injury. It has been attributed to such environmental factors as frost, heat, intense sunlight, wind burning and drought, alone and in various combinations. Also, it has been attributed to the attack of certain fungi which have been classified chiefly in the genus *Septoria*. In the case of many of the samples submitted to us, however, it has been impossible to attribute the injury to any obvious cause or, when a fungus was present, to assign this fungus accurately to any described form.

Late in the fall of 1938, badly blighted needles of *Pinus nigra* Arn. var. *austriaca* Aschers. & Graebn. were obtained in northern Illinois. Superficially these needles appeared to have been injured by insects, for some of them seemed to have been punctured and there was oozing of resin near the bases of the blighted regions. Microscopic examination of transverse sections of these needles revealed, however, that the punctures were small epidermal ruptures due to the development of young fungous stromata. Since none of these stromata were mature, a method of wintering the infected material was devised, so that the needles could be examined periodically and the development of the fungus studied in detail.

### The Method

Twelve lots of infected needles, each lot consisting of 50 fascicles and including at least 10 badly blighted fascicles, were

placed in as many test tubes. The open ends of the test tubes were covered with cheesecloth, and each tube was labeled according to a predetermined order of examination. The test tubes were then laid on the ground, in a well-drained grassy spot, so as to be subject to out-of-door winter weather. They were tilted slightly to allow water to drain out of them rather than collect in them.

Beginning with December 23, 1938, one test tube of needles was examined every 15 days. Beginning with March 10, 1939, the interval between examinations was shortened to 10 days and, beginning with April 5, to 5 days, in order to follow in detail the rapid development of the fungus, which accompanied warm spring weather.

Also, cultures of the fungus were made on artificial media, but they failed to produce spore-bearing structures.

For the purpose of hastening development at certain times, diseased needles which had been weathered in test tubes for various periods were placed over moistened filter paper in sterile Petri dishes and kept at laboratory temperature. Conidiospores were produced by well-developed stromata in 4 to 5 days under these conditions.

### Development of the Fungus

The first evidence of infection visible on the needle is a small brown or tan region up to 10 mm. long, which in a few days involves all sides of the needle, is sharply delimited basally and fades distally into the normal green of the leaf (frontispiece). Such a region may develop anywhere on the needle; usually, however, it develops on the distal half. Often, if an infected needle is held before a light, the

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†The writer wishes to thank Dr. L. R. Tehon and Dr. J. C. Carter for helpful suggestions during the preparation of this paper.



Fig. 1.—Cross sectional view in the mesophyll in the region of a lesion, showing how the mycelium of the causal fungus grows within the mesophyll cells and brings partial disintegration of these cells.

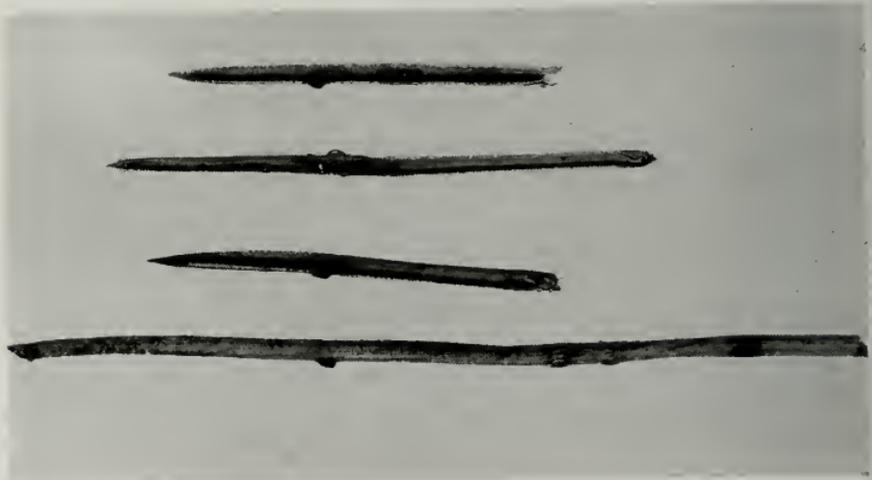


Fig. 2.—Fragments of infected needles after overwintering. Stromata appear in various stages of development. Not until the ectostroma is fully developed, as on the needle at the bottom of the illustration, do locules form and spores begin to be produced.

infected region will appear translucent.

The effect of the mycelium within a needle is evidently to cut off the flow of nutrients, or at least to weaken it, for the part of the needle distal to the infection soon dies. In the blighted part of a needle, hyphae can be found in abundance in and between the mesophyll cells, fig. 1; but they occur only rarely in the transfusion tissue and have not been found in the

laboratory from time to time during May had mature, sporulating, ruptured stromata.

### Morphology of the Fungus

The stroma of this needle-blighting fungus arises between the mesophyll and the hypodermis, fig. 3, and is seated on the mesophyll. The basal part of it is a



Fig. 3.—Section through two mature stromata. Origin of the stroma at the periphery of the mesophyll, dissolution of the hypodermis, variable extent of the entostroma, palisadelike arrangement of ectostromatic hyphae, poorly defined but mature and sporiferous locules, and adherent fragments of epidermis are evident.

vascular bundles. Although a fruiting body may appear at any point in the dead portion of a needle, it usually develops near the site of infection.

Under the out-of-door conditions described above, rapid enlargement of stromata began to take place on infected leaves between February 15 and 28, fig. 2. Between April 10 and 15, differentiated regions appeared in the upper parts of these stromata, in which the hyphae were lighter amber than elsewhere in the stromata. A month later these lighter regions had been transformed into locules, contained conidiophores and were producing conidia. Overwintered needles brought into the

pseudoparenchyma, from which hyphae push up between the hypodermal cells, usually dissolving them at the same time. These hyphae spread out laterally below the epidermis and form a compact, pseudoparenchymatic entostroma. Often the entostroma becomes extensive and has attachments to the mycelium in the mesophyll at several points. This multiple anchorage is suggestive of the dothideaceous family *Polystomellaceae* (Stevens 1925). Growth of the stroma, produced by the elongation of the stromatic hyphae, causes the epidermis above the stroma to split longitudinally, usually along a row of stomates. As the stroma emerges, it may

rip off sections of epidermis lying between rows of stomates; and these epidermal fragments usually remain attached to the top of the stroma.

The size and shape of the ectostroma are correlated with the vigor and extent of the hypostromatic mycelium, the thickness of the host cuticle and epidermis, and the ratio, as to volume of stromatic tissue, of ectostroma to entostroma. There naturally is, therefore, much variation.

The ectostroma ranges from 125 to 1,500  $\mu$  long, from 50 to 450  $\mu$  wide and up to 600  $\mu$  high. Usually it is elongated and loaf shaped, and its height often exceeds its width. It is nearly always oriented parallel to the longitudinal axis of the needle, fig. 2. The tips of stromatic hyphae, as they grow outward to form the ectostroma, secrete a gelatinous fluid. On the surface of the mature stroma this fluid hardens into a crusty, dark brown coating; within the stroma it cements together the walls of adjacent filaments.

The ectostroma consists of brown hyphae with numerous cross-walls. These hyphae are vertical, parallel and closely applied to each other. In microscopic view, they present the palisadelike appearance characteristic of the Dothideaceae. Cells of the stromatic hyphae are somewhat smaller than the cells of the hyphae in the mesophyll and transfusion tissues and are also darker.

The first indication of the development of sporiferous locules is a localized change in the color of hyphae in the upper part of the ectostroma. This change, which may occur in one to several places in each stroma, fig. 3, results in the formation of an ovate to tubular chamber which lies parallel to the longitudinal axis of the ectostroma. The tissue surrounding the locule is continuous with that of the stroma, and no distinct locular wall is developed. The continuity of tissue from stroma to locule wall also indicates relationship with the Dothideaceae. The locule is sporiferous around its entire inner surface.

Conidiophores arise directly as branches from the palisadelike hyphae forming the body of the stroma, and their bases form the poorly defined boundary of the locule. They are light amber to hyaline, unbranched, very numerous, densely packed and almost as long as the conidia but

slightly narrower. They cut off from their tips hyaline, septate, scoleciform spores which are blunt at the ends, straight or slightly curved and, in ratio of length to width, never greater than 10 to 1.

When the stroma is mature, a rift occurs along the top of each locule, which provides for the emission of spores. Spore dissemination is evidently aided by wind and by spattering raindrops.

### Taxonomy

A careful study has been made of all descriptions and, when possible, of exsiccated types or authentic specimens of the species which might resemble the Austrian pine fungus.

The majority of fungi associated with needle blight in various parts of the country have been placed in the genus *Septoria*. Spaulding (1909) reported *Septoria spaldicea* Patterson & Charles as the cause, in the East, of a blight of white pine needles similar to the brown-spot of longleaf pine. Graves (1914) associated *Ascochyta piniperda* Lind. (*Septoria parasitica* Hartig) with a blight occurring on young shoots of red and Norway spruce in North Carolina. Dearness (1928) described *Septoria pinicola* on blighted needles of the lower limbs of *Pinus virginiana* Mill. in Virginia. Hedgecock (1929) and Siggers (1932, 1934) studied *Septoria acicola* (Thüm.) Sacc. in connection with brown-spot on longleaf pine needles in the southeastern part of the United States and considered it a distinct threat to seedling plantations in that region. Boyce (1938, p. 98) has pointed out that brown-spot ranges westward to Kansas and Texas and occurs in Idaho on ponderosa pine and in Oregon on knobcone pine.

The taxonomy of *Septoria acicola*, the cause of brown-spot, has been given attention by several men; but it still is a moot question.\* At least two diseases, perhaps more, have been included under the term *Septoria* needle blight and attributed

\*After the manuscript of this article was submitted for publication, Paul V. Siggers defined the brown-spot disease, confirming the binomial *Lecanosticta acicola* (Thüm.) Syd. for the imperfect stage of the fungus associated with the disease and proposing the binomial *Scirrhia acicola* (Dearn.) Siggers for the perfect stage (Phytopath. 29(12): 1076-7, 1939). Later still, Frederick A. Wolf and W. J. Barbour also confirmed the binomial *Lecanosticta acicola* but considered the perfect state a *Systemema* and proposed for it the binomial *S. acicola* (Dearn.) Wolf & Barbour (Phytopath. 31(1):61-74, 1941).

to the brown-spot fungus. Sporiferous chambers contained in the top of a highly developed stroma such as that produced by the Austrian pine fungus are, however, conformable neither with the estromatic pycnidium of a typical *Septoria* nor with the non-septorioid structure of the brown-spot fungus.

Of Sydow's genus *Hemidothis* there are two species; both occur in Venezuela on the leaves of shrubby species of the melastomaceous genus *Miconia* Ruiz & Pav. From Sydows' (1916) original description and the exsiccati it is clear that the Austrian pine needle fungus cannot be assigned to *Hemidothis*, for in that genus the locules are partially liberated at the vertex, the stromata are arranged in concentric rings in the infected areas, and the conidia are much longer and narrower than in the pine fungus and are non-septate. Despite these points of difference, the dothideaceous structure of the stroma in both forms suggests that they may be related.

Clements & Shear (1931, p. 367) list *Septocyta* Petrak as a synonym of *Hemidothis* Sydow. Petrak's (1927) description of *Septocyta* indicates distinct similarities with the Austrian pine fungus; but the spores of *Septocyta* are long, threadlike and continuous. In *Septocyta* a dothideaceous relationship is suggested by the structure of the stroma and coniferous chambers.

Sydow & Petrak (1922) described a fungus associated with brown spots on pine needles in Arkansas and Oregon, which they later (1924) called *Lecanosticta acicola* (Thüm.) Sydow. According to Sydow's description, this fungus has a rim of hairlike appendages on its stroma, dark spores and branched conidiophores—characters markedly different from those of the Austrian pine fungus.

Hansborough (1936), in his paper on the Tympanis canker of red pine, has illustrations of the imperfect stage of *Tympanis*, which in arrangement of locules and in internal structure somewhat resemble the stromata of the Austrian pine fungus. He reports, however, that in *Tympanis* the conidiophores are branched and that the spores measure  $2-4 \times 1-2 \mu$  and are borne at the tips and on lateral branches of the conidiophores. The fact that the needle blight fungus on Austrian pine,

which is distinct generically as well as specifically from all previously described needle-blighting fungi, cannot be placed in any recognized genus warrants the proposal of a suitable genus. This genus is placed in the scolecosporous division of the Phomaceae and is closely associated therein with genera such as *Hemidothis* Sydow and *Septocyta* Petrak, which exhibit dothideaceous characteristics.

#### *Dothistroma* gen. nov.

Stroma dark, elongated, endogenous, becoming prominently erumpent and swollen, dothideoid, with a stalk extending into the substratum; composed internally of densely arranged, vertical, parallel, septate hyphae. Locules separate, one to several in the upper part of the stroma, ovate to tubular, not distinguished from the surrounding stroma, the entire inner face sporiferous. Conidiophores simple, arising directly from stromatic hyphae. Conidia hyaline, scoleciform, several-septate.

Stroma atratum, elongatum, endogenum, mox multo exsertum et bullatum, dothideoideum, cum pede in substrato extante, intus hypharum compactarum, verticalium, parallelarum compositum. Loculi sejuncti, unus vel plures in parte superiore stromatis, ovati usque tubulosi, non stromate circumdante distincti, in facie interna omnino sporiferi. Conidiophora simplicia, ex hyphis stromatum directe orientata. Conidia hyalina, scoleciforma, nonnulla-septata.

#### *Dothistroma Pini* sp. nov.

Stromata seated on the mesophyll, forming more or less extensive hypostromata between mesophyll and hypodermis, erumpent through rents in the epidermis, oriented parallel to the longitudinal axis of the needle, dull dark brown, 125-1500  $\mu$  long, 50-450  $\mu$  wide, up to 600  $\mu$  high. Locules oriented parallel to the longitudinal axis of the stroma, without a distinct wall. Conidia hyaline, scoleciform, 1- to 5- but usually 3-septate, blunt at the ends, straight or slightly curved, 16.5-29  $\times$  3.5  $\mu$ . Conidiophores numerous, approximately the same size as the conidia, hyaline or amber, dense, unbranched, producing conidia at their tips.

Stromatibus in mesophyllo stantibus, inter mesophyllum et hypodermidem hypostromatem plus minus magnum forantibus, per scissos in epidermide erumpentibus, cum axe longitudinali

foliorum parallelis, atrofuscis, 125-1500  $\mu$  longis, usque 600  $\mu$  altis; loculis cum axe longitudinali stromatum parallelis; conidiis hyalinis, scoleci-formibus, 1- usque 5- frequentissime 3-septatis, apicibus rotundatis, rectis vel curvulis, 16.5-29 x 3.5  $\mu$ ; conidiophoris numerosis, conidiis subaequantibus, hyalinis vel succineis, compactis, simplicibus, conidios in apicibus generantibus.

Type specimen: Collected by J. C. Carter, De Kalb County, Illinois, November 29, 1938, on *Pinus nigra* Arn. var. *austriaca* Aschers. & Graebn., Ill. Nat. Hist. Surv. Acc. No. 27,093.

Through the courtesy of Dr. Paul V. Siggers, the following specimens have been examined and found conspecific with the above: (1) on *Pinus flexilis* James, Waterloo State Forest, Ohio, February 26, 1936, C. C. Green col.; (2) on *P. nigra* Arn. var. *austriaca* Aschers. & Graebn., Springfield, Ohio, May 8, 1932, R. L. Beard col.; (3) Miami, Oklahoma, August, 1934, Moore col.; (4) Sherman Nursery, Charles City, Iowa, January, 1934, B. C. Helmick col.; (5) on *P. nigra* var. *calabrica* Schneid., Waterloo State Forest, Ohio, January 11, 1936, C. C. Green col.; (6) on *P. resinosa* Ait.,

Old Man's Grove, Hocking County, Ohio, February 26, 1936, C. C. Green col.

### Summary

In blighted needles of Austrian pine collected in northern Illinois in the fall of 1938, immature stromata indicated the cause of the blight. Infected needles were wintered out-of-doors and examined periodically. The stromata remained quiescent through the winter but very early in the spring began to develop and by March 1 had emerged as strongly eruptent, loaf-shaped structures. A month and a half later, pycnidial locules were becoming differentiated, and by May 15 conidia were being produced.

The distinctive dothideaceous structure of the stroma distinguished the fungus from every described group. For it the new genus *Dothistroma* is proposed.

The well-marked dothideaceous structure of the stroma and the spore characters place the new fungus in the scolecosporous group of the Phomaceae close to *Hemidothis* Sydow and *Septocya* Petrak.

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Contents: I. Nearctic alder flies of the genus *Sialis* (Megaloptera, Sialidae), by H. H. Ross; and II. Descriptions of Plecoptera, with special reference to the Illinois species, by T. H. Frison.
- Volume 21, Article 4.—Descriptions of Nearctic Caddis Flies (Trichoptera), with special reference to the Illinois species. By Herbert H. Ross. March, 1938. 84 pp., frontis. + 123 figs., foreword, index. \$1.00.
- Volume 21, Article 5.—Preliminary Studies on Parasites of Upland Game Birds and Fur-Bearing Mammals in Illinois. By W. Henry Leigh. August, 1940. 10 pp., frontis. + 2 maps.

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Volume 21

BULLETIN

Article 8

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# Duck Food Plants of the Illinois River Valley

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FRANK C. BELLROSE, JR.



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URBANA, ILLINOIS  
August 1941



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Duck flight at Lake Chautauqua, in the Illinois River valley a few miles above Havana. Some of the ducks, most of which are mallards, are dropping into the marsh smartweed beds.

# Duck Food Plants of the Illinois River Valley

FRANK C. BELLROSE, JR.

EACH year several million ducks pass through the Illinois River valley, scene of one of the greatest concentrations of migrating waterfowl in the United States. Over 90 per cent of the fall flight is made up of mallards, which have in recent years found an abundant food resource in the mechanically picked corn fields lying adjacent to the bottomland lakes. Even though corn amounts to a considerable percentage of the plant diet of the mallard,\* natural waterfowl feeding grounds still are important. Diving ducks and most baldpates, gadwalls, teal and pintails, as well as large numbers of mallards, congregate principally where natural food plants are abundant.

For the past 5 years the necessity for improvement of natural food beds in the Illinois River valley has been apparent. The large amount of money and effort being spent on artificial propagation of waterfowl food plants prompted the inauguration in 1937 of a study (Bellrose 1938) to determine the abundance and interrelation of aquatic plants and to discover optimum methods for management.

## Acknowledgments

Mr. Arthur S. Hawkins of the Illinois Natural History Survey staff has helped in many ways with the present study. Mr. Francis M. Uhler, Associate Biologist, U. S. Fish and Wildlife Service, has given many valuable suggestions and sound criti-

cisms. Messrs. Homer Bradley and Milferd Smith of the U. S. Fish and Wildlife Service have cooperated in studies made on the Lake Chautauqua National Wildlife Refuge.

## Illinois River Hydrography

The Illinois River is formed by the junction of the Des Plaines and Kankakee rivers in eastern Grundy County, near Channahon, Ill. From there, it flows 60 miles almost due west to Bureau, where it turns abruptly, flowing southwestward into the Mississippi River at Grafton. Its total length is about 270 miles, extending diagonally across the state from northeast to southwest. The major waterfowl habitat is located between Hennepin and Meredosia, a distance of about 140 miles, fig. 1.

Because its fall is slight—only 0.267 foot per mile over its length and 0.137 foot per mile from Utica to the mouth, a distance of 230 miles—the Illinois River is not able to carry its load and is in the process of building up its bottoms. Its immediate banks are higher than the surrounding bottomlands farther from the channel because in flood times the swift water of the channel drops its load where it meets the slower water of the flooded bottomlands.

The water level of the river and connected bottomland lakes fluctuates greatly with the season. The seasonal variation in water level over a 20-year period is shown in fig. 2. This variation appears to have been very similar throughout the valley. It will be seen in fig. 2 that the general seasonal trend is for a spring rise to occur in February and high water to continue through May; for low water

\*Harry G. Anderson, Junior Biologist, Illinois Natural History Survey, State Department of Conservation and U. S. Fish and Wildlife Service, working on Federal Aid Project 2-R, examined 822 mallard gizzards in 1938, 1,291 in 1939 and 428 in 1940. Corn constituted 40 per cent by volume of the organic food in the 1938 gizzards, 54 per cent in the 1939 gizzards and 24.6 per cent in the 1940 gizzards. The marked reduction in the per cent of corn in the 1940 gizzards was due to the abundance in that year of moist soil duck food plants in the central part of the Illinois River valley.

levels to occur during July, August and September; and for a small fall rise (25 per cent of the spring rise) to take place during October and November. Since the water generally fluctuates greatly during the plant growing season, it has a tremendous effect on aquatic life.

Because of drought, dredging, changes in the amount of water diverted from Lake Michigan, and creation of navigation dams on the Illinois River, the water levels of the river valley have undergone radical changes during the past few years. The yearly trend of water levels in the Illinois River, 1919-1939, is shown in fig. 3. It should be noted that, as a result of drought and a reduction in the amount of water diverted from Lake

Michigan, the level was considerably lower after 1930 than in the years just previous.

The seasonal fluctuations in water levels during 1938, 1939 and 1940, fig. 6, were abnormal in comparison with the seasonal trend represented in fig. 2. During the fall months of the years represented in fig. 6, there was no appreciable, consistent rise in the water levels. Between Nov. 28 and Dec. 17, 1940, a small rise occurred in the waters of the Illinois River at Havana. This was caused by the much publicized increase of about 9,000 cubic feet per second in diversion from Lake Michigan. Heavy precipitation resulted in high water throughout June and July, 1938, and from the middle of June

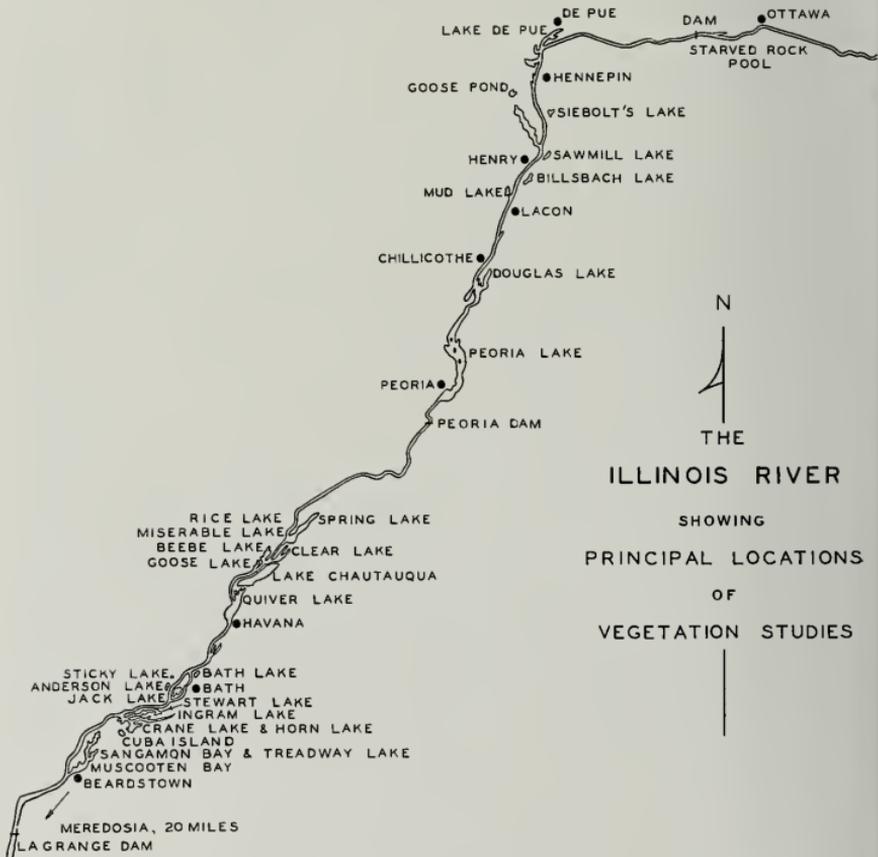


Fig. 1.—Principal concentration area of migratory waterfowl in the Illinois River valley. The map indicates the location of lakes involved in waterfowl food plant studies; also the location of dams and of cities and villages significant in this study.

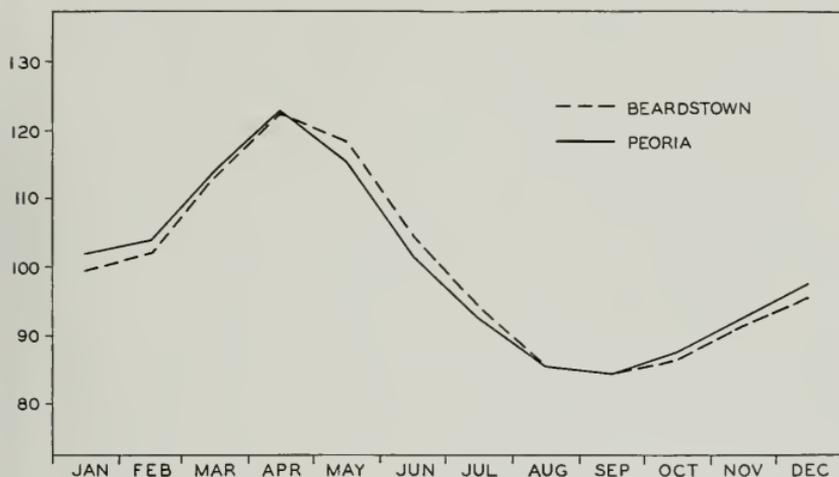


Fig. 2.—Index of seasonal variation in Illinois River water levels over a 20-year period, 1920-39, at Peoria and Beardstown. Figures indicate per cent of variance from normal, which is 100 per cent.

to nearly the middle of July, 1939. In 1940, there was a fluctuation of less than 2 feet of water at Havana, during May and June, and only relatively minor variations through the other months of the year.

Six navigation dams extend across the Illinois River system. Four dams, of the gate type, form navigation pools on the upper reaches of the Illinois and Des Plaines rivers. Two dams, of the wicket type, are located in the central section of the river. Only two lakes on the upper Illinois River are important waterfowl areas; they were formed by dams at

Starved Rock and Dresden Island. In both these lakes, beds of sago and longleaf pondweeds, wild celery, duck potato and other aquatic plants have in recent years become established as a result of the reduction of turbidity, the reduction of current and the stabilization of water levels by the dams.

The two wicket dams, one situated a short distance below Peoria and the other, the La Grange dam, below Beardstown, are in the center of the Illinois River waterfowl habitat. They therefore play an important role in any waterfowl habi-



Fig. 3.—Trend in water levels of the Illinois River at Havana, 1919-39. The profile represents a moving average of three. Scale in feet.

tat management program; they not only increase the size of certain waterfowl resting grounds, but they affect waterfowl food plants. The Peoria dam was placed in operation in December, 1938, and the La Grange or Beardstown dam on July 27, 1939. Figs. 4 and 5 show a stabilization of water levels above the dams, except at flood stages, after each dam was placed in operation. Fig. 6 shows marked fluctuations of water levels in 1938 and 1939 at Havana, midway between the dams. The fact that fluctuations shown for 1940 at Havana were relatively small may be accounted for by the lack of heavy precipitation and the reduced, even flowage from

Lake Michigan, rather than by the dams.

Water of some of the fluviatile lakes does not fluctuate with that of the river, for dams and natural and artificial levees retain the water during drought periods. The best example of this condition is at the Lake Chautauqua National Wildlife Refuge, where artificial levees stabilize the water level, fig. 7, except during periods of unusually high water, at which time the water rises over the spillways. From Feb. 14 to May 23, 1939, the water was above the 437.5-foot spillway elevation; it is obvious that during this period the water level inside the Chautauqua Refuge was practically identical with that of the river.

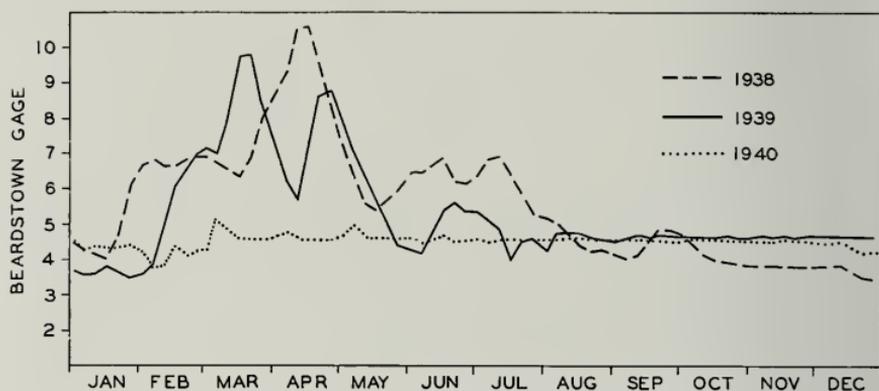


Fig. 4.—Seasonal fluctuation of Illinois River water levels at Beardstown, 1938, 1939 and 1940. Scale in feet. The decreased fluctuation in water levels, except at flood stages, in 1939 and 1940, is a direct result of the La Grange dam, placed in operation July, 1939.

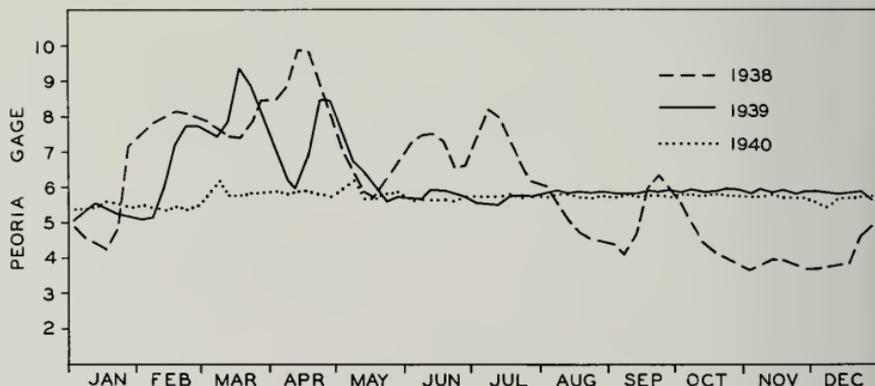


Fig. 5.—Seasonal fluctuation of Illinois River water levels at Peoria, 1938, 1939 and 1940. Scale in feet. The decreased fluctuation in water levels, except at flood stages, 1939 and 1940, is a direct result of the Peoria dam, placed in operation December, 1938.

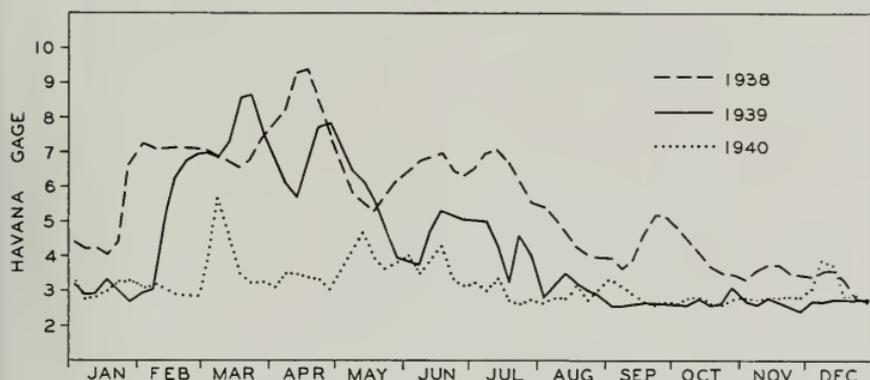


Fig. 6.—Seasonal fluctuations of Illinois River water levels at Havana, 1938, 1939 and 1940. Scale in feet. The river levels at Havana, midway between the La Grange and Peoria dams, apparently were little affected by these dams.

On either side of the river channel, from De Pue to Meredosia, numerous fluviatile lakes, ranging in size from 60 to 6,500 acres, dot the bottomlands, fig. 1. Together these lakes form at low stage about 56,000 acres of water surface, while the river channel covers an additional 15,000 acres. In relation to vegetation, lakes in the Illinois River valley may readily be grouped under three major types: (1) those with stable waters, except during flood stages; (2) those with fairly stable water levels, in which the water is high during flood times but is more or less retained during drought periods; and (3) those with widely fluctuating water levels, in which the water rises and falls with that

of the river. The lakes of the last type usually have a wide entrance connecting the lower end of the lake with the river, while the land separating lake from river is low and flat, fig. 8.

Prior to 1940, lakes with stabilized water levels covered approximately 5,680 acres between Ottawa and Meredosia. These included the Starved Rock Pool, formed by a navigation dam on the Illinois River below Ottawa; the remnant of Spring Lake, inclosed by levees within the Spring Lake Drainage District near Banner; and Lake Chautauqua, an abandoned drainage district above Havana.

Prior to 1940, lakes with semistabilized water levels covered about 7,920 acres ad-

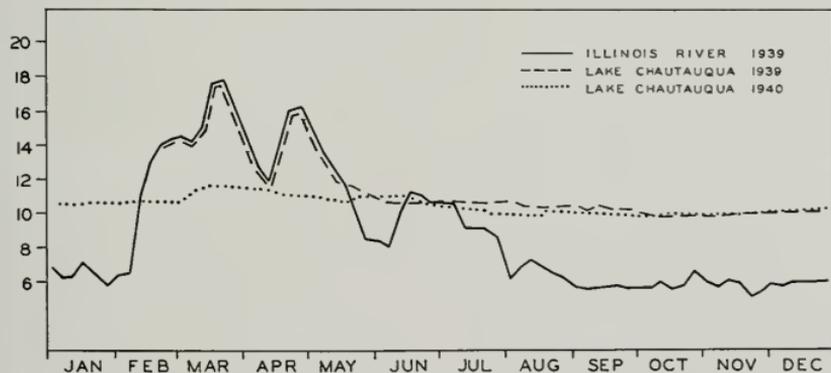


Fig. 7.—Water levels, in feet, of the Illinois River in 1939 and of Lake Chautauqua in 1939 and 1940. While water levels of the river fluctuate considerably, a stabilized water level is maintained in Lake Chautauqua except during flood periods such as occurred in the spring of 1939.

jacent to the Illinois River. These lakes were Douglas, near Chillicothe; Rice, Beebe and Goose, near Banner; Cuba Is-

wine, Sawmill, Siebolt's and Billsbach, near Henry; Mud and Wightman's, near Sparland; Upper and Lower Peoria, above

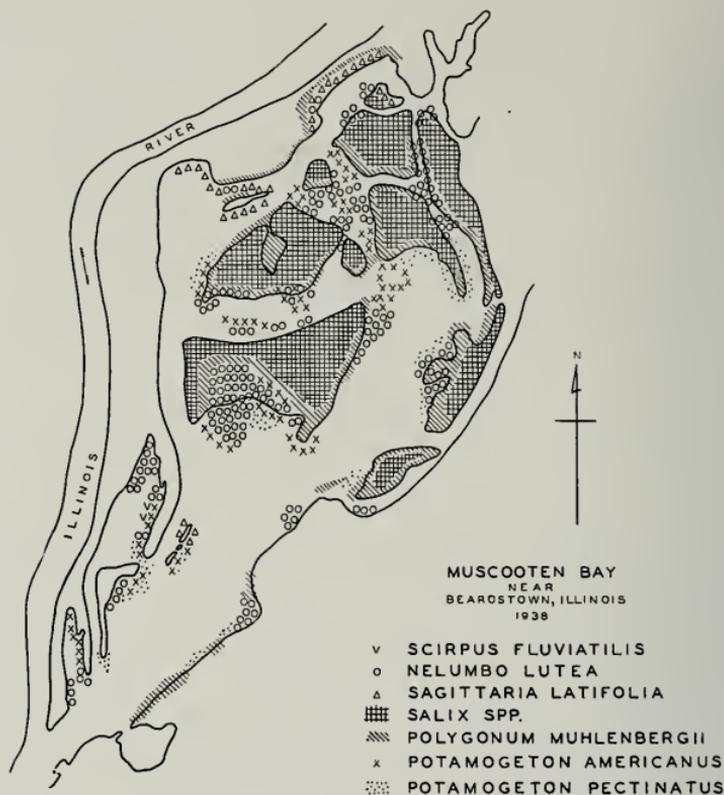


Fig. 8.—Vegetation map of Muscooten Bay, showing location of principal duck food beds. 1938. Muscooten Bay in 1938 had a scarcity of waterfowl food plants because of fluctuating water levels and high turbidity. A few patches of longleaf pondweed (*Potamogeton americanus*) occurred scattered among the islands of willow (*Salix* spp.), which protected them from the wind and thereby reduced the turbidity. Note that American lotus (*Nelumbo lutea*) and marsh smartweed (*Polygonum Muhlenbergii*) were the two most common waterfowl food plants. However, many beds of marsh smartweed failed to produce seed because by the time of flowering the water had receded from the beds. As shown on the map a few beds of duck potato (*Sagittaria latifolia*) occurred despite the fluctuating water levels.

land, near Chandlerville; and Jack\* and Anderson, near Sheldons Grove.

Prior to 1940, lakes with fluctuating water levels greatly predominated in area throughout the valley. This type covered about 43,000 acres and included the following lakes; Lake De Pue, Spring Lake and Goose Pond, near Bureau; Senach-

Peoria; Clear and Quiver, above Havana; Muscooten Bay, Treadway Lake, Sangamon Bay, Crane, Ingram and Stewart lakes, above Beardstown; and Meredosia Bay, above Meredosia. Upper and Lower Peoria lakes were then, and are, merely broad expanses of the river.

In 1940, because of the absence of spring floods and because of stabilization of water levels by the Peoria and La Grange dams, the character of many lakes

\*Regarded as a fluctuating lake in 1938; further observation in 1940 showed it belonged to the semistabilized type.

changed, with a resulting change in waterfowl food plants.

Hydrographically, Douglas Lake changed from the semistabilized to the stabilized type; Upper and Lower Peoria lakes, Mud and Wightman's lakes and Muscooten Bay from the fluctuating to the stabilized type; Goose Pond and Senachwine, Sawmill, Siebolt's, Billsbach and Treadway lakes changed from the fluctuating type to the semistabilized type of lake.

### Methods of Study

During the summer and fall of 1937, a general survey was made of the vegetation of certain lakes along the Illinois River (Bellrose 1938). In 1938, the scope of the study was broadened to include ascertaining the abundance of aquatic plants. Maps showing the area covered by various plant beds were constructed and a planimeter was then used to measure the area covered by each important plant spe-

Table 1.—Abundance of duck food plants in Class I lakes of the Illinois River valley—lakes with stable water levels. Figures in acres.

SPECIES OF PLANT	STARVED ROCK POOL		SPRING LAKE	LAKE CHAUTAUQUA		
	1939	1940	1938	1938	1939	1940
Muskgrass.....			trace			
<i>Chara</i> sp.						
Cattail.....	42.0	42.7				
<i>Typha angustifolia</i>						
Giant bur-reed.....	0.5			trace		
<i>Sparganium eurycarpum</i>						
Small pondweed.....					trace	7.8
<i>Potamogeton pusillus</i>						
Sago pondweed.....	12.0		trace	295.0	415.0	48.6
<i>Potamogeton pectinatus</i>						
Longleaf pondweed.....	10.0			452.0	146.3	218.0
<i>Potamogeton americanus</i>						
Bushy pondweed.....			78.0	trace	7.3	8.6
<i>Najas guadalupensis</i>						
Duck potato.....	18.6	60.8	25.0	9.0	32.0	23.4
<i>Sagittaria latifolia</i>						
Waterweed.....	trace		72.0			
<i>Anacharis canadensis</i>						
Wild celery.....	2.0	12.1				
<i>Vallisneria spiralis</i>						
Wild rice.....			0.5			
<i>Zizania aquatica</i>						
River bulrush.....	4.0	2.6	30.0	40.0	36.0	21.0
<i>Scirpus fluviatilis</i>						
Softstem bulrush.....	trace	trace				
<i>Scirpus validus</i>						
Greater duckweed.....	ab.		com.			
<i>Spirodela polyrhiza</i>						
Lesser duckweed.....	com.					
<i>Lemna minor</i>						
Mud plantain.....	1.5		25.0	trace	trace	trace
<i>Heteranthera dubia</i>						
Marsh smartweed.....				132.5	159.0	139.6
<i>Polygonum Muhlenbergii</i>						
Coontail.....	2.0		193.0	402.0	290.0	158.9
<i>Ceratophyllum demersum</i>						
American lotus.....			20.0	6.0	78.0	207.4
<i>Nelumbo lutea</i>						
Creeping water primrose.....						trace
<i>Jussiaea diffusa</i>						
Bladderwort.....			trace			
<i>Utricularia</i> sp.						

Note: ab. = abundant; com. = common



Table 2. (Continued)

SPECIES OF PLANT	GOOSE POND		SIEBOLT'S LAKE		SAWMILL LAKE		MUD LAKE		DOUGLAS LAKE		
	1939	1940	1938	1939	1940	1938	1939	1940	1938	1939	1940
Coontail.....	trace	33.8							32.0	40.0	103.2
<i>Ceratophyllum demersum</i>											
White water lily.....									6.0	54.0	24.7
<i>Castalia tinctoria</i>											
American lotus.....	159.0	227.5			64.0	40.5	44.6		94.0	132.0	276.6
<i>Nelumbo lutea</i>											
Marsh mallow.....	1.5					2.2					
<i>Hibiscus militaris</i>											
Spanish needles.....								0.5			
<i>Bidens</i> sp.											

cies. A similar procedure was followed in 1939 and 1940. The resulting data appear in tables 1-5.

Base maps for plotting the vegetation, water depths and transparency readings were traced from U. S. Engineer, Illinois River valley waterway, maps scaled 1 inch to 1,000 feet. Plant beds were drawn by aspection and rough triangulation, often aided by exact outlines of marsh growth on the base map. I have no delusions that this method approaches perfection, but after rechecking certain areas during 1939 and 1940 I feel that a maximum error in data of emergent species is 10 per cent, and in data of submerged and floating aquatic plant beds is 25 per cent. Density of small, scattered patches of aquatic species, such as coontail, sago and longleaf pondweeds,\* was determined by measuring the size of patches and estimating the number of patches per unit area.

#### Effect of Various Water Levels

Botanically, as well as hydrographically, lakes in the Illinois River valley may be placed in classes based on water levels. As lakes change from one hydrographic class to another, there is a lag of varying lengths in the aquatic vegetation change to conform with the altered water levels. Thus, while the water levels of Douglas Lake changed from semistabilized to stabilized conditions in 1939, the plant communities remained largely typical of a semistabilized area throughout 1940. On the other hand, aquatic plants of such fluctuating lakes as Siebolt's and Sawmill, and of Goose Pond, approached the characteristic of a semistabilized type in a single year. The plants of these lakes were classified with vegetation of semistable waters in table 8.

For convenience, lakes have been classified as follows: Class I, lakes with stable waters; Class II, lakes with semistable waters; and Class III, lakes with fluctuating waters.

Certain plants are more tolerant of environmental conditions than others and may exist under a variety of conditions. Tables 6-8 reveal American lotus, river bulrush, marsh smartweed and duck potato to be among the most tolerant aquatic spe-

\*Common names of plants are used throughout the text. The equivalent scientific names are included in the tables and in the appendix.



Table 4.—Abundance of duck food plants in Class III lakes of the Illinois River valley—lakes with fluctuating water levels. Figures in acres.

SPECIES OF PLANT	LAKE DE PUE	SPRING LAKE	BILLS-BACH LAKE	STEWART LAKE	INGRAM LAKE	SANGAMON BAY		TREADWAY LAKE		MUSGOOTEN BAY	
	1939	1939	1938	1938	1939	1938	1939	1938	1939	1938	1939
Giant bur-reed <i>Spartanium eurycarpum</i>	0.7										
Sago pondweed <i>Potamogeton pectinatus</i>				2.8	trace		0.5		2.0	trace	20.4
Longleaf pondweed <i>Potamogeton americanus</i>				2.0					0.8	0.9	trace
Duck potato <i>Sagittaria latifolia</i>	1.5	0.5			0.5		0.2		2.5	19.0	1.5
Duck millets <i>Echinochloa crusgalli</i> <i>Echinochloa frumentacea</i>					15.0				47.4	37.3	34.2
Nutgrasses <i>Cyperus strigosus</i> <i>Cyperus erythrorhizos</i>								trace	trace		
Spike rush <i>Eleocharis palustris</i>									3.8	4.0	
River bulrush <i>Scirpus fluviatilis</i>	134.0	198.0	48.0			16.0	9.8		29.0		4.35
Marsh smartweed <i>Polygonum Muhlenbergii</i>	37.0				27.0	5.0			40.2	3.6	65.2
Marsh mallow <i>Hibiscus militaris</i>	4.9										
Coontail <i>Ceratophyllum demersum</i>					trace						
American lotus <i>Nelumbo lutea</i>				297.0	642.0	80.0	53.8	96.8	58.0	142.7	136.8



cies. Other plants are unable to live under varying environmental conditions. Bushy pondweed, cattail, teal grass, millet and water hemp, as shown by tables 6-8, belong to this second type.

Examination of tables 1-8 discloses that water levels are a major influence on the Illinois River valley waterfowl habitat. Changes in levels have caused the decline or extinction of many areas as duck feeding grounds, and the creation or improvement of others. A few grounds have remained stabilized, but the majority have been subject to yearly, if not seasonal, changes.

**Class I Lakes, Stabilized Waters.**—Tables 1 and 2, as well as 6, 7 and 8, affirm the importance of stabilized water levels to submerged aquatic plants. In lakes with stable waters, the pondweeds, sago, longleaf and bushy, covered a larger percentage of area than any other aquatic

plant, according to these last three tables.

Lake Chautauqua, figs. 9 and 10, is the best example of this class. Levees and control gates aid in maintaining a fairly constant water level, which resulted in the formation of large beds of pondweeds and coontail in 1938.

In 1938 and early 1939, Douglas Lake was a semistabilized lake; the other bodies of water represented in table 2 were in the fluctuating class. With a greater stabilization of water levels by the Peoria dam, fig. 5, a decided shift toward submerged aquatic plants was noted in these lakes in 1939 and 1940. Sago pondweed acreage increased from 1 to 13 acres at Goose Pond, from 0 to over 281 acres at Siebolt's Lake and from 0 to 5 to 115 acres at Sawmill Lake. Waterweed increased from a trace to 6.4 acres at Douglas Lake. Coontail increased from a trace to 33.8 acres at Goose Pond, from 0 to 0.8 acre at Sie-

Table 6.—Aquatic plants and their relative abundance, expressed in percentage of total acreage of plants in 2 stable, 9 semistable and 8 fluctuating lakes of the Illinois River valley, August, 1938.

SPECIES OF PLANT	STABLE	SEMISTABLE	FLUCTUATING	TOTAL
American lotus.....	0.5	18.3	11.9	30.7
<i>Nelumbo lutea</i> .....				
River bulrush.....	0.6	20.7	4.5	25.8
<i>Scirpus fluviatilis</i> .....				
Marsh smartweed.....	1.6	9.3	1.4	12.3
<i>Polygonum Muhlenbergii</i> .....				
Coontail.....	7.3	4.6		11.9
<i>Ceratophyllum demersum</i> .....				
Longleaf pondweed.....	5.6	trace	0.4	6.0
<i>Potamogeton americanus</i> .....				
Duck potato.....	0.4	2.9	1.4	4.7
<i>Sagittaria latifolia</i> .....				
Sago pondweed.....	3.6	trace	0.2	3.8
<i>Potamogeton pectinatus</i> .....				
Smartweeds.....		1.6		1.6
<i>Polygonum</i> spp.....				
Bushy pondweed.....	1.0			1.0
<i>Najas guadalupensis</i> .....				
Waterweed.....	0.9			0.9
<i>Anacharis canadensis</i> .....				
Spike rush.....			0.6	0.6
<i>Eleocharis palustris</i> .....				
Mud plantain.....	0.3			0.3
<i>Heteranthera dubia</i> .....				
Rice cut-grass.....		0.2		0.2
<i>Leersia oryzoides</i> .....				
Marsh cord grass.....		0.2		0.2
<i>Spartina Michauxiana</i> .....				
Wild rice.....		trace		
<i>Zizania aquatica</i> .....				
White water lily.....		trace		
<i>Castalia tuberosa</i> .....				
Giant bur-reed.....			trace	
<i>Sparganium eurycarpum</i> .....				
Total.....	21.8	57.8	20.4	100.0

bolt's Lake and from 32 to 40 to over 103 acres at Douglas Lake. With the greater stabilization of the water, wild rice occurred in abundance during 1939 and 1940 at Douglas Lake.

Cursory inspection of Peoria Lake in 1938 revealed a few scattered beds of bushy, sago and longleaf pondweeds, and one wild celery bed of approximately 10 acres. The wild celery bed was located

Table 7.—Aquatic plants and their relative abundance, expressed in percentage of total acreage of plants in 3 stable, 7 semistable and 9 fluctuating lakes of the Illinois River valley, August, 1939.

SPECIES OF PLANT	STABLE*	SEMISTABLE	FLUCTUATING	TOTAL
River bulrush..... <i>Scirpus fluviatilis</i>	0.6	21.4	14.1	36.1
American lotus..... <i>Nelumbo lutea</i>	0.1	16.3	12.0	28.4
Marsh smartweed..... <i>Polygonum Muhlenbergii</i>	1.6	4.6	1.8	8.0
Coontail..... <i>Ceratophyllum demersum</i>	4.5	3.1	trace	7.6
Sago pondweed..... <i>Potamogeton pectinatus</i>	4.2	trace	0.2	4.4
Wild millet..... <i>Echinochloa crusgalli</i>			3.8	3.8
Duck potato..... <i>Sagittaria latifolia</i>	0.7	0.3	1.2	2.2
Longleaf pondweed..... <i>Potamogeton americanus</i>	1.5	trace	trace	1.5
Water hemp..... <i>Acnida tuberculata</i>			1.5	1.5
Rice cut-grass..... <i>Leersia oryzoides</i>		0.8	0.2	1.0
White water lily..... <i>Castalia tuberosa</i>		0.9		0.9
Wild rice..... <i>Zizania aquatica</i>		0.8		0.8
Bushy pondweed..... <i>Najas guadalupensis</i>	0.8	trace		0.8
Waterweed..... <i>Anacharis canadensis</i>	0.7			0.7
Nutgrasses..... <i>Cyperus strigosus</i> <i>Cyperus erythrorhizos</i>			0.5	0.5
Giant bur-reed..... <i>Sparganium eurycarpum</i>		0.1	0.3	0.4
Walter's millet..... <i>Echinochloa Walteri</i>			0.3	0.3
Mud plantain..... <i>Heteranthera dubia</i>	0.3			0.3
Spike rush..... <i>Eleocharis palustris</i>			0.2	0.2
Marsh cord grass..... <i>Spartina Michauxiana</i>		0.2		0.2
Cattail..... <i>Typha angustifolia</i>	0.2			0.2
Pickernelweed..... <i>Pontederia cordata</i>		0.1		0.1
Marsh mallow..... <i>Hibiscus militaris</i>			0.1	0.1
Reed cane..... <i>Phragmites communis</i>		trace		
Nodding smartweed..... <i>Polygonum lapathifolium</i>		trace	trace	
Cocklebur..... <i>Xanthium</i> sp.			trace	
Total.....	15.2	48.6	36.2	100.0

\*Cursory inspection showed vegetation in Spring Lake in 1939 similar to that in 1938; so its 1938 figures were added to this table.

Table 8.—Aquatic plants and their relative abundance, expressed in percentage of total acreage of plants in 2 stable, 9 semistable and 5 fluctuating lakes of the Illinois River valley, August, 1940.

SPECIES OF PLANT	STABLE	SEMISTABLE	FLUCTUATING	TOTAL
River bulrush.....	0.14	28.62	0.97	29.73
<i>Scirpus fluviatilis</i>				
American lotus.....	1.92	20.40	1.34	23.66
<i>Nelumbo lutea</i>				
Water hemp.....		1.16	11.52	12.68
<i>Acnida tuberculata</i>				
Coontail.....	1.63	6.10	0.05	7.78
<i>Ceratophyllum demersum</i>				
Duckweeds.....		5.04	..	5.04
<i>Spirodela polyrhiza</i>				
<i>Lemna minor</i>				
Sago pondweed.....	0.65	3.92	0.05	4.62
<i>Potamogeton pectinatus</i>				
Marsh smartweed.....	1.30	2.45	0.18	3.93
<i>Polygonum Muhlenbergii</i>				
Longleaf pondweed.....	2.04	0.05	..	2.09
<i>Potamogeton americanus</i>				
Nutgrasses.....		0.09	1.83	1.92
<i>Cyperus strigosus</i>				
<i>Cyperus erythrorhizos</i>				
Duck millets.....			1.66	1.66
<i>Echinochloa crusgalli</i>				
<i>Echinochloa frumentacea</i>				
Rice cut-grass.....		0.09	1.56	1.65
<i>Leersia oryzoides</i>				
Nodding smartweed.....		0.07	1.48	1.55
<i>Polygonum lapathifolium</i>				
Duck potato.....	0.78	0.21	0.29	1.28
<i>Sagittaria latifolia</i>				
Walter's millet.....		0.03	0.63	0.66
<i>Echinochloa Walteri</i>				
Cattail.....	0.39	..	..	0.39
<i>Typha angustifolia</i>				
Wild rice.....		0.29	..	0.29
<i>Zizania aquatica</i>				
Pickerelweed.....		0.26	..	0.26
<i>Pontederia cordata</i>				
White water lily.....		0.23	..	0.23
<i>Castalia tuberosa</i>				
Wild celery.....	0.12	..	..	0.12
<i>Vallisneria spiralis</i>				
Spanish needles.....		0.11	..	0.11
<i>Bidens</i> sp.				
Bushy pondweed.....	0.08	..	..	0.08
<i>Najas guadalupensis</i>				
Small pondweed.....	0.07	..	..	0.07
<i>Potamogeton pusillus</i>				
Waterweeds.....		0.05	trace	0.05
<i>Anacharis canadensis</i>				
<i>Anacharis occidentalis</i>				
Dotted smartweed.....		0.04	..	0.04
<i>Polygonum punctata</i>				
Spike rush.....		..	0.04	0.04
<i>Eleocharis</i> sp.				
Teal grass.....		..	0.03	0.03
<i>Eragrostis hypnoides</i>				
Giant bur-reed.....		0.02	..	0.02
<i>Sparganium eurycarpum</i>				
Longleaved ammania.....		0.02	..	0.02
<i>Ammannia coccinea</i>				
Total.....	9.12	69.25	21.63	100.00

between Upper and Lower Peoria lakes. Increased stabilization of water in 1939 resulted in bushy, sago and longleaf pondweed and coontail beds much greater in extent. With continued regular water levels in 1940, wild celery, sago and bushy pondweeds and coontail appeared throughout Upper Peoria Lake. Also a smattering of waterweed was found in 1940.

**Class II Lakes, Semistabilized Waters.**  
—According to tables 6, 7 and 8, river

weed covered no more than 3 acres, longleaf pondweed no more than 19 acres and coontail no more than a trace in any lake of this class. American lotus was about as abundant in lakes of this class as in lakes of Class II.

Among the emergent species, duck po-

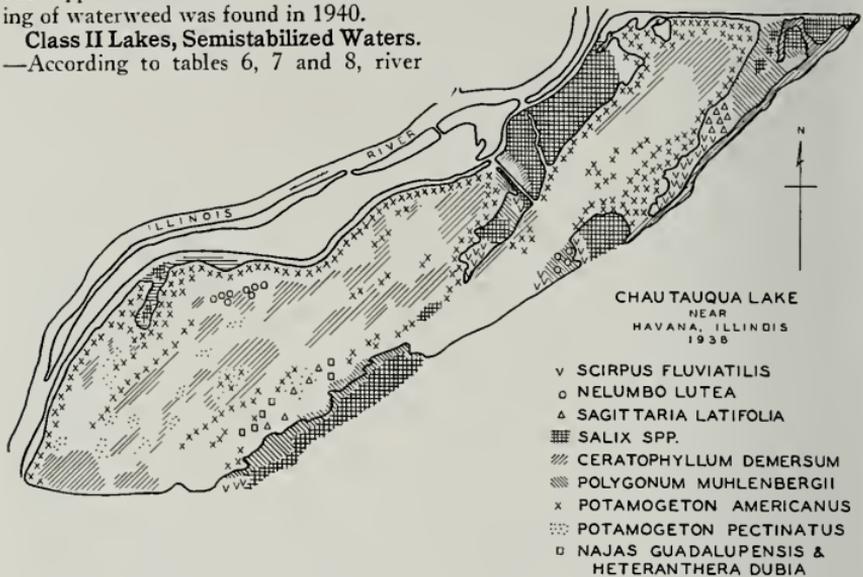


Fig. 9.—Vegetation map of Lake Chautauqua, showing location of principal duck food beds, 1938. Because of the great reduction necessary, the outlines in this and other similar maps have been simplified. Note extensive beds of longleaf pondweed (*Potamogeton americanus*) and coontail (*Ceratophyllum demersum*) through much of the lake; also extensive marsh smartweed beds (*Polygonum Muhlenbergii*) in and among tracts of willow (*Salix* spp.).

bulrush, American lotus, marsh smartweed and coontail were the predominant species in lakes with semistable water levels. Table 3 indicates that coontail in Class II lakes covered large areas that compared favorably in size with the areas of this plant found in Class I lakes. Sago and longleaf pondweeds occurred in only small quantities in Class II lakes. Other significant facts to be noted in table 3 are the presence of rice cut-grass and wild rice, the absence of wild celery and the scarcity of waterweed. Goose Lake, fig. 11, is typical of this class except that it contains an unusually large bed of duck potato.

**Class III Lakes, Fluctuating Waters.**—As shown in tables 4, 6 and 7, lakes with fluctuating water levels may be almost devoid of submerged and floating aquatic plants. Table 4 discloses that sago pond-

tato covered as much as 51 acres, giant burreed as much as 20 acres and marsh smartweed as much as 95 acres in a single lake of Class III. River bulrush covered 198 acres in one lake of this class. This was considerably less than the 414 acres found in a comparable Class II lake. Muscooten Bay, fig. 8, was in 1938 a typical Class III lake.

Lakes of Class III occasionally undergo an early summer metamorphosis, during which the water recedes to expose broad, extensive mud flats. In the summer of 1936, and to a lesser extent in 1937, many moist-soil plants of value as duck foods grew on these mud flats. Such plants as nutgrasses, wild millet, teal grass, nodding and largeseed smartweeds and water hemp or pigweed made up the bulk of this vegetation. Data in table 6, however, show

that during 1938 there was little development of such plants in the Illinois River valley. A glance at fig. 6 helps to explain this situation. The water remained high in lakes of this type throughout July. Shortly after the water level dropped in August, exposing mud flats, a subsequent rise drowned the immature moist-soil plants commencing to appear.

In 1938, Clear Lake had a dearth of moist-soil plants. In 1939, it had an

occurred in the Havana region in the latter part of June and throughout July, 1940, than in the equivalent 1939 period. Consequently, an unusual development of wild and Japanese millets, nutgrasses, smartweeds and water hemp occurred in 1940, table 5, on the mud flats of Quiver,

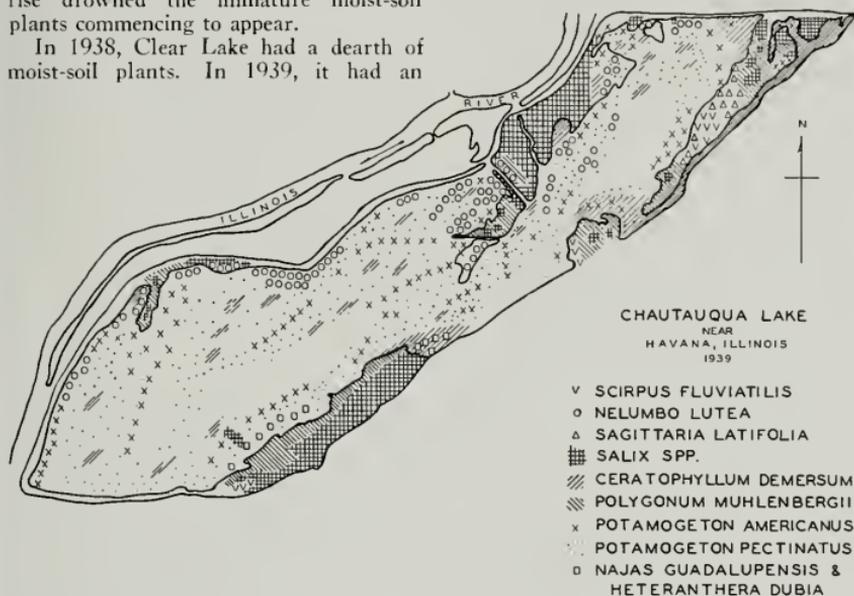


Fig. 10.—Vegetation map of Lake Chautauqua showing location of principal duck food beds, 1939. Compare this map with that for 1938. Note the increase in American lotus (*Nelumbo lutea*). Note also the decrease in coontail (*Ceratophyllum demersum*) and longleaf pondweed (*Potamogeton americanus*). Sago pondweed (*Potamogeton pectinatus*) showed an increase in 1939 but has since suffered a marked decline. The decrease in these three species started after 1937, when the levees were repaired, and has continued because the water depth has been held too high for sufficient light intensity to reach those plants that were established when the lake was shallower. A stabilized water level of increased depth has resulted in an encroachment of duck potato (*Sagittaria latifolia*) on river bulrush (*Scirpus fluviatilis*).

abundance of such plants, table 5. This change represents a typical metamorphosis of Class III lakes. As indicated by fig. 6, the water level of the Illinois River at Havana, a few miles below Clear Lake, averaged about 2 feet lower during July, 1939, than during July, 1938, and lower still during August and September, 1939. The low water caused much of the shallow, flat Clear Lake basin to be exposed as mud flats, on which moist-soil plants rapidly grew as the water receded. The water was too high at other bodies of water to expose mud flats of appreciable size.

As shown in fig. 6, a lower water stage

Bath, Clear, Crane, Horn and other lakes. At Clear Lake, fig. 12, water hemp covered over 930 acres, nodding smartweed 153 acres, nutgrasses over 84 acres and millets over 128 acres. Horn Lake, completely covered by American lotus in 1939, had 11.2 acres of Japanese millet and over 23 acres of water hemp in 1940.

#### Effect of Floods

Severe floods have at various times in the past poured through the Illinois valley. Exceptionally high water prevailed in most of the summer of 1927. This, it is reported, wiped out almost all the Ameri-

can lotus beds in the region and drowned innumerable pecan trees in the bottoms above Beardstown.

In 1938 the water level, after dropping in mid May, rose 2 to 3 feet in June and July, figs. 4-6. Such a small rise had no effect on the American lotus, fig. 13, the leaves of which rose with the water, but it left its mark on several other species.

by 2 feet of water. When mapping was done in August, there was scarcely a leaf left on the plants, which were covered with sediment. They failed to flower. Thus it

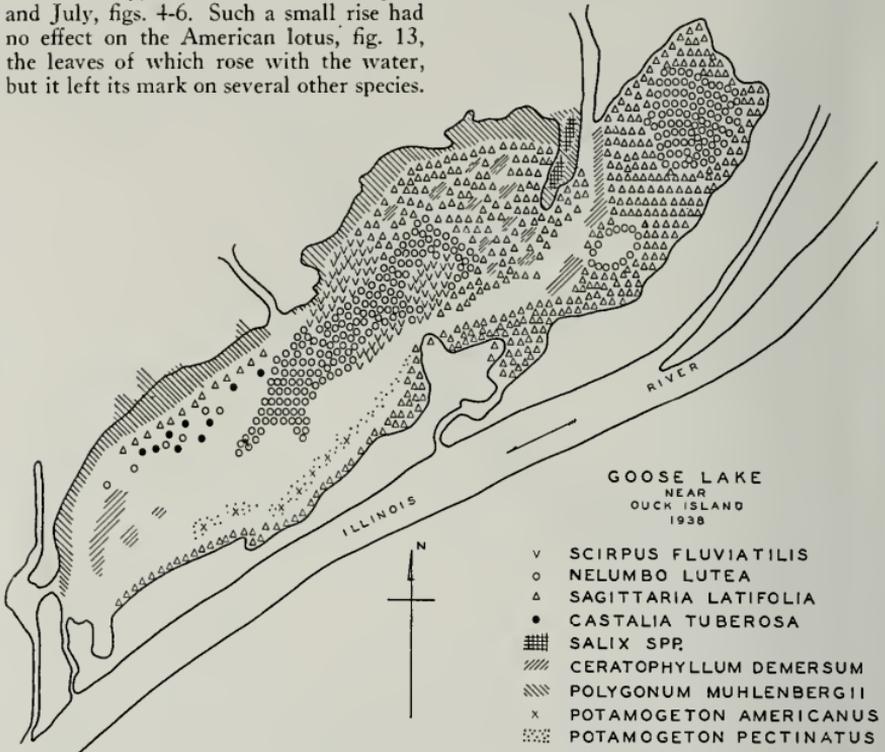


Fig. 11.—Vegetation map of Goose Lake, showing location of principal duck food beds, 1938. This lake is near Duck Island, a few miles south of Banner. Here semistable water levels resulted in large beds of duck potato (*Sagittaria latifolia*), marsh smartweed (*Polygonum Muhlenbergii*) and American lotus (*Nelumbo lutea*). High water in the spring of 1938 resulted in the disappearance the following year of much of the duck potato bed, the areas being taken over by river bulrush (*Scirpus fluviatilis*), American lotus (*Nelumbo lutea*) and coontail (*Ceratophyllum demersum*). Note the scarcity of longleaf and sago pondweeds (*Potamogeton americanus* and *P. pectinatus*).

For instance, only a trace of sago pondweed remained in Jack Lake in August, 1938, table 3, although in late May the lake had innumerable patches scattered over the area of several hundred acres. From the August appearance and association of the remaining patches, it was obvious that the greater part of the sago pondweed had been killed by the high water of June and July.

Table 3 shows 210 acres of duck potato at Goose Lake in 1938, fig. 11. A survey in June revealed these plants to be covered

is no wonder that only 15.5 acres of duck potato remained in 1939, and only 4.8 acres in 1940. River bulrush and American lotus occupied the vacated areas.

River bulrush, figs. 14, 15 and 16, began to send up shoots from its large tubers in mid May, 1938. With the high water in June and July of that year, fig. 6, many beds of river bulrush were inundated and the plants killed. Marsh smartweed stems and foliage, which rose with the water, were not inundated, and this smartweed began to spread over areas formerly

occupied by the river bulrush. Later, with the return of low water in August, a second growth of bulrush stems appeared from the resistant tubers. In 1939, with low water in June and July, river bulrush regained areas it had lost to marsh smartweed. With low water in 1940, river bulrush invaded marsh smartweed beds in several places.

Table 3 indicates the shift in abundance of these species at Rice, Miserable, Beebe and Goose lakes over a 3-year period. At

herbaceous plants to develop; it is also conducive to growth of willows, cottonwoods and buttonbush, plants of little value as sources of waterfowl food. In 1940, several areas of the exposed basins of Crane and Horn lakes were covered with seedling willows and cottonwoods. There is evidence that in other lakes willows and buttonbush, figs. 17 and 18, have in the past invaded exposed areas in periods of low water and maintained their position with the return of higher water. Thus,

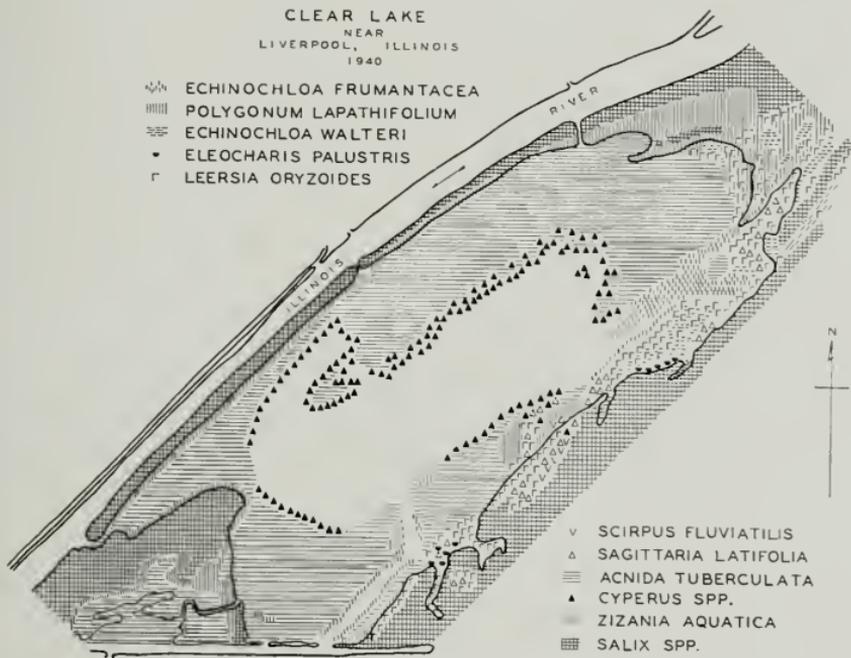


Fig. 12.—Vegetation map of Clear Lake, showing location of principal duck food beds, 1940. Clear Lake in 1940 was an excellent mallard and pintail feeding ground because of the extensive beds of moist-soil plants. Japanese and Walter's millets (*Echinochloa frumentacea* and *E. Walteri*), nutgrasses (*Cyperus strigosus* and *C. erythrorhizos*), water hemp or pigweed (*Acnida tuberculata*) and nodding smartweed (*Polygonum lapathifolium*) appeared on the exposed mud flats shortly after recession of the water in early summer. A small levee was constructed to enable springs and rains to flood these beds during the hunting season.

Beebe Lake, for example, marsh smartweed shifted from 124 acres to 11 acres to 18.2 acres; river bulrush, from 195 acres to 363 acres to 332.7 acres.

### Effect of Drought

Drought not only lowers water levels sufficiently to allow desirable moist-soil

they often become a pest by encroaching upon waterfowl feeding grounds during drought periods.

While various factors not understood at the present time may be partly responsible, I believe that the low water in Rice Lake in 1940, resulting from drought, was the principal cause of an increase in American lotus from 64 to over 317 acres,



Fig. 13.—American lotus (*Nelumbo lutea*), also known as yorkey nut. Able to withstand fluctuating water levels, it is very abundant, but unfortunately is a poor duck food. Seldom do ducks consume the hard, nutlike seeds of this plant.



Fig. 14.—River bulrush (*Scirpus fluviatilis*). This is often called flag in the Illinois River valley, where it covers thousands of acres. It is of little value as a waterfowl food plant, since it rarely produces seed. It reproduces by means of woody tubers and rootstocks.

table 3, with a corresponding decrease in coontail, a more valuable duck food plant, from 99 to 2.9 acres. Adjoining Beebe Lake, although lowered by the drought, averaged 8 inches deeper than Rice Lake. In Beebe Lake, coontail increased from 34 to over 418 acres, although American lotus was present in much of the same area. This increase in coontail was undoubtedly the result of shallower water, which was still not too shallow and which allowed greater bottom light intensity.

#### Effect of Water Fluctuation

The importance of fluctuating water levels as a factor affecting aquatic plants has been discussed, but the manner in which these levels directly influence various plants needs explanation.

Fluctuating water levels affect aquatic plants in several ways. During flood times in spring and early summer, adequate sunlight does not penetrate sufficiently deep to enable aquatic plants to make normal growth, as in their customary depths of water. If aquatic plant beds become established in the shallows during periods



Fig. 15.—An extensive bulrush bed at Rice Lake; a few fruiting heads of American lotus are visible.

of high water, these same beds are exposed with the return of normal or lower levels to drying and to fermentation of the vegetative parts. This exposure not only prevents waterfowl from utilizing the plants as food, but it also usually results in failure of the plants to reproduce. As pointed out elsewhere, American lotus and river bulrush, among the less valuable waterfowl food sources, are two of the few plants tolerant of such severe physical conditions.

Fluctuating water levels affect such marsh and moist-soil plants as wild and Walter's millets, figs. 19-20, chufa, rice cut-grass, certain smartweeds and pigweed, as well as aquatic plants. When these plants are inundated in their immature

more turbid the waters, the shallower becomes the maximum depth at which various species of aquatic plants are able to live.

During the summer of 1939 and 1940, the transparency of many lakes along the



Fig. 16.—Remnant of a bed of duck potato (*Sagittaria latifolia*) being encroached upon by river bulrush (*Scirpus fluviatilis*) in an area from which water has receded.

stages, as they frequently are during the summer, they drown through lack of sufficient carbon dioxide and oxygen. The more mature these plants become, the longer they are able to tolerate flooding. In 1938 and 1939, many seedling Japanese millet patches planted by duck clubs failed to develop because of inundation in July or August.

#### Factors Influencing Turbidity

With the exception of fluctuating water levels, turbidity is apparently the most potent factor affecting aquatic plant beds in the Illinois River region. Turbidity inhibits light penetration. The depth to which submerged and floating aquatic plants grow is dependent largely upon the amount of sunlight they obtain. Thus, the

Illinois River was measured by means of a Secchi disc. This disc is 10 centimeters (4 inches) in diameter and white in color. The maximum distance below the water surface that the outline of the disc is visible in the shade is used as a measure of the degree of transparency.

**Fluctuating Water Levels.** — Physical factors may change the transparency of part of a lake or an entire lake within a few hours. In order to compare transparencies as affected by water levels, it was necessary to consider only those readings not influenced by other factors. The transparency readings at Lake Chautauqua, a lake with stable waters, varied from 8 to 60 inches, with an average of 10 inches. The exceedingly clear water of this lake occurred in a narrow, spring-fed arm that is protected from wind. In lakes



Fig. 17.—Buttonbush (*Cephalanthus occidentalis*), also called buckbrush. It is a mediocre source of duck food.

with semistable water levels, Secchi readings ranged from 7 to over 32 inches, with an average of 10 inches. At Rice Lake, the disc was visible on the bottom at all depths, the greatest depth being 32 inches. Secchi disc readings for lakes with fluctuating water levels varied from 5 to 17 inches, with an average of 8 inches.

Thus, it is apparent that even lakes with stable and semistable water levels in the Illinois River valley have medium to high turbidity. Lakes with fluctuating waters have a greater turbidity, even at times other than flood periods, probably largely because of the paucity of vegeta-

tion. In times of high water, Class III lakes become very roily, transparencies being reduced to 4 inches and less.

**Waves.**—Waves are frequently as important as floods in causing lake waters to assume a roily condition. Observations made on Lake Chautauqua during the summer of 1940 yielded information of importance on this subject. Table 9 reveals that even moderate winds may result in a reduction of the transparency of water from 11 to 6 inches. Waves may stir the bottom soil and produce a high degree of turbidity within an hour or two. Once there is a heavy suspension of soil particles in the water, 1 to 3 days are required before these particles commence to settle noticeably (June 29—July 2, table 9).

Plants may be influential in curtailing turbidity caused by wave action and by fish. In the open water of Goose Pond a strong wind reduced the transparency from 11 to 3 inches in a few hours. In nearby American lotus beds, which contained coontail, the transparency readings ranged between 12 and 20 inches and were the same for identical positions before and after the wind.

At Siebolt's Lake in 1939, Secchi discs disappeared from sight at depths of 6 to 8 inches. No submerged or floating aquatic vegetation was noted in this lake that year, table 2. Following stabilization of water levels, the lake was almost covered by sago pondweed in 1940, and the Secchi



Fig. 18.—Buttonbush often occupies ground that could be utilized by better duck food plants.

disc was visible 16 inches below the surface. Similar instances in which aquatic plants increased the transparency of the water, through inhibiting wave action,

were noted at Sawmill Lake and other places.

**Fish.**—Rough fish—carp, buffalo, bullheads, catfish, sheepshead and dogfish—

Table 9.—Effect of waves on transparency of Lake Chautauqua, 1940.

DATE	INCHES, AVERAGE TRANSPARENCY	AIR CONDITION*	REMARKS
June 27...	10.4	Calm, 6.....	Lake smooth
June 29..	6.5	Moderate wind, 11..	White caps on lake
July 2..	11.0	Calm.....	Second readings made 2 hours after first
	6.5	Moderate wind, 10..	
July 11	21.0†	Moderate wind, 10	Bay protected from wave action; disc visible on bottom†
July 19	12.5	Calm.....	Lake smooth in A.M.; rough in P.M.
	7.8	Light wind, 9..	

\*Maximum miles per hour wind velocity expressed in figures.  
†Greatest depth of water at which reading was taken, 21 inches.



Fig. 19.—Wild millet (*Echinochloa crusgalli*). When low water levels expose mud flats in early summer, wild millet, the seeds of which are an excellent duck food, grows on many of the moist areas. Japanese millet (*Echinochloa frumentacea*) has a more compact head and is widely planted as a duck food. The inset shows wild millet growing on a mud flat exposed by receding water.



are at times important causes of turbidity in shallow lakes. They evidently create greater turbidity than fine fish because of their bottom-feeding habit. Their influence is more pronounced in shallow than in deep water.

In August, 1938, several turbid areas were noticed in the otherwise fairly clear water of Muscooten Bay. Investigations showed that rough fish were making the waters roily. Since then a like condition has been observed at several other lakes.

At Crystal Lake, in the bottomlands of the Mississippi River, opposite Burlington, Iowa, seining operations disclosed rough fish to be very abundant in 1939. Secchi

disc readings taken weekly from May to October of that year showed an average transparency of 15 inches. During the winter of 1939-40, the lake was frozen to such an extent that the rough fish population was greatly reduced. Secchi disc readings made during March and April, 1940, revealed a transparency of 34 inches. It is believed that rough fish reduced the transparency of these waters by nearly 2 feet.

Lynn Hutchens of the Cook County Forest Preserve District reports in a letter dated Jan. 8, 1941, the effect of fish on the transparency of McGinnis Slough in Cook County. Secchi disc readings in 1939 ran from 6 to 10 inches, with an average of 8 inches. During the winter of 1939-40, 18 inches of ice combined with snow to seal the slough from aeration and to cause the destruction of an estimated 95 per cent of the fish population. Sample counts in April disclosed approximately 50,000 black bullheads and 200,000 golden shiners dead on the shore of the slough. An immediate improvement in the transparency was noted, with Secchi readings averaging 40 inches during the summer of 1940. Fish undoubtedly caused a loss in transparency of at least 30 inches in McGinnis Slough.

**Soils.**—The composition of soil (*i.e.*, size and binding characteristics of soil particles) influences aquatic plants in Illinois River habitats much more than does fertility of the soil. Waves, currents and fish create greater turbidity where soil particles are fine and loose than where they are coarse or compact.

At Jack Lake, with readings taken in areas of similar depths, transparencies exceeded 20 inches in an area with a hard bottom, while, short distances away, over a soft bottom, transparencies averaged only 7 inches. The transparency of a shallow, silt-bottomed pond near Crane Lake averaged 3 inches. A section of Sawmill Lake having a very soft silt bottom gave a transparency reading of 4 inches; other areas with firmer bottoms gave readings of 19 inches.

**Pollution.**—In the Illinois River navigation pools above Utica, pollution seems to be an important factor in increasing turbidity. While transparencies in the lower pool (Starved Rock) vary from 13 to 36 inches, transparencies 50 miles up-



Fig. 20.—Walter's millet (*Echinochloa Walteri*). It has longer awns, smaller seeds and grows in wetter situations than wild millet (*Echinochloa crusgalli*). Both species are colloquially called corn grass.

stream (Dresden Island) vary from 5 to 10 inches. Since each pool acts as a settling basin, the lower one would seem to contain fewer suspended pollution particles. The effect of pollution on aquatic plants is probably largely that of diminishing the amount of sunlight penetrating the water, rather than that of restricting plant growth through lack of dissolved oxygen.

### Turbidity and Plant Abundance

Evidence at hand indicates that an average transparency of less than 9 inches through the growing season almost precludes development of submerged and floating aquatic plants, despite the fact that other conditions may be favorable.

At Crystal Lake, across the Mississippi River from Burlington, Iowa, not a trace of pondweeds or coontail was found in 1939; a transparency of 15 inches was recorded as approximately average at the time. In 1940, with transparency increased to 34 inches, small beds of sago pondweed appeared. A nearby pond, very turbid, contained no plants in 1939. In early 1940 the water cleared sufficiently to make visible a Secchi disc on the bottom at 30 inches. By June the pond contained a mass of muskgrass and leafy pondweed (*Potamogeton foliosus*).

Hutchens found only a few emergent plants and no submerged or floating aquatic plants in McGinnis Slough, Cook County, in 1939, when the water averaged 8 inches in transparency. He reports that, with the transparency increased to 40 inches in 1940, approximately 28 acres of giant bur-reed appeared. Submerged aquatic vegetation developed in the open waters of the lake. One dense bed of muskgrass, coontail and leafy pondweed covered about 44 acres, a bed of muskgrass and coontail covered approximately 98 acres, coontail and leafy pondweed grew on 2.8 acres, and muskgrass and coontail occurred in sparse growth over the rest of the lake. Since other environmental conditions were about the same in both years, it seems obvious that the increase in transparency was responsible for the appearance of aquatic plants in 1940. A transparency varying between 6 and 10 inches seems to have precluded the growth of aquatic plants at McGinnis Slough in 1939.

### Water Depth and Plant Abundance

The water level of Lake Chautauqua was practically the same from June 1 to Sept. 1 in 1939 and 1940, fig. 7. Although there is only one gauge reading for 1938, it is known that the water level was about 8 inches higher during the corresponding period in that year. However, the total abundance of coontail, fig. 21, and pondweeds, figs. 22, 23 and 24, has steadily decreased, table 1. These species aggregated about 1,149 acres in 1938, 859 acres in 1939 and 441 acres in 1940. It was believed at one time that wind action, combined with water depth, caused the decrease through diminishing transparency. A check of wind velocity records at Peoria, a short distance away, revealed that the number of days with a wind velocity of at least 9 miles per hour (for June, July and August) was 52 in 1938, 47 in 1939 and 41 in 1940. The total movement of wind for those months was 11,684 miles in 1938, 10,053 miles in 1939 and 10,535 miles in 1940. Wind action showed no appreciable increase in the years pondweeds and coontail were decreasing from 1,149 acres to 441 acres.

The water in Lake Chautauqua was shallower before its levee was repaired in 1938 than after. Perhaps the shallow water prior to 1938 favored establishment of certain aquatic plant beds, while the higher water maintained since then has been too deep to favor germination and propagation of pondweeds and coontail.

In areas of Lake Chautauqua where the Secchi disc normally becomes invisible at 11 inches, scattered patches of coontail grow in water up to 54 inches deep. Where the Secchi readings are 60 inches, coontail forms a dense mat 5 to 6 feet deep.

Bushy pondweed evidently requires high transparency. At Lake Chautauqua it grows only where the bottom can be seen, and then only in areas protected from waves creating roily waters. Probably because the water in those areas has become shallower each year, the bushy pondweed has increased from a trace to 7.3 to 8.6 acres, table 1. At Spring Lake, near Banner, the exceedingly clear water is undoubtedly the reason for abundance (78 acres) of this pondweed there.

In Lake Chautauqua areas where the transparency is normally 10 inches, sago



Fig. 21.—Coontail or hornwort (*Ceratophyllum demersum*), a favorite food of baldpates and gadwalls. It thrives in stable or semistable waters that are fairly clear and protected from waves.



Fig. 22.—Sago pondweed (*Potamogeton pectinatus*). This plant grows best in lakes with stable water, at depths of 2 to 4 feet. It is colloquially called teal grass and eel grass.



Fig. 23.—Longleaf pondweed (*Potamogeton americanus*), deer's tongue to most Illinois River residents. Ducks feed on the seed of this plant.

pondweed has ceased to thrive in water over 48 inches deep, and it is entirely absent from water over 56 inches deep. However, in the glacial (Fox River) lakes, we have found it growing in 70 inches of water having a transparency of 54 inches.

Martin & Uhler (1939) report longleaf pondweed growing at depths of 3 to

5 feet. Yet, at Lake Chautauqua, this species has not been found in water over 3 feet deep. In 1938, and to a lesser degree in other years, beds of longleaf pondweed extended through the lower lake on the spoilbanks of former drainage ditches, where the water was 8 to 20 inches shallower than elsewhere. This apparent restriction on the maximum depth at which this pondweed will grow in Lake Chautauqua must be due to turbidity.

The increase of coontail at Beebe Lake from 34 acres in 1939 to over 418 acres in 1940, table 3, I feel certain must be attributed to the lower water during the latter year. A transparency of 9 inches, combined with an average depth of 30 inches, apparently did not encourage dense growths of coontail in 1939. But the same transparency, with the water only 22 inches deep, permitted a greater light intensity to reach the plants, and was therefore more favorable for the formation of dense beds in 1940.



Fig. 24.—Longleaf pondweed beds at Lake Chautauqua, northeast of Havana. At Lake Chautauqua, where the water level is stable, extensive beds of this valuable duck food plant occur in water about 2 feet deep.

#### Other Factors in Plant Abundance

In addition to turbidity and water depth, many other factors influence the

abundance of aquatic plants. Among the most important are soil character, sedimentation and wave action.

**Soils and Sedimentation.**—The influence of soils on turbidity has been discussed. Soils in the Illinois River valley influence aquatic plants more by the extent to which they contribute to turbidity than by other properties they may or may not possess. The lake beds vary little in soil type. Beds in the upper portion of the valley are composed of Sawmill clay loam, while those in the middle part tend toward

Sawmill clay and Beaucoup clay loam. The lake basins of the lower part of the Illinois River region are made up of Sawmill clay plus Beaucoup clay. These soil types have a high fertility and are very productive.

The majority of bottomland lakes have large amounts of silt and clay particles deposited in their basins. During flood stages the river overflows its banks, thereby covering the bottomland and its lakes with a sheet of water containing a heavy load of soil. In the slowly moving back-



Fig. 25.—Marsh smartweed (*Polygonum Muhlenbergii*), red-top to most duck hunters because of its bright pink-red blossoms. When this plant grows in water 6 to 18 inches deep it produces seed, but when growing on dry ground it rarely produces either seed or flowers.

waters, sand first settles from the water and, a few hours after the water becomes quiescent, silt particles commence to settle. It is sometimes a matter of days, however, before fine, suspended clay particles begin to settle from motionless water.

Streams that flow into bottomland lakes are another important source of sedimentation. In the past 5 years, Crane Lake has been filling up at a rapid rate because of the deposits from the channel waters of the Sangamon River. Several other lakes are in the same predicament. If nothing is done to check sedimentation, these lakes will continue to shrink in size, eventually becoming tangles of buttonbush, fig. 18, willows and herbaceous vegetation of little use for waterfowl feeding or resting grounds.

Little can be done to prevent the dropping of sediment in fluvial lakes during flood periods of the Illinois River, but it may be feasible to divert the course of streams entering these lakes so that they will deposit their loads elsewhere. At the Mallard Club, near Bureau, small dams are used during the hunting season to hold water from channels of Bureau Creek, which flows through the marsh. After the season, spillways are lowered so that the marsh is no longer a huge settling basin for the streams entering it. It is also possible to retard silting in some lakes by employing soil conservation measures on adjacent drainage areas.

**Wave Action.**—Influences of wind and wave action on aquatic plants through reducing transparency have been discussed. The direct effect of wave action in tearing and uprooting plants, because it is more apparent, is generally overemphasized in the Illinois River region. Occasionally, however, after severe wind storms, the shore of Lake Chautauqua is littered by coontail and sago and longleaf pondweed plants. During September, 1939, many wild celery plants were uprooted from beds in the Starved Rock pool. Occasionally wind has been known to blow down clumps of bur-reed and other marsh plants with an insecure footing.

Turbidity caused by waves may be alleviated on large bodies of water by the construction of islands and levees at right angles to the prevailing winds. These earthen structures should be planted with willow, buttonbush, marsh smartweed,

river bulrush or hardstem bulrush in order further to reduce wave action and washing. Such areas furnish ideal shooting



Fig. 26.—Typical marsh smartweed beds in water 12 inches deep at Lake Chautauqua, near Havana.

stands on large lakes where there is a paucity of these places.

**Commercial Fishing.** — Commercial fishing is an important industry in the Illinois River valley, where the bottomland lakes yield an abundant supply of carp, buffalo, catfish and sheepshead. These fish are caught largely with hoopnets and seines. Hoopnets have little effect on aquatic vegetation. Seines may, and frequently do, injure beginning plant beds by uprooting small patches of coontail and pondweeds or breaking off the growing tips of young plants.

### Seed Production

Because seeds furnish the bulk of the plant food taken by ducks in the Illinois River valley, seed production is very important in determining the value of duck food plants.

We have made no quantitative measurement to date of seed production by various aquatic plants. Yet, from observation, it is obvious that seed production of several aquatic plants varies tremendously. We know too little concerning the environmental complexities that govern seed production.

On numerous occasions I have examined beds of giant bur-reed. Of more than 30 such beds inspected, only 2 were producing an appreciable supply of seeds. One bed

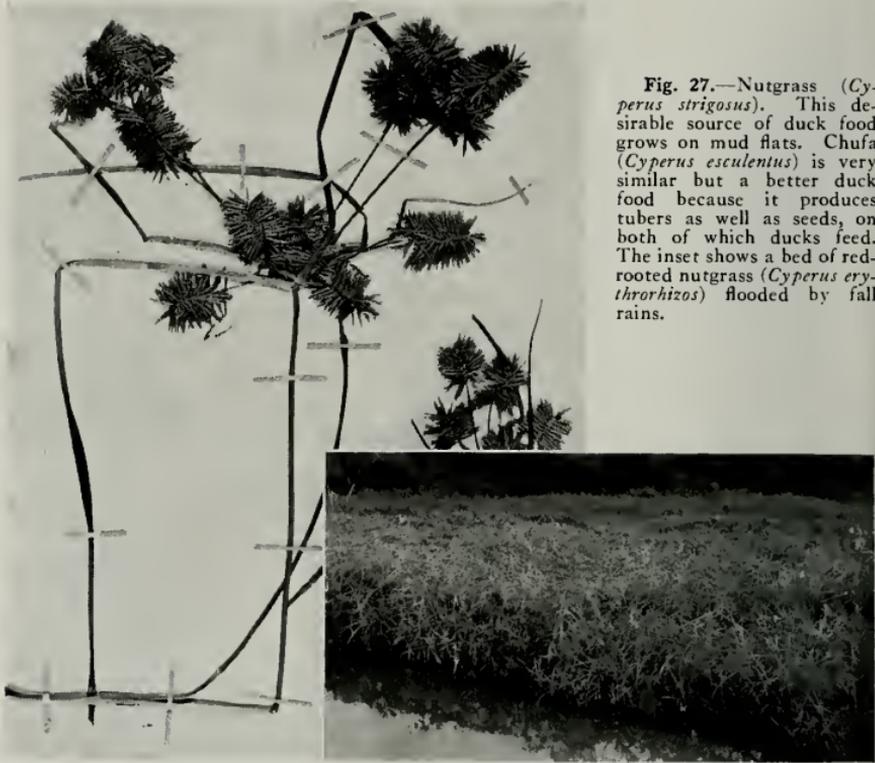


Fig. 27.—Nutgrass (*Cyperus strigosus*). This desirable source of duck food grows on mud flats. Chufa (*Cyperus esculentus*) is very similar but a better duck food because it produces tubers as well as seeds, on both of which ducks feed. The inset shows a bed of red-rooted nutgrass (*Cyperus erythrorhizos*) flooded by fall rains.

of 20 acres in Muscooten Bay had only one fruiting head per 16 linear feet in August, 1939. Two acres of giant bur-reed in Goose Pond in the same month had one fruiting head per 3 linear feet. The first bed was located in an area with more rapidly fluctuating waters than was the second.

Hutchens reports (letter, Jan. 8, 1941) that at McGinnis Slough in Cook County no seed was produced by giant bur-reed plants growing in water. Those growing on moist soil produced seed. The plants growing in water were 3 to 4 weeks later in development than those growing on moist soil.

Sago pondweed, fig. 22, is an erratic seed producer in the Illinois River valley. Often rated as one of the most valuable duck food plants, it falls short of this reputation in the Illinois valley because of its failure to produce seed in certain years. In 1938, inspection showed that longleaf pondweed beds in Lake Chautauqua, fig.

24, were producing fully twice as much seed as were sago pondweed beds of equal size. A study involving use and abundance of duck foods (Bellrose & Anderson 1940) corroborated this finding. Although at Lake Chautauqua sago pondweed produced more seed per plant in 1939 than in the previous year, the seed it produced in 1940 was approximately as much as in 1938. At Siebolt's and Sawmill lakes, sago pondweed produced little seed in 1940 notwithstanding the abundance of plants in those lakes, table 2. According to estimate, less than 0.5 per cent of the plants at these lakes, and at Goose Pond in 1940 only 2.0 per cent of the plants, had spikes bearing seed.

River bulrush, fig. 14, is a notoriously poor seed producer. Despite the fact that it covers several thousand acres in the Illinois River valley, I have found only two small beds that were fruiting extensively. One was at Lake Chautauqua in 1938, and the other at Goose Pond in 1940.

Stable waters may be conducive to fruiting, but such conditions do not insure it, since many beds in stabilized water areas have produced no seed. River bulrush propagates largely by rootstocks.

Much of the fruiting of marsh smartweed, figs. 25 and 26, is directly dependent on water depth. When growing in water 3 to 18 inches deep, this smartweed produces quantities of seeds, as observed at



Fig. 28.—Water hemp or pigweed (*Amaranthus tuberculatus*). This plant forms a rank growth on mud flats, frequently competing with Japanese millet. It is a good source of duck food, but not so good as either wild or Japanese millet. Pintails and mallards like the minute, dark-colored seeds of the water hemp.

Lake Chautauqua in 1938, 1939 and 1940, at Jack Lake in 1938, at Cuba Island in 1938 and 1939, at Beebe Lake in 1938, and elsewhere. At Flat Lake, in 1938, a large bed of marsh smartweed fruited heavily in water 14 inches deep; in 1940, the water depth had been increased to 36 inches, with the result that the smartweed was scattered, the plants sickly and the fruiting poor.

Numerous examples are known of marsh smartweed beds that failed to produce seed after the water had receded from the beds, leaving only moist soil. The beds at Jack Lake, fruiting heavily in 1938, were producing less than 1 per cent as much seed in 1940, when they were exposed by receding water levels. At Beebe Lake, in 1938, almost every plant was pink blossomed; in 1939, little water remained in the marsh smartweed zone, and only a few flowering spikes were noticed. By 1940, no water was left in the marsh smartweed zone, and scarcely a fruiting spike was found.

Observations alone are sufficient to show that moist-soil plants — wild millet, fig.

19, and Japanese millet, nutgrasses, fig. 27, water hemp or pigweed, fig. 28, smartweeds and rice cut-grass, fig. 29—produce more seed per unit of area than aquatic plants, such as longleaf and sago pondweeds, figs. 23, 24 and 22.

### Important Duck Food Plants

To determine the value of duck food plants in the Illinois River valley, Bellrose & Anderson (1940) compared the 1938 abundance and use of aquatic plants. Since numerous duck food plants, notably those in the moist-soil groups, were very scarce in 1938 because of high waters the value of all duck food plants was not ascertained. Compilation of the 1939 and 1940 data, when completed, should give an accurate index to the value of all important duck food plants in the Illinois River valley.

Essence of the report for 1938 was that rice cut-grass, figs. 29 and 30, was the best native duck food plant in the Illinois River valley in that year, and that coontail, fig. 21, marsh smartweed, fig. 25, and longleaf pondweed, fig. 23, were



Fig. 29.—Rice cut-grass (*Leersia oryzoides*), better known in the Illinois River valley as sawgrass. It is one of the best native duck food plants, growing on moist soil and in shallow water. Ducks feed on the rootstocks and seeds. The plant pictured here is bent to show both ends.

among the better plants. Giant bur-reed, duck potato, fig. 31, and buttonbush, fig. 17, rated as fair to poor sources of duck food. Sago pondweed, fig. 22, regarded usually as an excellent duck food plant, rated low in value in 1938, probably because of the fact that it produced little seed locally. Spike rushes, river bulrush, fig. 14, and American lotus, fig. 13, were

by Harry G. Anderson revealed not one trace of wild rice seed. When I visited Douglas Lake in August and September, 1939, thousands of red-winged blackbirds were congregated there, feeding upon the seed. They undoubtedly consumed most of the crop. Since there are only very limited areas suitable for the development of wild rice, it would seem that any plant-



Fig. 30.—Rice cut-grass beds in Quiver Creek, near Lake Chautauqua, September, 1940.

found to be practically worthless as food for ducks in the Illinois River valley in 1938.

Stomach analyses by Harry G. Anderson\* of 1939 and 1940 gizzards, while not complete, indicate that rice cut-grass still ranks first. Marsh smartweed, coontail and buttonbush seem to have dropped in relative value. Wild millet, fig. 19, and Japanese millet, pigweed, fig. 28, nut-grasses, fig. 27, and nodding smartweed appear to be among the top foods in these years, in which they were much more abundant than in 1938.

Wild rice, generally a highly rated duck food, is apparently of little value as a duck food in the Illinois River valley. Although 81 acres of this species grew in Douglas Lake in 1939, 108 duck gizzards obtained there in the fall of that year and examined

ings made—even though successful—would not produce much food for ducks in the Illinois River region; blackbirds would consume most of the seed.

### Plant Competition

As already indicated, there are among the waterfowl food plants certain species that are little utilized for food by ducks. These species are often in direct competition with more beneficial waterfowl food plants. Our studies have shown that despite their abundance in the Illinois River region, American lotus and river bulrush furnish little waterfowl food. They dominate most other forms of aquatic and marsh vegetation. In most places they must be considered weeds in the waterfowl habitat.

American lotus, fig. 13, which covers hundreds of acres with its broad oval

\*Working on Illinois Natural History Survey Federal Aid Project 2-R, referred to earlier in this paper.

leaves, has been seen to shade out beds of coontail and pondweeds. At Rice Lake, the decrease of coontail from 99 acres in



Fig. 31.—Duck potato (*Sagittaria latifolia*), a mediocre duck food, forms dense beds in shallow water and on moist soil. The seed is more important as a duck food than the tubers, which are usually too large and buried too deep to be of maximum availability to waterfowl.

1939 to 2.9 acres in 1940 must be attributed largely to the increase of lotus from 64 to over 317 acres in these same years, table 3. Nevertheless, lotus may, when it is not too dense, act as a nurse crop to coontail. Much of the 418.5 acres of coontail at Beebe Lake in 1940 was among open stands of lotus, while the 33.8 acres at Goose Pond were entirely among lotus. The increase of lotus at Lake Chautauqua from 6 to more than 207 acres in 3 years, table 1, has been directly responsible for the loss of several sago and long-leaf pondweed beds.

Lotus has continued to exist on mud flats during periods of low water, thereby frequently making inadvisable the sowing of Japanese millet and preventing the development of moist-soil plants on such habitats. A scattering stand of millet was obtained at the Central Illinois Club in 1939 and 1940 by broadcasting the seed among the lotus leaves. At Horn Lake, a sparse growth of millet was obtained where this method was tried in 1940; where lotus had been mowed before the seed was broadcast, dense beds of millet grew and thrived. Water hemp in 1940 assumed dominance over lotus at Crane and Horn lakes, where it completely crowded out several beds of the latter species.

River bulrush, fig. 14, a coarse marsh species, has been found to be an important factor in restricting the growth of marsh smartweed at Beebe and Goose lakes, as well as at other lakes. It has also been observed to encroach upon giant bur-reed, softstem bulrush, duck potato, chufa, rice cut-grass and wild millet beds, all species more useful to waterfowl than river bulrush.

Buttonbush, figs. 17 and 18, and willows tolerate long periods of inundation. In many lakes with fluctuating water levels, these species are encroaching upon such marsh plants as river bulrush, marsh smartweed and rice cut-grass. While our studies show that buttonbush furnishes fair duck food, willows are valueless as food. Both species cover many areas that could well be occupied by more desirable plants. However, willows have a place in the waterfowl habitat as cover and as a means of reducing wind action.

Certain species of green algae (*Chlorophyceae*) have destroyed submerged and floating plants on Lake Chautauqua and one or two other lakes. These algae in 1938 and 1939 formed dense mats over beds of sago and longleaf pondweeds and coontail, thereby excluding a large amount of sunlight from those plants. We do not know whether the pale, sickly appearance assumed by many pondweed beds at that time is the result of blanketing by algae or whether it is due to some other cause. During 1940, algae blown by the wind so matted some marsh smartweed beds of Lake Chautauqua as apparently to cause considerable loss of vigor in the smartweed plants. Martin & Uhler (1939) report that certain blue-green algae appeared upon decomposition to secrete a toxic substance that affected submerged seed plants. Possibly marsh smartweed, an emergent species, was affected by a toxin released by the algae.

#### Methods of Control

There are several methods by which American lotus, river bulrush and other weeds may be partially if not entirely controlled. They are (1) by altering existing water levels, (2) by cutting and (3) by using chemicals.

River bulrush may be partially if not entirely controlled by raising the waters of its

lake or marsh habitat. Although an increase of a few inches in the water level does not injure the river bulrush, it cannot tolerate water 20 or more inches deep during the growing period. At Lake Chautauqua, because of stabilized waters 10 to 18 inches deep, river bulrush has since 1938 become less abundant each year. Marsh smartweed, figs. 25 and 26, and

plants should be cut just before the flowering period, before the plants produce seed. With lotus, flowering does not usually occur before July, and it is believed that by that time the plant has stored sufficient energy to produce quickly new leaves and flower stalks. Experiments are now being conducted by Homer Bradley on Lake Chautauqua to determine if sev-



Fig. 32.—Machine for mowing aquatic plants. At the Lake Chautauqua National Wildlife Refuge, where this machine is shown in operation, it was possible to mow an acre of American lotus per hour.

duck potato, figs. 16 and 31, occupy areas formerly held by river bulrush.

We believe that the American lotus can readily be drowned by flooding the plants during the flowering period. In 1927, American lotus was extirpated from many sections of the Illinois valley by a summer-long flood. Buttonbush and willows also are controlled by flooding, but it is necessary to inundate these species for over a year. Cattail, marsh cordgrass, cane (*Phragmites communis*) and water willow (*Decodon verticillatus*), all marsh plants, are also readily controlled by inundation.

It is necessary to cut herbaceous aquatic plants over an extended period to eradicate the beds completely. Mowing at least twice per year for 2 or more years is necessary for such species as cattails, river bulrush and American lotus. With the possible exception of American lotus,

eral mowings, beginning in June and repeated at intervals throughout the summer, will control lotus more successfully than mowings made only before flowering occurs.

Mowing with a scythe may successfully remove patches of river bulrush, cattail, lotus and other marsh species. Several duck clubs have found it practical to remove lotus from mud flats and shallow water areas with scythes. At the Crane Lake Club, an average of 1 man-day was necessary to mow, by hand, 1 acre of lotus growing on moist soil.

A mechanical underwater weed cutter that can be purchased, fig. 32, consists of a sickle attachment operated by a small motor, mounted on the bow of a shallow-draft boat. At the Crystal Lake Club, across the Mississippi River from Burlington, Iowa, and at Lake Chautauqua, this mower has been used successfully to cut

American lotus. Under favorable working conditions, 1 acre of lotus was cut per hour. Mowing lotus with the mechanical weed cutter before leaves and flower stalks are extended above the water surface would result in faster mowing and would lessen trouble caused by vegetation piling up beneath the boat, but might necessitate three or four mowings per year.

Frederic Leopold reports that, at Crystal Lake, lotus beds mowed once in 1939 and twice in 1940 were reduced in size and much less dense in 1941 than check beds that had not been cut.

Several chemical sprays and dusts have been used in an attempt to control various aquatic and marsh weeds. At Crystal Lake, Frederic Leopold and Arthur Hawkins experimented with the use of copper sulfate and sodium chloride in the control of river bulrush. Only copper sulfate appeared to have any effect on this species. The chemical caused some loss of vigor in the plants, but did not materially retard their growth.

Martin & Uhler (1939) experimented with various chemicals on water chestnut and other worthless marsh plants on the Potomac River in 1935 and 1936, using chemicals in solution applied with a pressure sprayer and, where possible, also in the form of dusts. Chemicals they experimented with were sodium chlorate, sodium arsenite, sodium chloride, copper sulfate, iron sulfate, zinc chloride, ammonium thiocyanate, calcium oxide and a commercial herbicide.

They found that the most effective kill was obtained on calm, hot days of bright sunshine, and the best solution consisted of 1 pound of dry, powdered sodium arsenite and one-half pound of sodium chlorate dissolved in 1 gallon of water and sprayed over an area of 150 square feet of plant growth. River bulrush they controlled fairly well by a solution of ammonium thiocyanate: 1½ pounds of that chemical in 1 gallon of water applied to 150 square feet of marsh. They sprayed chemical solutions by means of 4-gallon, hand-operated sprayers capable of developing a pressure of 90 pounds.

At the present time chemical control of aquatic and marsh weeds is in the experimental stage. It is too expensive to use over extensive areas, results are uncertain

and many of the chemicals used are dangerous not only to wildlife and fish but also to man.

### Natural Propagation

Aquatic and marsh plants frequently make their appearance in newly created or altered habitats by natural methods of dispersal. Seeds and other propagative parts are carried by water, ducks and other water birds. Evidence indicates that seeds of certain plants may be deposited and remain viable on a lake bottom for several years, not germinating until suitable growth conditions prevail.

With increased stabilization of water, 5 acres of sago pondweed appeared at Sawmill Lake in 1939 and increased to over 115 acres in 1940, table 2. So far as is known, no plantings of sago pondweed were made there. Evidently because of improved environment, wild rice appeared in 1939 over 81 acres at Douglas Lake, where it had been absent for a number of years. Wild rice appeared in 1939 at Rice and Beebe lakes without being planted, table 3.

The rapidity with which most moist-soil plants appear by natural propagation when conditions become suitable is indicated in table 5. The occurrence of over 141 acres of water hemp and 79 acres of nutgrasses at Crane Lake, and 153 acres of nodding smartweed, over 84 acres of nutgrasses and nearly 931 acres of water hemp at Clear Lake is noteworthy in this respect. Wild millet has appeared with planted Japanese millet at these lakes. The nearly 50 acres of millet at Quiver Lake in 1940 came probably from seeds deposited by plants growing there in 1936 and 1937.

In 1937 and 1938, Gilbert Lake and sloughs near the mouth of the Illinois River were barren of plants except for chufa. Nearby Flat Lake contained, during the summer of 1938, scattered patches of water dock (*Rumex altissimus*), water plantain (*Alisma Plantago-aquatica*) and marsh cord grass.

In the summer of 1938, after the Alton navigation dam on the Mississippi River had been placed in operation these Illinois valley areas were flooded. Since then the pool level has been fairly constant during the summer season. By July, 1940, the

forest-lined sloughs were carpeted by greater and lesser duckweed, and they also supported extensive beds of mud plantain, coontail and sago pondweed. A few beds of longleaf pondweed, creeping water primrose, bladderwort, marsh smartweed and cattail were also growing there.

In July, 1940, extensive areas of Gilbert Lake were covered by longleaf pondweed. Scattered beds of mud plantain, coontail, American lotus, duck potato, water primrose, river bulrush and cattail occurred. In 1938, none of these species had been seen there.

Marsh smartweed appeared at Flat Lake in 1939, forming a bed of some 20 acres. In July, 1940, parts of this bed had died, apparently because of the deep water. Scattered patches of coontail and longleaf and sago pondweeds also dotted the lake.

A pond at the Crystal Lake Club apparently contained no vegetation in 1939. Lack of vegetation seemed to be due to high turbidity created by rough fish. Removal of the fish cleared the water in 1940. An abundance of muskgrass and leafy pondweed shortly afterward covered the area. No plantings of these species had been made.

No submerged and only a few emergent aquatic plants occurred in McGinnis Slough, Cook County, in 1939. When environmental conditions improved in 1940, approximately 28 acres of giant bur-reed, and over 144 acres of muskgrass, coontail and leafy pondweed appeared in the slough. No plantings of these species had been made.

From this evidence it appears that the sowing of duck food plants is not always essential to the establishment of waterfowl

feeding grounds, for frequently the plants become established by natural means, upon the creation of a suitable environment. The planting of duck food plants is often advisable, however, to speed development of natural food resources and to insure valuable species a start against competing weed species.

### Management Recommendations

For many years, duck clubs along the Illinois River have been attempting to improve the waterfowl habitat by planting numerous species of aquatic and marsh plants. Most of these plantings have been made with little regard for environmental conditions. Reports received from 31 representative duck clubs in the valley show that all but three of these clubs have planted waterfowl food plants of some sort in recent years.

Table 10 summarizes the results of waterfowl food plantings made by 28 duck clubs in the Illinois valley. Thirty-four plantings failed, while 22 plantings were at least partially successful. Japanese millet plantings were more successful than those of any other species; fair results were secured from duck potato plantings.

Since 1934, thousands of dollars have been spent by Illinois valley duck clubs for aquatic plant propagating material. In 1939, 12 clubs reported that in the previous 3 years they had spent more than \$970 on planting stock and more than \$320 on labor employed to sow it. Sixteen other clubs, of 26 answering a questionnaire sent out in 1940, reported that they had spent \$1,760 for duck food plantings in 1939. Three duck clubs spent \$1,050 for coontail, sago pondweed and several other

Table 10.—Results of waterfowl food plantings made by 28 duck clubs in the Illinois River valley in recent years.

SPECIES	DUCK CLUBS UTILIZING	DUCK CLUBS REPORTING SUCCESS	DUCK CLUBS REPORTING FAILURE
Japanese millet.....	22	12	10
Duck potato.....	9	4	5
Wild rice.....	8	2	6
Sago pondweed.....	5	1	4
Coontail.....	5	1	4
Pickeralweed.....	2	0	2
Smartweed.....	2	1	1
Hardstem bulrush.....	1	1	0
Reed or cane.....	1	0	1
Duckweed.....	1	0	1

plants in the spring and early summer of 1940. When I inspected these plantings in August and September of the same year, only fragmentary and unsatisfactory results were apparent. In one duck club pond, \$200 worth of coontail had been dumped, upon the recommendation of a specialist from an aquatic nursery. There was not a trace of coontail left when I inspected the area 3 months later. High turbidity and shallow water undoubtedly were responsible for its disappearance.

Field inspection indicates that widespread failure of aquatic plantings cannot necessarily be charged to poor stock but rather may often be caused by planting species where conditions are not suitable for their survival or by planting stock that is not indigenous to the region. Existing plants and environmental conditions should be noted, and species known to grow under similar conditions should be used. It must be remembered that, if a habitat becomes suitable for a particular species, that plant usually appears through natural dissemination of propagative parts.

What, then, can be done to improve waterfowl feeding grounds? Evidence presented heretofore in this paper indicates that improvement of the area by controlling water levels is the best attack. In the Illinois River valley there are two methods of controlling the water levels and thereby managing the habitat. Which method is to be followed must necessarily depend upon prevailing conditions in the area under consideration. Whether the level of drainage of the river is above or below the lake basin is of primary importance in determining the method to be used.

**Method A.**—The type of habitat resulting from the first method furnishes more food per unit area and attracts larger numbers of mallards and pintails than other types of habitats. It is, therefore, the optimum waterfowl habitat in the Illinois River valley.

The water levels should be lowered sufficiently by July 1 to leave at least 30 per cent of the area in mud flats, allowing such moist-soil plants as nutgrasses, water hemp or pigweed, various smartweeds, teal grass, wild and Japanese millets and rice cut-grass—all good duck food plants—to develop on the mud flats. These plants usually appear by natural means, without

the necessity of sowing. However, if they have not occurred on the grounds in a number of years, it is advisable to sow the mud flats with Japanese millet seed and tubers of chufa. Chufa might well replace other less valuable nutgrasses, which pro-



**Fig. 33.**—Small dam constructed at outlet of lake. The lake shown here is fed by springs; closing of the gate in the hunting season will flood the area.

duce no tubers and which are the more abundant of the species in the Illinois River valley.

In order to make the seeds, tubers or rootstocks of the moist-soil plants available to waterfowl, it is necessary to flood the beds in the fall months. Springs, streams, pumps and natural rises in the Illinois River are used in conjunction with dams, fig. 33, and levees to flood such areas. Fig. 2 shows that over a period of 20 years there is a trend toward a rise in the Illinois River waters during these months.

Management method A was used successfully in 1940 at Horn Lake, Clear Lake and Bath Lake. It is generally applicable to that region below the Peoria dam as far as Treadway Lake, near Browning, and to the Meredosia Bay region, near Meredosia.

**Method B.**—The type of habitat resulting from the second method is more attractive to diving ducks, baldpates and gadwalls than the first type.

Water levels should be maintained as nearly constant as possible at a depth of 2 to 3 feet. This creates a habitat suitable for such submerged and floating aquatic plants as longleaf, sago and bushy pondweeds and coontail. As a result of the water level created by the Peoria navigation dam, bodies of water between Peoria

and Henry appear to be best adapted to this type of management.

### Tolerant Food Plants

Where little can be done to improve the physical condition of a bottomland lake through stabilization or control of the water level, the only remaining alternative is to encourage vegetation that is tolerant of such an environment. The following plants have the ability to grow under conditions resulting from irregular fluctuations, and among them are a few important waterfowl food species which should be considered in a program to improve habitats through planting: giant bur-reed, duck potato, arrowleaf, rice cut-grass, wild millet, Japanese millet, teal grass, marsh smartweed, swamp smartweed, nodding smartweed, chufa, creeping water primrose and water hemp or pigweed. Giant bur-reed, duck potato, arrowleaf, rice cut-grass, marsh smartweed, swamp smartweed and creeping water primrose grow in shallow water (averaging less than 1 foot) and on mud flats and banks. Japanese and wild millets, teal grass, chufa, nodding smartweed and water hemp grow on moist to fairly dry soils.

As determined from examinations of duck gizzards by Harry Anderson\* and by Martin & Uhler (1939), rice cut-grass, wild millet, Japanese millet, marsh smartweed and chufa are among the most val-

uable waterfowl food plants in the Illinois and Mississippi river valleys.

Before 1940, creeping water primrose, fig. 34, had been found as far north as



Fig. 35.—White water lily (*Castalia tuberosa*) is a slightly better duck food than American lotus, from which it can be distinguished by its cleft leaves.

Gilbert Lake and sloughs near the Illinois River mouth. In 1940, I observed several beds in Lake Chautauqua, the first such record for this lake. Several bushels of water primrose plants were transplanted in July to lakes near Havana which have fluctuating water levels. They were planted on mud flats and in shallow water, and despite a 20-inch rise in water levels the plantings were thriving in October.

In regard to the value of creeping water primrose, Francis M. Uhler (letter, Jan. 22, 1941) states: "I have considered it a third-grade duck food, in about the same class as the white water lily (fig. 35), pickleweed and the arrowheads. In the region centering around Arkansas, mallards, ring-necked ducks, baldpates, blue-winged teal and wood ducks have been found to feed on water primrose seeds in fair quantities, sometimes eating thousands of seeds. A mallard contained more than 100,000 seeds of a *Jussiaea* that was not identified to species."

On the question of planting water primrose, Mr. Uhler states: "In areas like the Illinois River valley, where first-class duck foods are scarce because of fluctuating water levels, I would favor planting it in those areas where the better food plants cannot thrive, for it can tolerate irregular fluctuations in water levels that would destroy most of the truly aquatic plants."

In the propagation of aquatic and marsh plants, various parts are employed.

\*Working on Illinois Natural History Survey Federal Aid Project 2-R, referred to earlier in this paper.



Fig. 34.—Creeping water primrose (*Jussiaea diffusa*). Small areas of this plant occur near Havana and near the mouth of the Illinois River. A fair duck food, this southern plant may prove to be valuable in certain areas that lack first class duck foods.

Some kinds develop best from seeds, others from tubers, rootstocks, cuttings or entire plants. Time, method, cost and ease of planting are factors to be considered in selecting the types of propagating material. Smartweed seeds, for instance, are usually low in germination unless scarified or stored under conditions approaching natural freezing and thawing of winter. Pondweeds readily develop from cuttings, transplants and seeds. Japanese millet seed is inexpensive, easily sown and produces good results when natural conditions are favorable. Table 11 lists the parts of a number of waterfowl food plants most desirable to use in planting. Data on propagative parts have been adapted largely from McAtee (1939) and Martin & Uhler (1939).

Japanese millet and chufa are best sown on mud flats left exposed by receding waters. Such flats usually occur, as shown in fig. 2, in July and August. In the Illinois River valley, in order to assure maturity, this millet and chufa should be planted previous to July 15. Plantings made as late as Aug. 1, however, will occasionally mature before frost. Because of the low germination rate of dry-stored smartweed seeds, these seeds should usually be sown in the fall, unless stored as previously mentioned.

Other species of aquatic and marsh plants may be planted in the spring or fall months. Where there are large concentrations of waterfowl during the autumn, however, there is danger that the propagative material may be consumed by them. Planting in early spring is often unwise because of the erratic water levels created by high water, usually prevalent at that time. For most aquatic species, the latter part of May and the first part of June constitute the best planting period. By this time the migrating waterfowl have departed, the spring floods are usually subsiding, and yet the plantings should have sufficient time to mature before frost.

### Methods of Planting

Seeds of Japanese millet and smartweeds are easily broadcast over mud flats. Smartweed seeds may be broadcast in shallow water that will later recede, leaving exposed mud flats. Water-saturated seeds of most aquatic plants, such as the

pondweeds, will usually sink. If they float, they should be embedded in small clay balls and these dropped in water of the correct depth. With softstem and hardstem bulrushes, which are good duck food plants not to be confused with river bulrush, greater success has resulted from broadcasting the soaked seeds upon the moist soil along the edge of the water than from sowing them in shallow water. A bushel of seeds of these plants is sufficient to cover 1 acre.

Tubers of sago pondweed and white water lily are easily planted by embedding one or two tubers in a clay ball and dropping the balls overboard from a boat in the desired place. Rootstocks of giant bur-reed, spikerush, bulrushes, pickerelweed and marsh smartweed are easily planted by hand, the operator wading into the shallow water and embedding the rootstocks in the soft mud. Where the soil is hard, a hoe or spade may be found necessary to dig a pocket. Tubers of chufa may be broadcast on mud flats that are dragged or raked afterwards, or they may be planted to a depth of 1 or 2 inches by hand. About one bushel of chufa tubers is required for each acre to be planted, while 1,000 to 1,200 tubers and rootstocks of other aquatic and marsh plants are sufficient to sow 1 acre.

Leafy cuttings of the pondweeds grow successfully if short sections of the stem containing two or three nodes are covered by 1 inch of soil. They may be planted by hand in water up to 30 inches in depth, or in deeper water by first forming a ball of mud around several cuttings. The balls then should be dropped from a boat at the rate of about one per 2 square yards.

Lynn Hutchens and I planted several species of aquatic plants in early August, 1940, in the newly created Skokie Lagoons of Cook County. Most of the transplant material was gathered at Fox Lake. Approximately 2,500 longleaf pondweed plants, 4,000 muskgrass "tufts," 100 creeping water primrose plants and over 1,000 each of hardstem bulrush and giant bur-reed plants were used. When I inspected the Skokie Lagoons on July 21, 1941, I found dense longleaf pondweed beds around the margins of the lagoons where the plantings were made. I found only a few clumps of muskgrass and only two patches of creeping water primrose.

Perhaps due to bank washing, less than 10 per cent of the hardstem bulrush and giant bur-reed plants had survived, and no spread had occurred from these.

Dr. Lee E. Yeager of the Illinois Nat-

tural History Survey successfully transplanted a number of emergent species in 1940. In this instance, 1,500 duck potato transplants showed a survival of over 95 per cent, while both hardstem and soft-

Table 11.—Aquatic plants, with parts most suited for propagation, and optimum planting conditions.

SPECIES OF PLANT	PROPAGATING PARTS	OPTIMUM PLANTING CONDITIONS*
Giant bur-reed <i>Sparganium eurycarpum</i>	Rootstocks, entire plants, seeds	Moist soil to 12 inches
Sago pondweed <i>Potamogeton pectinatus</i>	Entire plants, tubers, leafy cuttings, seeds	2 to 4 feet
Longleaf pondweed <i>Potamogeton americanus</i>	Entire plants, leafy cuttings, seeds	18 inches to 3 feet
Bushy pondweed <i>Najas guadalupensis</i>	Leafy cuttings, entire plants	18 inches to 40 inches
Duck potato <i>Sagittaria latifolia</i>	Tubers, entire plants, seeds	Moist soil to 18 inches
Arrowleaf <i>Lophocarpus calycinus</i>	Entire plants, seeds	Moist soil to 18 inches
Waterweeds <i>Anacharis</i> sp.	Masses of plants	2 to 6 feet
Wild celery <i>Vallisneria spiralis</i>	Winter buds, rootstocks, seeds	30 inches to 5 feet
Rice cut-grass <i>Leersia oryzoides</i>	Rootstocks, entire plants, seeds	Moist soil to 6 inches
Wild rice <i>Zizania aquatica</i>	Seeds	1 to 3 feet
Japanese millet <i>Echinochloa frumentacea</i>	Seeds	Moist soil
Chufa <i>Cyperus esculentus</i>	Tubers, transplants	Fairly dry to moist soil
Spike rushes <i>Eleocharis</i> sp.	Rootstocks, entire plants	Moist soil
Common three-square <i>Scirpus americanus</i>	Entire plants, rootstocks, seeds	Moist soil to 6 inches
Softstem bulrush <i>Scirpus validus</i>	Entire plants, rootstocks, seeds	Moist soil to 12 inches
Hardstem bulrush <i>Scirpus acutus</i>	Entire plants, rootstocks, seeds	Moist soil to 20 inches
River bulrush <i>Scirpus fluviatilis</i>	Entire plants, rootstocks, woody tubers	Moist soil to 12 inches
Greater duckweed <i>Spiradela polyrhiza</i>	Masses of plants	Broadcast on water surface
Pickeralweed <i>Pontederia cordata</i>	Rootstocks, entire plants	3 inches to 14 inches
Marsh smartweed <i>Polygonum Muhlenbergii</i>	Rootstocks, entire plants	Moist soil to 18 inches
Swamp smartweed <i>Polygonum hydropiperoides</i>	Entire plants, seeds	Moist soil to 8 inches
Nodding smartweed <i>Polygonum lapathifolium</i>	Seeds, transplants	Fairly dry to moist soil
Largeseed smartweed <i>Polygonum pennsylvanicum</i>	Seeds, transplants	Moist soil
Coontail <i>Ceratophyllum demersum</i>	Masses of plants	2 to 5 feet
American lotus <i>Nelumbo lutea</i>	Rootstocks, seeds	20 inches to 40 inches
White water lily <i>Castalia tuberosa</i>	Tubers	28 inches to 40 inches
Creeping water primrose <i>Jussiaea diffusa</i>	Entire plants, roots, seeds	Moist soil to 3 feet (in protected areas)
Buttonbush <i>Cephalanthus occidentalis</i>	Cuttings, transplants	Moist soil to 6 inches

\*Measurements indicate optimum depth of water in which seed may be sown or plant parts planted.

stem bulrush and white water lily, aggregating over 3,000 plants, showed an average survival of about 90 per cent. This planting was made about mid June on Lake Glendale, an 80-acre artificial lake flooded only 3 months previously, in the Shawnee National Forest in Illinois.

Dr. Yeager used the entire plants, with as little disturbance to the roots as possible. The duck potato stock averaged about 6 inches high. Care was taken in digging to avoid disturbing the soil about the roots or dislodging the tuber. The plants were transported by truck to the planting site, 2 miles distant, and set within a few hours after being dug. Planting was in moist soil and in shallow water, and consisted merely of setting each duck potato clump in a hole roughly cut to fit, followed by light firming with the foot. In August, 2 months later, these plants averaged nearly 2 feet in height, and in addition, each had given rise to an average of about five other plants.

The softstem and hardstem bulrushes were lifted as "sod" clumps; and the water lily stock consisted of 8- to 10-inch lengths of the large, fleshy roots. The lilies were buried in the bottom soil; the bulrushes were planted in the moist soil along the shore. The water lily stock was leaf-clipped, although this operation may not have been necessary. Hardstem bulrush transplanted in June matured seed later in the season.

Fragments of the growing branches of coontail and waterweed readily grow into entire plants. While fragments or masses of these plants may by themselves become attached to the bottom after being placed in the water, it is advisable to anchor some plants to the bottom. Such attachment prevents the plantings from being washed ashore or displaced by wind. An oar or forked stick is often satisfactory in anchoring masses of these plants to the bottom. About 8 bushels of these species are necessary to plant 1 acre.

At Lake Chautauqua National Wildlife Refuge, the placing of willow and buttonbush cuttings in moist soil readily resulted in growth. There was an exceptionally high success of the buttonbush cuttings. Failure of a number of plots was due to wave washing and to flooding.

The depths best suited for propagating aquatic and marsh plants in the Illinois

River valley are given in table 11. The figures are based on depths at which the plants were found growing in the bottomland lakes. Only the normal depth range of the plants is listed. Abnormal variance created by drought or floods is not given. For example, American lotus often exists on mud flats in midsummer, and grows in 10 feet of water during the spring. River bulrush and marsh smartweed have been observed living for short periods in water 4 or more feet in depth; longleaf pondweed has existed, temporarily, on mud flats.

### Summary

1. The major waterfowl habitat in Illinois extends along the Illinois River for 140 miles, coinciding with the distribution of bottomland lakes.

2. The water levels of the river and the connecting bottomland lakes customarily fluctuate greatly with the season. Recently navigation dams have stabilized water levels in many lakes.

3. At other lakes, natural and artificial levees stabilize and control water levels.

4. With respect to water levels, the bottomland lakes lying adjacent to the Illinois River may be grouped into three classes: stable, semistable and fluctuating.

5. Abundance of aquatic plants in various lakes of the Illinois River valley was determined by plotting the vegetation beds on base maps and measuring the areas by means of a planimeter.

6. A comprehensive survey of plant species in 1938, 1939 and 1940 in more than 20 lakes in the Illinois River valley revealed that sago and longleaf pondweeds, coontail and marsh smartweeds predominated at lakes with stable water levels. River bulrush, American lotus and coontail topped the list in semistable lakes. In lakes with fluctuating waters, only river bulrush and American lotus were abundant. In 1936, 1937 and 1940, however, moist-soil plants—such as millets, smartweeds, nutgrasses and water hemp—were very abundant on the mud flats about certain lakes of this last class.

7. Floods which occur between June and September may be destructive to aquatic plants. A reduction in the abundance of sago pondweed, American lotus, duck potato and river bulrush is often directly traceable to high water.

8. Drought may not only lower water levels sufficiently to enable desirable moist-soil herbaceous plants to develop on mud flats, but it may also be conducive to growth of buttonbush and willows, species of little or no value as sources of waterfowl food.

9. Turbidity is influenced by fluctuating water levels, wave action, fish, plants, soils and pollution.

10. A transparency of less than 9 inches, through the growing season, almost precludes development of submerged and floating aquatic plants.

11. Soils and sedimentation, wave action and commercial fishing are other factors influencing the development of aquatic plants.

12. The amount of seeds produced by certain duck food plants varies annually and with the habitat in which the plant grows. Moist-soil plants apparently produce more seeds per unit area than aquatic plants.

13. Rice cut-grass, coontail, marsh smartweed and longleaf pondweed were the best duck food plants in the Illinois River valley in 1938, when moist-soil plants were wanting. Wild and Japanese millets, pigweed, nutgrasses and nodding smartweed were among the top-ranking foods in 1939 and 1940.

14. American lotus, river bulrush, buttonbush and willow furnish little or no duck food, and are undesirable in many waterfowl feeding grounds, since they compete with more valuable duck food plants.

15. Present methods for control of aquatic and marsh weeds leave much to be desired. Natural, manual, mechanical and chemical methods may be employed. Flooding and cutting the weeds by hand or by a mechanical device appear to be the most practical methods.

16. Aquatic and marsh plants spread into newly created or altered habitats by natural dispersal methods.

17. Only fair and temporary benefits have thus far resulted from thousands of dollars spent by duck clubs on waterfowl food plantings.

18. At least partial control of water levels through small dams and levees is

necessary if duck clubs in certain areas are to achieve maximum results from waterfowl food planting programs.

19. Two desirable methods of managing waterfowl habitats in the Illinois River valley are as follows:

(a) Lower waters early in summer, exposing mud flats for development of moist-soil plants such as nutgrasses, pigweed, smartweeds, rice cut-grass, wild and Japanese millets. This method is, in general, suited to the area between Peoria and Browning.

(b) Maintain water level at depths of 2 to 3 feet for development of aquatic plants such as sago, longleaf and bushy pondweeds and coontail. This method is, in general, suited to the region between Henry and Peoria.

20. Where it is impossible to improve physical conditions, plantings should be made only of those species tolerant of fluctuating water levels and turbidity.

21. In certain years it is possible to take advantage of natural conditions to plant Japanese millet and chufa on mud flats.

22. Aquatic and moist-soil plants generally appear naturally in areas when suitable environmental conditions occur.

23. Desirable duck food plants may be propagated from one or more of the following: tubers, rootstocks, winter buds, leafy cuttings, seeds and transplants of entire plants.

24. The most favorable planting time in the Illinois River valley is late May and early June.

25. Water-saturated aquatic plant seeds often sink in water; if they float, they should be embedded in mud balls before being planted. In shallow water, tubers and rootstocks of aquatic plants may be planted directly in the bottom; in deep water, they should be embedded first in mud balls, which can then be dropped in the desired place.

26. Marsh plants usually thrive on moist soil, or in water not more than 18 inches deep. Aquatic plants do best in water 18 inches to 4 feet in depth. Lack of transparency in water is a limiting factor in the depth to which aquatic plants will grow.

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## APPENDIX

## List of Waterfowl Food Plants in the Illinois River Valley

The following is a list of all but the rarer plants occurring in the Illinois River valley that may be used as food by waterfowl. With few exceptions the classification and nomenclature follow Gray's *New Manual of Botany, Seventh Edition*.

Common and Vernacular Names	Scientific Names		
Muskgrass	<i>Chara</i> spp.	Blunt spike rush, wiregrass	<i>Eleocharis obtusa</i> (Willd.) Schultes
Giant bur-reed, burhead	<i>Spartanum eurycarpum</i> Engelm.	Common spike rush, wiregrass	<i>Eleocharis palustris</i> (L.) R. & S.
Longleaf pondweed, deer's tongue	<i>Potamogeton americanus</i> C. & S.	Arrow arum, wampee, duck corn	<i>Peltandra virginica</i> (L.) Kunth
Leafy pondweed	<i>Potamogeton foliosus</i> Raf.	Greater duckweed, teal moss, seed moss, floating duck's meat	<i>Spirodela polyrrhiza</i> (L.) Schleid.
Small pondweed	<i>Potamogeton pusillus</i> L.	Submerged duckweed, star duckweed, star duck's meat	<i>Lemma trisulca</i> L.
Sago pondweed, teal grass, eel grass	<i>Potamogeton pectinatus</i> L.	Lesser duckweed, teal moss, seed moss floating duck's meat	<i>Lemma minor</i> L.
Bushy pondweed, southern naiad	<i>Najas guadalupensis</i> (Spreng.) Morong.	Minute duckweed	<i>Lemma minima</i> Phillippi
Water plantain	<i>Alisma Plantago-aquatica</i> L.	Watermeal	<i>Wolffia columbiana</i> Karst. & S.
Arowleaf, arrowhead	<i>Lopholacarpus colycinus</i> (Engelm.) J. G. Sm.	Pickerweed	<i>Wolffia punctata</i> Griseb.
Duck potato, wapato, arrowhead, bootjack	<i>Sagittaria latifolia</i> Willd.	Mud plantain, water star-grass	<i>Pontederia cordata</i> L.
Stiff arrowhead, duck potato	<i>Sagittaria cuneata</i> Sheldon	Tall dock, pale dock	<i>Heteranthera dubia</i> (Jacq.) MacM.
Waterweed, elodea	<i>Sagittaria rigida</i> (Pursh) Engelm.	Curly dock, yellow dock	<i>Rumex altissimus</i> Wood
Narrow-leaved waterweed	<i>Anacharis canadensis</i> (Michx.) Planch.	Swamp dock	<i>Rumex crispus</i> L.
Wild celery, tape grass	<i>Anacharis occidentalis</i> (Pursh) Vict.	Nodding smartweed	<i>Rumex verticillatus</i> L.
Creeping eragrostis, love grass, teal grass	<i>Vallisneria spiralis</i> L.	Marsh smartweed, red-top, shoestring, water smartweed	<i>Polygonum lapathifolium</i> L.
Common reed, cane	<i>Eragrostis hypnoides</i> (Lam.) BSP.	Largeseed smartweed	<i>Polygonum Muhlenbergii</i> (Meisn.) Wats.
Wild rye	<i>Phragmites communis</i> Trin.	Water pepper	<i>Polygonum pennsylvanicum</i> L.
Marsh cord grass, slough grass, marsh hay	<i>Elymus virginicus</i> L.	Dotted smartweed	<i>Polygonum Hydropiper</i> L.
White grass	<i>Spartina Michauxiana</i> Hitchc.	Lady's thumb	<i>Polygonum punctatum</i> Ell.
Rice cut-grass, saw grass	<i>Leersia virginica</i> Willd.	Swamp smartweed, white water smartweed	<i>Polygonum Persicaria</i> L.
Catch-fly grass	<i>Leersia oryoides</i> (L.) Sw.	Arowleaf tearthumb	<i>Polygonum hydropiperoides</i> Michx.
Wild rice	<i>Leersia lenticularis</i> Michx.	Water hemp pigweed, hogweed	<i>Polygonum sagittatum</i> L.
Witchgrass	<i>Zizania aquatica</i> L.	Coontail, hornwort, foxtail moss, water moss, moss	<i>Acrida tuberculata</i> Moq.
Switchgrass	<i>Panicum capillare</i> L.	Yellow pond lily, spatterdock	<i>Ceratophyllum demersum</i> L.
Fall panicum, spreading switchgrass	<i>Panicum Gollingeri</i> Nash	White water lily, pond lily	<i>Nymphaea advena</i> Ait.
Wild millet, barnyard grass, duck millet, corn grass, duck corn	<i>Panicum virgatum</i> L.	American lotus, yawky, yorkey nut, yonkpin	<i>Castalia tuberosa</i> (Paine) Greene
Japanese millet, duck millet	<i>Panicum dichotomiflorum</i> Michx.	White water buttercup	<i>Nelumbo lutea</i> (Willd.) Pers.
Walter's millet, corn grass, tall duck millet	<i>Echinochloa crusgalli</i> (L.) Beauv.	Water cress	<i>Ranunculus aquatilis</i> L. var. <i>capillaceus</i> DC.
Nutgrass, straw-colored cyperus, teal grass	<i>Echinochloa frumentacea</i> (Roxb.) Link	Fox grape	<i>Radicula Nasturtium-aquaticum</i> (L.) Britten & Rendle
Nutgrass, red-rooted cyperus, teal grass	<i>Echinochloa Walteri</i> (Pursh) Nash	Riverbank grape	<i>Vitis labrusca</i> L.
Chufa, ground almond, nutgrass, teal grass	<i>Cyperus strigosus</i> L.	Marsh mallow	<i>Vitis vulpina</i> L.
American bulrush, three-square	<i>Cyperus erythrorhizos</i> Muhl.	Long-leaved ammannia	<i>Hibiscus militaris</i> Cav.
Softstem bulrush, tule, roundstem bulrush	<i>Cyperus esculentus</i> L.	Water willow, swamp loose-strife	<i>Ammannia coccinea</i> Rottb.
Hardstem bulrush, big bulrush, tule	<i>Scirpus americanus</i> Pers.	Creeping water primrose, floating primrose willow	<i>Decodon verticillatus</i> (L.) Ell.
River bulrush, flag, three-square flag	<i>Scirpus validus</i> Vahl.	Water milfoil	<i>Jussiaea diffusa</i> Forsk.
Dark-green bulrush	<i>Scirpus acutus</i> Muhl.	Swamp privet	<i>Myriophyllum</i> spp.
	<i>Scirpus fluviatilis</i> (Torr.) Gray	Fog-fruit	<i>Forestiera acuminata</i> (Michx.) Poir.
	<i>Scirpus atrovirens</i> Muhl.	Bladderwort	<i>Lippia lanceolata</i> Michx.
		Buttonbush, buckbrush	<i>Utricularia</i> spp.
		Greater ragweed	<i>Cephalanthus occidentalis</i> L.
		Lesser ragweed	<i>Ambrosia trifida</i> L.
		Western ragweed	<i>Ambrosia artemisiifolia</i> L.
		Cocklebur	<i>Ambrosia psilostachya</i> DC.
		Spanish needles, beggarticks, pitchforks	<i>Xanthium</i> spp.
			<i>Bidens cernua</i> L.
			<i>Bidens comosa</i> (Gray) Wiegand
			<i>Bidens trichosperma</i> (Michx.) Britton
			<i>Bidens frondosa</i> L.



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