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The Life History and Ecology of Ptilostomis Postica (Walker) (Trichoptera: Phryganeidae) in Greenbottom Swamp, Cabell County, West Virginia

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THE LIFE HISTORY AND ECOLOGY OF *PTILOSTOMIS POSTICA* (WALKER) (TRICHOPTERA: PHRYGANEIDAE) IN GREENBOTTOM SWAMP, CABELL COUNTY, WEST VIRGINIA

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Mary Beth Roush

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as meeting the research requirement for the master's degree.

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Department of Biological Sciences

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Dean of the Graduate School

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ABSTRACT

The life history and ecology of *Ptilostomis postica* (Walker) from Greenbottom Swamp in Cabell County, West Virginia were investigated from December 1977 to December 1978. Length-frequency histograms indicate the life cycle is univoltine. Larvae achieved their greatest growth rate (75%) from fall to winter. Case length showed its greatest increase (70.3%) for this same period. There was high correlation between case length and body length in fall (r = 0.72) and winter (r = 0.87), however, a low correlation (r = 0.18) was found in spring. The diet of the larvae changed from carnivorous in fall and winter to omnivorous in spring. Pupation began at the end of April and lasted approximately three weeks. Adult emergence began on 12 May, peaked on 20 May, and lasted two weeks. Chi-square tests for pupae and adults showed no deviation from a 1:1 sex ratio at the 0.05 level. Adults are nocturnal and live less than one month.

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CHAPTER I

INTRODUCTION

Since fresh waters are one of the most basic resources, the communities that live within them and maintain the ecological harmony are subjects of high priority for scientific study. Caddisflies, members of the order Trichoptera, are an important component of freshwater systems. They are among the most abundant aquatic immatures in the streams and waters of West Virginia.

Caddisflies have evolved the means to exploit resources of the full range of freshwater habitats, making themselves important in the trophic levels of most aquatic systems. Diversification in their larval stages has brought about a close dependence of caddisflies on particular features of their aquatic environment. This has led to an important application of caddisflies in freshwater biology, for it can serve as an important indicator of the level of pollution within a body of water. Caddisflies have a biotic importance value of class I (sensitive).

On the whole, these insects have attracted little attention. The adults are small brown or grey moth-like insects and are active mainly at night. The larvae live in the water and most are concealed by cases that blend in with the environment.

Numerous stream and fish food surveys have established caddis larvae as an important item in the diet of trout (Pennak, 1978).

The objective of this investigation, part of an overall study of the Trichoptera of West Virginia, was to study the life history and ecology of the caddisfly *Ptilostomis postica* (Walker) in Greenbottom Swamp. Hopefully, this study will provide a better understanding of its place in the community.

CHAPTER II

REVIEW OF THE LITERATURE

An investigation of the literature reveals that most of the early writings and research concerning the Trichoptera was done by European and other foreign entomologists. Except in the description of species, American entomologists have had an inconsiderable share in this work and the American forms are very inadequately known. There is, however, a great deal of information available concerning this order of insects.

H. A. Hagen and R. McLachlan published considerable numbers of works laying much of the foundation of caddisfly studies. McLachlan's (1874) monograph of the European fauna is a monumental work that surpassed all previous publications in the systematic knowledge of the order Trichoptera. McLachlan's work has been followed with numerous publications by Klapalek, Ulmer, Thienemann, Ris, and Martynov, so that the adult Trichoptera of Europe are now well-known.

A large proportion of the immature stages of the European species have been described, mostly by Klapalek, Struck, Siltala, and Thienemann. Ulmer (1909), besides describing a great number of species in shorter papers, has provided keys to the known European forms. Lestage's (1921) work brings the studies even more up to date. Hickin (1942-

1954) published a study of the larvae of the British Trichoptera. The cases and case-building are the subject of several shorter studies and are mentioned in many of the above works.

The trichopterous fauna of North America is little known. There are doubtless a great number of undescribed species in the eastern United States and Canada, and the western fauna has hardly been investigated. Walker (1852) described 59 American species from material in the British Museum. Sixty-three species were added by Hagen (1873). Banks (1892, 1907) described 303 species and published very useful catalogs for the order, plus a number of keys to the genera of various groups. Vorhies (1909) has described and figured several Wisconsin species, including the entire life history for each. Milne (1939) published a work on North American larvae.

Betten's (1934) work stood for many years as the most authoritative study on North American caddisflies. The work is a general account of the life history and the habits of all stages, including a description of the external anatomy with particular reference to features of interest to the systematist. There are generic descriptions, with keys, of all North American genera, and specific descriptions of all North American species east of the Mississippi River and north of Mexico. All other North and Central American species are listed with complete references so that the report can serve as a catalog for the entire continent. Betten and Mosely (1940) published a paper on the original Walker types in the

British Museum. Ross (1941) described several new species, with descriptions and new records, devoting much work to the problem of arranging and rearranging the taxonomy of the order. Ross's drawings and descriptions were so definitive, the work led to the publication of the Caddisflies, or Trichoptera, of Illinois (Ross, 1944). All species and regroupings of Trichoptera were treated in this book, and all known North American species were reported. This work contains biological life cycles, habitat preference, distribution, a checklist of the Nearctic Trichoptera and overall complete classification of the group. The book is still recognized today as the handbook of trichopteran entomology.

Since Ross' work, caddisfly literature has slowly added to the existing records with new collections, distributional records, and studies. Identification has been improved at the generic level since Ross' work by his contribution to the revised edition of Ward and Whipple (Edmundson, 1959). Taxonomic refinement by Ross (1944), Denning (1956), Flint (1960) and others has developed the classification of the Nearctic Trichoptera into a useful asset for scientific study. Wiggins (1972) reported on the proceedings of the International Congress of Entomology in 1968; studies on systematics, ecology, and phylogeny for the Phryganeidae were discussed. Wiggins (1977) published the most recent reference work for identification, and study of the structure and biology of the larvae of the North American genera.

Hagen (1873) added 63 species to the known North American species of caddisflies in his monograph on the family Phryganeidae. He has published an extensive amount of information on this family. Martynov (1924) published a revision of the family with attention to classification and evolution. Sibley (1926) published figures of the larval structure of _N. postica_. Phryganeids from New England, including information on _N. angustipennis_ have been studied and reported by Banks (1951). Wiggins (1960a) conducted a preliminary systematic study of the North American larvae of the Phryganeidae, including a description of _Ptilostomis_. Wiggins (1961) discussed some additional records of _P. ocellifera_ (Walker) from Newfoundland. Taxonomic confusion of _P. postica_ (Walker) and _P. ocellifera_ (Walker) was discussed.

Gatjen (1926) researched the food of phryganeid larvae through foregut analysis. The subjects of his study were 3 species of _Neuronia_ (= _Ptilostomis_). Crichton (1957) published a detailed study on the mouthparts of adult caddisflies, in particular, _Phryganea striata_ L. in the same family as _Ptilostomis postica_. Included in this article is a comparative study of mouth parts and observations on feeding of caddisflies. A study by Smirnov (1962) investigated the nutrition of caddis worms, the subject being _Phryganea grandis_ L. Shapas and Hilsenhoff (1976) reported the feeding habits of some lotic phryganeids of Wisconsin. _Ptilostomis_ sp.

was one species studied by examination of foregut contents.

Particular attention has been paid to the unusual case-building behavior of caddisfly larvae. Fankhauser and Reik (1935) published a very interesting report on case-building of caddisfly larvae of N. (= Ptilostomis) postica. They conducted experiments with alternate materials for case-building and studies on the use of legs in case building. Ross (1964) divided the case-building habits into 5 categories. The tube-makers (to which P. postica belongs) are discussed with reference to morphological and behavioral evolution. Merrill (1967) experimented with case recognition behavior in ten families of caddis larvae, including Ptilostomis ocellifera. She tested the species for recognition and entry speed.

The unusual pupal mandibles in the family has also been the subject of much research. Wiggins (1960b) published a report that describes the structure of the mandibles, sieves, membranes, along with a discussion of the occurrence of degenerate pupal mandibles in other families. Phylogenetic considerations are discussed in this paper. The problem of systematics in stream ecology is presented by Wiggins (1966) using the reduced mandibles as an example.

Wiggins (1973) discussed diapause, egg observations, and oviposition as they apply to the Phryganeidae as special adaptations to life in temporary water habitats.

Two taxonomic studies in the order Trichoptera have recently been completed in West Virginia. Applin and Tarter

(1977) reported on the larval forms of the genus *Rhyacophila*, family Rhycophilidae, in West Virginia. The investigation included a taxonomic study and distributional information. Hill and Tarter (1978) studied the adult caddisflies of the family Limnephilidae presenting taxonomic descriptions and statewide distributions. Hill et al. (1978) reported state records of the family Phryganeidae in West Virginia.

CHAPTER III

TAXONOMY, DISTRIBUTION, AND MORPHOLOGY

Taxonomy

The Nearctic genus *Ptilostomis* Kolenati (1859) contains four recognized species (Ross, 1944): *P. semifasciata* (Say) and *P. ocellifera* (Walker) are transcontinental; *P. angustipennis* (Hagen) and *P. postica* (Walker) are known only from the eastern half of the continent (Wiggins, 1977). The genus *Ptilostomis* was originally described by Kolenati from Alaska. This genotype may constitute a fifth nearctic species but it has never been identified definitely. The adult female was first described as *Neuronia postica* Walker (1852). The male of this species was described by Betten and Mosely (1940) as the male of their new species *simulans* (Ross, 1944). Vorhies (1909) mistakenly described the larva and pupa of *P. ocellifera* as *N. postica*. Lloyd (1921) described the larva of *N. postica*, but this, too, could well be *ocellifera* since the two were often confused at that time (Wiggins, 1960a). Wiggins (1977) reported associated larvae for *P. postica* but diagnostic characters have not been found to distinguish the larvae.

A phylogenetic classification of this species is as follows (Wiggins, 1977; Merritt and Cummins, 1978):

PHYLUM Arthropoda
SUBPHYLUM Mandibulata
CLASS Insecta
SUBCLASS Pterygota
DIVISION Endopterygota
ORDER Trichoptera
SUPERFAMILY Limnephiloidea
FAMILY Phryganeidae
SUBFAMILY Phryganeinae
GENUS *Ptilostomis* Kolenati
P. postica (Walker)

Distribution

The family Phryganeidae is distributed in the Holarctic region. In North America there are 10 genera with 27 species. Ross (1944) reported the genus *Ptilostomis* to occur in 12 states and Canada (Figure 1). Tarter (pers. comm.) has recorded *Ptilostomis* from thirteen counties in West Virginia (Figure 2). *Ptilostomis postica* has been reported from Georgia, Illinois, Maryland, Massachusetts, Michigan, Mississippi, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Virginia, Washington, D. C., West Virginia, Wisconsin, and Canada (Betten, 1934; Flint, pers. comm.; Ross, 1944; Tarter, pers. comm.) (Figure 1). *Ptilostomis postica* has been recorded from only Berkeley County in West Virginia (Tarter, 1977) (Figure 2).

Figure 1. Range of the genus *Ptilostomis* (●) and *P. postica* (▲) in the United States.

a

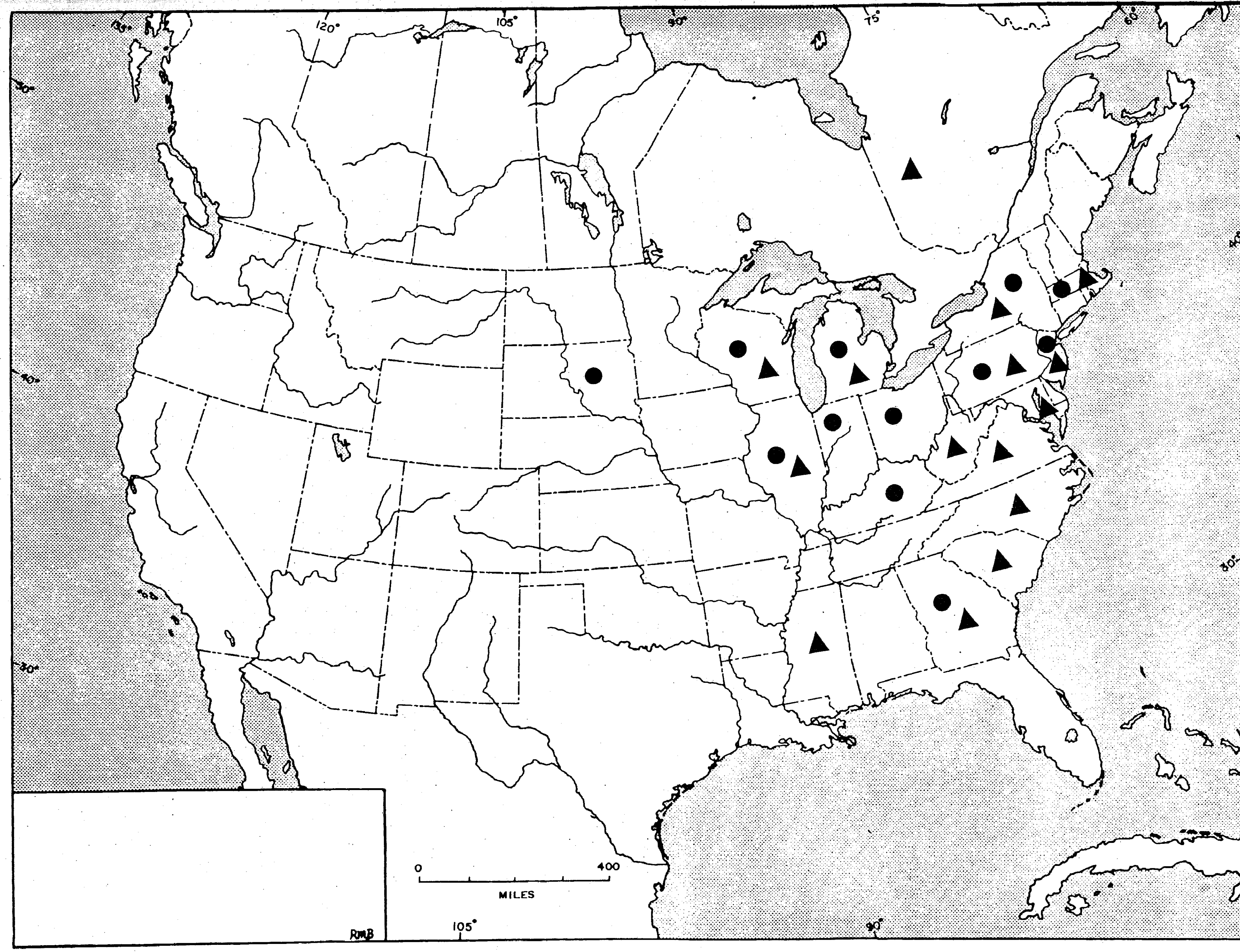
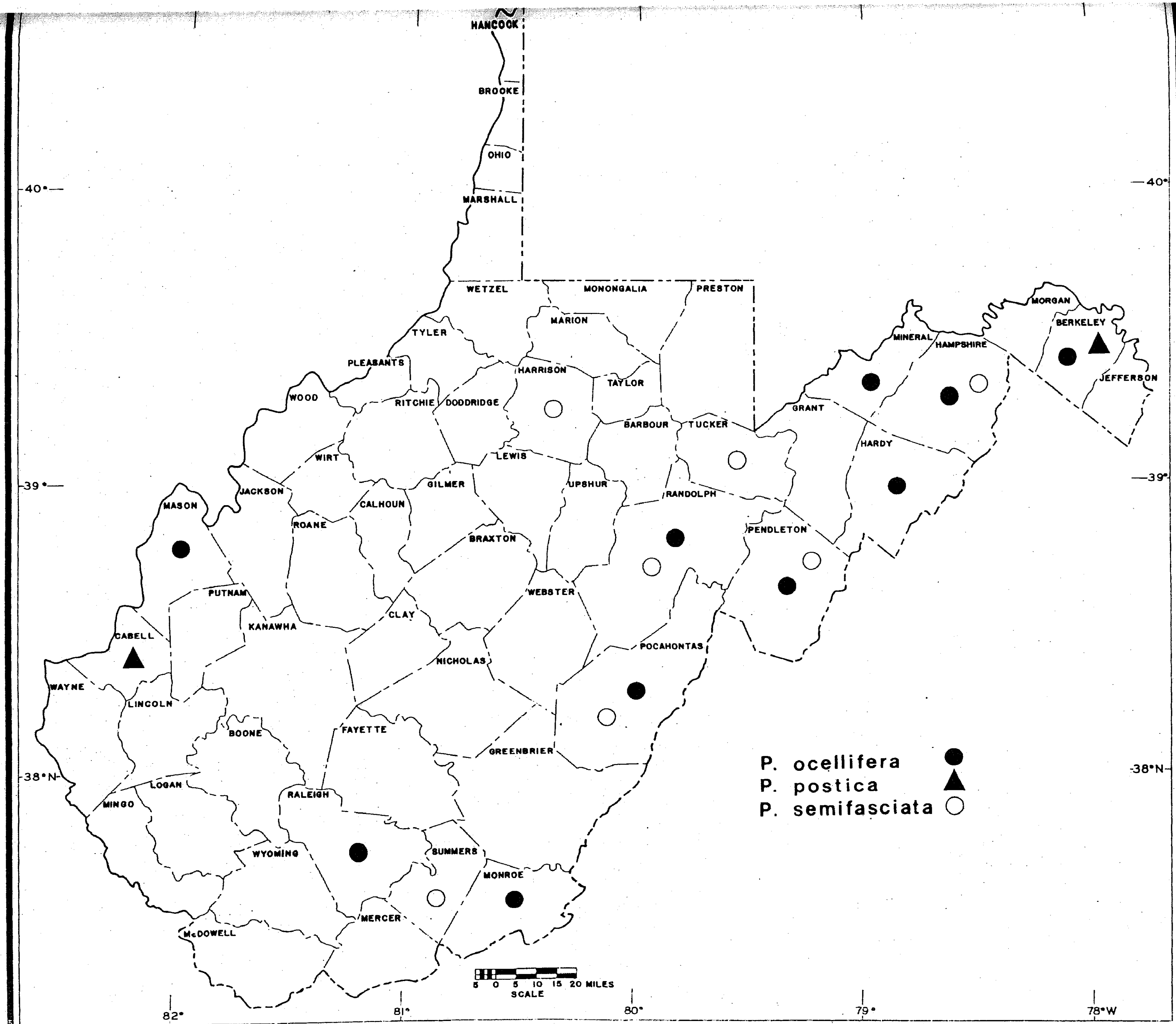


Figure 2. Range of the species of *Ptilostomis* in West Virginia. *P. ocellifera*, *P. postica*, and *P. semifasciata*.


P. ocellifera
P. postica
P. semifasciata
HANCOCK
BROOKE
OHIO
MARSHALL
WETZEL
MONONGALIA
PRESTON
MARION
TYLER
PLEASANTS
HARRISON
TAYLOR
WOOD
RITCHIE
DODDRIDGE
BARBOUR
TUCKER
GRANT
MINERAL
HAMPSHIRE
MORGAN
BERKELEY
JEFFERSON
HARDY
WIRT
LEWIS
JACKSON
GILMER
UPSHUR
RANDOLPH
MASON
CALHOUN
ROANE
BRAXTON
PENDLETON
PUTNAM
WEBSTER
CLAY
KANAWHA
CABELL
NICHOLAS
POCAHONTAS
WAYNE
LINCOLN
BOONE
FAYETTE
GREENBRIER
LOGAN
MINGO
RALEIGH
WYOMING
SUMMERS
MONROE
MERCER
McDOWELL
40°
39°
38°N
82°
81°
80°
79°
78°W
5 0 5 10 15 20 MILES
SCALE

Morphology

The name Trichoptera is derived from the Greek *trichos* ('hair') and *pteron* ('wing'), in reference to the dense hair covering the wings of the adults (Wiggins, 1977). Caddisflies, one of the largest groups of aquatic insects, are holometabolous. Most species of North American caddisflies are univoltine (Merritt and Cummins, 1978).

Larvae in the family Phryganeidae are large, often over 40 millimeters long, but are remarkably homogeneous in structure (Figure 3A). The larvae are more slender and agile and the intersegmental constrictions are more prominent than in the other tube-case families. These characteristics are conveyed in the term suberuciform which is generally applied to the Phryganeidae (Wiggins, 1977). A prominent prosternal horn is present in all species, and there is a median sternellum on the prosternum in all Nearctic genera except one. The mesonotum is largely unsclerotized. Light markings on both mesa- and meta-nota appear to coincide with attachments of muscles to the cuticle (Figure 3B). Comb-like spines, the coxal combs, are present on the basal leg segments in all genera, but are seen in most only as raised points under moderate magnification (50X) (Figure 3E). Mouthparts of Phryganeidae have a slender, sclerotized galea more similar to the Hydropsychoidea than the other families in the Limnephiloidea. Humps of segment I are prominent and gills are single. Segment I always bears two ventral gills on each side and segments II-V usually have a complete set of

Figure 3 (from Wiggins, 1977).

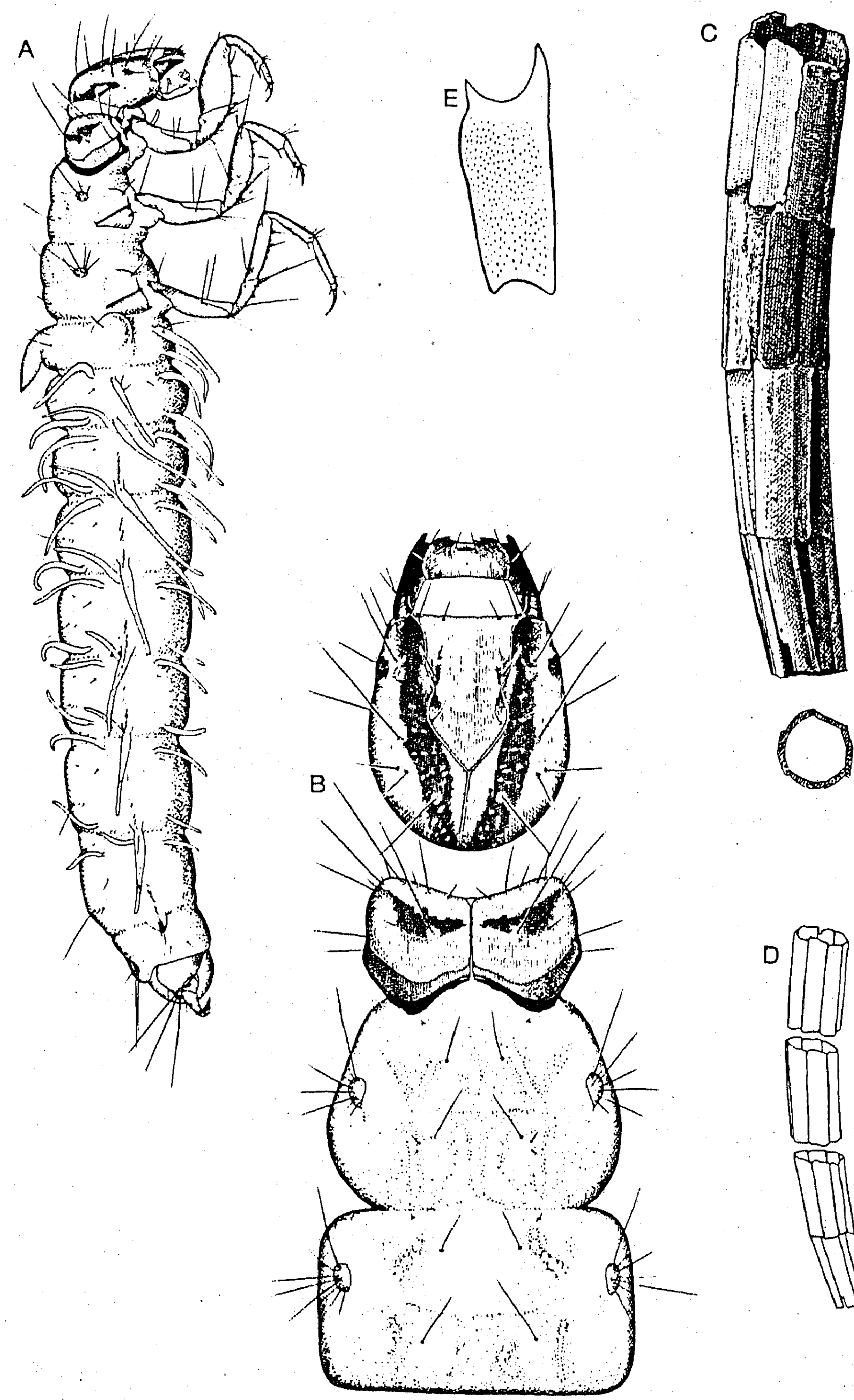
A. Larval stage of *P. postica*.

B. Head and thorax of larva of *P. postica*.

C. Case of *P. postica* larva.

D. Ring structure of case of *P. postica* larva.

E. Coxal comb of *P. postica* larva.


A
E
C
B
D

six single gills on each side. Arrangement of gills often provides characters of taxonomic value. The lateral abdominal fringe is well-developed. Lateral tubercles are absent. Segment IX bears a small dorsal sclerite with at least one pair, and sometimes two, of major setae (Wiggins, 1977).

Ptilostomis larvae have a dark transverse band on each side of the pronotum, separated from the anterior border by an area of light ground color of approximately the same length (Figure 3B). Tibia of the fore and middle legs appear under magnification only as tiny points spread over much of the ventral surface of the coxa. On segments I-VI, abdominal gills are complete, the anterolateral gill on segment VII is variable, and all three anterior gills are present on VIII although the anterodorsal gill is variable (Wiggins, 1977).

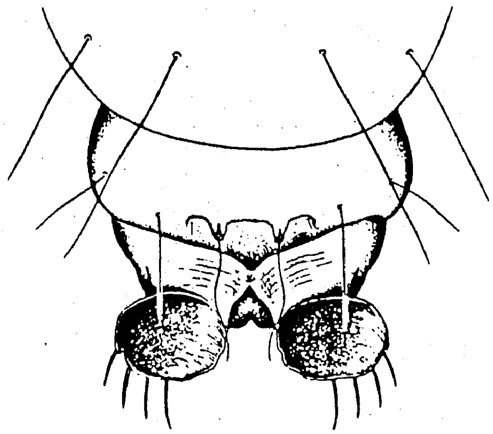
Case construction is usually begun soon after hatching. Substrate materials are selected with the legs and cut to correct size with the mouthparts. There are large glands in the anterior portion of the body that produce a glue-like substance for cementing the materials together to form the case. The case is lined with a silken substance (Pennak, 1978). The larvae of Phryganeidae are tube-case makers. These portable cases are composed of pieces of plant material fastened together to make a smooth cylinder (Fankhauser and Reik, 1935) (Figure 3, C and D).

The case is sealed with a mesh, or sieve, at the posterior end and the head and thorax of the larva protrude from the anterior end. The larva can swim quite freely and drag its house along with it (Ross, 1964). Larvae of most species have five instars (Merritt and Cummins, 1978) after which the case is fastened with silk to a solid substrate. The anterior end of the case is closed off and pupation begins.

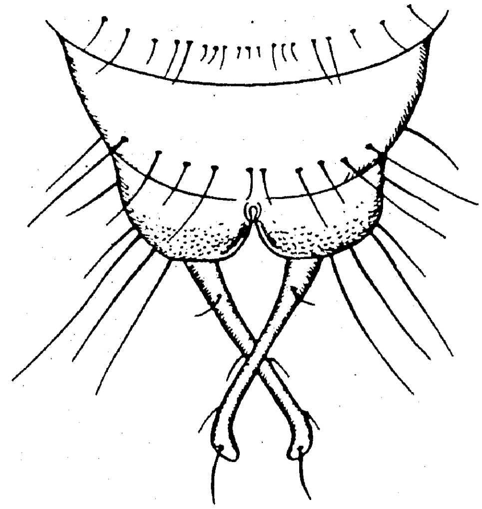
The pupa develops compacted wings which conform tightly to the body, and the legs are folded ventrolaterally. The middle tarsi bear a dense fringe of hairs, making the leg more effective for swimming from the pupal case to the surface. The abdominal segments bear paired dorsal sclerites called hookplates. Hookplates are designated as anterior or posterior in accordance with their position on a particular segment. Hooks on anterior plates are directed anteriorly. These abdominal sclerites engage with the silken lining of the pupal case, enabling the insect to move within. Pupal gills generally coincide with larval gills. At the apex of the abdomen is a pair of anal processes, short and lobate in Ptilostomis (Merritt and Cummins, 1978) (Figure 4). The pupal stage generally lasts from two to three weeks. Aided by the dorsal abdominal hooks on the pupal integument, the pharate adult, largely free of the pupal cuticle, is able to ram its way through the loose covering (plant pieces loosely attached with silken strands) to the outside, leaves the case and swims to the surface. Eclosion occurs either on the water surface or on some emergent object (Wiggins, 1960b; Merritt and Cummins, 1978).

Adult caddisflies are small to medium-sized mothlike

Figure 4. Anal processes at end of abdomen of pupae of Phryganeidae compared to Limnephilidae (from Wiggins, 1966).



PHRYGANEIDAE



LIMNEPHILIDAE

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insects and are found associated with their larval and pupal aquatic habitat (Pennak, 1978) (Figure 5). They are crepuscular or nocturnal, and flight is quite rapid. The wings are hairy and scaly and are folded rooflike over the body when at rest. The mouthparts are feeble and specialized for liquid ingestion. The antennae are filiform and the compound eyes are large (Pennak, 1978). The adults of the genus *Ptilostomis* are brown, with an angulate dark brown mark in the hind wings (Ross, 1944). The shelflike projection of the male ninth sternite and the broad ninth sternite of the female are diagnostic for *P. postica* (Figure 6). The base of the tenth tergite of the male has two pairs of processes which angle suddenly and run parallel with the segment; the dorsal pair is very long, the lateral pair short. The ninth segment of the female has two lateral finger-like processes and a mesal triangular process. The ventral process of the bursa forms a short fork which is narrow and small (Ross, 1944).

The adult stage of most phyganeid caddisflies is short-lived, and lasts thirty days or less. The greater part of the life history is spent as a larva, and it is this stage that winters over in most species (Pennak, 1978).

In general, members of the family Phryganeidae favor marshes and lakes, but some species are taken in rivers and streams (Ross, 1944). *Ptilostomis* larvae have been taken in both lentic and lotic waters, ranging from cool streams to lakes and temporary vernal pools (Wiggins, 1977).

Figure 5. Adult stage of P. postica.

45

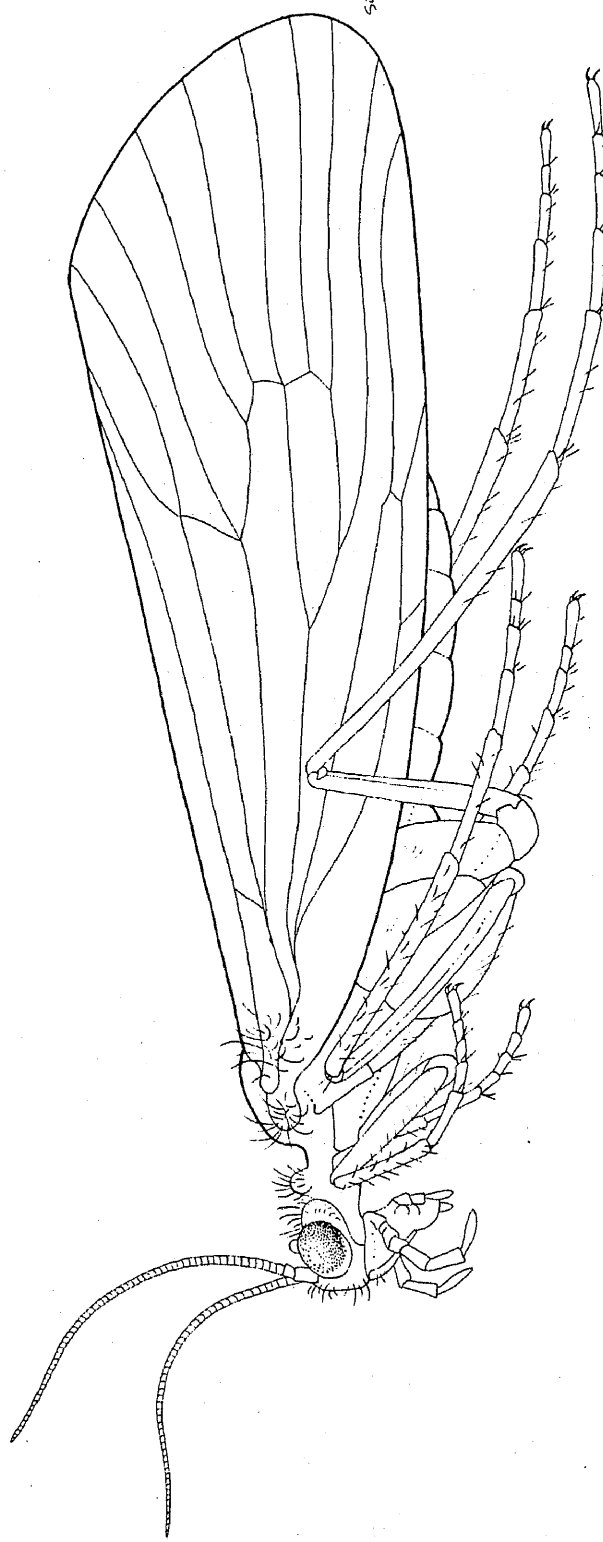
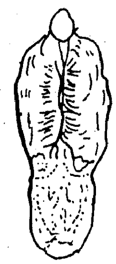
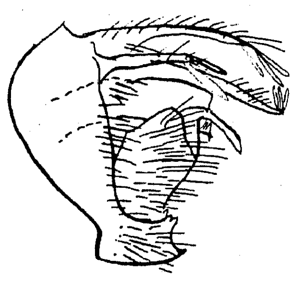


Figure 6. Adult male and female genitalia of *P. postica* (from Ross, 1944).

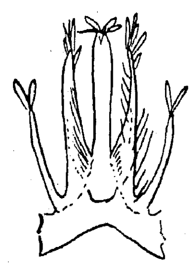


ventral

lateral



lateral



dorsal

CHAPTER IV

DESCRIPTION OF THE STUDY AREA

Greenbottom Swamp lies in the northwestern corner of Cabell County, West Virginia, approximately 8050 meters east of Homestead on State Route #2. The approximate north latitude is 38° 35' with an approximate west longitude of 82° 15'.

West Virginia is situated in the temperate climatic belt of the world. The climate is a result of several factors. Warm tropical winds from the south and cool polar winds from the north meet here. The actual fronts between the two shift from day to day and season to season so as to be north, south, or directly over the state at different times. The storm tracks may pull in cold air from the north or warm air from the south, with accompanying changes in temperature and precipitation from day to day. This accounts for frequent and rather abrupt changes in the daily weather (Janssen, 1964).

The topography of the area is generally rough, hence, West Virginia is known as the Mountain State. In the northwestern part of the state, however, the hills are more rounded and the hillsides less precipitous. The valleys of the larger streams vary from one-half to one mile in width. The bottom lands are very narrow (Krebs and Teets, 1913).

There are two types of river systems within the state. The western two-thirds of the state is separated from the eastern third by the Allegheny Front, or Appalachian Divide. West of this line, all the streams drain into the Ohio River and on to the Mississippi and Gulf of Mexico. These streams follow rather haphazard courses. The tributaries enter the main rivers at angles that are less than that of right angles. This is called a dendritic drainage system. This drainage pattern is caused by the way the rocks lie in this part of the state. In the west, the rock layers are nearly horizontal, being only very slightly rumpled and slanting gently toward the northwest. As a consequence, the streams cross much wider areas of the same kind of rock, which allows them to flow rather gently down the slopes toward the Ohio River (Janssen, 1964). Heavy flooding usually occurs during early spring, when winter is breaking and the snow is melting. This is especially true along the Ohio River (Krebs and Teets, 1913).

The excellent drainage condition of West Virginia results from its relatively large amounts of precipitation. The state as a whole has a mean annual average precipitation between 45 and 50 inches. Most of the rain falls at night during the spring and early summer. The state as a whole has a mean average temperature between -1 C in January, and 23.9 C in July. The prevailing winds during all seasons are mostly from the southwest (Janssen, 1964).

The known geologic history of West Virginia began on the bottom of the sea at the beginning of the Paleozoic Era, more than half a billion years ago. This sea acted as a great settling basin for mud, silt, sand, gravel, and other materials dumped into it by great rivers. As the sediments were deposited, making layers of great thicknesses, their accumulating weight caused the bottom to sink deeper from time to time. The basin would fill to the top, sink, fill with sea water, fill with sediments again, sink, and so on for many millions of years. At the end of the era, during the Appalachian Revolution, tremendous pressures buckled up these beds of rocks made from the compacted sediments from the sea bottom to build the Appalachian Mountains. It is these beds of rocks that today form the hills and mountains of West Virginia (Janssen, 1964).

The whole region was elevated into a great plateau, and the rivers cut deep valleys into it. That is the reason why all today's Appalachian ranges have long, nearly flat tops as they represent all that is left of the plateau surface. The predominant substrate of the study area is Pennsylvanian sandstones and shales (Janssen, 1964).

Greenbottom Swamp is unique in that the number of swamplands are limited in this part of the state. This particular swamp occupies a greater area than all the other local wetlands combined. This location is also unique in that it is a naturally occurring wetland area with a continual supply of fresh water. A small unnamed branch flowing east to west through the swamp and feeding directly into the Ohio River accounts for the water supply of the area. The stream flows year-round and the water level of the inner areas rarely drops below 0.5 meters (McCoy, 1975; Furry, 1978).

The study area is rectangular in shape and is located approximately 550 meters from the Ohio River's south edge. The swamp proper is 1450 meters long with a contiguous marsh on the north end which continues another 2100 meters forming about 14 hectares of swamp forest (Furry, 1978). This study was confined to the southern edge of the swamp. Average water depth varies from 0.5 meters during dry periods to 1.2 meters during the wettest periods (Furry, 1978). Winter freeze-over has been complete and of extended duration during the course of this study. The elevation of the area is 168 meters above sea level (McCoy, 1975).

The study area is bordered on one side by the Chessie System Railroad along with West Virginia State Route #2 and by cultivated fields on the other. The area is divided by a fence running north-south and surrounded by another so that cattle can be pastured here throughout the year (McCoy, 1975). Large trees are located along the southern edge resulting in a shade canopy for the immediate study area.

In the permanently inundated areas, the only tree which remains alive and viable is black willow, *Salix nigra* Marsh. Dispersed among the living black willows are many dead trees. The three most important of the nonliving, standing species are black willow, sycamore (*Platanus occidentalis* L.), and silver maple (*Acer saccharinum* L.) (Furry, 1978). These same species are alive and viable along the southern edge of the swamp along with some oak (Quercus spp.). Button-bush saplings (Cephalanthus occidentalis L.) have the greatest density of any woody plant seedling in the swamp. They occur in thicket-like stands making the swamp barely penetrable in places. Only 18 species of the herb seedling class are present with all species occurring in the spring and autumn floras. During the spring season, water meal, Wolffia punctata Griseb., was the most important species within the cover type, followed by duckweed, Lemna minor L. The amount of duckweed increases throughout the summer months while the amount of water meal remains constant (Furry, 1978).

Old Geologic Survey maps indicate the swamp has been present since 1913. The large number of stumps, fallen trees, and standing dead trees is evidence of a relatively young swamp. However, the high density of button-bush, along with the extensive cover of floating plants and the high diversity of emergent species suggests the swamp has achieved a reasonable level of stability (Furry, 1978).

Much farming and grazing occurs around the study area which may affect the pollution levels in the biotic community through the use of pesticides and chemical fertilizers, and the presence of organic waste products.

CHAPTER V

MATERIALS AND METHODS

This study was initiated in December, 1977 and completed in December, 1978. Collections were made on a monthly basis during the study period. However, due to the lack of specimens in certain months, it was decided to select one month as a representative of each season and make all calculations on a seasonal basis (Figure 7A,B,C,D).

All specimens, upon return to the laboratory, were placed in four dram vials containing 70 percent ethanol and stored for later examination.

Physical Methods

Monthly water temperatures were taken with a Taylor maximum-minimum thermometer placed on the swamp bottom approximately 0.3 meters below the water surface. Temperatures were also recorded with an instantaneous mercury thermometer (Celsius) at the time of collection of benthic samples.

Chemical Methods

Water chemistry tests were performed at the collection site with a Hach chemical kit, Model AL-36B. All tests were completed at the time of collection. Hydrogen-ion concentration (pH) was measured colorimetrically. Dissolved oxygen and

Figure 7A. Greenbottom Swamp (winter).

Figure 7B. Greenbottom Swamp (spring)......7C. (summer)

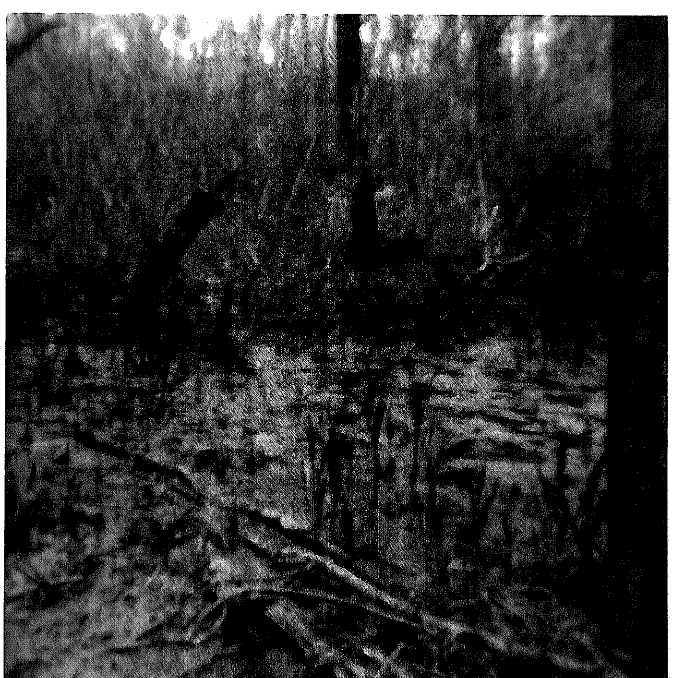


Figure 7D. Greenbottom Swamp (fall).

carbon dioxide were measured and recorded in mg/l. Total hardness and alkalinity were measured and recorded in mg/l of $CaCO_3$. Oxygen saturation values were calculated using the dissolved oxygen concentration, temperature, and altitude of the study area. A nomogram designed to calculate these values was employed (Reid and Wood, 1976).

Larval Stage

Sampling techniques. Larvae were collected using a long-handled dredge with a mesh size of 60 threads/inch. The dredge was used to scoop up mud and leaf debris from the bottom of the swamp. The material in the net was dumped into a large flat pan and examined for specimens. Larvae were preserved in 70 percent ethanol for return to the laboratory.

Development. The total length of the larvae was measured to the nearest 0.5 mm using a centimeter rule. The mean, range, standard deviation, and standard error of the mean were calculated. Size classes were determined by length-frequency histograms arranged in 2 mm length groups. Head width, measured to the nearest 0.001 mm, was used to measure growth. The measurement was taken across the broadest part of the head under 1.5X magnification with a binocular microscope using an ocular micrometer. Differences in head width of the larvae were used to calculate the mean, range, standard deviation, and standard error of the mean. Percent growth from one season to the next was calculated using the mean head width value. Larval instar designations were determined by using head width measurements.

Case construction. Case length measurements were made with a centimeter rule and recorded to the nearest 0.5 mm. The number of rings in each case was recorded and each ring length was measured to the nearest 0.5 mm. Using a dial vernier caliper, the diameters of the anterior and posterior openings of each case were measured to the nearest 0.05 mm. The mean, range, standard deviation, and standard error of the mean were calculated for these values. The cases were examined for sieves and a record was made if one was observed. The regression analysis of case length on total length of larvae was calculated and a coefficient of correlation determined.

Food habits. All larvae foreguts were examined to determine food habits. The head was removed with micro-dissecting scissors and the abdomen was split open dorsally to remove the foregut. The contents of the foregut were then removed and placed on a clean glass slide for a complete scan under a dissecting binocular microscope and then transferred to a compound microscope for closer examination to identify the contents. The entire slide was scanned quickly for any large remains, and a running tally of the major taxa observed was kept on a composite sheet. The number of foreguts containing one of these taxa was recorded, the mean was determined, and the data were analyzed by percent frequency of occurrence. A grid method was used to determine the amount of detritus and diatoms. Using a Whipple eyepiece consisting of 100 grid squares, each foregut was examined in three different fields (300 grid squares) and a record was made of presence or absence of detritus or diatoms in each of the squares. A mean was determined for each foregut and the data were analyzed by percent frequency of occurrence per 100 squares.

Pupal Stage

Habitat and collection. Pupae were first collected in April. The swamp bottom was scraped for mud and debris with a long-handled dredge net of mesh size 60 threads/inch. However, most pupae were found embedded in logs. Submerged logs were examined by pulling away rotting bark and loose pieces of vegetation to uncover pupal cases embedded in soft wood (Figure 8). Cases were retrieved and placed in 70 percent ethanol for return to the laboratory.

Development. Total length was measured to the nearest 0.5 mm with a centimeter rule. Head width was used to measure growth and the measurements were made the same as for larvae. The range, mean, standard deviation, and standard error of the mean were calculated for both length and head width.

Case construction. Measurements were made the same as for larvae.

Food habits. All foreguts were examined to determine food habits.

Adaptations. The pupae developed wing pads and measurements were made for both pair of wings on one side of each

Figure 8. Collection of pupal stage of *P. postica*.

specimen under a binocular microscope (1.5X magnification) using a centimeter rule. The measurements were made to the nearest 0.5 mm and used to calculate growth rate of wing pads. The pupae also construct a sieve plate on the posterior end of the case. The presence of a sieve plate was recorded and a diameter measurement can be taken from the posterior opening measurement for the case. The anterior opening was examined for any special adaptations.

Sex ratio. All specimens were sexed, and a chi-square test was conducted at a confidence limit of 0.05 to determine if a 1:1 ratio exists for males and females.

Reproduction. Testes were removed from some of the males for growth comparisons.

Adult Stage

Collection. Adults were first collected at dusk on May 12 and the procedure was repeated every three days until no adults were captured. Collection was made in two ways: (1) with Ward's ultraviolet light trap (8 watts) and (2) with a fluorescent tube light placed on a sheet. The trap was operated by power pack batteries. Seventy percent ethanol was placed approximately one inch deep in the bottom of a bucket and the insects flew into the panels and were trapped when they fell into the ethanol. The tube light was operated by car battery using an EICO 1070 inverter via the cigarette lighter. The tube light attracted the adults and they were hand-picked as they perched on the sheet. These specimens were also placed in 70 percent ethanol for return to the laboratory. The first method is good for collecting a large diversity of insects, but the second method allows for more selectivity in specimen collection. All specimens were returned to the laboratory, and the study insects were separated for later examination.

Development. Total length was measured to the nearest 0.5 mm using a centimeter rule. Mean, range, standard deviation, and standard error of the mean were calculated from the measurements. Total length including wings and wing length were measured to the nearest 0.5 mm with a centimeter rule. Both the meso- and meta-thoracic wings were measured on one side of each adult. The mean, range, standard deviation, and standard error of the mean were calculated from these measurements.

Food habits. All foreguts were examined to determine food habits.

Sex ratio. All specimens were sexed, and a chi-square test was conducted at a confidence limit of 0.05 to determine if a 1:1 ratio exists for males and females.

Reproduction. Many attempts were made to determine fecundity by direct count of ovarian eggs. All adult females were examined for eggs. An attempt was also made to find egg masses in the field by examining leaf debris, bark of tree trunks, swamp vegetation, and submerged logs. Male testes were removed from some specimens and measurements were made for growth comparisons.

CHAPTER VI

RESULTS AND DISCUSSION

Swamp Environment

Temperature. The average annual temperature in the swamp for the study period was 9.8 C. The monthly extremes were 0 C in December, January, and February and 40 C in September (Table 1).

Water chemistry. Table 1 presents the chemical parameters studied and values obtained for each month. The hydrogen ion concentration (pH) ranged from 6.0 to 7.7, with an average of 6.7. The dissolved oxygen concentration ranged from 2.0 to 12.0 mg/l in July and January, respectively, with a mean of 5.8 mg/l. Carbon dioxide values ranged from 15 mg/l in December, January, February, March, and November to 40 mg/l in July. The mean was 23.3 mg/l. Alkalinity was tested for bicarbonate and carbonate ions. Bicarbonate alkalinity values were 0 mg/l all year; carbonate alkalinity values ranged from 17.1 mg/l in January and February to 85.5 mg/l in May, June, and September. The mean carbonate alkalinity value was 57 mg/l. Total hardness ranged from 51.3 to 205.2 mg/l in February and July, respectively, with a mean of 107 mg/l.

All values found for the chemical parameters reflect a good water quality environment which will support an abundant fauna.

Table 1. Temperature and water chemistry analysis of Greenbottom Swamp, Cabell County, West Virginia, 1977-78.

	Water temperature (C)	Maximum temperature	Minimum temperature	pH
*D	0-0.5	8	0	6.5
J	0	(ice)	(ice)	7
F	0	(ice)	(ice)	6
*M	17	--	--	7.7
A	16	25.5	2	7
M	27	--	--	7
J	31	--	--	6.5
J	27	39	15	6.25
A	16	39	15.5	6.25
S	14.5	40	9	6.5
O	12	21	7	6.5
*N	0	15	4	7.0

Table 1 concluded.

	pH	DO Concen. (mg/l)	Free CO_2 (mg/l)	Alka. (mg/l-$CaCO_3$)	Hard. (mg/l-$CaCO_3$)	Oxygen Sat.(%)
*D	6.5	6	15	51.3	85.5	41.82
J	7	12	15	17.1	104	83.64
F	6	8	15	17.1	51.3	56.1
*M	7.7	11	15	68.4	102.6	114.24
A	7	7	20	68.4	119.7	71.4
M	7	3	35	85.5	119.7	38.76
J	6.5	4	35	85.5	171.0	55.08
J	6.25	2	40	68.4	205.2	25.5
A	6.25	4	30	34.2	68.4	40.8
S	6.5	7	25	85.5	102.6	69.36
O	6.5	3	20	34.2	68.4	27.54
*N	7.0	3	15	68.4	85.5	20.91

* Representative months for seasonal calculations.

Larval Stage

Development. Length-frequency histograms indicated that this population of P. postica contained only one size class (Figure 9). The earliest and smallest larvae were collected in November, 1978. Their average length was 13.3 mm, with a range of 9.0 to 10.0 mm. The last and largest larvae were collected in March, 1978. The average length was 30.69 mm, ranging from 27.0 to 34.5 mm.

Wiggins (1977) stated that there is a single generation per year for all Ptilostomis species, and reported the length of Ptilostomis larvae up to 35 mm.

Head width was used to show the seasonal variation in growth (Figure 10). The larvae grew most rapidly from fall (November) to winter (December). The mean head width in the fall was 1.2 mm, with a range of 0.96 to 1.65 mm. The mean head width for winter was 2.06 mm, ranging from 1.39 to 2.44 mm. This represents the greatest growth rate, 75 percent throughout the year. The largest mean head width was in the spring at 2.38 mm, ranging from 2.18 to 2.57 mm. This represents a growth rate from winter to spring of 14 percent. Growth was retarded during the winter when water temperatures were at their lowest and the swamp habitat was frozen over (Table 1).

An attempt was made to determine the number of larval instars using head width measurements (Figure 11). The graph shows a definite grouping of head widths, indicating three different instars. However, no larvae were found from July

Figure 9. Length-frequencies at seasonal intervals of *P. postica* larvae from Greenbottom Swamp. M = March, D = December, N = November and number = sample size.

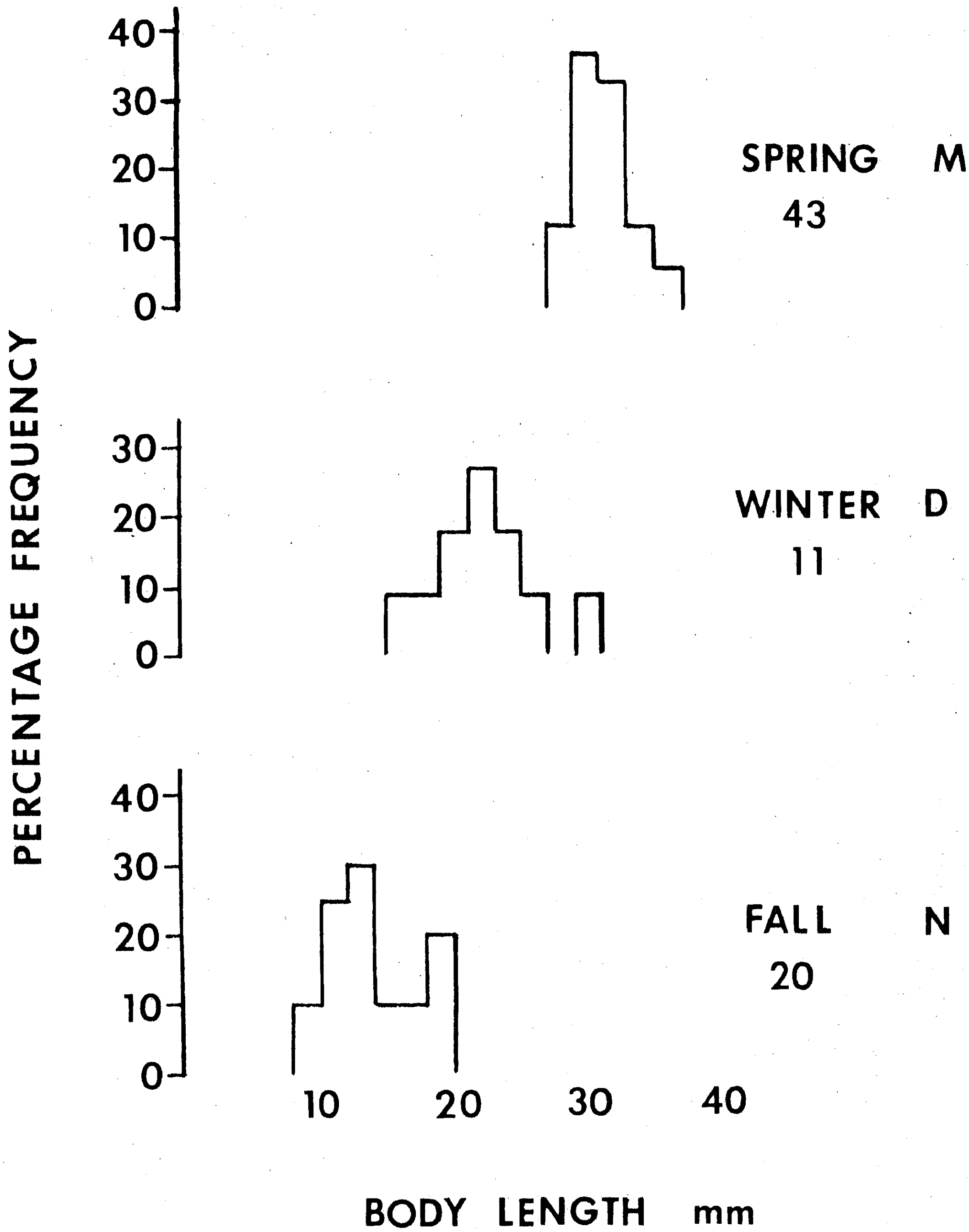

PERCENTAGE FREQUENCY
40
30
20
10
0
SPRING M
43
30
20
10
0
WINTER D
11
40
30
20
10
0
FALL N
20
10
20
30
40
BODY LENGTH mm

Figure 10. Seasonal variation of the head width in *P. postica* larvae. Horizontal lines = means, vertical lines = ranges, open rectangles = one standard deviation, shaded rectangles = standard error of the mean, letter = representative month, number = sample size, and percentage = growth rate.

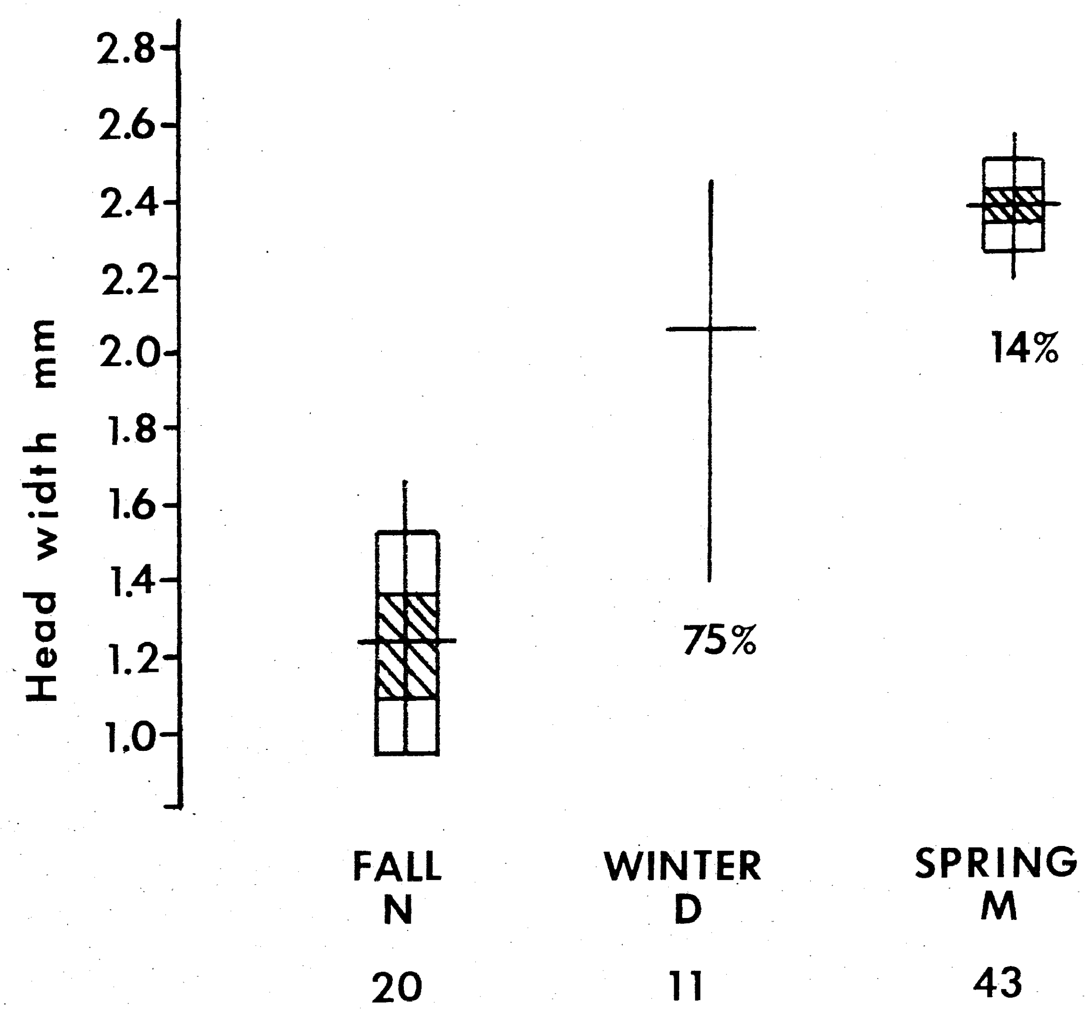
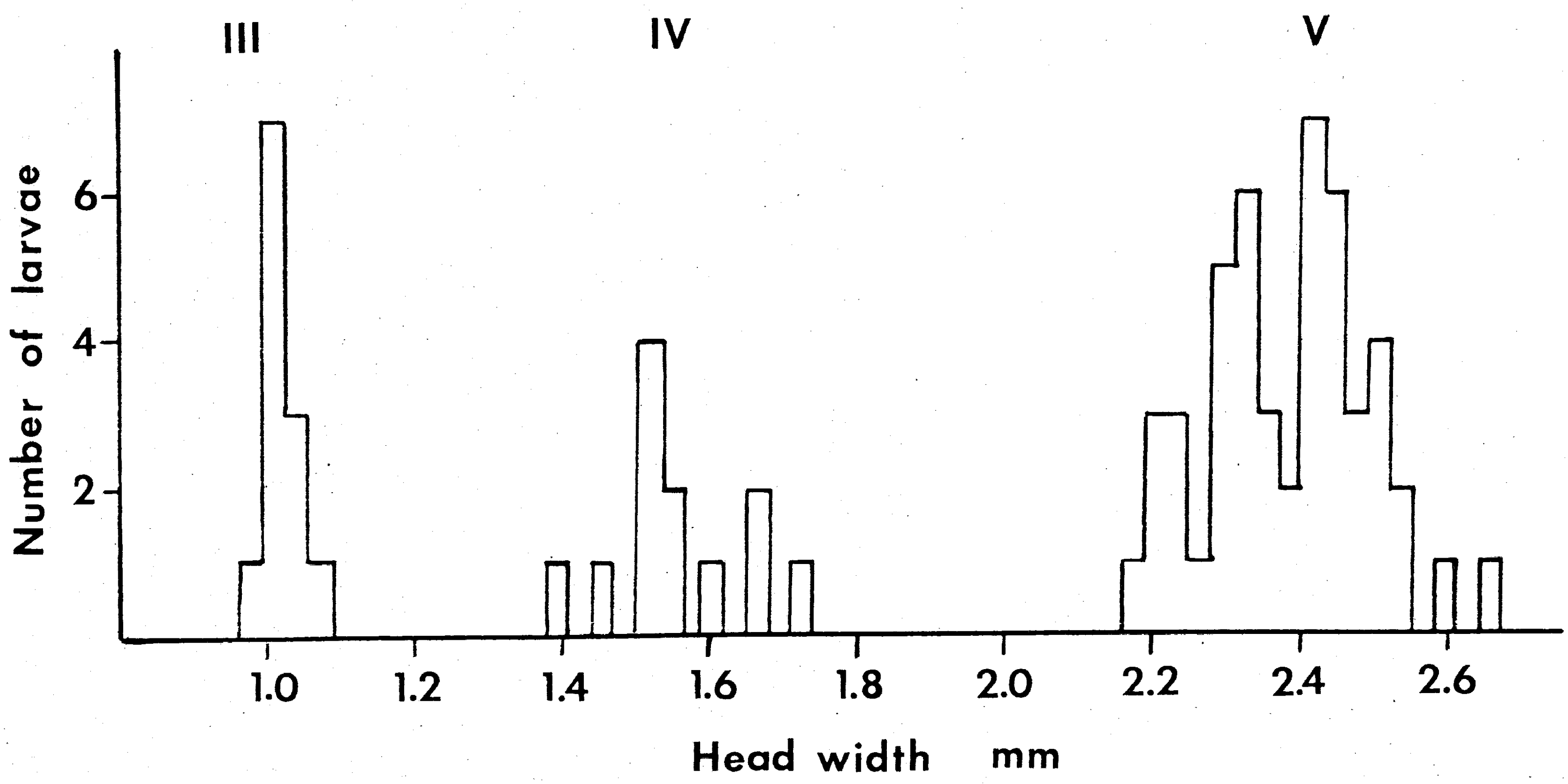

Head width mm
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
75%
14%
FALL
N
20
WINTER
D
11
SPRING
M
43

Figure 11. Head width of all larvae versus number of larvae of *P. postica* to determine instar number.

Instar	Head width ranges mm
I	—
II	—
III	0.96 - 1.87
IV	1.38 - 1.73
V	2.16 - 2.66

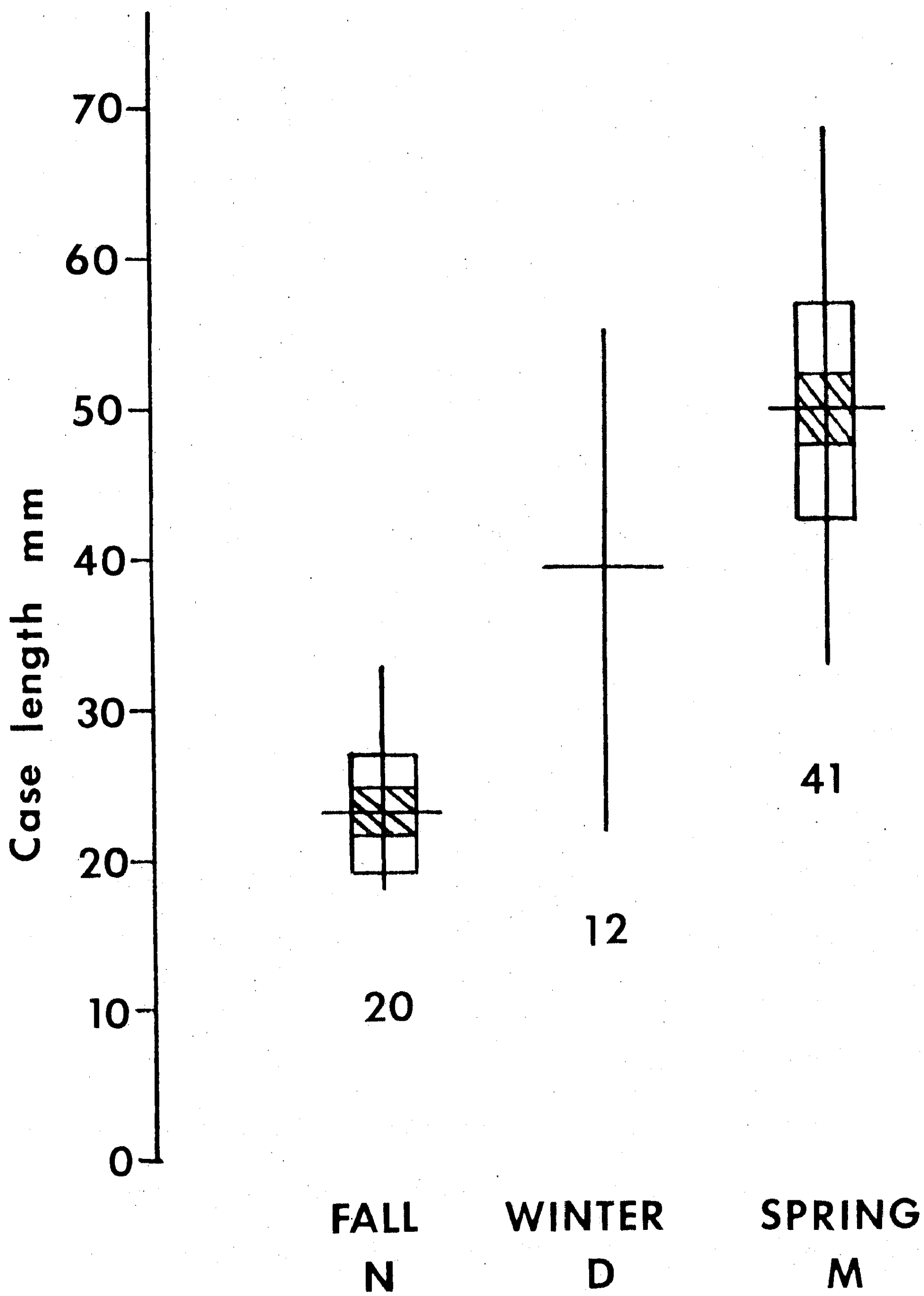


to October. This could eliminate one or more size classes from the calculations. Pennak (1978) stated that for most Trichoptera there are typically five instars between the egg and pupa, although some few species have six or seven. The duration, and possibly the number, of these instars, depends on the particular species as well as water temperature and amount and type of food. A single particular larval instar may last only 15 days, or it may persist for several months, depending on these conditions. Siltala (1907) and Wesenberg-Lund (1911, 1913) stated that the larvae of European phryganeids grow rapidly during the summer and early fall and reach the last larval stage in October. In this stage they pass the winter months. Wiggins (1973) reported living, first-instar, phryganeid larvae (of unknown genus), still within a gelatinous matrix, beneath wet leaves in a pool basin in Algonquin Park, Ontario in October, 1960. Wiggins (1977) reported final instars of *P. ocellifera* in a littoral region of a British Columbia lake from November to June.

Case construction. Case measurements also show seasonal variation in length (Figure 12). The mean case length in the fall (November) was 23 mm, ranging from 18 to 33 mm. The case length for winter ranged from 22 to 55 mm, with a mean of 39.3. This represents an increase of 70.3 percent. The case length for spring ranged from 33 to 69 mm, with a mean of 50.0 mm. This represents a 27.2 percent increase in length. Wiggins (1977) reported the length of the larval case up to 60 mm.

The number of rings and ring length measurements are

Figure 12. Seasonal variation of the case length in *P. postica* larvae. Horizontal lines = means, vertical lines = ranges, open rectangles = one standard deviation, shaded rectangles = standard error of the mean, letter = representative month, and number = sample size.



Case length mm
70
60
50
40
30
20
10
0
20
12
41
FALL
N
WINTER
D
SPRING
M

presented in Table 2 to show seasonal variations. The number of rings varies from 3 to 6 with no evident pattern. Case rings show a general increase in length from season to season. A comparison of the diameter of the anterior and posterior openings of the case is presented in Table 3. The case increases in diameter toward the anterior end.

Sieves were not observed on any of the cases collected in the fall and winter. Four of the cases collected in spring had posterior sieves indicating that construction of a sieve plate is probably related to pupation.

There was high correlation between case length and body length in fall ($r = 0.72$) and winter ($r = 0.87$) (Figure 13). The following equations were calculated to express this relationship:

$$\text{(Fall)} \quad Y = 11.65 + .86X$$

$$\text{(Winter)} \quad Y = -10.61 + 2.25X$$

Where Y = the case length (mm) and

X = total body length (mm).

However, a low correlation ($r = 0.37$) was found between case length and body length in spring (Figure 14). The following equation was calculated to show this relationship:

$$Y = 27 + .74X$$

These data indicate that body length and case length are closely related in fall and winter. In spring, case construction continues as larval growth slows down.

The cases collected in the fall were composed of dead leaf material and a few grass blades. They were brown and green and the different texture of the grass blades was

Table 2. Seasonal variation of case rings.

		Number of rings	Ring 1	Ring 2	Ring 3
Larvae:					
Fall (N)	$\bar{X}$	4.85	5.8	5.25	5.125
	Range	4-6	4.0-8.5	3.5-7.5	2.5-7.0
	$\bar{X}$	5.33	9.08	8.83	8.0
Winter (D)	Range	5-6	4.5-12	6-12	5-12
	% increase		56.6	68.2	56.1
	$\bar{X}$	4.71	11.27	11.01	11.25
	Range	3-6	6-15	8.5-14	8-14
	% increase		24	24.7	40.6
Pupae:					
April	$\bar{X}$	4.69	11.57	10.99	10.79
	Range	4-6	3.5-15	7-14	7-14
	% increase		2.7	-0.2	-4.1
May	$\bar{X}$	4.5	12.67	8.33	11.17
	Range	3-6	11-14	3-11.5	7-13.5
	% increase		9.5	-24.2	3.5

Table 2 concluded.

		Ring 4	Ring 5	Ring 6*
Larvae:				
Fall (N)	$\bar{X}$	4.45	3.23	3
	range	2.5-6.5	2.0-4.5	2-5
	$\bar{X}$	7.75	5.375	2.83
Winter (D)	range	4-13	2-12	2-4
	% increase			
	$\bar{X}$	10.07	9.33	7.75
	range	3-14	2-14	6-9.5
	% increase	29.9	73.6	173.9
Pupae:				
April	$\bar{X}$	10.49	7.66	5.67
	range	4-13	2.5-13	3.5-8.5
	% increase	4.2	-17.9	-26.8
May	$\bar{X}$	10.25	7.5	7.0 (1)
	range	7-13.5	5-10	---
	% increase			

* Only a very small sample had 6 rings.

Table 3. Seasonal variation of case openings.

		Anterior Opening (mm)	Posterior Opening (mm)
Larvae:			
Fall (N)	$\bar{X}$	3.6	2.5
	Range	2.3-5.0	1.5-3.8
Winter (D)	$\bar{X}$	5.2	3.8
	Range	3.9-6.7	2.4-5.4
Spring (M)	$\bar{X}$	6.4	6.0
	Range	4.1-7.8	4.9-8.0
Pupae:			
April	$\bar{X}$	6.8	5.81
	Range	5.5-8.2	4.2-6.6
May	$\bar{X}$	6.3	5.8
	Range	6.1-6.6	4.9-6.3

Figure 13. Regression analysis of body length versus case length for *P. postica* larvae. Number in parentheses = sample size in fall and winter.

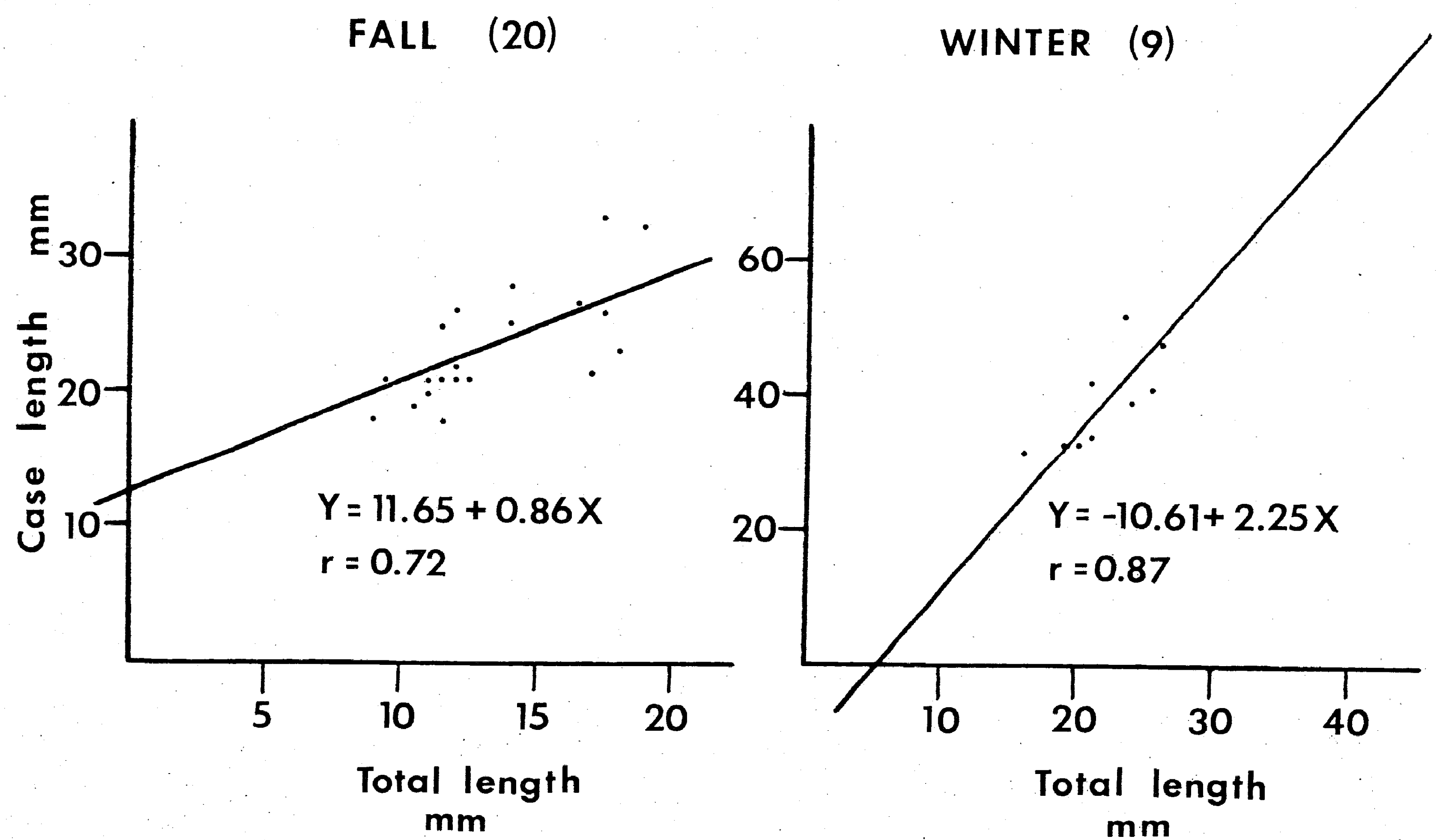
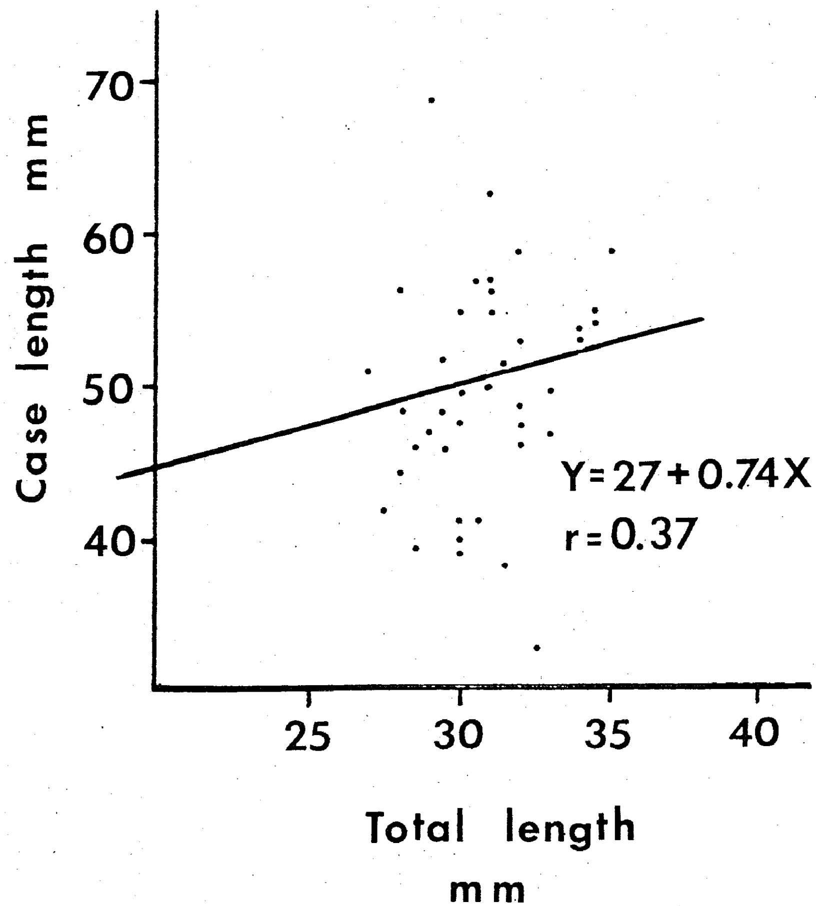

FALL (20)
WINTER (9)
Case length mm
30
20
10
60
40
20
Y = 11.65 + 0.86X
r = 0.72
Y = -10.61+ 2.25X
r = 0.87
5
10
15
20
10
20
30
40
Total length mm
Total length mm

Figure 14. Regression analysis of body length versus case length for *P. postica* larvae. Number in parentheses = sample size in spring.

SPRING (41)



Case length mm
70
60
50
40
25
30
35
40
Y=27+0.74X
r=0.37
Total length
mm

apparent even after the color was bleached from storage in 70 percent ethanol. Rings were not necessarily uniform in material. Some rings were a mixture of dead leaf material and grass blades. The cases collected in winter and spring consisted entirely of dead leaf material. The shape of the case was straight or slightly curved, and rounded in cross section.

According to Fankhauser and Riek (1935), the larval case of P. postica is a slightly curved or straight tube, wide open at both ends. The diameter of the tube may be the same from end to end or increase slightly toward the anterior end. It is usually six-sided in cross-section and consists of three to five rings of building units placed end to end. The rectangular leaf segments are cut and fitted together with remarkable regularity and very little overlap. All natural cases observed have been made of dead leaves, or grass blades, or a mixture of both. Adjoining rings may contrast in color, as they are often made of different materials. Each ring is usually uniform in its material, although segments of leaves and grass blades are sometimes used in the construction of the same ring.

One of the cases examined from the spring collection contained the remains of a case within the larger case of the larvae. The old case had a smaller diameter, smaller ring length, and was about one-half the length of the larger case. Ross (1944) stated that young larvae make cases which are miniatures of those made by larger larvae, and the case is enlarged as the larva grows. According to Pennak (1978), caddisfly larvae add to the case at the anterior end. Depending on the species, larvae may tear off the posterior part of the case or leave the old case and build a new one.

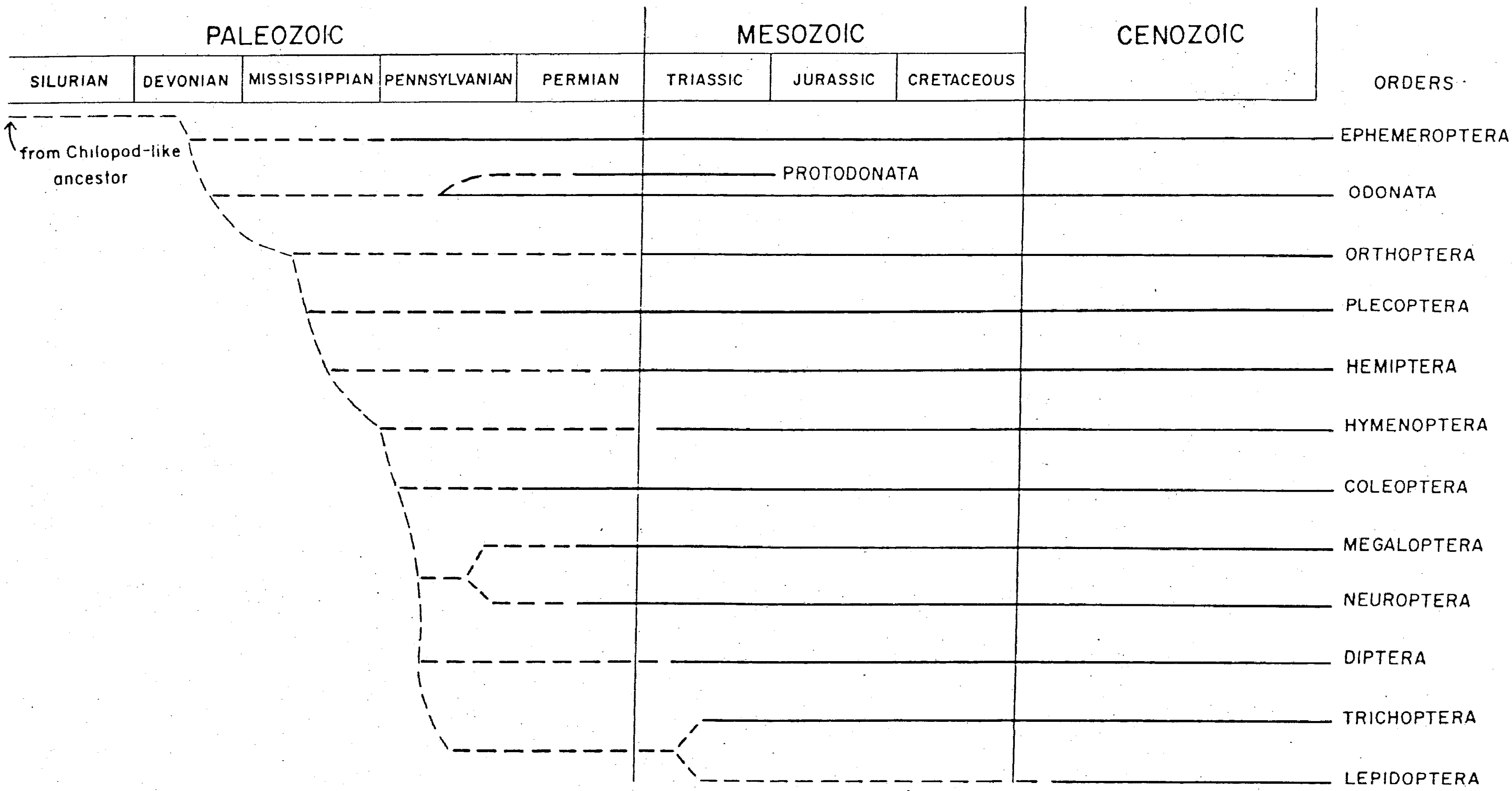
The larva of P. postica, once it has begun to add a new ring at the anterior end of the case, completes this addition rather rapidly, often with segments of the same leaf. On the other hand the larva may pause for several days, or even weeks, before it adds another ring in front (Fankhauser and Reik, 1935). According to the same article, the larva fastens the segments together with a silken secretion of the spinning glands. The posterior convoluted portion of the two glands is visible on both sides of, and posterior to, the midgut. Two tubes enter the head, and taper to very fine ducts that run parallel to the ventral mid-line until they reach the lower lip, where they open at the tip. The mandibles are used for grasping the dead leaves, while the mesothoracic legs are more slender and resemble the metathoracic legs.

Fankhauser and Reik (1935) experimented with case-building of P. postica with natural and alternate building materials. Removal of the larvae from the old cases caused the larvae to become extremely restless. They burrowed out of sight beneath any materials present, and began construction of a new case. The larvae required a point of attachment from which to start construction. The cutting of a building unit was preceded by a 'sizing-up' of the piece of material. The larva showed an efficient manipulation of the material with the pro-and mesothoracic legs. A rough preliminary sheath was constructed first, followed by a more regular final case at the anterior end. Speed of construction causes the difference in the stages. The early portions were constructed rapidly (2-3 cm in 4 hours), the well-defined rings added later on much more slowly. The results showed that given alternate building materials, the larvae built typical cases, nearly typical, or very crude cases, depending on the material. They adapted to procedures that differed strikingly from the normal building process. Given a choice of building materials, the larvae always chose a material that could be used without cutting or that could be easily trimmed for the early stages of construction. Construction of the final case, however, always involved a 'preference' for dead leaf material. Amputation of the first or second pair of legs did not prevent the larvae from constructing fairly compact cases. Larvae must therefore be capable of co-ordinating the movements of the remaining legs for building activities.

Merrill (1969) reported that phryganeid larvae removed from their cases have greater ability for re-entry than do most other families. Entry was also more rapid for phryganeids.

The root of case-making behavior traces back to a early point in the evolution of winged insects (Figure 15). Experimental evidence in the Lepidoptera, the closest ally of the caddisfly, suggests a common ancestor. The occurrence of a common ancestor of Trichoptera and Lepidoptera would

Figure 15. Phylogeny of insect orders showing relationship of Trichoptera and Lepidoptera plotted against the geological time scale (Merritt and Cummins, 1978).


PALEOZOIC
MESOZOIC
CENOZOIC
SILURIAN
DEVONIAN
MISSISSIPPIAN
PENNSYLVANIAN
PERMIAN
TRIASSIC
JURASSIC
CRETACEOUS
ORDERS
from Chilopod-like ancestor
PROTODONATA
EPHEMEROPTERA
ODONATA
ORTHOPTERA
PLECOPTERA
HEMIPTERA
HYMENOPTERA
COLEOPTERA
MEGALOPTERA
NEUROPTERA
DIPTERA
TRICHOPTERA
LEPIDOPTERA

be in the Triassic, about 200 million years ago. Various modifications now known have evolved in about the last 150 million years (Ross, 1964). Case makers evolved from the net makers between early Triassic and Cretaceous, a span of less than 100 million years. Tube-case makers represent the final stage in case-making behavior. The Phryganeidae are regarded, however, as the most primitive among the tube-case makers.

Food habits. The information for foregut analysis is presented in Table 4. The diet of the larvae collected in the fall consisted primarily of the copepod, *Cyclops* sp., with a mean of 4.82 per foregut and an 85 percent frequency of occurrence. A mean of 2.1 ostracods per foregut was found with a 50 percent frequency of occurrence. A mean of 0.42 diatoms per foregut were found with a 20 percent frequency of occurrence, and a mean of 11.55 per foregut of detritus with a 100 percent frequency of occurrence was observed. The rest of the diet consisted of cladocerans, midge larvae, rotifers, filamentous algae, and some unidentified materials. In winter, the diet of the larvae consisted primarily of the copepod, *Cyclops* sp., and ostracods, with means of 4.33 and 2.33, respectively, per foregut examined, and a 55 percent frequency of occurrence for each. Diatoms occurred in a mean of 1.19 per foregut examined with a 73 percent frequency of occurrence. A mean of 18.39 per foregut examined was found for detritus with a 100 percent frequency of occurrence. The remainder of the diet consisted of cladocerans, midge

Table 4. Seasonal foregut analysis of *Ptilostomis postica* larvae from Greenbottom Swamp, Cabell County, West Virginia. $\bar{X}$ = Mean, %FO = Percentage Frequency of Occurrence.

Fall (N)	Category	Taxa	$\bar{X}$	%FO
	Copepod	*Cyclops* sp.	4.82	85
	Ostracod		2.1	50
	Cladocerans		1.0	15
	Midge larvae	*Chironomus* sp.	1.0	5
	Rotifer		1.0	5
	Filamentous algae		1.0	20
	Unidentified		1.0	30
Grid method:	Detritus		11.55	100
	Diatoms		0.42	20
		Navicula		
		Unidentified		
Winter (D)	**Category**	**Taxa**	**$\bar{X}$**	**%FO**
	Copepod	*Cyclops* sp.	4.33	55
	Ostracod		2.33	55
	Cladocerans		1.75	36
	Midge larvae	*Chironomus* sp.	1.0	9
	Rotifer		11.0	9
	Dipteran		1.0	9
	Filamentous algae	*Microspora*	1.0	9
	Unidentified		1.0	18
Grid method:	Detritus		18.39	100
	Diatoms		1.19	73
		Navicula		
		Cymbella		
		Fragilaria		
		Pinnularia		
Spring (M)	**Category**	**Taxa**	**$\bar{X}$**	**%FO**
	Ostracod		4.5	20
	Midge larvae	*Chironomus* sp.	2.0	20
	Rotifer		9.0	5
	Filamentous algae		1.0	5
	Unidentified	Odonata	1.0	5
Grid method:	Detritus			
	Diatoms			
		Navicula		
		Pinnularia		
		Cymbella		

larvae, rotifers, dipterans, filamentous algae, and unidentified material. In spring, the diet shifted and consisted primarily of ostracods and midge larvae, 4.5 and 2.0 per foregut examined, respectively, with a 20 percent frequency of occurrence for each. Detritus, a mean of 27.12 per foregut examined, had a 100 percent frequency of occurrence. The rest of the diet consisted of rotifers, filamentous algae, diatoms, and unidentified material. The larvae are largely carnivorous early in their life cycle, shifting to a more omnivorous diet in later stages. No empty foreguts were observed for larvae.

Wiggins (1977) stated that generally phryganeid larvae are omnivorous, with a few predaceous for at least part of their life cycle. Pennak (1978) classified phryganeids as grazers, feeding on algae, fungi, detritus, and often very small invertebrates. They pick up material at random that is resting or loosely attached to the substrate. Merritt and Cummins (1978) classified *Ptilostomis* larvae into two functional feeding groups: (1) shredders (herbivores) and detritivores (chewing feeding mechanism), and (2) engulfers (predators)--carnivores. Shapas and Hilsenhoff (1976) reported *Ptilostomis* spp. from the Mecan River in Wisconsin that were exclusively carnivorous. Wiggins (1977) reported *P. ocellifera* from a British Columbia lake with late instars largely predaceous in feeding.

Pupal Stage

Development. Fifty-two pupae were collected in April and May. The first pupa was collected on 23 April and the last on 16 May, a period of about 3 weeks. Pennak (1978) stated that the pupal stage of most Trichoptera lasts about two weeks. Merritt and Cummins (1978) reported the stage to last from two to three weeks.

The average length of the April pupae was 21.84 mm, with a range of 17 to 27.5 mm. The pupae collected in May had a mean length of 22.23 mm, with a range of 18 to 23 mm.

The average head width for April was 2.77 mm, ranging from 2.4 to 3 mm. The head width for May ranged from 2.3 to 2.7 mm, with a mean of 2.62 mm.

Case construction. The mean case length for April was 49.58 mm, ranging from 36 to 72 mm. The mean case length for May was 44.33, ranging from 37 to 52 mm. There should be little or no variation in growth from the spring (March) measurements. The growth rate for spring to April is -0.8 percent and for spring to May is -11.3 percent (probably the large difference is due to small sample size in May).

The number of rings and ring length measurements are presented in Table 2. The number of rings varies from 3 to 6 with no evident pattern. Case rings show a very slight or negative growth rate from the larval to pupal stage.

A comparison of the diameter of the anterior and posterior openings of the case is presented in Table 3. The case increases in diameter from the posterior to the anterior end.

Food habits. All foreguts were empty. The pupae do not feed.

Adaptation. Variations in wing pad length for pupae presented in Table 5 show very little change from April to May. Posterior sieves were observed for 32 out of 39 pupal cases examined.

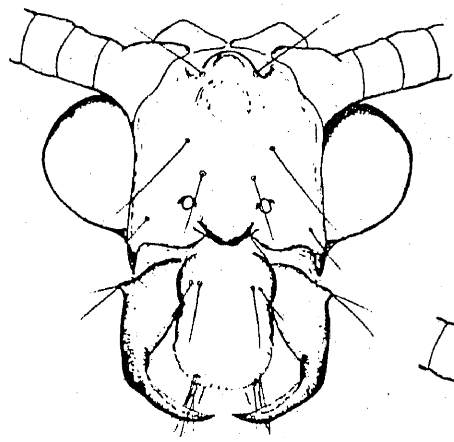
According to Wiggins (1972), a new hypothesis was proposed supporting a line of caddisflies arising in lotic waters. This group is characterized by larvae which construct ring-type cases, but which have lost the typical trichopteran pre-pupal habit of spinning a silken sieve membrane across the anterior end of the case, and by pupae in which the mandibles were reduced to membranous lobes which lack a cutting edge because they were no longer essential for escape from the pupal case (Figure 16). This line eventually gave rise to the genus *Ptilostomis*. This is an example of an economy in structure following a change in behavior (Wiggins, 1964). In the Greenbottom Swamp study, the anterior opening of the case was examined for any special adaptation. The end of a few cases appeared jammed with debris. According to Wiggins (1960b), the anterior opening of the case is closed off only with plant pieces drawn loosely together with silken strands (Figure 17). These can be easily dislodged by the pupae without cutting.

Sex ratio. In April, 25 female and 16 male pupae were collected. The chi-square test showed no significant deviation from the 1:1 sex ratio at the 0.05 confidence level. Only six females and 5 males were collected in May. These data were

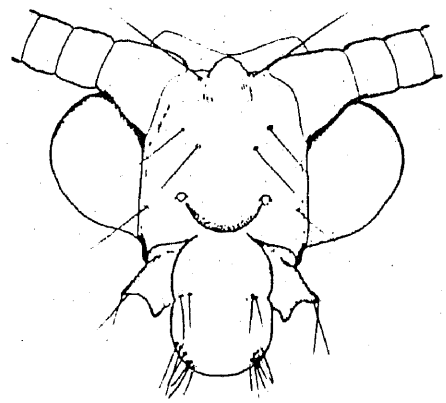
Table 5. Comparison of lengths of first and second pair of wing pads of *P. postica* pupae.

		1st pair	2nd pair
April	$\bar{X}$	8.0	6.4
	Range	6.0-9.7	5.3-7.3
May	$\bar{X}$	8.1	6.5
	Range	6.7-9.3	5.7-7.3

Figure 16. Face view of reduced mandibles of *P. ocellifera* pupa (structure same as for *P. postica*) compared to full-size mandibles of *Phryganea cineria* pupa (Wiggins, 1966).

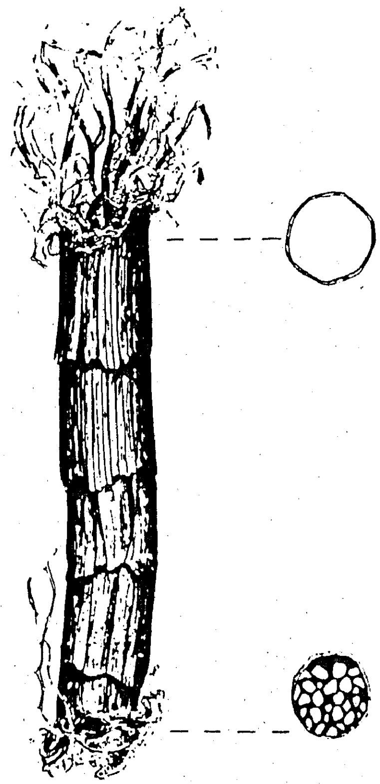


Phryganea cinerea



Ptilostomis ocellifera

Figure 17. Pupal case of P. ocellifera, with cross-sections at the anterior and posterior ends (same structure as P. postica); sieve plate of pupal case (Wiggins, 1966).



Ptilostomis ocellifera

combined with that of April and the chi-square test repeated. The chi-square value was also acceptable for these data.

Reproduction. No eggs were observed in female pupae. Figure 18 shows the relative size of the testes removed from a pupa.

Adult Stage

Development. The first adult was collected on 12 May and the last on 27 May, a period of about two weeks. Thirty-one adults were collected, all after dusk. In one hour, 1, 12, 14, and 4 adults were collected on May 12, 17, 20, and 27, respectively. Merritt and Cummins (1978) stated that most adult caddisflies probably live less than one month. Pennak (1978) reported that the adult stage lasts 30 days or less.

The total length of an adult ranged from 12.5 to 20 mm, with a mean of 17.35 mm. The total length with wings ranged from 18.5 to 26 mm, with a mean of 22.6 mm. Wings length for the first pair of wings ranged from 17 to 23 mm, with a mean of 19.84 mm; for the second pair, wing length ranged from 14.5 to 19.5 mm, with a mean of 17.28 mm.

Food habits. Adult foreguts were all empty. The adult has reduced mouthparts, capable only of liquid ingestion. Crichton (1957) published an extensive account on the structure and function of the mouthparts of the adult phryganeid *Phryganea striata* L. Included is a discussion of the mouthparts and feeding habits of related species.

Figure 18. Relative size of testes of male pupa of *P. postica*.

Sex ratio. Twenty females and 11 males were collected. A chi-square test showed no significant deviation from a 1:1 sex ratio at the 0.05 confidence level.

Reproduction. No eggs were observed in adult females or in the field. According to Wiggins (1973), Mr. O. S. Flint in Michigan reported that adults belonging to the genus *Ptilostomis* deposited eggs in August 10 to 20 cm above the water surface of streams. Gelatinous masses of eggs were attached to the undersides of a log and an overhanging bank. Oviposition of *Ptilostomis* sp. females above the water surface suggests that the gelatinous matrix surrounding the eggs retains moisture when exposed to air for a longer period than the egg masses of some other phryganeids.

Testes measurements were made on six specimens. They ranged from 3.6 to 5 mm, with a mean of 4.3 mm.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. The life history and ecology of the caddisfly *Ptilostomis postica* (Walker), from Greenbottom Swamp, Cabell County, West Virginia were studied in detail from December 1977 to December 1978.
2. *Ptilostomis postica* has been collected and reported from Georgia, Illinois, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia, Washington D. C., West Virginia, Wisconsin, and Canada. Prior to this study, it had been reported from only Berkeley County in West Virginia.
3. Length-frequency histograms indicate that the population is univoltine. The larvae attained their greatest growth rate (75.0 %) from fall (November) to winter (December).
4. Case construction also reflects an increase in length. The greatest increase (70.3 %) occurred from fall to winter.
5. There was a high correlation between case length and body length in fall ($r = 0.72$) and winter ($r = 0.87$). However, a low correlation ($r = 0.18$) was found in spring.
6. The larvae of *P. postica* change their diet seasonally. During fall and winter, the larvae are largely carnivorous. In spring, they are largely omnivorous.

7. Pupation began at the end of April and lasted approximately three weeks.
8. The chi-square test for pupae showed no significant difference from the expected 1:1 ratio at the 0.05 confidence level.
9. Adult emergence began at dusk on 12 May, peaked on May 20, and lasted two weeks. Adults ingest only liquids if anything. They are nocturnal.
10. The chi-square test for adults showed no significant difference from the expected 1:1 ratio at the 0.05 confidence level.

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