Section 5 EPHEMEROPTERA

5.1 LAB NOTES for the EPHEMEROPTERA

Readings: M&C pp 94-97; Hilsenhoff p.7

Keys: Edmunds 1984 (in M&C, chap 10); Hilsenhoff pp 6-11

5.2 Principal taxonomic literature:

Allen, R.K. 1980. Geographic distribution and reclassification of the subfamily Ephemerellidae (Ephemeroptera:Ephemerellidae). pp.71-79 in J.F. Flannagan & K.E. Marshall (eds.) Advances in Ephemeroptera biology. Plenum, N.Y. 552 pp.

Berner, L. 1950. The mayflies of Florida. Univ. Fla. Stud. Biol. Sci. Ser. A 4:1-267.

Berner, L. 1975. The mayfly family Leptophlebiidae in the southeastern United States. Fla. Ent. 58:137-156.

Burks,D.D. 1953. The Mayflies of Illinois. Bull. Ill. Nat. Hist. Surv. 26:1-216.

Edmunds, G.F. Jr., 1972. Biogeography and evolution of the Ephemeroptera. Ann. Rev. Ent. 17:21-43.

Edmunds, G.F. Jr.,S.L. Jensen and L.Berner, 1976. The mayflies of North and Central America. Univ. of Minnesota Press, Minneapolis, 330.p

Flowers,R.W.& W.L. Hilsenhoff. 1975. Heptageniidae (Ephemeroptera) of Wisconsin. Great Lakes Entomol. 8:201-218.

Koss, R.W. 1968. Morphology and taxonomic use of Ephemeropteran eggs. Ann. Entomol. Soc. Amer. 61:696-721.

Leonard, J.W. & F. A. Leonard. 1962. The mayflies of Michigan trout streams. Cranbrook Inst. Sci. Bull. No. 43.

McCafferty, W.P. & G. F. Edmunds Jr. 1979. The higher classification of the Ephemeroptera and its evolutionary basis. Ann. Ent. Soc. Am. 72:5-12.

McCafferty, W.P 1991. Towards a phylogenetic classification of the Ephemeroptera (Insecta): a commentary on systematics. Ann. Entomol. Soc. Amer. 84:343-360.

Muller-Liebenau, I. 1973. Morphological characters used in revising the European species of Baetis Leach. In: Proceedings of the first international congress on Ephemeroptera, W.L. Peters and J.G. Peters, eds., pp 182-198, E.J. Brill, London.

Needham,J.G., J.P. Traver and Y.C. Hsu. 1935. The biology of mayflies with a systematic account of North American species. Comstock, Ithaca.

5.3 Notes on Taxonomy:

We will be following McCafferty recent higher-level taxonomy in terms of subordinal classification: modified from the Ephemeroptera section of Nomina Insecta Nearctica, Vol. 4, pp. 89-117 by W. P. McCafferty.

Order Ephemeroptera

Suborder Carapacea (1)
- Family Baetiscidae

Suborder Furcatergalia (9)
- **Infraorder Lanceolata** (leptophlebiids)
  - Family Leptophlebiidae
- **Infraorder Palpotarsa** (the primitive burrowing mayflies)
  - Family Behningiidae
- **Infraorder Scapphodonta** (the burrowing mayflies)
  - Family Potamanthidae
  - Family Polymitarcyidae (=Euthyplociidae + Polymitarcyidae)
  - Family Ephemeridae (=Ephemeridae + Palingeniidae)
- **Infraorder Pannota** (the pannote mayflies)
  - Superfamily Caenoidea
    - Family Neoephemeridae
    - Family Caenidae
  - Superfamily Ephemerelloidea
    - Family Ephemerellidae
    - Family Leptohyphidae (=Tricorythidae, subfamily Leptohyphinae)

Suborder Pisciforma (6)
Family Acanthametropodidae
(=Acanthametropodidae + Analetrididae)
(=Siphlonuridae, subfamily Acanthametropodinae)
Family Ameletidae
(=Siphlonuridae, subfamily Siphlonurinae in part)
Family Ametropodidae
Family Baetidae
Family Metretopodidae
Family Siphlonuridae
(=Siphlonuridae, subfamily Siphlonurinae in part)
Suborder Setisura (5)
Family Isonychiidae
(=Oligoneuriidae, subfamily Isonychiinae)
(=Siphlonuridae, subfamily Isonychiinae)
Family Oligoneuriidae
Family Pseudironidae
(=Heptageniidae, subfamily Pseudironinae)
(=Siphlonuridae, subfamily Pseudironinae)
Family Arthropleidae
(=Heptageniidae, subfamily Arthropleinae)
Family Heptageniidae
(=Heptageniidae, subfamily Heptageniinae)

5.4 some recent synonymies for taxa found in Michigan:

current = old

Tricorythodes (Leptohyphidae) = Tricorythodes (Tricorythidae)

Pentagenia (Palingeniidae) = Pentagenia (Ephemeridae)

Litobrancha recurvata = Hexagenia recurvata

(Ephemerella + Drunella + Serratella + Dannella + Eurylophella + Attenella) =Ephemerella (sensu lat.)

Isonychia (Isonychiidae)=Isonychia (Oligoneuriidae)= Isonychia (Siphlonuridae)

Ametropodidae + Metretopodidae = Ametropodidae (prt.)

(Stenonema + Stenacron) = Stenonema

Anepeorus = Spinadis

Nixe = Heptagenia (part)

Leucrocuta = Hepatgenia (part)

Anthopotamus = Potomanthus

Acentrella = Psudocloeon

Centroptilum = Cloeon (part)

Procloeon = Cloeon, Centroptilum (parts)

Acerpenna = Baetis (part)

Diphetor = Baetis (part)

Labiobaetis = Baetis (part)

5.5 fix for couplet on Ephemerid nymphs:

1a) Frontal process bifid w/ acutely pointed projections.................Pentagenia,Ephemera

1b) Frontal process conical..Hexagenia, Litobrancha

5.6 Notes on Sexual dimorphism and other features of adult mayflies:

In most Ephemeroptera, the eyes of the male are large and in proximity on the vertex, while those of the female are small and separate. In many species of Caenidae and Tricorythidae, however, the eyes of both sexes are small. In males of Baetidae and some Leptophlebiidae, the upper facets of the eyes are raised on a stalk (= turbinate or semiturbinate).

Generally, the legs of Th_1 are much longer than legs of Th_{2-3} in males, while in females, legs of Th_{1-3} are subequal. In Polymitarcyidae, however, the legs on Th_{2-3} in males and Th_{1-3} in females are vestigial. All legs of both sexes are vestigial in North American Behningiidae (genus Dolania).

In the families Tricorythidae, Caenidae, and Baetidae, and in some Neotropical Leptophlebiidae, the HW (on Th_3) are greatly reduced or completely absent. In some Baetidae, the HW are small and without a costal projection in males, and minute in females. In other baetids, HW are absent in both sexes. In at least a few populations, males have HW but females do not.

The abdomen externally consists of $Ab_{1-10}T$ and $Ab_{1-10}S$. The posterior portion of Ab_7S of males is called the subgenital plate and is variable in form. Paired appendages called the forceps (=claspers) arise from the posterior margin of the subgenital plate (fig. 10.83, p. 110 in M&C84). In some genera, the forceps are 1-segmented (e.g., *Caenis*, *Tortopus*). More generally, the forceps consist of 2, 3, or 4 segments. Dorsal to the subgenital plate are paired penes, which often are fused mesally. In most taxa, the penes are sclerotized, but in the Baetidae they are membranous and extrudable. The genitalia of male mayflies can be seen through the pellicle of the subimago and the mature nymph, although the structures are less developed than in the imago. The posterior portion of Ab_9S of females is termed the subanal plate. The posterior margin of the subanal plate, although generally rounded and w/o prominent processes, is variable in form and can have taxonomic value. In a few genera, the female has a rudimentary ovipositor. Unassociated adult females can not in some cases (e.g., some Ephemerellidae and Tricorythidae) be easily or reliably determined to genus.

Classification of wing venation will differ between authors. Early Ephemeropterists (Needham, Traver, & Hsu 1935, Burks 1953) followed the Comstock classification of venation, and considered R_{4+5} to be a branch of R_5. Later workers (Edmunds, Jensen, & Berner 1976) used the system of Tillyard, which interpreted this vein as a branch of M. Thus, R_{4+5} of Comstock = MA of Tillyard ($R_4 = MA_1$ and $R_5 = MA_2$). Page 96 in M&C84 gives Tillyard's (1932) #2441 system applied to Ephemeroptera. In the Tillyard system, MA (MA_1 and MA_2) is convex and MP (MP_1 and MP_2) is concave. The branched vein MA(+) is the most obvious landmark for identifying venation of the mayfly FW.

Venation is reduced in the HW and often is difficult to interpret. Reduction in the number of wing veins and wing size (especially HW) is frequently associated with reduction in body size, and apparently has evolved independently in several lineages (e.g., Caenidae, Baetidae, Tricorythidae) (Edmunds 1972).

In North America, Heptageniidae and Baetidae A. have 2 caudal filaments, while Leptophlebiidae and Ephemerellidae A. have 3 caudal filaments. When the median terminal filament is vestigial, it often is represented by a tapered rudiment of 1 or few segments. When fully-developed caudal filaments have been broken, the basal remnants are of normal diameter.

Subimagines have dull, translucent wings, dull body surfaces, and setae on the wing margins. Imagines of some smaller species, however, retain setae on the wing margins. The caudal filaments are usually covered w/fine setae in subimagines and are glabrous in imagines. Caudal filaments generally are much longer in the imago than in the subimago. In some genera, the molt to the imago can be incomplete, with the wings retaining the subimaginal pellicle, and the caudal filaments may not be shed. In a few taxa, there is no imaginal stage in the females.

5.7 Table of Habitat Preferences

SLOW CURRENT

Burrowing Nymphs

Sand and gravel
Ephemera simulans

Mud
Hexagenia limbata
Hexagenia atrocaudata (beaver ponds)
Hexagenia recurvata (cold streams)
Hexagenia rigida (warm streams)

Clinging Nymphs

Leaf drift and similar detritus
Serratella deficiens
Ephemerella needhami
(also in submerged plant beds)
Drunella walkeri (also under stones)
Stenonema canadense (also under stones)
Stenonema frontale (also under stones)
Stenonema pulchellum
(prefers submerged logs)
Stenonema tripunctatum
Stenonema vicarium (also under stones)
Leucrocuta hebe (also under stones)
Heptagenia pulla

Silt and finer detritus
Tricorythodes spp. (cold streams)
Brachycercus lacustris (warm streams)
Caenis forcipata (spring-holes)
Caenis jocosa
Caenis simulans
Ephemerella needhami (also leaf drift and

plant beds)
Ephemerella simplex
Eurylophella lutulenta
Eurylophella temporalis
Serratella deficiens
Baetisca laurentina (cold streams)
Baetisca obesa (warm streams)
Leptophlebia cupida
Leptophlebia nebulosa
Stenonema heterotarsale

Submerged plant beds
Ephemerella needhami (also leaf drift and submerged logs)
Callibaetis ferrugineus (quiet water only)
Baetis hiemalis (quiet water only)
Baetis intercalaris (oftener in gravel riffles)
Baetis pygmaeus

Free-swimming nymphs
Siphlonurus alternatus
Siphlonurus quebecensis
Siphlonurus rapidus
Procoleon album (warm streams).
Metretopus borealis (Pre—Cambrian bedrock streams)

FAST CURRENT

Gravel and rubble
Drunella cornuta (Pre—Cambrian bedrock streams)
Drunella lata
Ephemerella dorothea
Ephemerella excrucians
Ephemerella invaria
Ephemerella rotunda
Ephemerella subvaria
Paraleptophlebia adoptiva
Paraleptophlebia debillis
Paraleptophlebia mollis
Paraleptophlebia praepedita (warm streams)
Baetis brunneicolor

Baetis cingulatus
Baetis intercalaris (also plant beds)
Baetis tricaudatus

Acentrella spp.
Epeorus vitreus (fast water only)
Rhithrogena jejuna
Rhithrogena impersonata
Rhithrogena pellucida
Rhithrogena sanguinea

Underside of stones
Drunella walkeri (more often in leaf drift)
Stenonema canadense (also in leaf drift in fast water)
Stenonema fuscum
Stenonema frontale (also in leaf drift)
Stenonema ithaca
Stenonema luteum (fast water only)
Stenonema nepotellum (fast water only)
Stenonema pulchellum (more often on submerged logs)
Stenonema vicarium (also in leaf drift)
Leucrocuta hebe (oftener in leaf drift)

Free-swimming nymphs
Isonychia bicolor
Isonychia harperi
Isonychia sadleri
Siphloplecton basale

4.7.1 Table of Ephemeroptera taxa in class collection

Family	Genus	Vial #	Stage
Batidae	Baetis		
Baetidae	Callibaetis		
Baetidae	Acentrella=Pseudocloeon		
Baetiscidae	Baetisca		
Caenidae			A
Caenidae	Caenis		
Ephemerellidae			A
Ephemerellidae	Drunella		
Ephemerellidae	Ephemerella		
Ephemerellidae	Serratella		
Ephemeridae			A
Ephemeridae	Ephemera		
Ephemeridae	Ephemera		A
Ephemeridae	Hexagenia		
Ephemeridae	Litobrancha		
Heptageniidae			A
Heptageniidae	Epeorus		
Heptageniidae	Heptagenia (check for Nixe)		
Heptageniidae	Rithrogena		
Heptageniidae	Rithrogena		A
Heptageniidae	Stenacron		
Heptageniidae	Stenonema		
Heptageniidae	Stenonema		A
Leptophlebiidae	Leptophlebia		
Leptophlebiidae	Paraleptophlebia		
Leptophlebiidae	c.f. Paraleptophlebia		A
Metrotopodidae	Siphlopecton		
Isonychiidae	Isonychia		
Potomanthidae	Anthopotamus=Potomanthus		
Ameletidae	Ameletus		
Leptohyphidae	Tricorythodes		

5.8 Table of Manistee Emergence Sequence for Ephemeroptera

Mayflies found in a single gravel riffle in the Pere Marquette River with dates of emergence (data from Leonard and Leonard 1962; note names have not been updated)

taxa	April	May	June	July	Aug	Sept	Oct
Baetis vagans		xxxxxx...					
Ephemerella subvaria		xxx					
Paraleptophlebia praepedita		xxxxx					
Ephemerella invaria			xxxxxxx				
Baetis cingulatus			xxxxxxxxxxxxxxxxxxxxxxx				
Leptophlebia cupida			xxx				
Siphlonurus quebecensis			xxxxxxx				
Pseudocloeon anoka			xxxxxxxxxxxxxxxxx				
Epeorus vitreus				xxxxxxxxxx			
Stenonema vicarium				xxxxxx			
Ephemerella rotunda				xxx			
Paraleptophlebia mollis				xxxxxxxxxxx			
Baetisca laurentia				x			
Ephemerella dorothea				xx			
Siphlonurus rapidus				x			
Ephemerella needhami				xxxxxx			
Centroptilum album				xxx			
Drunella lata				xxxxxxxxxx			
Stenonema rubrum				xxxxxxxxxxxx			
Siphlonurus alternatus				xxxxxxx			
Drunella walkeri				xxxxxxx			
Hexagenia limbata					xxxxxxxx		
Heptagenia hebe					xxxxxxxxxxxxxx		
Rhithrogena impersonata					x		
Ephemerella simplex					xxxxx		
Brachycercus lacustris					xxxxx		
Serratella deficiens					xxxxx		
Tricorythodes stygiatus					xxxxxxxxxxx		
Isonychia bicolor						xxxxxxxxx	

5.9 Doc Leonard's lecture notes:

The Mayflies constitute the insect order Ephemeroptera. Their adult life, which often lasts less than 24 hours, is reflected in their scientific name which is derived from the Greek 'ΕΦΈΜΕΡΟS which means “enduring but a day,” (in German: Eintags fliegen). Poetical references to “Mayfly existence” as the epitome of brevity usually equated somehow or other with tragedy, are not based on sound biology however. In the immature aquatic stages Mayflies usually live at least a year and occasionally longer. The nymph of our largest burrowing species, *Hexagenia*, usually lives two years throughout most of its range except in the South. Furthermore, their durability, adaptability and tenacity of life as a form are attested by the long record of existence of Mayflies on the earth. As indicated earlier, recognizable Mayflies start to show up in the fossil record of the Upper Carboniferous and they appear to have been abundant during the Permian. They are probably less abundant today than during those long—distant times when fresh water was much more extensive over the earth than now. But they still make up a significant segment of the life of inland waters. F. M. Carpenter of Harvard has summarized the number of known species of Mayflies with the total known number of species of all insects on a percentage basis as follows:

1.In the Permian the Mayflies numbered 3.5 percent of the total.

2.In the Mesozoic they numbered 2 percent of the total.

3.In the Tertiary they numbered 0.3 percent of the total.

4.And in recent times. they number >0.1 percent of the total.

Whether it is safe to go along with Carpenter and conclude that Mayflies are “weaklings” which are steadily falling behind in the race for possession of the earth is debatable; rather, their numbers may simply reflect the availability of suitable habitat and may vary with variation in the habitat.

5.9.1 Life Cycle

The life cycle of the Mayfly comprises 4 stages: egg, nymph, subimago, and imago or adult.

The eggs vary greatly in size and shape among the different species. They may be ellipsoid or rounded and range from as small as 0.07 mm in width to as large as 0.3 mm in length. The number of eggs that may be deposited by one female has not been very thoroughly investigated. A University of Michigan study of *Hexagenia limbata* by Burt Hunt showed the number of eggs per female varied from 2,260 to 7,684 with the average of about 4,000. Mayfly eggs are in almost every instance laid in water and either settle to the bottom, or adhere to submerged objects, where they hatch, usually, in about 2 to 6 weeks.

The nymph, which emerges from the egg, lives under water until its growth is completed. It is characterized by typical hemimetabolous nymphal appearance, that is, it has the parts of its body well differentiated into head, thorax, and abdomen; its legs are large, jointed, functional legs; the wings are developing in pads on the outside of the body, and the abdomen retains its comparatively primitive arrangement of 10 segments. The abdomen terminates in 3, rarely 2, slender tails or caudal filaments. The gills are attached to the outer edge of the abdomen of several of the abdominal segments. The exact number of segments with gills and the location of gills vary and are of taxonomic utility. This appearance of the gills on the abdominal segments is an easy means of distinguishing Mayfly nymphs from those of the Stoneflies (Plecoptera) whose gills, when present, are borne on the under surface of the abdomen. Furthermore, the gills of Mayfly nymphs are almost always plate—like or have a plate—like element in one way or another, whereas those of the stoneflies are almost always filamentous.

In most of our Michigan species, and that would be true throughout the northern part of the United States and adjacent parts of Canada, the nymph lives approximately one year, i.e., univoltine. Since the integument is formed of tough in—elastic chitin, the nymph can grow only by shedding its skin, as is typical of forms having this type of metamorphosis. As many as 30 molts or instars have been observed in the completed cycle of growth of a Mayfly nymph.

In typical or representative species, when growth is complete, the nymphal skin splits down the back, often underwater, and the winged form or subimago emerges into the air. The nymph swallow air to help burst skin. The subimago flies from the surface of the water to some sheltered resting place nearby where, after a short but variable interval, it sheds its skin for the last time and enters the imago or adult stage. Mayflies, it should be noted again, are the only insects which molt after developing functional wings. The subimago resembles the imago in overall appearance but looks softer and fuller in color than the adult. Its wings are generally rather opaque, tinted with grey or blue or yellow or olive. Heavy pigmentation along the veins may give the wings a mottled appearance that rarely persists in the imago. The legs and tail are shorted in the subimago than in the imago. The male genitalia are not well enough formed to permit the male subimago to mate, although experiments have shown that the sexual products, sperm as well as eggs, are mature at this stage.

The subimaginal stage varies in its duration, not only with the species, but also with weather conditions. During a spell of unseasonably cold, wet weather in mid—June, a male *Hexagenia limbata* spent approximately 56 hours as a subimago and still finally transformed successfully. Many species emerge as subimagos in late afternoon or evening and make their final molt 20 to 24 hours later. In *Tricorythodes*, the final molt takes place within minutes after emergence, but often is incomplete, with subimaginal skin remaining on the wings, giving them a very white appearance (snowy). In the genus *Ephoron,* known from some Michigan warm water streams, including the Huron River, the males molt immediately after emerging, but the females do not molt at all and remain subimagos throughout their brief winged existence.

The adult Mayfly usually has two pairs of wings, the forewings much larger than the hind pair. In a few species the hind pair does not develop. The wings in the adult stage are clear and membranous, supported by a more or less dense network of veins. In repose, they are held together vertically over the back like those of a butterfly. The front legs are always longer than the middle and hind legs, and are longer in the male than in the female. The compound eyes are almost always large and in many species are much larger in the male than in the female. In many species, particularly the members of the family Heptageniidae, the compound eyes appear to make up about 80% of the total bulk of the head. The antennae, which are borne on the head between and below the eyes, are short and bristle—like. By the time Mayflies reach the winged stage, an almost complete atrophy of mouth parts and alimentary tract has taken place. Enough energy must be stored in the body during the nymphal stage to carry the insect through the balance of its life cycle. Undoubtedly the heavy musculature of the thorax provides for storing of some of this energy. The abdomen is largely, to all intents and purposes, simply an air bubble. It may function as an aerostatic organ, but even this seems debatable. In the male, it remains essentially empty and in those with semi—transparent body walls, one can see the color of the substrate, daylight, or whatever, through the abdomen with ease. In the gravid female, however, the eggs fill the body and render it at least as heavy as if there were still a functional digestive tract therein.

The mating of adults usually takes place very soon after completion of the final molt from subimago to imago. In most species, death ensues shortly after mating and egg—laying. In *Tricorythodes*, winged existence appears to last only for 4 or 5 hours. In *Hexagenia*, males may live long enough to engage in mating flights on two successive days. And female imagos which retain their eggs can also live long enough to mate on either of two successive days, according to the work of Hunt, cited earlier.

The mating flight, which is composed of recently transformed male adults, often forms over the stream in late afternoon or early evening. Individual specimens fly upward and forward for a short distance, glide down almost to the surface of the water, then fly up and forward again. In a swarm of several hundred individuals, the effect is of a rapid confused dance. Actually, if one can force himself to follow the flight of a single individual, the sense of confusion vanishes and the motions of flight seem actually quite leisurely and deliberate. Soon, females join the swarm, often rising and falling in flight, but not through as wide a span as the males. The male approaches the female from below and behind, grasps her by the thorax with his elongated front legs, and completes the mating act on the wing. Released by the male, the female soon deposits her eggs and shortly thereafter dies. It might not come amiss to stress again the fact that in the Mayflies, as indeed in many other insects, the adult stage is comparable to the flower of the plant. It exists only to permit the species to reproduce, and where man may expect to spend only a 1/5 to 1/7 of his life cycle as “immature” it is quite customary for insects to spend 90% of their life as an “immature.”

Methods of egg—laying vary from species to species, but fall into one or the other of 4 general types. In one, illustrated by *Hexagenia*, eggs are extruded from the paired oviducts in two long packets, which usually adhere to each other. They may be dropped while the female is a foot or two above the water. More often, the female drops to the surface of the water with spent wings extended, and squeezes out the eggs in her death struggle. In a second type, illustrated by *Paraleptophlebia debilis*, the eggs are extruded to form a rounded mass which is dropped from a height of several feet in a maneuver suggestive of dive bombing. In a third method common among the Heptageniidae, the female flies low over the surface and strikes the water at intervals with the tip of her abdomen, washing off a few eggs at each encounter (this type of oviposition suggest that of many of the Libelluline dragonflies). In a fourth type, observed for *Baetis* and closely related genera, the female lights on a rock or other object protruding from the water and crawls under the surface depositing her eggs while submerged.

It may be remarked that Mayflies have acquired a wide variety of common names but none of them is very specific and some may be applied by the layman to several different insects. “Mayfly” is perhaps the most generally accepted and understood common name for members of the Order. Other names include shadfly--presumably because many of the species emerged in New England at the time the shad were on their spawning run in the pre—pollution era, sandfly——a name one still hears commonly around the sandy—shored Great Lakes, and drake——a name which many laymen especially anglers reserve for a few types of adult males characterized by having only 2 visible tails (the middle one being aborted). In Michigan, particularly along the Lake Huron shore and the Detroit River, a common name for the great swarms of *Hexagenia limbata* when they hatch is Canadian soldier. This, I suppose, because they often appear to be coming from the Canadian side. Canadian names for this species include Yankee raider and Ohio volunteer. In Wisconsin it is the Green Bay fly.

5.9.2 Distribution

About 75 species of Mayflies are known to occur in Michigan trout streams. No doubt many more will be found in the future, as well as an approximately equal number from lakes. Hilsenhoff lists 159 species from Wisconsin. In Burk's 1953 Bulletin on Illinois Mayflies, he stated that over 550 species are known from North America north of Mexico. In 1976, Edmunds, Jensen and Berner listed 622 species. One of the reasons it is difficult to build up a really accurate state list is that adults may be on the wing for only a few hours of a single day throughout the entire year and it requires an awfully lucky coincidence for collector and Mayfly to be at the same place at the same time. The nymphs, of course, are available to the collector the year around, but in many instances they can't be identified with certainty. The collector needs some means for rearing them through to the adult stage in captivity and to be lucky enough to have a few males come through the entire cycle.

Table 5.7 gives an ecological listing of how common Mayflies in Michigan are distributed in relation to the environment. Mayflies do vary widely in their requirements, and the stream species have much more economic importance to the fisheries than those in lakes. Some species seem to be able to thrive in almost any situation that is relatively free from pollution, and some species inhabit streams and lakes alike. The two common genera of burrowers, *Hexagenia* and *Ephemera*, are found not only in both lakes and streams, but in both cold and warm water situations. Adaptations of form and physiology presumably determine the distribution.

Nymphs of the family Ephemeridae, which includes the genera just mentioned, possess flanged legs, and have tusks developed from their jaws (mandibles) which enable them to burrow in bottom materials. Their gills, which are long and feathery, are constantly in motion. Together with an undulating movement of the abdomen, the gills serve to keep a current flowing through the burrow, insuring a steady supply of well—oxygenated water and water—borne food.

Nymphs of the family Heptageniidae have strongly flattened, legs as well as body. The older literature claims *Stenonema*, *Heptagenia*, and *Epeorus* offer little resistance to strong current, as they cling to stones or other submerged objects. Actually, flattening may be a disadvantage in fast water. Once the body tilts, it may be swept away by the current. The flattening also enables them to find a suitable niche between the bark and the wood of drowned timber, a situation where several larger *Stenonema* are particularly common. Nymphs of *Rhithrogena* do have a current—resisting advantage in the form of expanded gills which form what used to be thought of as a suction cup perhaps enabling them to cling to bottom materials in the fastest water. Hynes (1970) proposes that the enlarged gills divert water flow and thus greatly increase friction.

The large, highly stream—lined nymphs, such as those of some *Siphlonurus*, *Siphloplecton*, and *Isonychia* are strong swimmers, and so are able to occupy deep, swift runs. Hilsenhoff, however, says *Siphloplecton* live in slow current at the edge of big rivers. Such contradictions in the literature only point out the paucity of direct observations on various species in the genus. Rows of long spines along the front legs of the above genera serve as a snare to trap floating food, and heavy fringes of hairs along the tail form an effective fin which enables them to swim rapidly with or against the current, and so escape predators where other species might be at the mercy of the stream.

In the Leptophlebiidae, nymphs of Leptophlebia are most frequently encountered in comparatively slack water near the stream edge where they clamber among detritus. Nymphs of *Paraleptophlebia*, however, are common in chinks under gravel in midstream.

The weird—looking spiny nymphs of *Baetisca* are sluggish and seems to be most at home in backwaters where fine organic debris accumulates. They settle down in lightly compacted material of this sort, now and then swimming to a new position with extremely rapid undulating movements of the tail.

Nymphs of *Ephemerellidae* are, in the main, rather generalized in structure, and hence are able to occupy a wide range of stream habitats. Species of the *Ephemerella* are most abundant in gravel bottom sections of streams where velocity of the current is between 1 and 2.5 feet/second and the water less than 24 inches deep. They occupy interstices among the gravel, but judging by their frequent appearance in drift nets, are often dislodged and borne downstream by the current. *Serratella deficiens*, a small species, seems to prefer comparatively quiet detritus—blanketed stream edges where it is often found in company with *Leptophlebia*. *Drunella lata*, like members of *Ephemerella*, frequents the interstices of gravel beds, but it is particularly abundant where marl deposits on the gravel provide additional anchoring points. Nymphs of *Ephemerella needhami* often clamber around submerged vegetation while the sluggish flattened nymphs of *Drunella walkeri* semi—burrow in silt deposits near the stream edge.

Quiet, comparatively shallow waters are favored by the Caenidae whose species are, in fact, more numerous in lakes than in streams.

Many species of *Baetis* and all our known species of *Centroptilum* and *Pseudocloeon* are highly streamlined and occupy gravel—bottomed sections. They dart quickly from place to place by means of a rapid undulating movement of the tail, coming to rest in chinks between and under stones.

In Michigan streams, at least, particularly in the glacial till country, the greatest number of Mayfly nymphs, both in species and in individuals, will be encountered in gravel riffle areas. One such riffle in the Pere Marquette River in Lake County sampled in May, yielded nymphs of 33 species; a square—foot bottom sample from a gravel area in the North Branch of the Au Sable River in Crawford County, contained 1,374 Mayfly nymphs, 1,277 of them *Ephemerella invaria* and *subvaria*.

5.9.3 Economic Importance

It is customary in practice, if not by definition, to regard economic entomology as a field concerned almost exclusively with those insects whose activities are damaging or destructive to man and his interests. In this view, Mayflies would be excluded from economic entomology. They are rarely destructive. In certain areas of the tropics and subtropics there are burrowing species (*Campsurus*) whose burrows are sometimes so deep and so numerous as to damage small earthfill dams and dikes, a nuisance in irrigation. Mayflies may, upon occasion, bring annoyance to the motorist who drives through a mating swarm and finds his windshield thickly plastered with crushed bodies and sticky egg masses. Lake shore dwellers may have to contend with offensive odors for a few days after windrows of dead Mayflies have washed up on the beach. The real economic value of Mayflies lies in their importance in the food chain or energy cycle of the life of inland waters. Most Mayfly nymphs are plant eaters, although we are learning that more and more species are carnivores. Most of our game fishes are carnivorous; and so the plant-eating, “primary consumer” Mayflies are one of the preeminent converters which transform plant material into animal protein. They feed on a wide range of plant material——algae, diatoms, rooted aquatic vegetation, and plant debris——and convert it into a form palatable to fishes.

5.9.4 Predators and Other Enemies

Mayfly nymphs are fair game for any aquatic predator. Some of those which escape direct consumption by fish may be devoured by other aquatic insects, which in turn may be eaten by fish. During emergence from nymph to subimago, the insect is vulnerable to attack by fishes often while still underwater. Once on the wing, it attracts the attention of birds, bats, and a variety of predatory insects, including dragonflies, damselflies, and hornets. Spider webs levy their toll. Even after the subimaginal Mayfly has reached the shelter of streamside vegetation, it is not safe. Here it may be captured by jumping spiders, wolf spiders, predacious beetles, birds, and mammals——especially flying squirrels.

Large mating flights, which usually take place in late afternoon and evening, draw predators which are normally active at that time. Along trout streams in particular, cedar waxwings, chimney swifts, and rough—wing swallows, are particularly in evidence during Mayfly flights. Furthermore, dusk—loving or crepuscular dragonflies of the genera *Aeschna* and *Boyeria* are important predators. Many females, of course, are devoured by fish during or immediately after egg—laying.

5.9.5 Pollution

An economic role beyond that of serving as food for fishes and other forms of animal life is filled by Mayflies through their usefulness as indicators of water pollution. Nymphs are quite sensitive to chemical or industrial waste pollution. Their absence or relative abundance at a given site can tell the experienced biologist a good deal about what has happened there: whether pollution has occurred, and if so, what its nature was, and when it took place.

5.9.6 Bait

One Mayfly of the north central region has direct and economic value. Nymphs of the large burrower, *Hexagenia limbata*, known in Michigan as “wigglers,” are a favored bait for ice fishing and command a good price from bait dealers. Commercial collectors of these forms often dump large quantities of bottom debris on the ice while they search for the nymphs and these piles are often left behind to create unsightly nuisances. In fact, it was largely concerted protest from riparian owners, those with summer cottages and year—round homes on lakes, which led to Hunt undertaking his doctoral study of the economic importance of *Hexagenia limbata* in Michigan.

5.9.7 Importance to Anglers

Fishing with an artificial fly was well-known to the ancient Greeks and no doubt originated long before the dawn of recorded history. Early man fished for food, but it seems safe to guess that he enjoyed fishing for its own sake and that he found particular satisfaction in thinking he had tricked a fish into taking an imitation insect for the real thing. Since the days of Izaak Walton, a voluminous literature on fly tying and fly fishing has been built up, especially in English. Over the centuries, devoted anglers have experimented with almost every possible fly tying material and have endeavored to mimic almost every insect which finds its way into or onto the water.

Out of these experiments have come a number of fairly well—standardized patterns, a majority of which are fondly imagined to imitate one or another species of Mayfly. Caddisflies, stoneflies, and others have received their share of attention, but the mayfly is the fly fisherman's insect par excellence. Many of the patterns tied in America today originated in the British Isles, and we have inherited some of the British anglers' names and language. In fly fishing parlance, the subimago becomes the “dun” and the imago the “spinner.” Names for flies themselves are often poetically descriptive——Blue Winged Olive, Evening Dun, Iron Blue Dun, and Pale Watery, for example.

It is perhaps worth a little diversion into this area of sportsmanship, because it is obvious that those who go into fish management jobs are going to need to have at least a nodding acquaintance with fly fishing literature and lore. Because of the long history of fly fishing in the British Isles and the interest of anglers there in stream insects, virtually every British Mayfly has acquired a common name, which generally applies also to the artificial imitation. American anglers have not yet learned to recognize many of our native Mayflies well enough to give them individual common names. Some attempts have been made to fit names of the British “cousins” to American species, but with dubious success. And the few efforts made by American authorsportsmen to devise common names for our Mayflies have won scant following again owing to the failure of most anglers to look at the various species discerningly.

Whether or not an artificial fly which appears closely to resemble a natural insect has the same degree of resemblance from a trout's viewpoint, is often debated. A fish may take a fly either from hunger or from curiosity and be securely hooked in either case. But for the angler who likes to tie his own flies, much of the fun lies in meeting the challenge to create an artificial fly as like its natural counterpart as human eyes and skill can make it. Undoubtedly, this interest of anglers accounts for the appearance of a growing number of volumes presenting colored illustrations of fly patterns, and in a few infrequent instances, color photographs of the insects themselves.

Again, some knowledge of Mayflies and their habits will enhance the success of any angler regardless of the type of lure being used. During a heavy emergence or egg-laying flight of Mayflies, trout in particular, as well as some other fish, are stimulated by the sudden availability of easy food, and show increased interest in the angler's offering. Many fishermen hold to the idea that few Mayflies are on the wing after the first week or so of July in the north center region, and hence tend to abandon the sport after that time. Actually, one species or another is emerging throughout the warm months of the year. By knowing what to look for and when and where, the angler can be fairly sure of an opportunity to cast to rising fish throughout the open season.

The angler can learn to forecast a “hatch” or emergence by lifting stones from the stream bed and examining the wing pads of Mayfly nymphs he finds clinging to their surface. A few days before the nymph is ready to transform, the wing pads turn dark——nearly black. When a light line can be discerned between the developing wing and the enclosing pad, the insect is beginning to shrink away from the nymphal skin and emergence is only hours away.