

Checklist

(for turning in results)
to be sure that we have everything we need to use your data

For Tier 2 Identification*:

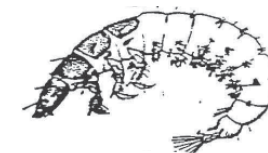
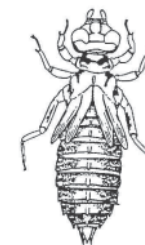
- 2 completed "Sampling Protocol" sheets (one for each replicate sample)
- 5 completed "Reporting Sheets for Sampling" - Physical Survey/Habitat Assessment pages (p.44-48 of HBRW guidance document)
- 4 Completed BMI Sorting Worksheets (4 metric worksheets optional)
- Containers of identified organisms preserved in 70% alcohol, each labeled with sampling location and sampling date
- Container of sorted but unidentified organisms preserved in 70% alcohol labeled with sampling location and sampling date

For Tier 3 Identification:

- 2 completed "Sampling Protocol" sheets (one for each replicate sample)
- 5 completed "Reporting Sheets for Sampling" - Physical Survey/Habitat Assessment pages (p.44-48 of HBRW guidance document)
- 2 Completed Family Level Data Sheets (not included in this booklet - go to the CSI website or ask at the lab for these)
- Containers of identified organisms preserved in 70% alcohol, each labeled with sampling location and sampling date
- Container of sorted but unidentified organisms preserved in 70% alcohol labeled with sampling location and sampling date



Rough Guide to **BMI with**



*As of the summer of 2013, tier 2 identification will be the goal for CSI volunteer groups. Volunteers who wish to identify organisms to tier 3 (family level) are encouraged to do so and will be supported by CSI staff.

The Community Science Institute works together with community volunteers and participants in the CSI high school/college stream monitoring program to monitor benthic macroinvertebrates in Finger Lakes Streams as indicators of water quality. This “guide” is a compilation from a variety of sources. It is a work in progress meant to assist volunteers and students with this work. Any comments, suggestions, or questions are welcome (*adriannalouise@gmail.com*).

Step-by-step procedures, reporting sheets and explanations of metrics have been adapted from the Hudson Basin River Watch Guidance Document of 2004 (www.hudsonbasin.org/HBRWGD04.pdf). Other sources are cited where appropriate.

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BMI = Benthic Macroinvertebrates

*bottom-dwelling organisms
with no backbone
that you can see without a microscope*

Origin of the Protocols

The following pages outline the protocols involved for sampling, sorting and analysis of benthic macroinvertebrate samples collected as a part of Community Science Institute efforts to monitor water quality. The protocols were developed in the 1990's for use by volunteer stream monitors by Hudson Basin River Watch in cooperation with the New York State Department of Environmental Conservation (who, in order to keep track of water quality in the state, is mandated to engage in bio-monitoring activities by the U.S. Environmental Protection Agency under the Federal Clean Water Act of 1972).

Scientific Rigor

In collecting samples, sorting, identifying and recording data, please strive to be as meticulous as possible, following the protocols as carefully and completely as possible and recording your data thoroughly and legibly. This is what gives all of our data its meaning. To this end, be sure to fill out the BMI Protocol sheet (example on page 32 of this document) and strive for the highest level of QA/QC possible (see discussion on page 32).

Equipment for Benthic Macroinvertebrate Sampling

Essential Items	Purpose
BMI Sample Sheets and appropriate physical survey sheets	For permanent record of collection
Clipboard	To hold field sheet
Collection net: 18"x8" w/ 0.8-0.9 mm mesh size	To catch dislodged organisms during collection
Forceps	To pick critters off net and sieve bucket
4"-6" deep white tray (larger than 18"x8")	To observe live samples for picking & to remove critters from net for preservation
Small white containers/ice cube trays	To sort live critters into groups
Float (orange or tennis ball)	To measure stream current
Stop watch	To measure stream current
Tape measure (50' minimum) width or 50' string marked in 10' sections and velocity	To measure segment length
1 qt. Mason jars w/ rubber seal lids or watertight plastic tubs (perhaps safer, overall)	To hold preserved samples
90% de-natured ethyl alcohol	To preserve samples
Labeling tape and pencils	To label sample containers

Other Recommended Items	Purpose
Waders or high boots	To keep your feet dry
Field magnifiers	To identify critters streamside
Sieve bucket (#30 mesh)	To collect and transfer samples for preservation
USGS topographic map	To help locate collection sites
5-gallon bucket	All purpose container
Life jackets	For safety in deeper water

Collecting BMI Samples

Two replicate samples are collected in a riffle with a substrate of rock, cobble, gravel and sand. The DEC defines a riffle as an area that is shallow enough for the surface to be broken by the substrate. Depth should be less than one meter. Current speed should be between 0.40 and 0.75 meters/second (roughly 1-2 feet/sec).

Each replicate sample is collected by disturbing the stream bottom by foot along a diagonal 5 meter transect, for 5 minutes. The samples are preserved for later analysis.

Step by Step Procedure

Step 1: Assemble collection equipment and supplies (see previous page).

Step 2: Go to your stream and identify a riffle for collection. It should have a velocity somewhere between 0.40 and 0.75 meters/second (roughly 1-2 feet/sec) and be shallow enough for the surface to be broken by the substrate (less than one meter).

Step 3: Measure a 200' segment that contains the riffle habitat from which the sample will be collected.

Step 4: Conduct physical survey/habitat assessment for this 200' segment (Complete the 5 pages entitled "Reporting Sheets for Sampling" shown towards the end of this document).

Step 5: Wade into the riffle and look for an appropriate spot to place the net. There should be at least 5 meters of riffle upstream of the net, in a diagonal direction.

Step 6: Have one person place and hold the net on the river bottom at the collection spot, with the opening of the net facing upstream.

Step 7: Have another person stand 0.5 meter directly upstream from the net opening and disturb the stream bottom by foot for 30 seconds so that organisms are dislodged and carried by the current into the net. Use a shuffling motion, disturbing the substrate a few inches down. Avoid kicking the substrate into the net.

Step 8: When you've finished at the first spot, carefully lift the net out of the river. Walk upstream 0.5 meter in a diagonal direction, and repeat (see figure 1). Leave the sample in the net. Continue until a total of 5 meters are sampled along a diagonal transect as wide as the net (10 times). This should be completed in a total of 5 minutes. The resulting collection of organisms in your net is one replicate sample. If your stream is narrow, you can modify your transect to be at more of a diagonal upstream to fit in 5 meters. If, however, you reach the other side of the stream before completing your 10 kick-sample sets, start back across the stream (again, working your way at an angle slightly upstream).

Metrics

EPT Richness: An estimate of numbers of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa represented in a subsample. These are considered to be mostly clean-water organisms and their presence generally is correlated with good water quality.

To calculate this metric, count the number of mayfly, stonefly and caddisfly taxa identified in each replicate subsample.

>7=no impact, 3-7=slight impact, 1-2=moderate impact, 0=severe impact

Taxa Richness: An estimate of the number of different taxa represented in a subsample. It is a rough measure of the diversity of the macroinvertebrate community. In general, the greater the number of taxa (higher richness), the less impacted the stream.

To calculate, count the total number of different taxa identified in each replicate subsample.

>13=no impact, 10-13=slight impact, 7-9=moderate impact, <7=severe impact

Biotic Index: This metric incorporates the various average tolerance values of different groups of benthic macroinvertebrates which range from 0-10 (intolerant to tolerant).

To calculate, multiply the number of organisms in each major group by the corresponding group tolerance value. For each replicate subsample, add the results for all groups and divide by the total number of organisms you picked for that replicate.

0-4.5=no impact, 4.51-5.5=slight impact, 5.51-7=moderate impact, 7.01-10=severe impact

Percent Model Affinity (PMA): This is a measure of similarity to a model non-impacted community for New York State based on percent abundance in 7 major groups. Percent Composition values are compared to a model community established by the NYSDEC for a non-impacted stream. The model is based on a typical summertime community, so this metric may not be useful for samples taken in the early spring or late fall. [40% Ephemeroptera, 5% Plecoptera, 10% Trichoptera, 10% Coleoptera, 20% Chironomidae, 5% Oligochaeta, and 10% Other]

To calculate, use the worksheet entitled "Benthic Macroinvertebrate Major Group Percent Composition & Model Affinity Worksheet" (page 38).

>64=no impact, 50-64=slight impact, 35-49=moderate impact, <35=severe impact

BAP (Biological Assessment Profile): BAP value combines the previous four metrics into a single value between 0 and 10. This number represents the overall assessed impact for each site (0=severely impacted and 10=unimpacted).

10-7.5=no impact, 7.5-5=slight impact, 5-2.5=moderate impact, 2.5-0=severe impact

* Since the BAP value incorporates PMA values, be sure to read its description for the limitations on that metric if sampling any time other than summer.

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

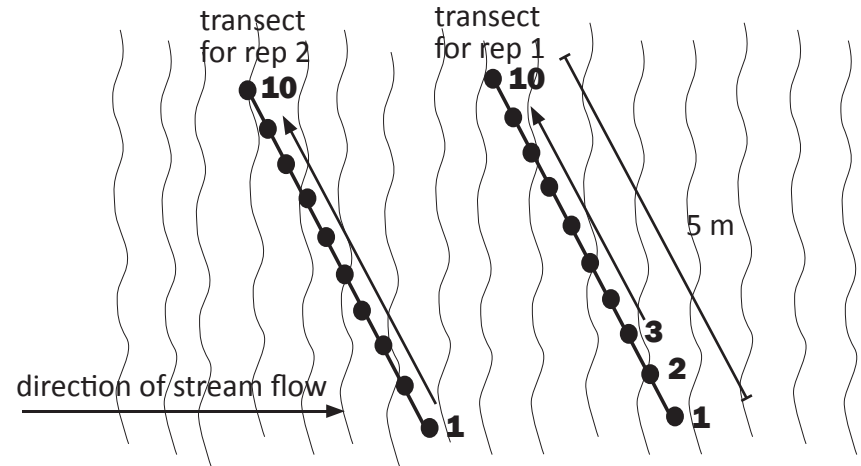


figure 1 - Diagram of riffle area being sampled showing sampling transects. Note that the diagonal 5 meter transect angles slightly upstream and that the rep 2 transect is upstream of the rep 1 transect.

Step 9: If there is a lot of fine sediment in your sample, try to remove as much as possible. This can be done easily while the sample is still in the net by submerging the net partially in the stream (keeping the opening completely above the surface of the water), and swirling to rinse sediments out of the net. Be careful not to lose any of your sample.

Step 10: Bring the sample to shore and transfer the contents of the net to a watertight plastic tub using 90% isopropyl alcohol for preservation*. Thoroughly pick the net of all organisms. Make sure the sample is completely submerged in alcohol (not exposed to air). Tightly cap the jar and label with the site name or number, date, replicate, and sampler names. Your sample will keep until you are ready for analysis. Analysis of preserved samples is typically done on a separate day/days after the samples have been collected. It is done in a lab or other location with access to stereo dissecting microscopes.

Step 11: Fill out the "Sampling Protocol" section of the "BMI Protocol Sheet." Complete a separate "BMI Protocol Sheet" for each replicate.

Step 12: Repeat steps 5-11 for your second replicate (upstream of the original transect yet still within the riffle). Make sure the net is thoroughly picked clean of organisms before you collect the second replicate.

* Note on preserving samples: Be sure to drain all water from sample before submerging the sample in 90% isopropyl alcohol. Use about 40 ounces of 90% alcohol for the preservation of each replicate (can be purchased at a few local drugstores...be sure it's 90% for this initial preservation).

Optional

Metric Worksheets - page 4 of 4

HBRW Tier 2

BMI Major Group Percent Similarity Worksheet

School/Group _____ River/Stream _____ Site _____
 Sampling Date _____ Name of person(s) conducting analysis _____

Major Group	Replicate 1 (or volunteer group results)	Replicate 2 (or outside evaluator's results)	Lesser of 2 Values
Stonefly			
Mayfly			
All Caddisfly except netspinner			
Gilled Snail			
Dobsonfly, Alderfly			
Dragonfly			
Crane Fly			
Watersnipe Fly			
Water Penny Beetle Larvae			
Whirligig Beetle			
Other Beetles			
Net Spinner Caddisfly			
Black Fly			
Midge			
Damselfly			
Water Mites			
Crayfish			
Clam			
Scud			
Other Snails (not Gilled)			
Leech			
Sowbug			
Aquatic Earthworm			
SUM	100%	100%	

Instructions:

- Determine the percent composition of each major group in each replicate and record in the second and third columns, accordingly. Each column must add up to 100.
- For each major group, compare the percent composition of the first replicate with that of the second replicate. Find the lesser of the two values, and record in the fourth column.
- Sum all of the lesser values to get the percent similarity of the two samples. A percent similarity of 75% or greater is the goal for Tier 2.

For Comparing Outside Evaluator and Volunteer Group Analyses: Use the same procedure above for each replicate being compared. Use the second column for your group's results and the third column for the outside evaluator's results. Check the box below and indicate for which replicate this percent similarity was calculated.

This Percent Similarity is between volunteer group and outside evaluator's results. It is calculated for Replicate # _____

Percent Similarity

Analysis of Preserved Samples

Analysis may also be done using a live sample, though this requires a modification of procedures (see Hudson Basin River Watch Guidance Document) and is generally not considered to be as accurate.

Step by Step Procedure

Step 1: Mark a shallow (1" or less) white tray into 12 equal size squares with a permanent marker. Number each square from 1-12.

Step 2: Pour the first replicate sample into a 30 mm sieve, pouring off the alcohol (the sampling net could be used if you don't have a sieve).

Step 3: Place the sample in the tray, rinsing the preservation bucket and sieve off into the tray with water.

Step 4: Add H₂O to an inch or so deep and spread out the sample evenly.

Step 5: Randomly choose a square (pick number out of a hat) and pick all the organisms in that square. As you pick, sort them using petri dishes or labeled ice cube trays with enough 70% isopropyl alcohol to keep them wet at all times.

Step 6: Pick at least 1/4 of the squares in the tray (3 out of 12), selecting each square at random.

Step 7: If you do not have at least 100 organisms after picking the first 3 squares, continue randomly picking a square at a time, until you have at least 100 organisms. This is your "sub-sample." Note: Pick the entire square once you start—do not pick 1/2 a square!

Step 8: Once you have at least a 100 organism sub-sample (or have picked the entire sample), review the sorting that you have done and organize the categories more accurately.

Step 9: Using the ID to Order guide on pages 7-10 of this booklet, the Sorting Worksheets at the end of this document and a stereo dissecting microscope, further sort organisms, putting "likes" together. Record numbers of each organism in tally boxes, including descriptions under "Other" category for organisms that don't already have a designated box.

Step 10: Once you've recorded your tallies on the sorting worksheets, preserve identified specimens in 70% isopropyl alcohol in containers labeled with the sampling date, site name and rep 1 or rep 2. Put any organisms you were unable to identify into a separate "unknown" container (in 70% alcohol). All of these organisms will be retained at the CSI BMI lab temporarily in case further investigation is warranted.

Step 12: Fill out the "Sample Analysis Protocol" section of the "BMI Protocol Sheet." Complete a separate "BMI Protocol Sheet" for each replicate.

Step 13: Repeat for the second replicate and have an outside evaluator analyze your samples.

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

Optional Metric Worksheets - page 3 of 4

HBRW Tier 2

Graphing Percent Composition Worksheet

Attach this graph to the appropriate Percent Composition Worksheet

NY "model community"

Organism	Percentage
MAYFLY	40%
STONEFLY	5%
CADDISFLY	10%
MIDGES	20%
BEETLES	10%
AQUATIC EARTHWORMS	5%
OTHER	10%

Your Sample:
(color in appropriate %'s)

Hudson Basin River Watch Guidance Document 70 BENTHIC MACROINVERTEBRATE SAMPLING AND ANALYSIS

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

Taxonomy

- Kingdom (Animalia)
- Phylum (Arthropoda)
- Class (Insecta, Oligochaeta, Hirudinae...etc.)
- Order (Ephemeroptera, Plecoptera, Trichoptera...etc.)
- Family (Heptageniidae, Perlidae, Hydropsychidae...etc.)
- Genus
- species

Aquatic Insect Orders

- Ephemeroptera (Mayflies)
- Odonata (Dragonflies & Damselflies)
- Plecoptera (Stoneflies)
- Hemiptera (True Bugs)
- Trichoptera (Caddisflies)
- Lepidoptera (Moths)
- Coleoptera (Beetles)
- Megaloptera (Dobsonflies, fishflies, alderflies)
- Neuroptera (Spongillaflies)
- Diptera (True flies)

EPT=

- Ephemeroptera (Mayflies) - the temporary winged ones
- Plecoptera (Stoneflies) - the twisted winged ones
- Trichoptera (Caddisflies) - the hairy winged ones

pleco = (G) twine, twist, braid; twisted

Tricho = (G) a hair

Ephemero = (G) for a day, temporary

ptero= (G) a wing, a feather, a fin

Some Good References for ID to Family

A Guide to Common Freshwater Invertebrates of North America, by J. Reese Voshell, Jr., with Illustrations by Amy Bartlett Wright - Least technical- has colorful illustrations and highlights important features of different families

Aquatic Entomology: The Fisherman's and Ecologists' Illustrated Guide to Insects and Their Relatives, by W. Patrick McCafferty, with illustrations by Arwin V. Provonsha - More technical and thorough, but also gives interesting ecological discussion of different families of organisms

Freshwater Invertebrates of Northeastern North America, by Barbara L. Peckarsky, Pierre R. Fraissinet, Marjory A. Penton, and Don J. Conclin, Jr.- Most technical and very thorough- helpful because it is specialized to our region

HBRW Tiers 2 & 3 Optional Metric Worksheets - page 2 of 4

% Composition + Model Affinity Worksheet

School/Group _____ River/Stream _____
 Site _____ Sampling Date _____
 Name of person(s) conducting analysis _____

Percent Composition = $\frac{\text{\# Individuals of Major Group}}{\text{Total \# of all organisms in sub-sample}} \times 100 =$ _____

REP 1

Major Group	\# Individuals of Major Group in rep 1	Total \# of all organisms in sub-sample rep 1	Percent Composition	NYSDEC Model Community	Absolute Difference
Mayfly	+ T1= _____	x 100 = _____	40%		
Stonefly	+ T1= _____	x 100 = _____	5%		
Caddisfly	+ T1= _____	x 100 = _____	10%		
Midge	+ T1= _____	x 100 = _____	20%		
Beetle	+ T1= _____	x 100 = _____	10%		
Aquatic Earthworms	+ T1= _____	x 100 = _____	5%		
Others	+ T1= _____	x 100 = _____	10%		
Rep 1 Total \# organisms	T1		Rep 1 Sum =		

REP 2

Major Group	\# Individuals of Major Group in rep 2	Total \# of all organisms in sub-sample rep 2	Percent Composition	NYSDEC Model Community	Absolute Difference
Mayfly	+ T2= _____	x 100 = _____	40%		
Stonefly	+ T2= _____	x 100 = _____	5%		
Caddisfly	+ T2= _____	x 100 = _____	10%		
Midge	+ T2= _____	x 100 = _____	20%		
Beetle	+ T2= _____	x 100 = _____	10%		
Aquatic Earthworms	+ T2= _____	x 100 = _____	5%		
Others	+ T2= _____	x 100 = _____	10%		
Rep 2 Total \# organisms	T2		Rep 2 Sum =		

Using the "BMI Sorting Worksheets," count the number of organisms for each major group identified in your sub-sample and record in the first column (do this separately for each replicate sample). Sum the total number of organisms in your sub-sample (T1 or T2). For each major group, divide the number of individuals of that group by the total number in your sub-sample. Multiply by 100 to calculate percent composition. To Calculate the absolute difference between percentages for the NYSDEC model community and your sub-sample subtract the lower percent from the higher percent. For each replicate, multiply the sum by 0.5 and subtract this number from 100 to find the Percent Model Affinity. Take the average of your results for rep 1+2 for your final PMA value. Note that impact level is only relevant to summer sampling. For a visual comparison, graph the percent composition in the "Graphing Percent Composition Worksheet."

Rep 1 Percent Model Affinity = $100 - (\text{sum of absolute differences} \times 0.5) =$ _____

Rep 2 Percent Model Affinity = $100 - (\text{sum of absolute differences} \times 0.5) =$ _____

PERCENT MODEL AFFINITY = $\frac{\text{Rep 1 PMA} + \text{Rep 2 PMA}}{2} =$ _____

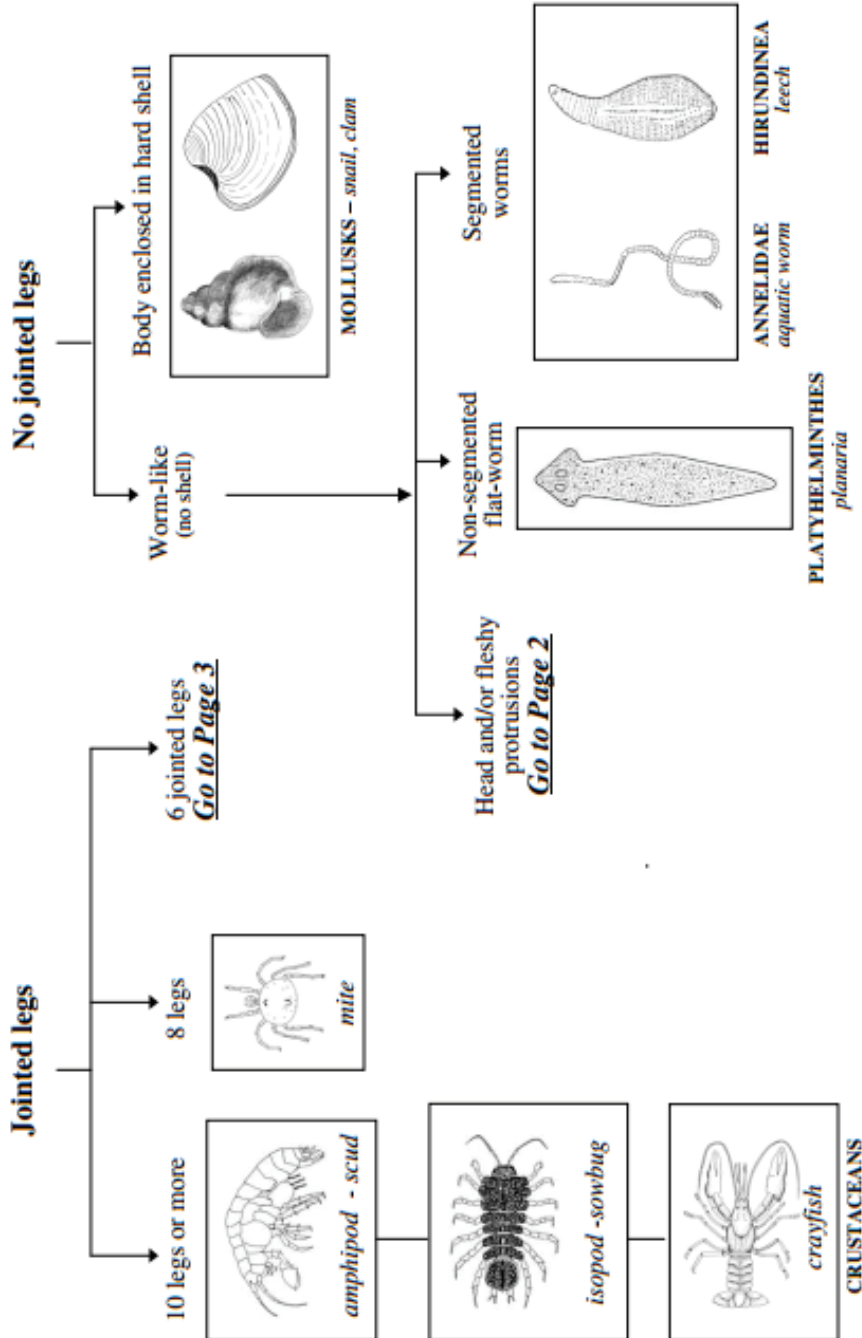
Percent Model Affinity (PMA)	>64% non-impacted	50-64% slightly impacted	35-49% moderately impacted	<35% severely impacted
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Identification to Order

from Stroud Water Resource Center Leaf Pack Network Manual



Identification Guide to Freshwater Macroinvertebrates



Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBRW Tiers 2 & 3 Optional Metric Worksheets - page 1 of 4

Major Group Biotic Index Worksheet

School/Group _____ River/Stream _____
 Site _____ Sampling Date _____
 Name of person(s) conducting analysis _____

Major Group	A # of Organisms in Sub-sample		B Group Tolerance Value	C Biotic Value for Group	
	rep 1	rep 2		rep 1	rep 2
Stoneflies			1		
Mayflies			2		
All Caddisflies except netspinner			2		
Gilled Snails			3		
Dobsonflies, Alderflies			4		
Dragonflies			4		
Crane Flies			4		
Watersnipe Flies			4		
Water Penny Beetle Larvae			4		
Whirligig Beetles			4		
Other Beetles			5		
Net Spinner Caddisflies			5		
Black Flies			5		
Non-biting Midges			6		
Damselflies			6		
Water Mites			6		
Crayfish			6		
Clams			6		
Scuds			7		
Other Snails (not gilled)			7		
Leeches			7		
Sowbugs			8		
Aquatic Earthworms			9		
TOTALS	D1	D2		E1	E2

Instructions: Using the "BMI Sorting Worksheets," count the number of organisms for each major group identified in your sub-sample and record in column A (do this separately for each replicate sample). Sum the totals of column A for rep one and rep 2 and record in D1 and D2. Multiply the number of organisms in each major group by the group tolerance value (column B) and record in column C (for each rep). Sum the totals of column C for rep 1 and rep 2 and record in E1 and E2. For the Biotic Index Score, divide E1 by D1 and E2 by D2 and then take the average.

Rep 1 Biotic Index Score = $\frac{E1 \text{ (total biotic value)}}{D1 \text{ (total \# organisms in your sub-sample)}}$ = _____

Rep 2 Biotic Index Score = $\frac{E2 \text{ (total biotic value)}}{D2 \text{ (total \# organisms in your sub-sample)}}$ = _____

BIOTIC INDEX = $\frac{\text{Rep 1 Biotic Index Score} + \text{Rep 2 Biotic Index Score}}{2}$ =

Biotic Index	0-4.5 non-impacted	4.51-5.50 slightly impacted	5.51-7.00 moderately impacted	7.01-10 severely impacted
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The following 4 worksheets are optional when turning your results in to the lab. Our spreadsheets will do most of these calculations automatically when we enter the data from the sorting worksheets, but this is a way to figure them out on your own.

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBW Tiers 2 & 3 Required 4 of 4

BMI Sorting Worksheet - p.4

School/Group _____ River/Stream _____
 Site _____ Sampling Date _____
 Name of person(s) conducting analysis _____

MOLLUSKS	TRUE BUGS <i>Megaloptera</i>	OTHER
Snail - flat spiral Class - <i>Gastropoda</i>  <div style="text-align: right;">no 1 rep 2</div>	Water Strider <i>Gerridae</i> -narrow body -extremely long legs -up to 1 1/2"  <div style="text-align: right;">no 1 rep 2</div>	Water Mites Class - <i>Arachnida</i> (Order <i>Acari</i>) -4 pairs of legs  <div style="text-align: right;">no 1 rep 2</div>
Gilled Snail - left-opening Class - <i>Gastropoda</i>  <div style="text-align: right;">no 1 rep 2</div>	Water Boatman <i>Corixidae</i> -distinct pattern on wings -rostrum short, blunt and triangular -up to 1"  <div style="text-align: right;">no 1 rep 2</div>	Other -describe <div style="text-align: right;">no 1 rep 2</div>
Gilled Snail - right-opening Class - <i>Gastropoda</i>  <div style="text-align: right;">no 1 rep 2</div>	Backswimmer <i>Notonectidae</i> -up to 1"  <div style="text-align: right;">no 1 rep 2</div>	Other -describe <div style="text-align: right;">no 1 rep 2</div>
Fingernail Clam Class - <i>Bivalvia</i> -up to 1/2"  <div style="text-align: right;">no 1 rep 2</div>	Giant Water Bug <i>Belostomatidae</i> -up to 1 1/2"  <div style="text-align: right;">no 1 rep 2</div>	Other -describe <div style="text-align: right;">no 1 rep 2</div>
Other Mollusks -describe <div style="text-align: right;">no 1 rep 2</div>	Other True Bugs -describe <div style="text-align: right;">no 1 rep 2</div>	Other -describe <div style="text-align: right;">no 1 rep 2</div>

To calculate a Taxa Richness estimate, add up the number of different taxa found. Count the number of boxes that have tallies for all 4 Sorting Worksheets (NOT the number of tallies). Record the Taxa Richness estimate in the box on this page.

TAXA RICHNESS = no 1 | rep 2

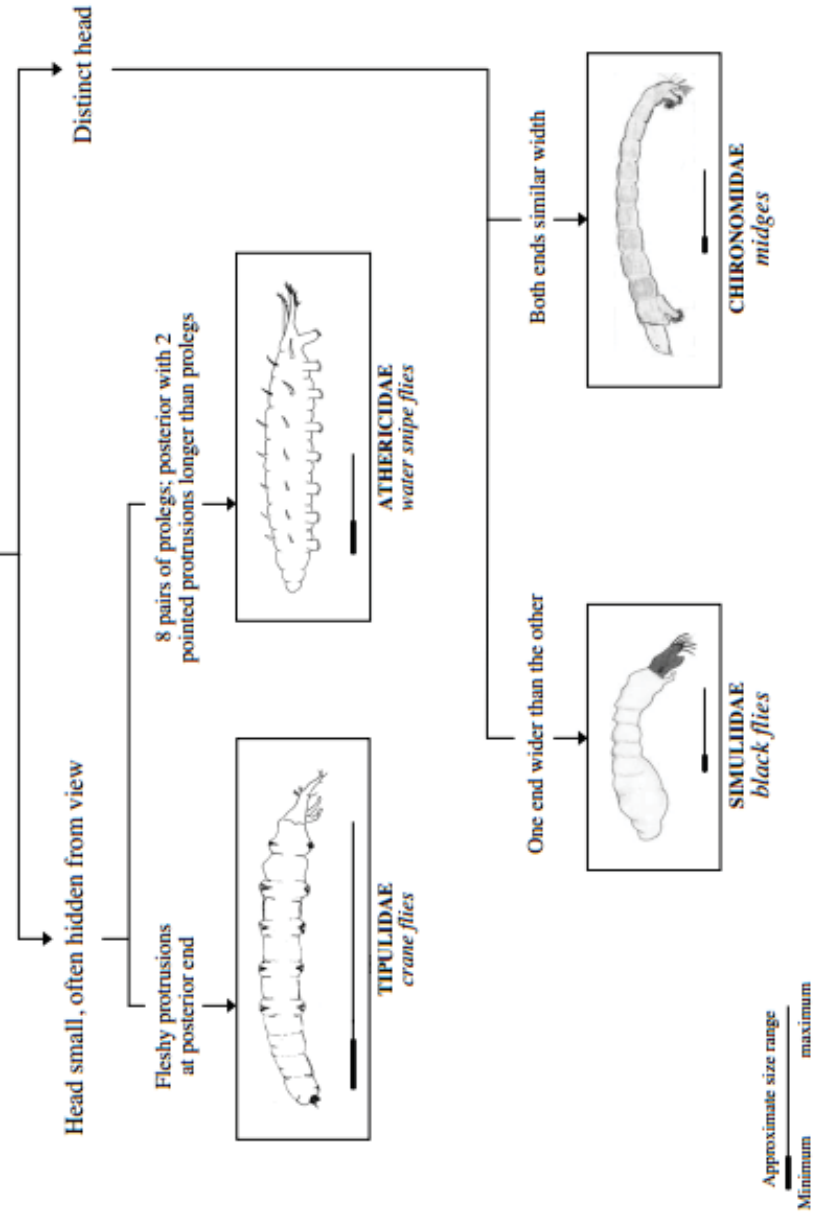
Note: sizes do not include tails



Page 2

Worm-like with distinct head or fleshy protrusion

DIPTERA - true flies



Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

Required

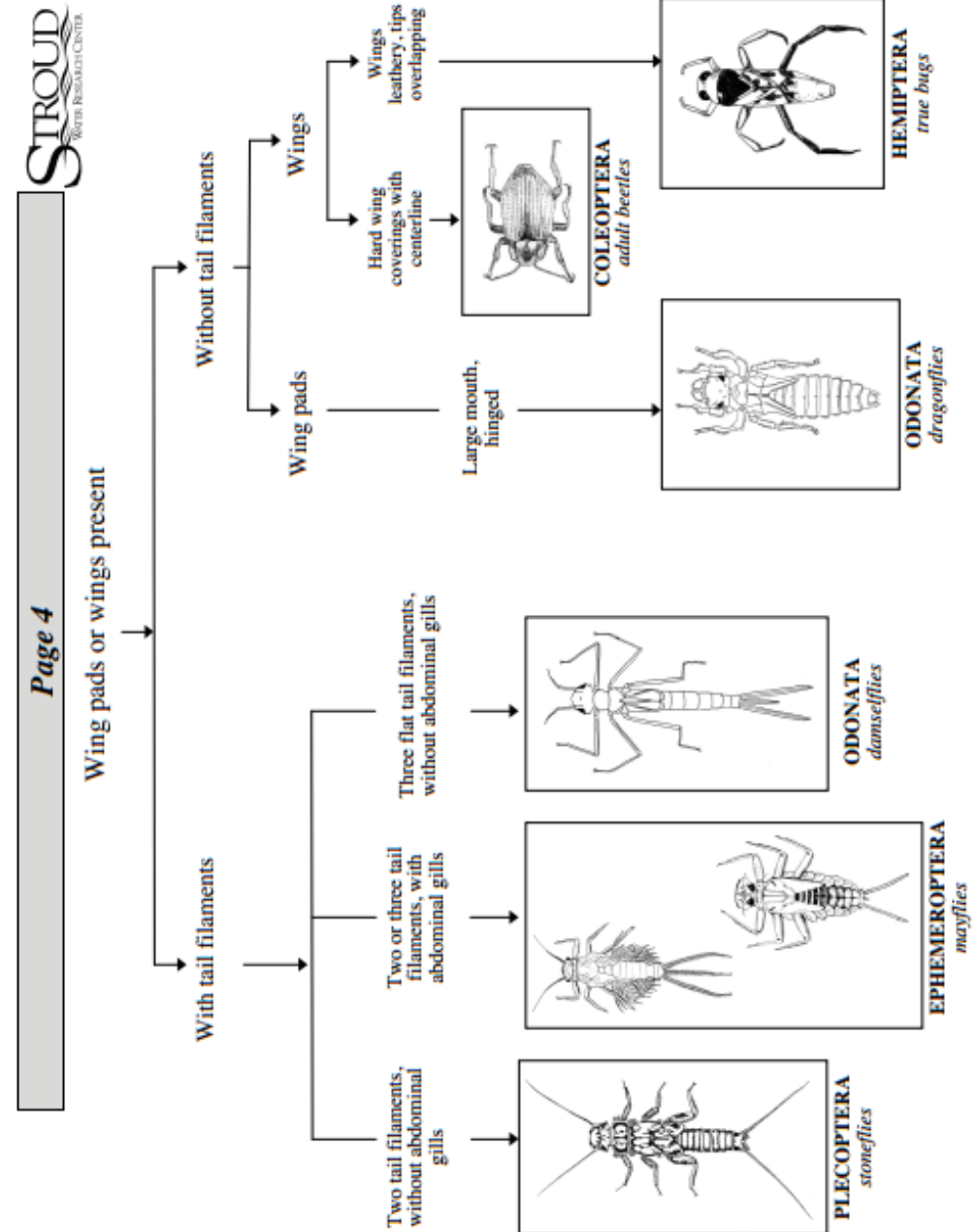
BMI Sorting Worksheet - p.2

HBRW Tiers 2 & 3 2 of 4

School/Group _____ River/Stream _____
 Site _____ Sampling Date _____
 Name of person(s) conducting analysis _____

BEETLES <i>Coleoptera</i>	TRUE FLIES <i>Diptera</i>	DRAGONFLIES/DAMSELFLIES <i>Odonata</i>
Water Penny Beetle Larvae <i>Psephenidae</i> -body flat -head and legs visible only from underside 	Non-biting Midge Larvae <i>Chironomidae</i> -smaller than 1/2" -paired prolegs at both ends -distinct head 	Club-tail Dragonfly <i>Gomphidae</i> -antennae are 4-segmented (4th tiny) -up to 1 1/4"
Riffle Beetle <i>Eimidae</i> -adults usually smaller than 1/8" -larvae are usually curved slightly 	Black Fly Larvae <i>Simuliidae</i> -smaller than 1/2" -head has a pair of fans -lower abdominal segments are swollen 	Darner Dragonfly <i>Aeshnidae</i> -antennae are 6-segmented -flat lower lip (side view) -up to 2"
Predaceous Diving Beetle <i>Dytiscidae</i> -adults up to 1" -larvae up to 2" 	Crane-fly Larvae <i>Tipulidae</i> -wide variety of body shapes within family -end of abdomen with lobes and gills -can be up to 4" long 	Skimmer Dragonfly <i>Libellulidae</i> -scoop-shaped lower lip (side view) -up to 1.5"
Whirligig Beetle <i>Gyrinidae</i> -adults up to 1" -larvae up to 1.5" 	Watersnipe Fly Larvae <i>Athericidae</i> -up to 3/4" -pairs of prolegs on underside of body -2 protrusions at end longer than prolegs -highly reduced head 	Other Dragonflies -describe
Crawling Water Beetle <i>Halipidae</i> -1/4"-1/2" 	Other True Flies -describe 	Damselfly Various Families -3 oar-shaped tails (gills) -up to 1 1/4"
Other Beetles -describe 	Other True Flies -describe 	Damselflies -describe

Note: sizes do not include tails

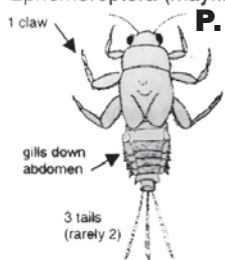


Identification to Family (rough guide)

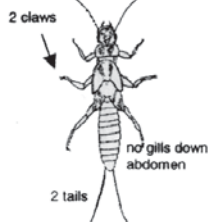
from Anne Gallagher Stream BioAssessment Kit

For anyone wanting to try family-level identification (for tier 3 HBRW protocols) or simply get a sense of some of the diversity found within the different Orders of aquatic invertebrates, on the following pages you will find brief descriptions of the most common families of BMI. Non-insects are only identified to Class.

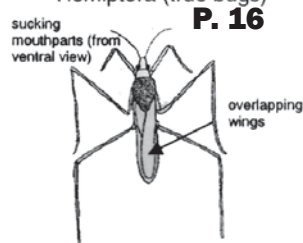
Ephemeroptera (mayflies) **P. 12**



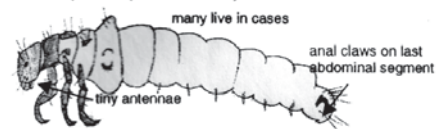
Plecoptera (stoneflies) **P. 13**



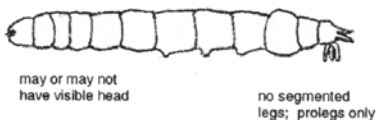
Hemiptera (true bugs) **P. 16**



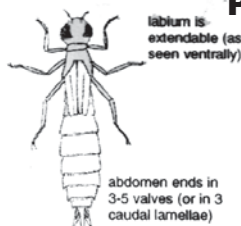
Trichoptera (caddisflies) **P. 14**



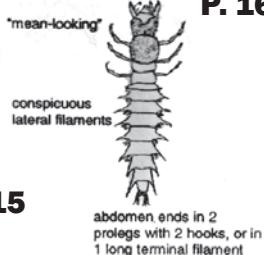
Diptera (true flies) **P. 15**



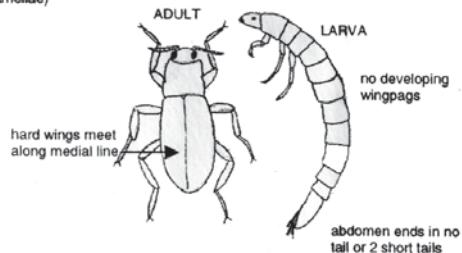
Odonata (dragonflies, damselflies) **P. 16**



Megaloptera (fishflies, hellgrammites) **P. 16**



Coleoptera (beetles) **P. 15**



Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBRW Tiers 2 & 3 Required 1 of 4

BMI Sorting (& EPT Richness) Worksheet

School/Group _____ River/Stream _____
 Site _____ Replicate _____ Sampling Date _____
 Name of person(s) conducting analysis _____

MAYFLIES <i>Ephemeroptera</i>	STONEFLIES <i>Ephemeroptera</i>	CADDISFLIES <i>Trichoptera</i>
Fatheaded Mayflies <i>Heptageniidae</i> -body flattened and eyes on top of head -often appear to have no neck -legs often quite stocky 	Common Stoneflies <i>Pteridae</i> -branched gills where legs attach (under) 	Netspinner Caddisflies <i>Hydropsychidae</i> -branched gills on underside of abdomen -top of all 3 thoracic segments sclerotized -curves like a "C" when dead
Brushlegged Mayflies <i>Isonychiidae</i> -long fringe of hairs on inner forelegs -often larger than other mayflies -streamlined teardrop shape from the side 	Other Stoneflies -describe 	Fingernet Caddisflies <i>Philopotamidae</i> -orange heads, lighter bodies (in alcohol) -meso- and meta-notum membranous -T-shaped membranous labrum (seen from top)
Spiny Crawler Mayflies <i>Ephemerellidae</i> -no gills on first few abdominal segments -"tails" tend to be stiff and spiky -"spines" on outer edge of abdomen 	<ol style="list-style-type: none"> Sort and identify organisms to the level of order (stoneflies, caddisflies, beetles, true bugs, etc.). Within each order, try to distinguish different taxa and sort organisms accordingly. Count the number of organisms of each taxa and mark a tally in the appropriate box next to the picture of the taxa. For taxa not pictured, make up your own description, write it in the "other" box for the appropriate order, and indicate with a tally the number of organisms found for that taxa. To calculate an EPT Richness estimate, add up the number of different mayfly, caddisfly and stonefly taxa found. Count the number of boxes that have tallies. Record the EPT Richness estimates for each rep below and then take their average. 	
Small Minnow Mayflies <i>Baetidae</i> -middle "tail" is short or missing -tend to be smaller than other mayflies -streamlined teardrop shape from the side 	Other Caddisflies w/stone cases -describe 	
Other Mayflies -describe 	Other Caddisflies w/square cases -describe 	
rep 1 EPT Richness = _____ rep 2 EPT Richness = _____ Rep 1 EPT Richness + Rep 2 EPT Richness 2 EPT RICHNESS = _____		Other Caddisflies -describe
>7 = non-impacted 3-7 = slightly impacted 1-2 = moderately impacted 0 = severely impacted		

Fill out the 4 BMI Sorting Worksheets for each sample analyzed. Record numbers of like organisms matching descriptions (provided or created by you) in tally boxes on the following 4 sheets. Save organisms in 70% alcohol for verification and temporary storage at the CSI lab. Turn these sheets in with preserved specimens. Turn in any unidentified organisms at the same time in a separate container.

Quality Assurance/Quality Control (QAQC) refers to activities that allow data users to associate a level of confidence to the information provided. The HBRW QAQC Guidelines are organized into three levels, A, B, and C. As the level of QAQC increases (C being the highest), so does the level of confidence in the information. Information with higher levels of confidence will generally have greater applications for use by local and state government agencies.

Required

BMI Protocol Sheet

School/Group _____ River/Stream _____
 Site _____ Replicate _____ Sampling Date _____
 Name of person(s) conducting analysis _____

Sampling Protocol

QAQC Level A	QAQC Level B & C
<input type="checkbox"/> Used 18"x8" net with mesh size between 0.8-0.9 mm <input type="checkbox"/> Sampled in a riffle 0.45-0.75 m/sec and > 1 meter deep <input type="checkbox"/> Sampled 5-meter-long diagonal transect in 5 minutes <input type="checkbox"/> Nets thoroughly cleaned of organisms between samples <input type="checkbox"/> Physical/habitat survey attached <input type="checkbox"/> Sampling spots labeled on sketches in physical survey	<input type="checkbox"/> Checked all boxes under A <input type="checkbox"/> Two replicates collected from at least one site per sampling day (required for B and C) <input type="checkbox"/> Whole replicate samples preserved in alcohol (required for C)

Describe sampling methods if different from above (indicate mesh size if not 0.8-0.9 mm):

Sample Analysis Protocol

Selected and analyzed a sub-sample (Tiers 2 & 3)
 Total number of organisms in sub-sample (minimum of 100 organisms recommended) _____
 Describe procedure for selecting sub-sample:

Equipment used for ID: (circle) none X magnifier X dissecting scope (indicate power)

Author & title of reference used to identify macroinvertebrates _____

Voucher specimens used (optional) List of specimens attached

Number and percent of organisms in sub-sample that you believe you have:

Positively identified _____ number _____ % of total
 Tentatively identified _____ number _____ % of total
 Not identified _____ number _____ % of total

BMI Data Reporting Sheet attached Raw BMI worksheets attached

QAQC Level C only:

Name & phone of outside evaluator _____

Outside lab's results attached (raw data and Percent Similarity Worksheet)

Be sure to fill out another "BMI Protocol Sheet" for your second replicate sample.

Sample Status Log

	By Whom	Date	Notes
Turned in to Lab			Accepted by _____
Rep 1 Sorting			
Rep 1 ID			
Rep 2 Sorting			
Rep 2 ID			

page 1 of 2

The first part of this sheet is to be completed at the time of sampling and the second part at the time of sample analysis. A separate sheet should be filled out for each replicate sample (total of 2). The "Sample Status Log" at the bottom of the page will be used to track the status of each sample. This page will be kept in a binder at the lab and updated as the sample is processed.

MAYFLIES

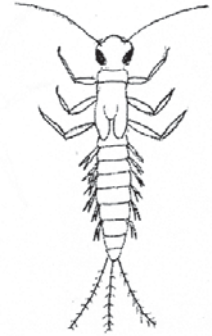
Small Minnow Mayfly
Baetidae middle terminal filament is short or missing; antennae are long



Common Burrower Mayfly
Ephemeridae has tusks that curve upward; abdominal gills curve dorsally



Prongilled Mayfly
Leptophlebiidae abdominal gills 2-7 are forked, fringed, or with double lamellae ending in points



*Fill out one of these sheets for each replicate sample.

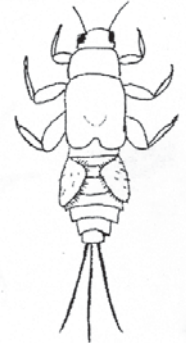
Spiny Crawler Mayfly
Ephemerellidae no gills on abdominal segment 2 (sometimes 1 and/or 3), so bug looks like it has a waist



Flatheaded Mayfly
Heptageniidae body flattened and eyes on top of head



Little Stout Crawler Mayfly
Tricorythidae gills on abdominal segment 2 are large and triangular



Brushlegged Mayfly
Isonychiidae long fringe of hairs on inner fore legs

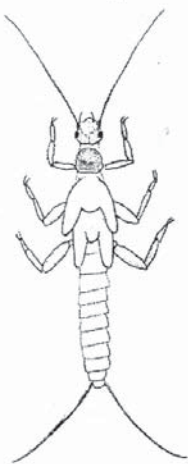


Small Squaregill Mayfly
Caenidae gills on abdominal segment 2 are squarish and overlapping

STONEFLIES

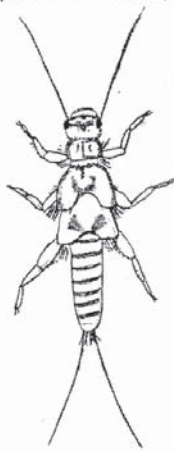
Rolledwinged Stonefly

Leuctridae long abdomen – extended legs don't reach the end of it; has non-predator mouth parts*



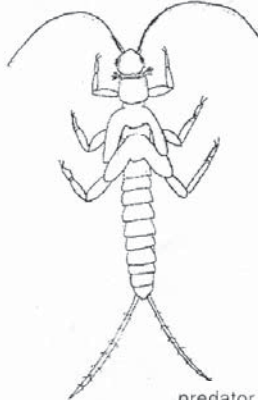
Common Stonefly

Perlidae brown and tan pattern on head and thorax; branched gills along thorax; has predator mouth parts



Nemourid Stonefly

Nemouridae branched cervical gills; has non-predator mouth parts

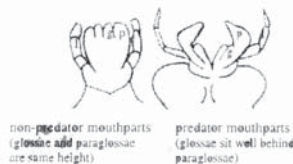


Perlodid Stonefly

Perlodidae no gills along thorax; has predator mouth parts



predator v. non-predator mouthparts of stoneflies:



g = glossa
p = paraglossa
l = labial palp

non-predator mouthparts (glossae and paraglossae are same height)

predator mouthparts (glossae sit well behind paraglossae)

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBRRW All Tiers

Site Drawing:

Draw a "bird's-eye" sketch of your 200' long river segment up and downstream from your sampling site, recording:

1. Your sampling sites – include where you collected chemical and BMI samples, and measured velocity and cross section area.
2. Direction of water flow – indicate with arrows.
3. Location and orientation of any photos taken.
4. In-stream habitat – riffles, pools, runs, large woody debris, boulders, aquatic plants, overhanging vegetation, etc.
5. Streambanks – steep & gently sloping areas, naturally vegetated, bare, eroding, clear-cut, or mowed areas, artificially protected areas, etc.
6. Channel – wide & narrow areas, meanders, shaded & exposed areas, unnatural alterations, dams, culverts, etc.
7. Human land uses – roads, houses, driveways, parking lots, storm drain pipes, sewage pipes, factories, farms, livestock crossings, recreational use, logging, etc.

SAMPLE ONLY

Sampling Site Description: Describe exactly where you collected chemical and BMI samples and measured velocity and cross section area.

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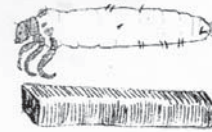
PHYSICAL SURVEY

It is important to complete a site drawing (part of the physical survey) to record features visually and document the location of your specific collection site(s). If you prefer to document features visually with photographs, a site map is still important for documenting the specific location of your collection site(s).

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

CADDISFLIES

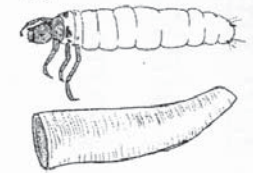
Humpless Case Maker
Brachycentridae
 meso- and often metanotum have some conspicuous sclerotized plates; pronotum is divided by a furrow across the middle; case cylindrical or 4-sided and made of vegetation



Common Netspinner
Hydropsychidae
 dorsum of all 3 thoracic segments are sclerotized; curves like a C when dead

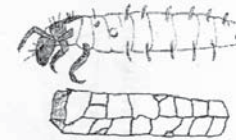


Longhorned Case Maker
Leptoceridae meso- and often metanotum have some conspicuous sclerotized plates; antennae are visible; hind legs are very long; cases vary



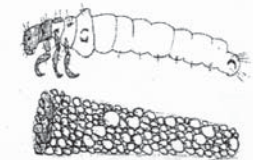
Lepidostomatid Case Maker

Lepidostomatidae
 meso- and often metanotum have some conspicuous sclerotized plates; first abdominal segment has lateral but no dorsal hump; cases are 4-sided, tapered and made of vegetation or sand



Strongcase Maker

Odontoceridae meso- and often metanotum have some conspicuous sclerotized plates; first abdominal segment has both lateral and dorsal humps; cases are made of rocks and are extremely hard



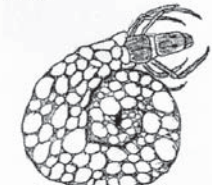
Saddlecase Maker

Glossosomatidae meso- and metanotum are mostly membranous; anal claw is short; case is a dome of rocks



Snailcase Maker

Helicopsychidae coiled case of sand grains or small rocks, like a snail shell



Northern Case Maker

Limnephilidae meso- and often metanotum have some conspicuous sclerotized plates; has a prosternal horn; cases vary



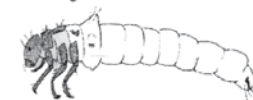
Fingernet

Philopotamidae meso- and metanotum are mostly membranous;



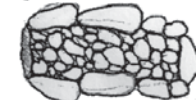
Uenoid Case Maker

Uenoidae meso- and often metanotum have some conspicuous sclerotized plates; has a prosternal horn; case is a mix of sand grains and small stones



Freeliving Caddisfly

Rhyacophilidae meso- and metanotum are mostly membranous; anal claw is long; live specimen is often greenish



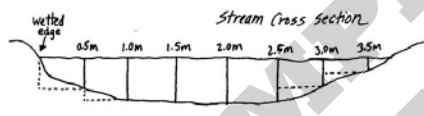
HBRW Tiers 2 & 3

Flow Worksheet

School/Group _____ River/Stream _____ Site _____
 Name of person(s) measuring flow _____ Date & Time _____

Area of the Stream's Cross-Section:

- Stretch a tape measure from wetted edge to wetted edge.
- At 0.5 meter intervals, across the entire width of the stream, measure the depth (in meters) and record in the table at right. (If stream is more than 10.5m wide, measure in 1m intervals).
- Each segment you measured is like a small rectangle (see diagram below). The area of each rectangle equals its depth times its width. Since the width of each rectangle is 0.5 meter, the area of each rectangle is 0.5 times its depth, in square meters.



interval (m)	depth (m)	interval (m)	depth (m)
wetted edge	0	5.5	
0.5		6.0	
1.0		6.5	
1.5		7.0	
2.0		7.5	
2.5		8.0	
3.0		8.5	
3.5		9.0	
4.0		9.5	
4.5		10.0	
5.0		10.5	

4. The total cross section area of the stream is estimated by adding up the areas of all the rectangles. This is the same as adding up all the depths you measured and multiplying by 0.5. Record your total cross section area estimate in the box at right. (If measured at 1m intervals, simply add the depths).

Sum of depths

x .5 =

Total Cross Section Area

Left side

Center

Right side

SUM:

Avg. Time: (sum/9) sec.

Velocity of the Stream's Water:

- Record the distance of the marked course in the space below.
- Record the number of seconds it takes the float to travel the marked course. Do this 9 times (3 times on the left side of the stream, 3 times in the center, and 3 times on the right side) and record the average time.
- Calculate the average velocity by dividing the distance of the course by the average time. Convert to underwater velocity by multiplying by 0.85.

Distance m / Average Time sec

X 0.85 =

Average Underwater Velocity m/sec

Flow:

The flow, or discharge of the stream, is the volume of water that moves past a site in a certain amount of time. Calculate the flow by multiplying the total cross section area by the average underwater velocity.

Average Velocity m/sec

x

Cross Section Area m²

=

FLOW m³/sec

x 35.32 =

Compare to USGS Data ft³/sec

©Hudson Basin River Watch Guidance Document 48 PHYSICAL SURVEY

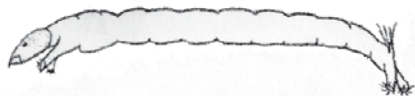
* Note: If you don't have a way to measure in metric, record in English units and convert later.

TRUE FLIES

Aquatic Snipe Fly
Athericidae extremely reduced head; end of abdomen has a pair of caudal processes that are longer than its prolegs



Non-biting Midge
Chironomidae paired prothoracic and anal prolegs; no prominent tubercles or setae



Black Fly
Simuliidae head has a pair of fans; lower abdominal segments are swollen (so looks somewhat like a bowling pin)



Crane Fly
Tipulidae extremely reduced head; end of abdomen with lobes and gills

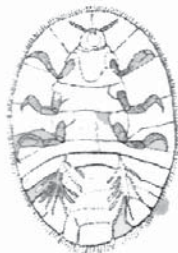


BEETLES

Riffle Beetle
Elmidae larvae: dorsal side of all abdominal segments sclerotized; adult: long, slender antennae



Water Penny Beetle larva
Psephenidae body oval and flat; head and legs visible only ventrally



Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBRW Tier 3

Stream Bottom Survey

Evaluate your specific BMI collection site (riffle area)

School/Group _____ River/Stream _____
 Survey Site _____ Survey Date & Time _____
 Name of person(s) completing survey _____

1. Set up 2-4 transects across the stream, in riffle habitats.
2. Starting at the water's edge, take one step at a time toward the opposite bank. With each step, reach over the toe of your wader with your forefinger without looking down and feel the substrate material closest to your large toe (could be mud or sand; does not have to be a rock). Pick it up (if possible), measure its size, and mark a tally in the appropriate column in the "Substrate Size Table" below.
3. If the substrate is a cobble, be careful as you pick it up out of the stream bottom so you can estimate how much it is covered up by silt or sand. Feel with your fingers for the edge of the cobble where it emerges from the silt or sand, and keep your fingers on that edge as you pick it up. Often there will be a "bathtub ring" line on the cobble where the level of the silt or sand was. There is also often algae growing on the top surface of the cobble down to that line. Estimate the percentage that the cobble is embedded and check the appropriate box in the "Cobble Embeddedness Table" below.
4. Continue until you have sampled approximately 50 substrate sizes and 20 cobbles.
5. In the "Substrate Size Table," total the tallies for each substrate type and record these numbers in the second row. Calculate the percentage of each substrate size by dividing the number of tallies by the total number (this should be approximately 50) and multiplying by 100.

Substrate Size Table

Substrate Type	Silt/Clay/Mud <small>(makes the water cloudy if disturbed)</small>	Sand <small>(up to 0.1")</small>	Gravel <small>(0.1-2")</small>	Cobbles <small>(2-10")</small>	Boulders <small>(>10")</small>	Bedrock <small>(solid rock covers stream bottom)</small>
Tallies						
# of Tallies						
Percentage						

Cobble Embeddedness Table

Cobble #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0-25%																				
25-50%																				
50-75%																				
75-100%																				

50% embeddedness indicates doubtful habitat for many macroinvertebrates, trout, and egg survival

Based on your results, estimate the average embeddedness of the whole site:

Average Embeddedness: _____ %
(record on physical survey/habitat assessment form)

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PHYSICAL SURVEY

The "Stream Bottom Survey" form provides you with more specific information about the most important element of BMI habitat in the stream.

Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

Assessment Factors: Circle the box that best applies for each assessment factor.

Assessment Factor	Excellent	Good	Fair	Poor
Riffle size	Well-developed riffle, as wide as stream & as long as 2x stream width	Riffle as wide as stream but riffle length less than 2x stream width	Riffle not as wide as stream and length less than 2x stream width	Riffles or run virtually nonexistent
Substrate size (at BMI collection site)	Cobble predominates; boulders, gravel common	Cobble less abundant; boulders and gravel common	Gravel, boulders or bedrock prevalent; some cobble	Large boulders and bedrock or sand & silt prevalent; cobble lacking
Shelter for fish	Snags, submerged logs, undercut banks, or other stable habitat are found in over 50% of the site	Snags, submerged logs, undercut banks, or other stable habitat are found in 30-50% of the site	Snags, submerged logs, undercut banks, or other stable habitat are found in 10-30% of the site	Snags, submerged logs, undercut banks, or other stable habitat are found in less than 10% of the site
Embeddedness (at BMI collection site)	Rocks in stream <25% embedded; very little sand, silt, or mud	Rocks 25-50% embedded; can easily turn over	Rocks 50-75% embedded and firmly stuck in sediments	Rocks >75% embedded; bottom mostly sand, silt, or mud
Flow pattern (deep is > 2 ft)	All 4 patterns present: slow/deep, fast/shallow, fast/deep, slow/shallow	Only 3 of 4 flow patterns present	Only 2 of 4 flow patterns present	Dominated by 1 flow pattern
Channel alteration	Stream straightening, dredging, artificial embankments, dams or bridge abutments absent or minimal; stream with meandering pattern	Some stream straightening, dredging, artificial embankments, or dams present, usually near bridge abutments; no recent channel alteration	Artificial embankments present to some extent on both banks; and 40-80% of stream site straightened, dredged, or otherwise altered	Banks shored with gabion or cement; over 80% of the stream site straightened and disrupted
Stream bank cover and stability*	Banks stable; no evidence of erosion; bank covered by vegetation or rock	Moderately stable; small areas of erosion; most of bank covered by vegetation or rock	Largely unstable; almost half of bank has areas of erosion or is not covered by vegetation or rock	Unstable, eroded; less than half of bank covered by vegetation or rock, or rock slumping into creek
Disruption of riparian bank coverage* (land bordering stream bank)	Mature trees and vegetation; most growing naturally; no disturbance by forestry, grazing, or mowing	Trees, woody plants, soft green plants dominate; some disruption but not affecting full plant growth potential	Obvious disruption; patches of bare soil, cultivated fields or closely cropped vegetation are the norm	Not much natural vegetation left or it has been removed to 3" or less in height
Width of riparian vegetation zone*	More than 35 yards wide; human activities have not impacted zone	Zone 12-35 yards wide; marginal impact from human activities	Zone 6-12 yards wide; impact from human activities evident	Zone less than 6 yards wide; lots of nearby human activities
Litter	No litter (metal or plastic) in area	Very little litter; accidentally dropped	Litter fairly common; purposely dropped	Lots of litter present; obviously dumped

*if the two banks are very different, assess the worst side

Given the assessment above, how would you rate your habitat overall? _____

Describe how land uses / human activities may be impacting the stream.

DRAGONFLIES/DAMSELFLIES

Darner Dragonfly
Aeshnidae antennae are 6-segmented



Clubtail Dragonfly
Gomphidae antennae are 4-segmented, and 4th segment is tiny



FISHFLIES/ALDERFLIES

Hellgrammite
Corydalidae abdomen ends in 2 prolegs, each with 2 hooks



Alderfly
Sialidae abdomen ends in a long terminal anal filament



TRUE BUGS

Water Boatman
Corixidae distinct pattern on wings; rostrum short, blunt, and triangular



Water Strider
Gerridae narrow body; extremely long legs



NON-INSECTS

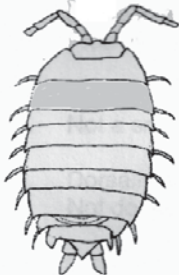
Snails (Class Gastropoda)



Clams (Class Bivalvia)



Sowbugs (Class Crustacea, Order Isopoda)



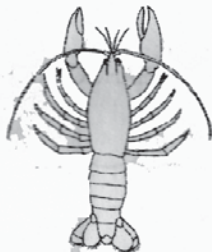
Scuds (Class Crustacea, Order Amphipoda)



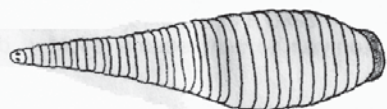
Aquatic worms (Class Oligochaeta)



* Crayfish (Class Crustacea, Order Decapoda)



* Leeches (Class Hirudinea)



Get copies of worksheets from the CSI website or at the lab:
www.communityscience.org

HBRW Tiers 2 & 3

Physical Survey / Habitat Assessment

Assess a 200 foot segment up & downstream from your sample site

School/Group _____ River/Stream _____

Survey Site _____ Survey Date & Time _____

Name of person(s) completing survey _____

Weather: Today _____ Temperature: Air _____ °C
 Past 2 days _____ Water _____ °C

Sampling Site Type (Select one from each row)

Stream Size	Headwater Tributaries		Creeks and Streams			Larger Rivers		
Gradient	FAST (primarily riffle)		VARIED (pools and riffles)			SLOW (low gradient)		
Surrounding Land Use	Forested		Agricultural		Residential		Urban	
	dense	sparse	pasture-land	crop-land	rural	village	suburban	Residential/commercial/industrial

Stream Width: The stream is on average _____ meters wide and _____ meters deep.

Water Level: Compared to the height of the stream channel, the water level seems relatively: high medium low

Water Appearance/Odor:

Turbidity substantially greater than natural conditions: Yes No

Describe: _____

Oily film, grease globules, or unusual odor or color present Yes No

Describe: _____

Algae or Weed Growth: Substantially greater than natural conditions: Yes No

Describe: _____

Upstream Dam: Yes No How far upstream: _____

Average Velocity of Sampling Site:

Average time it takes to flow 3 meters:

a) 3 m / _____ sec = v1 _____

b) 3 m / _____ sec = v2 _____

0.45 – 0.75 m/sec is optimal for BMI collection

AVERAGE: _____ m/sec

Average Depth of Sampling Site: _____ meters

Fill out the 5 “Physical Survey/Habitat Assessment” forms every time you collect a BMI sample. The habitat of the river greatly affects the nature of the BMI community. Without habitat information, your BMI data is less valuable. Calculate flow and velocity using the Flow Worksheet.

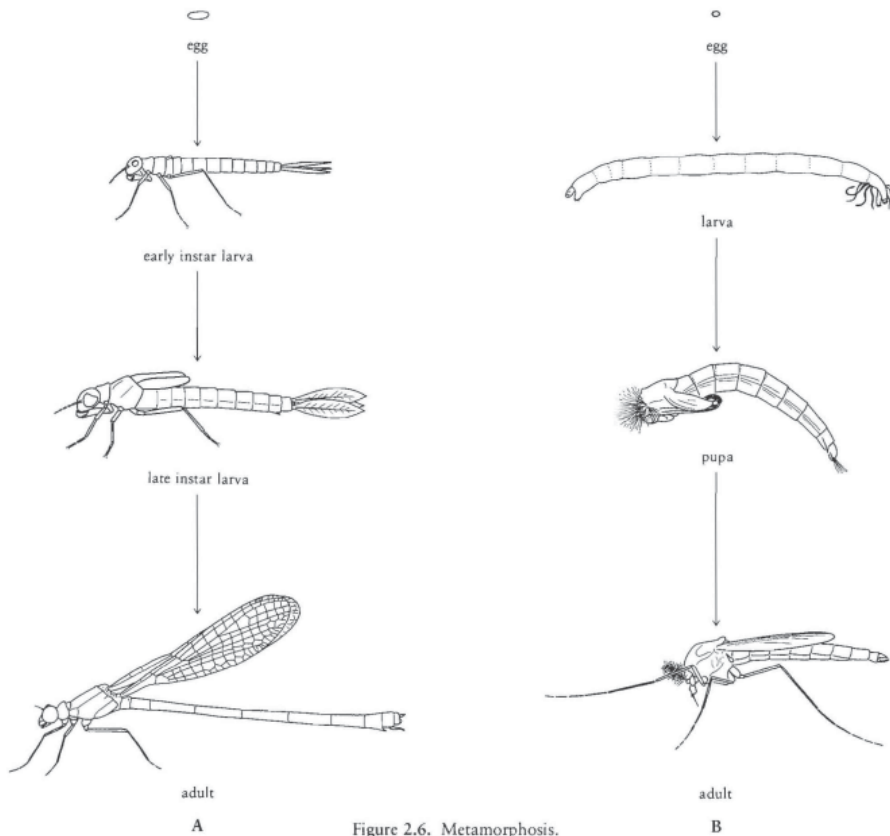


Figure 2.6. Metamorphosis. A. Incomplete metamorphosis, damselfly. B. Complete metamorphosis, midge.

possess well-developed compound eyes and wing pads (in species that have wings as adults). The degree of morphological and ecological difference between larvae and adults varies considerably from one insect group to the next.

The terms **nymph** and **naiad** are sometimes used for the larval stage of insects with incomplete metamorphosis. The term *larva*, however, is more universally accepted in the zoological sciences.

COMPLETE METAMORPHOSIS

Aquatic insects that possess a pupal stage have a complete kind of metamorphosis, which is generally regarded to be a more advanced kind of development (see Fig. 2.6B). In these insects growth takes place mainly in the larval stages, and maturation takes place mainly in the pupal stage. Larvae lack wing pads and compound eyes; their eyes are either highly reduced or composed of a single facet or group of single facets. Differences between larvae and adults are usually extreme.

Anatomy and Life Stages Of Aquatic Insects

From *Aquatic Entomology: The Fisherman's and Ecologists' Illustrated Guide to Insects and Their Relatives*, by W. Patrick McCafferty, with illustrations by Arwin V. Provonsha

Anterior: Refers to the head end of the body or that part of a structure closest to the head of the body.

Posterior: Refers to the tail end of the body or that part of a structure closest to the tail of the body.

Dorsal: Refers to the upper or top part of the body or structure.

Ventral: Refers to the lower or bottom part of the body or structure.

Lateral: Refers to the side of the body or structure.

Medial: Refers to the longitudinal midline of the body or structure.

Basal: Refers to the origin of a structure, generally closest to the point of attachment to the body.

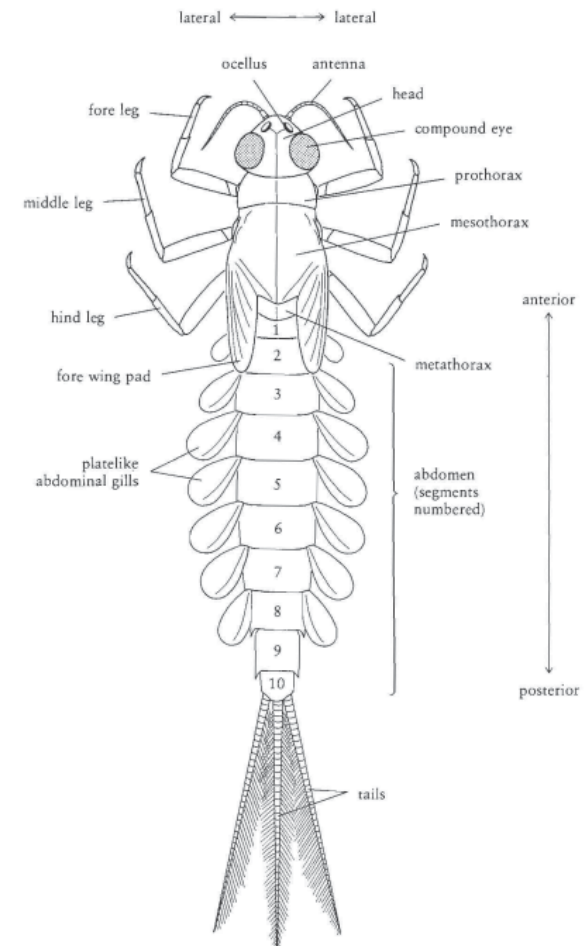


Figure 2.1. Mayfly larva, dorsal view.

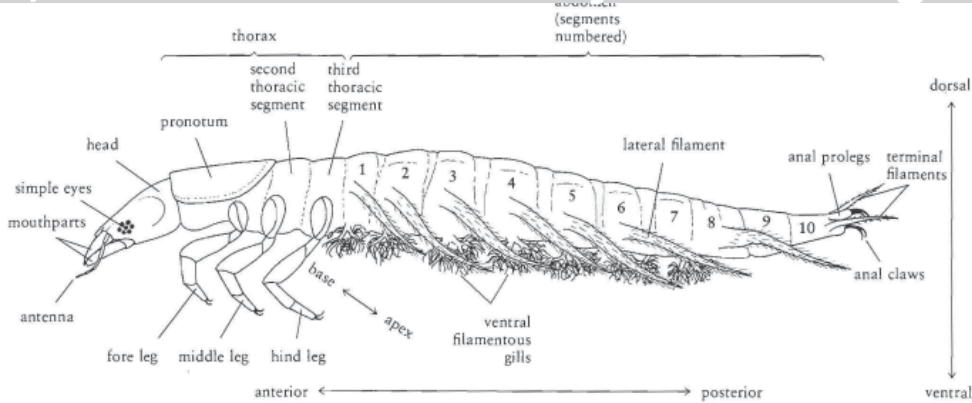


Figure 2.2. Dobsonfly larva, lateral view.

Distal: Refers to that part of a structure furthest from its point of attachment to the body. The **apex** is the distal end or tip of a structure. The term **apical** is generally synonymous with *distal*.

Shapes of bodies or body parts are often important in describing insects. A **dorsoventrally flattened** body or structure is flattened or depressed from top to bottom and is generally wider (side to side) than it is thick (top to bottom). A **laterally flattened** body or structure is flattened or compressed from the sides and is generally thicker (top to bottom) than it is wide (side to side).

Other important terms refer to the shape of a margin or end of a structure. A **rounded** or **convex** structure is more or less evenly curved outwardly. An **emarginate** or **concave** structure is notched or hollowed out or has an inwardly curved margin. A **truncate** structure is more or less square-shaped or has a blunt apex. An **acute** structure has a more or less pointed apex.

Body Divisions

The generalized insect body (Figs. 2.1, 2.2) is divided into many ringlike **segments** and three major **regions**. The first region is the **head**, which appears to be a single segment but is actually composed of six or seven fused segments. The head is usually capsulelike and contains the feeding apparatus and many of the sensory organs.

The second region, or **thorax**, is posterior to the head and is composed of three segments: the **prothorax** (anterior or first thoracic segment), the **mesothorax** (second or middle segment), and the **metathorax** (posterior or third segment). Appendages used for moving the body are located on the thorax.

Posterior to the thorax is the third body region, or **abdomen**. The abdomen is generally the longest region and is composed of several segments (often from 8 to 11). Various appendages and external structures are located on the abdomen of some insects.

Body regions are not distinguishable in some insects. When the thorax and abdomen are undifferentiated, they are together known as the **trunk**.

During the postembryonic phase of development, insects can generally be referred to as **immatures**, even though there may be either one or two major stages during this phase, depending on the kind of insect and the kind of metamorphosis it undergoes. These postembryonic stages are discussed below.

LARVA

The **larval stage** occurs in all aquatic insects. It follows the egg stage and is followed by either the adult stage or a transitional stage that precedes the adult. Growth (and maturation to varying degrees) occur during the larval stage, and there are three or more instars (larval instars). The relative terms “young larvae” and “mature larvae” refer to early instar larvae and late instar larvae, respectively. Larval instars may vary considerably from one to another in many aquatic insects and are sometimes given special names.

SUBIMAGO

The **subimago** (or subimaginal stage) is a unique transitional stage found only in mayflies. It follows the larval stage and precedes the adult stage. Unlike other pre-adult stages known among insects, it is a fully winged form. The subimago is a maturation stage and includes only one instar.

PUPA

The **pupal stage** is a transitional stage that occurs in more advanced groups of insects. It is primarily a maturation stage and includes only one instar. Depending on the kind of insect, the pupa may be quiescent or active. It also may be either free-living or encased in a cocoon or puparium. A **puparium** is found in some advanced groups of Diptera and is made from the modified skin of the last larval instar.

Kinds of Metamorphosis

Two basic kinds of metamorphosis occur among aquatic insects (see Table 2.1). The kinds of postembryonic stages involved in development determine the kind of metamorphosis. Larvae conveniently reflect these different kinds of metamorphosis by their possession of certain morphological traits.

INCOMPLETE METAMORPHOSIS

Aquatic insects that do not possess a pupal stage have an incomplete kind of metamorphosis, which is generally regarded to be a more primitive kind of development (see Fig. 2.6A). The larvae of these insects undergo both growth and maturation. The larvae (except for very young larvae)

TABLE 2.1 KINDS OF METAMORPHOSIS FOUND AMONG AQUATIC INSECTS

Incomplete Metamorphosis	Complete Metamorphosis
Ephemeroptera	Megaloptera
Odonata	Neuroptera
Plecoptera	Coleoptera
Hemiptera	Trichoptera
	Lepidoptera
	Diptera

sess segmented, tail-like structures at the end of the abdomen, and although these are known to specialists by various technical terms, they are herein simply referred to as **tails**. **Genitalia** (the primary external reproductive organs) are located on the abdomen of adult insects, but they are not generally used for the level of identification covered in this book.

Metamorphosis and Life Stages

During its life cycle (Fig. 2.5) every aquatic insect goes through a series of changes in form (the process of metamorphosis) as it develops from egg to adult. These different forms of the insect are known as **life stages**, and they make up two distinct phases of development. The first phase—embryonic development—occurs in the **egg stage**. The second phase—postembryonic development—includes all stages between the time the egg hatches and the time the insect becomes reproductively mature. Reproductive maturity is reached in the **adult stage** (sometimes also called the **imago**), which possesses functional sexual organs and is able to reproduce. The ecological requirements and associated morphological and behavioral adaptations of the different stages of an aquatic insect may be quite different; usually one or more stages are terrestrial. A knowledge of life cycles and stages is therefore very important to the student of aquatic entomology.

Postembryonic Development

Postembryonic development includes both growth and maturation of the individual. **Growth** is generally considered to be increase in size, whereas **maturation** is the progressive morphological and physiological attainment of adult attributes (wings, genitalia, etc.), which are fully developed at adulthood.

Since insects have an exoskeleton, it must be periodically shed, and a new, larger one reformed to accommodate the growing individual. The process of shedding the exoskeleton is known as **molting**, and the shed exoskeleton is commonly referred to as a **cast skin**. The period between any two molts is known as a **stadium**, and the individual during this interval is referred to as an **instar**. The number of developmental instars may be constant or variable, depending on the species or group of insects. The number of instars during postembryonic development may range from 4 to 40 or more.

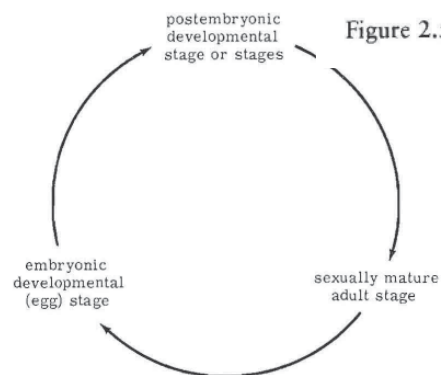


Figure 2.5. Insect life cycle.

The Body Wall

The outer skin of insects is actually an external skeleton known as the **exoskeleton**. The exoskeleton can be relatively hard (**sclerotized** or **platelike**) or thin and soft (**membranous** or **fleshy**), depending on the kind of insect or part of the body. The texture of the exoskeleton and the presence or absence of various kinds of outgrowths are often diagnostic.

SCLERITES

Any piece of body wall is a **sclerite**. A sclerite is bounded by membranous areas or lines known as **sutures**. **Tergites** are dorsal sclerites (often platelike areas) of a body segment. **Sternites** are the ventral sclerites of a segment. Some insects also have sclerites on the sides of the body, or **pleural area**.

OUTGROWTHS OF THE BODY WALL

Socketed outgrowths are **setae**, and these are referred to in this book by the descriptive terms **hairs**, **bristles**, **spurs**, or **scales**, depending on their thickness and shape. **Spines** and **processes** are robust, often acute, unsocketed outgrowths or extensions of the exoskeleton. The location and density of any of the above outgrowths can be important in identifying insects. The presence and location of punctures, furrows, and sutures can also be important.

Aquatic insects sometimes have additional outgrowths, such as **gills**, **filaments**, and **papillae**. These are often thin-walled and of various shapes and are most often located on the abdomen, but sometimes on the thorax, head, or appendages. Gills may be platelike (Fig. 2.1) or filamentous (Fig. 2.2) and branched or unbranched. Papillae are sometimes eversible.

Structures of the Head

The insect head possesses the eyes, antennae, and mouthparts. These structures vary considerably and thus are important for identification.

EYES

A pair of **compound eyes** (multifaceted) is present laterally on the heads of many insects (Fig. 2.1). Compound eyes are reduced to a single facet or group of single facets in many other insects (Fig. 2.2). In addition to the eyes, many insects possess two or three **ocelli** (single-faceted organs), which appear as spots on the dorsal or anterior part of the head.

ANTENNAE

Antennae are paired, segmented appendages of the head that usually arise between the eyes. They are highly variable in size and shape, often being filamentous (Figs. 2.1, 2.2) or variously expanded or clubbed.

MOUTHPARTS

Because mouthparts are highly variable, depending on the feeding adaptations of the insect, only a generalized plan is discussed here (Fig. 2.3). The **labrum** is a platelike “upper lip” that is attached to the front margin of the head and is the most anterior mouthpart. Posterior to the labrum and at the sides of the mouth is a pair of **mandibles**, followed by a pair of **maxillae**. Each maxilla possesses a lateral armlike appendage known as the **maxillary palp**. At the posterior of the mouth is the “lower lip,” or **labium**. The labium can generally be divided into the body of the labium and the **labial palps**, which are lateral, segmented, armlike appendages. An additional

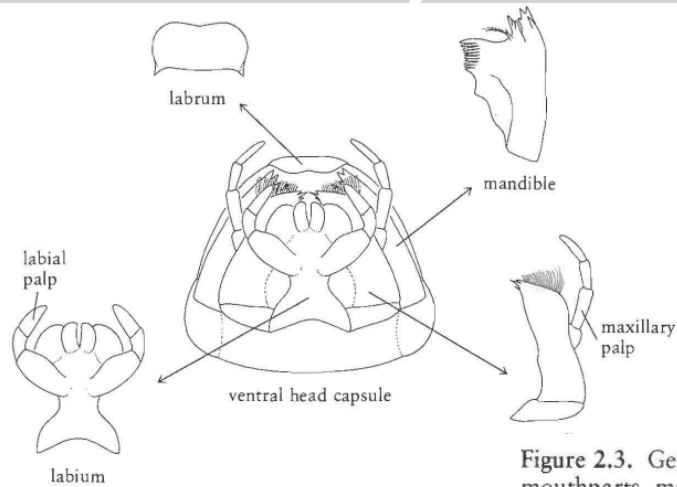


Figure 2.3. Generalized mouthparts, mayfly larva.

mouthpart present in some insects is the **hypopharynx**, a medial structure closely associated with the base of the labium and generally located between the maxillae.

Structures of the Thorax

Segments of the thorax are often relatively robust, since they encase muscles used to move the wings and legs. The terms **notum** or **notal** refer to the dorsal portion of a segment; the size, shape, and degree of sclerotization of the **pronotum** (dorsal portion of the first thoracic segment) and other nota are often diagnostically important.

LEGS

In the generalized insect (Figs. 2.1, 2.2), each thoracic segment possesses a pair of segmented legs. The basal leg segment, the **coxa**, is followed distally by the **trochanter**, **femur**, **tibia**, and **tarsus** (Fig. 2.4A). The tarsus is often subdivided into **tarsal segments** (segment 1 is always the most basal). A **claw** or pair of claws is usually present at the end of the leg. The pairs of legs are referred to as the **fore**, **middle**, and **hind** legs. Filamentous gills are present at the base of one or more pairs of legs in certain aquatic insects.

Many immature insects do not possess thoracic legs, but some possess **prolegs**. **Prolegs** are fleshy, usually unsegmented, leglike (usually short) outgrowths. Thoracic prolegs are present most often as a single ventral pair on the first thoracic segment.

WINGS

One or two pairs of wings are present in most adult insects. The generalized wing is a membranous, flaplike structure that articulates with the side of the thorax. The **fore wings**, or first pair of wings, are located on the second thoracic segment, and the **hind wings**, or second pair of wings, are located on the third thoracic segment. When only one pair of wings is present, the wings are located on the second thoracic segment.

Rigidity of membranous wings is maintained in part by the **wing veins** (Fig. 2.4B); **longitudinal veins** run from the base lengthwise, and **crossveins** connect longitudinal veins. The anterior margin of the wing is known as the

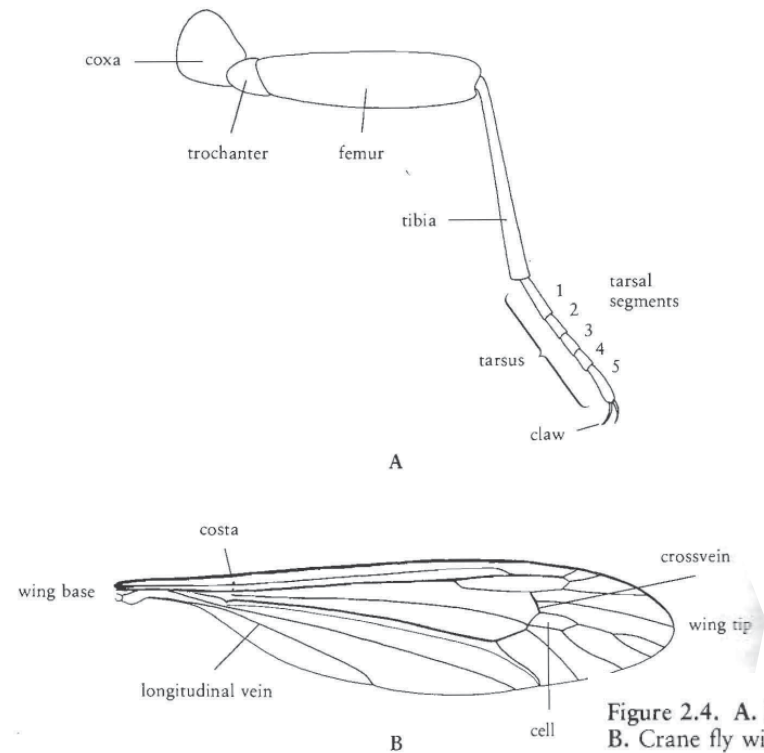


Figure 2.4. A. Beetle leg. B. Crane fly wing.

costa. **Cells** are areas of the wing enclosed by veins. The complex terminology of wing veins differs somewhat from group to group; veins are illustrated and labeled in parts of this book where they must be used.

Fore wings are sometimes variously modified into structures that, when folded over the back of the insect, protect the hind wings. Wings of certain species of aquatic insects never become fully developed. Immature insects may or may not have externally developing wings. These developing wings, including their encasements when present, are referred to as **wing pads**.

Structures of the Abdomen

The number of abdominal segments and an indication of the exact segments on which certain structures occur are often important for identification. Segments are consistently numbered, beginning with the most anterior segment as segment 1. Abdominal segments may appear to be subdivided in some insects.

Paired structures that sometimes occur on the abdomen include **lateral filaments**, **gills** of various kinds, and **prolegs** (Figs. 2.1, 2.2). These occur only on certain segments or serially on several segments. Those that occur at the end of the abdomen are often referred to as **terminal** or **anal** (e.g., **anal prolegs**).

Diagnostically important structures often occur at the end of the abdomen. These include **breathing tubes** or **siphons**, **caudal lamellae**, **anal prolegs**, various lobes, gills, filaments, and papillae. Many aquatic insects pos-