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To accompany the peer-reviewed article by Thomas A. Miller, Ph.D.:
"Designing Insects" (Oct. 2004)
http://www.actionbioscience.org/biotech/miller.html

Insect Biology and Biodiversity (June 2009)

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Grades & Levels:

- **Activity 1, 2:** Middle School
- **Activity 1, 2, 3**: High School, general biology
- **Follow-up activities:** Middle – High School

Time Recommendations:

- 1 class periods for review of article and related content questions and introduction to lesson activities
- time for field/lab activities will depend on the activity selected and the way in which it is used; estimated minimum time for activities ranges from 2 class periods to 2 weeks

NSES (USA) Content Standards, 9-12:

NSES 1.2. Unifying Concepts & Processes: Evidence, models & explanation
NSES 2.1 Science as Inquiry: Abilities necessary to do scientific inquiry
NSES 4.6. Life Science: Behavior of organisms
NSES 8.2. Science in Personal & Social Perspectives: Nature of scientific knowledge
NSES 7.6. Science in Personal & Social Perspectives: local, national, & global challenges
Note: View the NSES content standards on this site to choose other curricular applications for additional activities at: http://www.actionbioscience.org/educators/correlationcharts.html

Washington State 2008 Science Standards Addressed:

EALR 4: Life Science*;* Big Idea: Ecosystems (LS2)
Core Content: *Maintenance and Stability of Populations*
Content Standard: 9-11 LS2B, 9-11 LS2C, 9-11 LS2E,

Mathematics Connections

A1.8.A Analyze a problem situation and represent it mathematically.
7.2.E Represent proportional relationships using graphs, tables, and equations, and make connections among the representations.
A1.3.B Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
A1.6.B Make valid inferences and draw conclusions based on data.
A1.7.D Solve an equation involving several variables by expressing one variable in terms of the others.

A1.3.B Represent a function with a symbolic expression, as a graph, in a table, and using words, and make connections among these representations.
A1.6.B Make valid inferences and draw conclusions based on data.

Key Words Include:
Entomology, insect, caterpillar, moth, exotic (introduced) species, parasitoids, pupation, larva, host species, metamorphosis, native species

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Background: Spring Leafrollers in the Pacific Northwest

Leafroller caterpillars, the immature stage of small moths, are abundant in spring on many fruit trees and ornamental plants in the Pacific Northwest, and they include a diverse mix of native and introduced exotic species. Leafrollers get their common name from the larval habit of rolling plant leaves to create caterpillar-feeding shelters. Introducing students to the biology and species diversity of these insects can provide hands-on experience to students and introduce them to scientific investigation and from very simple to complex scientific principals.

These activities involve backyard insect collecting, easy rearing of caterpillars to the adult moth, and identification of the moth species collected. It provides opportunities to introduce students to diverse biological concepts such as insect life stages, insect-plant associations, exotic insect introductions, insect survival strategies, and natural insect controls. The methods and information gathering activities can be tailored to include diverse scientific techniques (data management, biological survey methods, use of identification keys, and analysis of results).

The first activity demonstrates insect biology and metamorphosis by collecting caterpillars found in rolled-up and partially eaten leaves in spring (April-May) and rearing them to adult moths in individual containers. Leaves from the host plant (the plant the caterpillars were found on) provide food as needed for the growing caterpillars. Not all caterpillars collected will survive to become moths, since some will be killed by insect diseases or parasitoids. Parasitoids are small flies or harmless wasps that reproduce on or inside caterpillars, ultimately killing them (which is how parasitoids are different from parasites, which normally don't kill the host animal).

Activity 1: Rearing Caterpillars to Adults.

1. Students, with teacher or parental supervision as needed, seek out and collect rolled-leaves with caterpillars. Note - when opening rolled leaves to see the caterpillars inside, the caterpillars will sometimes "bail out" of the leaf shelter

and hang on silk threads to escape (a catch tray or bucket underneath is helpful to return them to the leaf).

2. Individual caterpillars in rolled-leaves are placed in small containers, and collection information (date, host plant type, location) recorded. Any loose caterpillars collected can be placed on a whole leaf, and only one leaf is needed in each container (no water or other items). Containers with caterpillars are kept at room temperature and not in direct sunlight.

3. Periodically (daily to weekly) larvae are checked for condition, changes in stage (pupation, adult emergence) observed and recorded, and an additional host leaf added for food if necessary. Moldy or dried out leaves should be replaced with fresh, whole leaves (and moldy leaves removed), and caterpillars transferred.

4. When final (adult) stage of moth (or parasitoid) is reached, they may be kept alive for up to two weeks (longer if refrigerated) to complete this activity.

5. Compare adult moths (and parasitoids) reared to determine the number of kinds (species) found on various host plants. Adult moths and parasitoids can be photographed for additional identification activities and released outdoors, or dispatched by freezing and preserved (or disposed). (See followup activities for preservation options).

List of Materials Needed

Rearing containers – 1, 2, or 3 ounce, Plastic portion cups with lids. Available at restaurant supply and grocery outlets, translucent plastic cups with clear snap-on lids are inexpensive, durable, and safe for handling. (Best example: *2 oz, Plastic Portion Cups, CTS-B200, Pactiv Corp., Lk. Forest, Il 60045* with *Plastic Portion Lids, PLSL20000000, BG/FS-LS2Z*)

(Optional) Plastic tray or bucket to hold below rolled leaves to catch escaping caterpillars when opening leaf rolls to find or examine caterpillars.

Activity 2: Involves Identification of Reared Adult Moths (and Parasitoids).
(How Many Species were Found and How Many are Introduced Exotic Leafrollers?)

Introduced exotic leafrollers are more common than native species on some host plants in areas of the Pacific Northwest. Host trees that tend to have the most diversity of exotic and native species include apple, cherry, other fruit trees, and alder, as well as many ornamental plants like roses and hawthorns.

Identification of leafrollers can be an informative and relatively easy process by comparing live insects with picture guides available on-line. Host plant associations, identification characteristics, insect structures, and seasonal timing, are only a few of the biological concepts and information gathering activities that can be included with

identification. Both caterpillars and adult moths of the most common leafrollers in the Pacific Northwest can be identified with on-line resources at: http://www.invasives.wsu.edu/defoliators/index.html*)*, which also has additional information and links to related topics.

Activity 2:

1. Students, with teacher or parent assistance if needed, use observed characteristics (color of head, body and other caterpillar parts) of reared insects along with biological information (i.e. host plant, location, season) to identify them with on-line resources.

2. Rearing results and identification information is used to determine number of leafroller species found, native or exotic origin, larval mortality due to parasitoids (natural control), and other biological and ecological concepts.

List of Materials Needed
Computer and Internet Access –
http://www.invasives.wsu.edu/defoliators/index.html

Activity 3: Involves Researching and Discussing the Ecological Role of Leaf-feeding Caterpillars, Natural Population Controls, and the Impacts of Pesticides
(How are leafrollers important to the local ecology and economy?)

Insects in general, and leaf-feeding caterpillars in particular, are essential food for nesting birds in spring. Almost all birds feed insects to their young, even those birds that eat seeds and other food items as adults, and many rely exclusively on insect larvae to raise young. The overall abundance and diversity of insects, as a year-round food source for mammals, fish, and birds is a measure of the health and stability of most ecosystems.

Most insect leaf-feeding is cosmetic in effect and does little harm to the host plant. Even during cycles of high-populations (insect outbreaks), significant leaf loss of host plants is rarely fatal and usually has no lasting effects on plant health. On the other hand, bark-boring and internal (trunk, stem, or root) feeding insects, as well as sap feeding insects, tend to affect host plant health much more than leaf-feeders.

Parasitoids, predatory insects, spiders, and insect diseases, along with vertebrate predators are the natural controls of insect populations that balance and stabilize healthy ecosystems. Use of chemical pesticides to reduce or prevent leafroller can disrupt or eliminate all of these natural population regulators. Alternatively, selective/bacterial insecticides (like *Bacillis thuringiensis*) and biological control augmentation such as parasitoid releases or planting parasitoid-attracting flowers or shrubs can reduce leafroller prominence without disrupting the natural controls.

Activity 3:

1. Rearing results are tabulated by outcomes; i.e. successful adult leafroller moth, adult parasitoids, or disease mortality (larvae die from mold or infection and discolor/decompose). Within these categories, the diversity of species (kinds) of each is also determined and recorded.

2. The resulting numbers are compared and used to calculate relative diversity and affect on leafroller abundance.

3. The ecological importance and roles of leafrollers and other leaf-feeding caterpillars can be researched and reported to add significance (and relevance) to the results and conclusions of these activities.

Simplified Sample Results Table (Examples, with suggested/dummy data)

Caterpillar # (or student, site, etc.)	**Host Plant**	**Results (or Species)**
1 (Bill D. 1, City Park 1, etc.)	Apple	*Archips rosanus*
2 (Bill D. 2, City Park 2, etc.)	Cherry	Parasitoid wasp 1
3 (Bob G. 1, Mill Creek Park2, etc.)	Apple	*Archips rosanus*
4 (Bill D. 2, City Park 1, etc.)	Apple	Died (disease)
5 (Sue B. 1, Riverside Park 3, etc.)	Apple	Moth 1 (brown stripes)
6 (Mary G. 2, Lakeside Park 3, etc.)	Pear	*Choistoneura occidentalis*

Results (Criteria or Calculation)	**Number**	**Details**
Archips rosanus	12	Exotic leafroller species
Choistoneura occidentalis	3	Native leafroller species
Died (diseased)	4	
Parasitoid wasps	3	Two species of wasp
Unknown moth 1	1	
Total Exotic Moths	18	Five species
Total Native Moths	9	Three species
Etc……		

Follow up Questions / Discussion Points / Activities

Activity One (Insect Biology and Metamorphosis)

1. What are the stages of insect development observed and the elements of insect life cycle not observed in these activities?
2. What are the benefits to the larva from rolling leaves?

3. What are other kinds of leaf-feeding insect behaviors or strategies? (Web-making, leaf-mining, etc.)
4. How many ways is silk used by the larva? (Rolling leaves, secure movement on leaves and in rolls, escape – bailout security line).

Activity Two (Identification and Immigrant Status)

1. How are the species different (i.e. What are the characters used to identify leafrollers)? (Larvae – color of head, body. Adults – color/shape of wings. Both – host plant).
2. Are introduced exotic species good or bad and why?
3. Are the host plants native or exotic?

Activity Three (Leafroller Ecological and Economic Importance)

1. Were the host plants harmed by leafrollers?
2. Why are leafrollers important to the ecosystem?
3. Are leafrollers important economically?
4. Could pesticides used to control leafrollers affect the ecosystem?
5. How and why could introduced exotic leafrollers be a problem?

Preservation of Adult Specimens – Specimens may be either pinned or mounted in glass or plastic display boxes. Pinned and labeled specimens (for keeping in individual collections or donated to Museum, University, or other research collections) may need certain standardized pins, techniques, and information on labels. (http://www.extension.umn.edu/distribution/youthdevelopment/DA6892.html) Mounting specimens (unpinned, in natural position) in glass cases or plastic boxes is an easy durable option, but does require the cases and techniques (http://www.home-museum.com/How-To-Arts/Riker/Riker.htm)