FIGURE SET HEADER for Set #3

Figure Set 3: Indirect effects of biological control of knapweed.

Purpose: To allow students to teach each other about the cascading effects resulting from an introduced biological control agent, involving the invasive knapweed, the biological control agent (gall flies), mice, and hantavirus.
Teaching Approach: Jigsaw
Cognitive Skills: (see Bloom's Taxonomy) — Comprehension, Interpretation, Synthesis
Student Assessment: essay quiz, concept map

BACKGROUND for Set #3 (back3.html)

Background

For Instructor and Students

Biological control is a costly means to control invasive species and also a risky endeavor, as not all biological control agents introduced manage to effectively control target species. Further, introduced biocontrol agents have been found to have unanticipated and negative effects on the community to which they are introduced. Typically, such reported negative effects have included instances of host-switching or non-target effects. Less frequently reported are the indirect effects that introduced agents can have on food web interactions. The figures used in this jigsaw activity come from peer-reviewed articles which report information on the indirect effects of two *Urophora* species (gall flies) which were introduced to control populations of the invasive spotted knapweed (*Centaurea maculosa*).

Two species of gall flies (*U. affinis* and *U. quadrifasciata*) were introduced in the early 1970s to control populations of spotted knapweed. The gall flies lay their eggs in the undeveloped flower heads of knapweed. The developing larvae of the gall flies effectively decrease seed production of the knapweed. However, this decrease in seed production does not translate into reductions in the populations of the invasive knapweed. (Another instance of individual level effects not translating into population level effects – see previous figure sets in this issue). Therefore, the gall flies continue to persist in populations of knapweed and (as we will see) have the potential to indirectly affect human health.

The purpose of this jigsaw activity is to piece together the relationships between the invasive knapweed, the biocontrol agents (gall flies), deer mice, hantavirus, and human health.

For Instructor Only

Although the gall flies did not successfully reduce populations of knapweed, they do provide an additional food source for native deer mice (*Peromyscus maniculatus)*, which allows deer mice populations to increase in areas with knapweed populations. Deer mice are known reservoirs for hantavirus, a virus that can be deadly to humans. Therefore it is postulated that increases in deer mice populations could lead to higher risks of hantavirus in humans.

The following figures come from three papers, each of which investigates separate aspects of the indirect effects of an introduced biological control agent.

The first figure (3.1), from Pearson, McKelvey, and Ruggiero (2000), illustrates that the monthly variation in % stomach content (of deer mice) that consists of gall fly larvae corresponds with the yearly cycle of gall fly and deer mouse life cycles. Students should realize after seeing this figure that deer mice are consuming gall flies as a large portion of their diet, and are only consuming gall flies when they exist as larvae within the seed heads of the knapweed. Instructors may wish to pose a question to students to address this portion of the figure. As an example, ask students: why does the dependent variable decline in June-Aug?

The second figure (3.2) is from Pearson and Callaway (2006), which illustrates that gall fly larvae density is higher in areas with higher knapweed density.

The third figure (3.3), also from Pearson and Callaway (2006), illustrates that the abundance of deer mice, the abundance of seropositive (carrier of virus) mice, and the proportion of seropositive mice are all higher in populations containing higher densities of knapweed.

FIGURES for Set #3 (figure3.html)
3.1 is two images, a and b
3.2 is one image
3.3 is one image

Figure—these are already labeled a) and b)
Figure 3.1a.jpg
Figure 3.2a.jpg

Legend
Figure 3.1. Stomach content analysis of deer mice from 1997-1998. Data in (a) represent mean number (± 1 standard error) of gall fly larvae found per deer mouse (in the stomach contents) each month. The arrows indicate different points in both the life cycle of the deer mouse and the gall fly. Data in (b) depict the percent of different dietary items of the deer mouse that are represented in their stomach contents each month. (From Pearson, D.E., McKelvey, K.S., and L. F. Ruggiero. 2000. Non-target effects of an introduced biological control agent on deer mouse ecology. *Oecologia* **122**: 121-128.)

Figure
Figure 3.2 gall fly larvae and knapweed relationship

Legend
Figure 3.2. Data points depict the mean density of gall fly larvae (± 1 standard error) present in two populations of knapweed, one of high density (solid points) and one of low density (open

points) across several years (From Pearson, D.E. and Callaway, R.M. 2006. Biological control agents elevate hantavirus by subsidizing deer mouse populations. *Ecology Letters* **9**: 443-450.)

Figure
Figure 3.3 (a-c) mice knapweed and seropositive relationship

Legend
Figure 3.3. Data on deer mice populations (± 1 standard error) across several years in areas of high density of knapweed (solid points) and low density of knapweed (open points). (a) Abundance of deer mice. (b) Abundance of seropositive mice (mice that are carriers of hantavirus). (c) Proportion of deer mice captured that were seropositive (From Pearson, D.E. and Callaway, R.M. 2006. Biological control agents elevate hantavirus by subsidizing deer mouse populations. *Ecology Letters* **9**: 443-450.)

STUDENT INSTRUCTIONS for Set #3 (students3.html)

Student Instructions

Part 1: Individual instructions for each group

Group that receives Figure 3.1

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine Figure 3.1 and understand what the axes and data points mean. Attempt to make a conclusion about what information the figure is trying to get across. After everyone has completed this, talk amongst your group to discuss details of the figure and come to a consensus regarding the message the authors wanted to convey with the data presented in the figure. You will need to understand the information thoroughly as you will be teaching others about it shortly. Recall and share with your group any issues or difficulties you may have had with the figure so everyone will be prepared to explain such issues to others if they happen to arise. Perhaps practice teaching it to each other within your group. For example, ask your fellow students: why does the dependent variable decline in June-Aug?

Your figure is from a paper by Pearson, McKelvey, and Ruggiero published in the journal Oecologia in 2000. The researchers examined what role the larvae of gall flies play in the diets of deer mice across a seasonal gradient. The results of their study are an important piece in the ecological puzzle we will be piecing together to understand the unintended indirect effects of an introduced biological control agent.

Gall flies (*Urophora* species) were introduced in the early 1970s as biological control agents. These biocontrol agents were intended to control populations of the invasive spotted knapweed, *Centaurea maculosa*. This species of knapweed has spread throughout the western portion of the United States and can be highly problematic on rangelands and within natural areas. The biocontrol agents successfully reduced seed production of the knapweed. However, as you have seen, impacts on individual levels of fitness (success) do not necessarily translate into impacts on populations. The biocontrol agents do not effectively control populations of knapweed. However, the introduced gall flies, because knapweed still exists, continue to persist and have indirect effects on food webs and can potentially indirectly affect human health.

Group that receives Figure 3.2:

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine Figure 3.2 and understand what the axes and data points mean. Attempt to make a conclusion about what information the figure is trying to get across. After everyone has completed this, talk amongst your group to discuss details of the figure and come to a consensus regarding the message the authors wanted to convey with the data presented in the figure. You will need to understand the information thoroughly as you will be teaching others about it shortly. Recall and share with your group any issues or difficulties you may have had with the figure so everyone will be prepared to explain such issues to others if they happen to arise. Perhaps practice teaching it to each other within your group.

Your figure is from a paper by Pearson and Callaway published in the journal *Ecology Letters* in 2006. The researchers examined populations of knapweed (in low and high densities). One of the objectives of their study was to determine if there are differences in the presence of gall flies based on occurrence of knapweed (the species of invasive plant gall flies were introduced to control). Under low density conditions, knapweed was estimated to be present in <2% of the study site. At the high density study sites, knapweed was estimated to represent >20% of the vegetation. They wanted to know if more knapweed leads to more gall flies. The results of their study are an important piece in the ecological puzzle we will be piecing together to understand the unintended indirect effects of an introduced biological control agent.

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Group that receives Figure 3.3:

Read through this page of directions and information thoroughly before examining the accompanying figure.

Individually examine Figure 3.3 and understand what the axes and data points mean. Attempt to make a conclusion about what information the figure is trying to get across. After everyone has completed this, talk amongst your group to discuss details of the figure and come to a consensus regarding the message the authors wanted to convey with the data presented in the figure. You will need to understand the information thoroughly as you will be teaching others about it shortly. Recall and share with your group any issues or difficulties you may have had with the figure so everyone will be prepared to explain such issues to others if they happen to arise. Perhaps practice teaching it to each other within your group.

Your figure is from a paper by Pearson and Callaway published in the journal Ecology Letters in 2006. The researchers examined populations of knapweed (in low and high densities). One of the objectives of their study was to determine if mice are present in different abundances based on the abundances of the knapweed. Further, the researchers were also interested in the nature of the mice that were present in these knapweed populations. In particular, they wanted to know if these mice were seropositive (carriers of hantavirus), how many mice were seropositive, and what proportion of the mice present were seropositive (all in relation to the density of knapweed). The results of their study are an important piece in the ecological puzzle we will be piecing together to understand the unintended indirect effects of an introduced biological control agent.

Gall flies (*Urophora* species) were introduced in the early 1970s as biological control agents. These biocontrol agents were intended to control populations of the invasive spotted knapweed, *Centaurea maculosa*. This species of knapweed has spread throughout the western portion of the United States and can be highly problematic on rangelands and within natural areas. The biocontrol agents successfully reduced seed production of the knapweed. However, as you have seen, impacts on individual levels of fitness (success) do not necessarily translate into impacts on populations. The biocontrol agents do not effectively control populations of knapweed. However, the introduced gall flies, because knapweed still exists, continue to persist and have indirect effects on food webs and can potentially indirectly affect human health.

Part 2: Instructions for everyone

Step two – Mixed groups:

Each group member should have a different piece of information that no one else in the group has knowledge of. Your responsibility is to now teach your group the piece of information you are an expert on so the entire group can understand how the introduced biological control agents (gall flies) can have the potential to indirectly affect human health.

NOTES TO FACULTY for Set #3 (faculty3.html)

Faculty Notes

Divide students into equally sized groups to form 3 total groups. Assign one group to Figure 3.1, one group to Figure 3.2, and one group to Figure 3.3. In a larger class, you can divide students into 6 groups (two groups to each figure). There are three different portions of the story or rather three "pieces" of information represented by the three figures, respectively. Students are then to interpret the data given in their figure and ensure that each member of their group thoroughly understands the information, as they will be required to explain it to someone who has not seen the figure yet. Give students sufficient amount of time to accomplish this. Then assign students to new groups, so that each member of each new group has information from a different figure. Therefore the new groups should each contain 3 members, one student having information about Figure 3.1, one from Figure 3.2, and one from Figure 3.3. These students are now to teach each other their "pieces" of information to "piece together the puzzle" with the goal of understanding the indirect effects of the introduced biocontrol agents. (Make sure that students read the figure legends. In particular, make sure students understand that 'seropositive' means that the mice are carriers of hantavirus. If this is not understood, it can create problems.) You may need to inform students that transmission rates will increase with increases in the density of the carriers. Instructors could enforce this concept by asking students to consider the conditions under which diseases spread more rapidly (among crowded residential college students, etc). *For information about use of Jigsaws in teaching see http://tiee.ecoed.net/teach/teach_glossary.html.*

As a breakdown of the figures, students should be able to conclude that (1) gall fly larvae are present in large densities in areas that contain knapweed, (2) deer mice are present in large densities in areas that contain knapweed, (3) deer mice diets primarily consist of gall fly larvae and their diets fluctuate with the life cycle of the gall fly, and (4) both the density and proportion of deer mice that carry hantavirus are higher in areas that contain knapweed. Therefore the continued presence of knapweed allows for the persistence of gall flies, which provide additional food for deer mice, carriers of hantavirus, a virus that is transmitted to humans and can be fatal. Further, instructors may wish to discuss with the students the issue of correlation and causation. Although the separate pieces of the puzzle suggest that more knapweed allows more biocontrol agents to flourish, which allows more mice to live in knapweed areas, which in turns causes more and a greater proportion of seropositive mice, instructors could explain that these were correlations, and causation has not been supported by manipulative experiments.
Building on the discussion of correlation vs. causation, instructors could discuss with students how an experiment could be designed in this system. Alternatively, if manipulative experiments are not possible in science, instructors may wish to discuss how researchers/scientists deal with this situation.

Student Assessment

Essay Quiz

If a seed chewing biological control agent is found in Asia, discuss the costs and benefits of introducing this agent to the United States to control *Lespedeza cuneata*.

Concept Map

Have students create a concept map to depict the relationships between knapweed, gall flies, deer mice, hantavirus, and human health. Ask them to consider other components of the system, such as native plants, native insects, small mammals, gallfly parasitoids, and predators (see box 1 from Pearson, D.E. and Callaway, R.M. 2003. Indirect effects of host-specific biological control agents. Trends in Ecology and Evolution 18 (9): 456-461.) Concept maps are useful tools. They help students organize ideas about interconnected phenomena and faculty to literally "see" what students are thinking about a particular topic. If your students have not worked with concept maps before, briefly describe what they are, perhaps with an example. For more information go to http://www.flaguide.org/cat/conmap/conmap1.php