Jigsaw: Indirect Effects of a Biological Control Agent

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ABSTRACT

One major focus within ecology and conservation biology is that of invasive species. Invasive species cause significant ecological and economic harm and therefore effective management strategies are of utmost importance. One common yet controversial method proposed to control invasive plant species is biological control. This activity explores a particular set of research papers that focus on the control (and subsequent consequences) of a noxious invasive plant species. Students work through figures in a jigsaw format to piece together a specific scenario regarding the biological control of an invasive species, potential cascading effects that can occur in an ecosystem when additional species are introduced, and potential consequences of such introductions to human health.

INTRODUCTION

This paper addresses an important ecological and conservation biology issue (invasive species) in a jigsaw format. The jigsaw can be used to both expand upon the topic of invasive species and (more specifically) explore ethical and scientific issues surrounding the use of biological control. This activity has been used in upper-level courses (ecology, conservation biology) with a high level of success. However, with some modification and patience, it can also be used in introductory biology and environmental science courses.

STUDENT OUTLINE

All students are given a general introduction to the activity that should contain both background information on the specific topic surrounding invasive species and basic instructions as to the goals of the activity and how each part of the activity will work or function (handout 1).

Handout 1 (all students):

Background Information:

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. Therefore, the gall flies continue to persist in populations of knapweed and (as we will see) have the potential to indirectly effect 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.

Basic Instructions:

Part1: Expert Groups: You will be broken into groups where your goal is to become experts on the information presented in your figure. **Note: You will be given more specific instructions on other handouts.**

Part2: Mixed Groups: You will now be shuffled into new groups so that each member of this mixed group has a piece of information that no one else has knowledge of. You must now teach each other these pieces of information to piece together the ecological puzzle.

Once groups have been assigned and assembled, each group (see instructor's notes below) should receive a different handout corresponding to the three different pieces of information needed to work this jigsaw with specific instructions (found directly below) and also a handout with each

respective figure and accompanying legend. I typically pull these figures directly from the original articles (with a citation) and then create a new figure legend that is more straightforward for a student (who has not read the article) to understand. You can also modify the original published figures for a more simplistic presentation of the data. As these figures are published, they have not been reproduced here due to copyright laws. However, the figures that are used for this activity are listed below with respect to the figure that they correspond to for this activity.

Handout 2 (for different groups):

Expert Group 1: Part 1

Figure 1: Read through this page of directions and information thoroughly before examining the accompanying figure (figure 1 a & b from Pearson, McKelvey, and Ruggiero (2000)).

Individually examine figure 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.

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 did and 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.

Expert Group 2: Part 1

Figure 2: Read through this page of directions and information thoroughly before examining the accompanying figure (figure 1 from Pearson & Callaway (2006)).

Individually examine figure 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). They wanted to know if there was more knapweed, were there more gall flies present. 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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Expert Group 3: Part 1

Figure 3: Read through this page of directions and information thoroughly before examining the accompanying figure (figure 2 a, b, & c from Pearson & Callaway (2006)).

Individually examine figure 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 did and 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.

Handout 3: Mixed Groups: Part 2:

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 come to understand how the introduced biological control agents (gall flies) can have the potential to indirectly affect human health.

INSTRUCTOR'S NOTES

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:

Jigsaws are a teaching technique which employ cooperative learning. For this jigsaw, students are broken into 3 (for this activity) equally sized groups (expert groups). Each group is assigned a different piece of information about the ecological issue in the form of a figure. Group members are to work as a team to interpret the figure and become "experts" on their particular piece of information. When this step is completed, the students are then to reassemble into new groups (mixed groups), such that each new group contains one "expert" member from each of the original groups (expert groups). Students must then teach the group their individual pieces of information in order to assemble the ecological puzzle and understand the big picture.

Note: In larger classes, students can be broken into more groups. In this scenario, several groups will have identical pieces of information.

Background Information:

For Instructor Only:

Although the gall flies did not successfully reduce populations of knapweed, they do provide an additional food source for 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 (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.

The second figure (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), 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.

Instructions:

Discuss the background information regarding this ecological issue with the students, perhaps utilizing a powerpoint presentation with pictures of the species involved. You can either hand out the background information (found under student outline section above) before or after the discussion. Then proceed to divide students into equally sized groups to form 3 total groups. In a larger class, you can divide students into 6 groups. There are three different portions of the story or rather three "pieces" of information represented by the three figures, respectively. Assign one group to figure 1, one group to figure 2, and one group to figure 3. In larger classes you can assign two groups to each of these figures. Give **each student** two handouts appropriate to the group: an instruction sheet and a figure sheet (handout 2). 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 ask that students form new groups, so that each member of each new group has information from a different figure. Give **each group** instructions for the second part (handout 3). Therefore the new groups should each contain 3 members, one student having information about figure 1, one from figure 2, and one from figure 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.)

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.

Assessment:

Student assessment can consist of an essay debating the costs and benefits of biological control. Further diagram quizzes, where students depict the relationships between knapweed, gall flies, deer mice, hantavirus, and human health, can be used to determine students understanding of the cascading effects of this biocontrol introduction through the food web. Other components of the system can be added, such as native plants, native insects, small mammals, and predators such that a flow diagram can be created (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.)

Additional References:

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