Parasitoids

Introduction to Parasitoids

The image of the creature below represents the adult stage of a parasitoid species in the Alien franchise films starring Sigourney Weaver. Although the aliens are fictional, parasitoids are not. Numerous species of parasitoids have been identified by researchers and many estimate their numbers to be much higher than we presently know. The first part of this lab is to introduce you to parasitoids, followed by a more focused examination of **parasitoid wasps**.

Alien Xenomorph-ViaFlicker JohnGiez. CC 2.0

Ichneumon wasp on flower feeding – via Wikimedia Commons | Charles J Sharp | CC4.0

Read ***Current Biology Vol 14 No 12. R456. Quick guide. Parasitoids***

After reading through the guide, watch the following video clip. If you have a digital copy of the handout, you can click the *url* or image to access it. Type in the *url* if you have a printed copy.

Body Invaders | National Geographic

https://youtu.be/vMG-LWyNcAs

Beautiful wasp zombifies cockroach

https://youtu.be/-ySwuQhruBo

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Species Interactions

One way to describe the interactions between different species is to determine whether one species has a positive, negative, or neutral effect on a second species. Below is a table of some common species interactions.

Species Interaction	Effect on Species 1	Effect on Species 2
Competition	-	-
Predation	+	-
Herbivory	+	-
Mutualism	+	+

Based on what you have read and watched so far, how would you describe the interaction between a parasitoid and its host?

Fill in the table below to indicate this.

Species Interaction	Effect on Host	Effect on Parasitoid
Parasitoid-Host		

Of the species interactions listed in the table above, what does the parasitoid-host interaction most resemble?

The relationship between a parasitoid and its host eventually leads to the death of the host species, obviously lowering its fitness (very similar to predator-prey interactions). It would therefore be advantageous to avoid being parasitized. What could a host species do to avoid parasitoids and reduce that risk? (*Hint: think of ways prey species try to avoid predators*)

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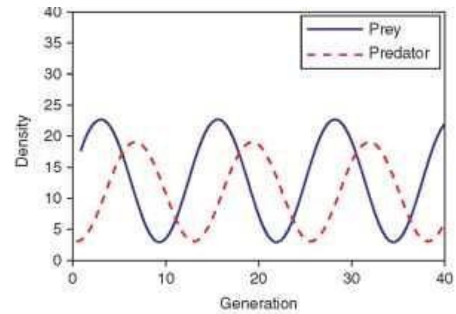
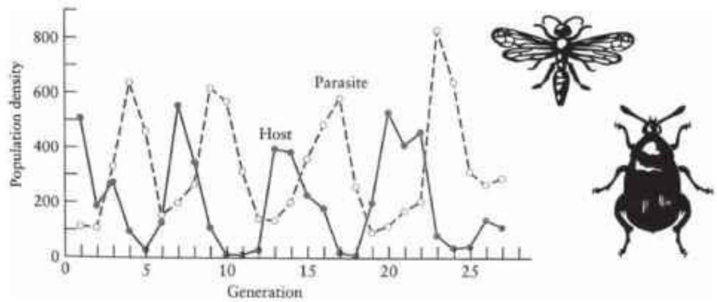
When ecologist examine how populations of predators and their prey change over time, in many cases, they have observed an oscillating or cyclic nature to them, see (a) below. Similarly, ecologist and entomologists working in labs have observed the same type of pattern among parasitoids and hosts, see (b) below. In nature, these types of patterns are nowhere near as obvious, but represent null models we can use.

a

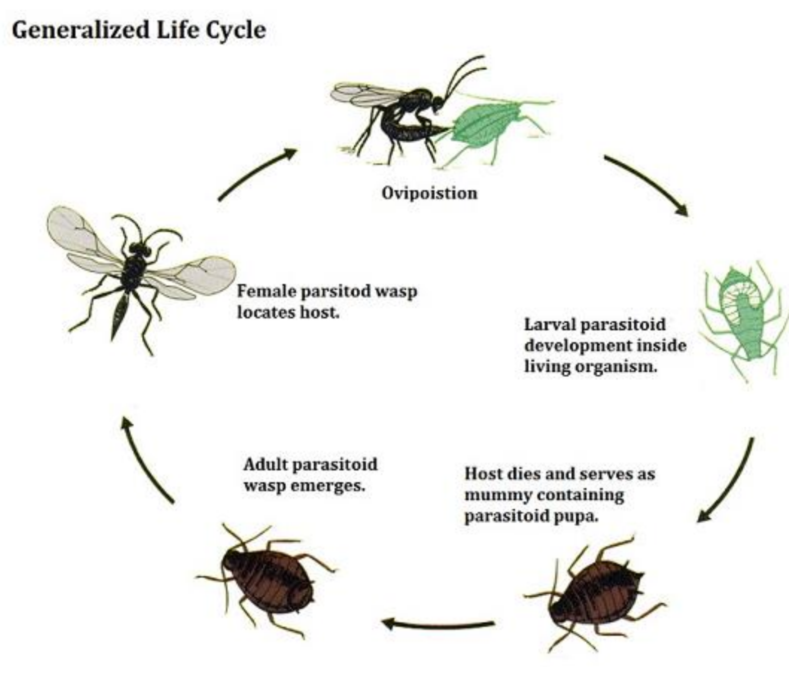


b



Parasitoid Wasps

Of the 14% of insects estimated to be parasitoids, most belong to the order Hymenoptera (wasps, bees, sawflies, and ants). Like all parasitoids, the female locate hosts on which to oviposit (lay eggs). Some lay eggs on hosts, others use an ovipositor and pierce the hosts body to deposit eggs, still while others lay eggs near hosts. Many people familiar with T.V. nature programs have usually seen a video of a parasitoid wasp, attacking, and stinging a tarantula in order to paralyze it. Tarantula hawks, as they are known, then drag the tarantula to a den, deposit an egg on it abdomen, and cover the den. A few weeks later, a new adult tarantula hawk will emerge and begin the life cycle again. Regardless of the mechanism, the results are still the same: the host's eggs hatch and the larva feed on the host, leading to its death.



Some parasitoid wasps are known to illicit "zombie" behaviors in their hosts that often protect developing larva from being predated or, in some cases, becoming the victims of another parasitoid. As mentioned earlier,

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parasitoid-host interactions are similar to those seen in predator-prey interactions. As a way to help you explore this, and to develop your quantitative reasoning skills, you will complete a modeling exercise below using Microsoft Excel. No prior experience is needed and the spreadsheet does all the calculations. You will only be manipulating the parameters (values that describe the system) of the model and will not be solving any equations.

Parasitoid-Host Model*

*Based on: "Systems of Difference Equations—Host-parasitoid Models" by Claudia Neuhauser. Edited by J.W. Felts

Parasitoids play an important role in biological control. A successful example is *Trichogramma* wasps that parasitize insect eggs. These wasps are reared in factories for field releases. Every year, millions of hectares of agricultural land are treated with released *Trichogramma* wasps; for instance, to protect sugar cane from the sugar cane borer, *Chilo* spp., in China, or to protect corn fields from the European corn borer, *Ostrinia nubilalis* Hübner, in Western Europe. Another successful example of biological control of an insect pest is the parasitoid wasp *Aphytis melinus* that regulates the red scale (*Aonidiella aurantii*), which damages citrus trees in California.

The importance of parasitoids in pest control stimulated both empirical and theoretical work. Theoretical studies of host-parasitoid interactions go back to Thompson (1924) and Nicholson and Bailey (1935). The work of Nicholson and Bailey was particularly influential. They introduced discrete generation, host-parasitoid models of the form

(1a) $$N_{t+1} = \lambda N_t e^{-aP_t}$$

(1b) $$P_{t+1} = cN_t (1-e^{-aP_t})$$

Where:

N_t = density of host species in generation t
P_t = density of parasitoid in generation t
a = searching efficiency of parasitoids
λ = host reproductive rate
c = average number of viable eggs laid by a parasitoid on a single host.

for *t*=0,1,2,.... Here, *N* and *P* denote the population sizes of susceptible hosts and searching adult female parasitoids at time *t* and *t*+1, respectively. The parameter λ is interpreted as the net growth parameter. We see from the first equation that hosts grow exponentially in the absence of parasitoids (*P*=0). The term e^{-aP_t} is the fraction of hosts that are not parasitized (and thus $1-e^{-aP_t}$ is the fraction of hosts that are parasitized) at generation *t*. Parasitized hosts produce parasitoids. The parameter *c* is equal to the average number of female parasitoids produced per parasitized host. All parameters are nonnegative.

The Nicholson-Bailey model assumes that hosts and parasitoids encounter each other randomly. This means that the total number of encounters is proportional to the product of host and parasitoid densities. That is,

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$$N_e = \#\text{encounters per unit time between hosts and parasitoids} = aHP$$

Therefore, the average number of encounters per host is given by

$$\lambda = \frac{N_e}{H} = aP$$

The probability that a host escapes parasitism is equal to the probability that a host encounters 0 parasitoids. Equations of the form (1) are systems of difference equations. They are suitable for populations that reproduce in discrete time.

You will use an Excel spreadsheet to model what happens when you change the values of the parameters that govern the model.

Step 1

Download the spreadsheet for the Nicholson-Bailey model, which is also located on the course Moodle Page. The parameters in the initial model are a=0.023, λ=1.5, and c=2, with initial values N_0=25 and P_0=10.

Your worksheet (Tab: "Steps 1 and 2") looks like

	A	B	C	D	E
1	**Nicholson-Bailey Model**				
2					
3	**a**	**b**	**c**	**N_o**	**P_o**
4	0.023	1.5	2	25	10
5					
6					
7	**Time**	**N_t**	**P_t**		
8	0	25	10		
9	1	29.79501	10.27332		
10	2	35.28718	12.54045		
11	3	39.66838	17.68318		

Where the entries in Row 4 and Row 8 are values.

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Cell B9 is '=$B$4*B8*EXP(-$A$4*C8)' represents the equation 1a from the introduction

Cell C9 is '=$C$4*B8*(1-EXP(-$A$4*C8))' represents the equation 1b from the introduction

(a) Plot the temporal dynamics for t=0,1,2,...,50 for the above set of parameters using the graphing ability of Excel. Plot both host and parasitoid densities as functions of time in one plot (two lines on a single graph).

(b) Looking at the dynamics, what are your predictions about densities of both species in future generations?

(c) The simulations indicate that at times the densities become very small. How could you modify the simulations to deal with extremely low densities so that this becomes biologically more realistic?

(d) Repeat the simulations you did in (a) but now choose λ=0.5 and plot the temporal dynamics for t=0,1,2,...,50. Plot both host and parasitoid densities as functions of time in one plot. Describe the difference between the dynamics in (a) and in (d).

Step 2

Assume that the parasitoid is absent in Equation (1). What are the dynamics for the host then? That is, analyze the behavior of the host dynamics in the absence of the parasitoid by removing it from the model.

Finally, as a lab group, change the various parameters of the model in a way that you choose. However, choose something new, that the lab has not asked you to do. Provide the details of what you changed and what the results were is the space below.

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Why do you think the populations reacted this way?

Go back and look at the model and the parameters. Of those present, which one(s) do you think are not constant? What do you think would happen if you allowed those values to vary?

Anisopteromalus calandrae

Using the resources available to you via the internet, you and your lab group should use the space below to report a short and concise *natural history* of the parasitoid wasp *Anisopteromalus calandrae*. We will be using this parasitoid wasp in a few weeks in experiments with *Callsobruchus maculatus*. You may use a separate sheet to type your answers. The description should include the following:

1) Physical description
2) Locations where it is normally found
3) Differences in males and females
4) Information regarding host species(s)
5) A description of its life cycle
6) A short description on the wasps' behavior

Post Lab Exercise and Authentic Research Preparation

As our first research-based project, students in BIO 111 will conduct experiments using both essential oils and parasitoid wasps against the cowpea weevil, *C maculatus*. You have already (or should have) conducted research regarding bean beetles when you designed and set up your own experiments in the second week of lab. You also conducted a small background research exercise regarding *A. calandrae* above. The following should be completed **BEFORE** you return to lab next week when we will begin our first set of experiments with essential oils. Watch Alien (1979) if you would like a different perspective of parasitoids (optional).

1) Conduct a scholarly search for one peer-reviewed research article that covers the topic of essential oils and cowpea weevils (hint: use the course's cowpea weevil library in Moodle). You may also use Google scholar. Read the article, and save it as a pdf. If you would like to print a copy to bring with you, feel free or have an electronic copy that is accessible in lab.

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2) Conduct a search for and answer the following questions:
   a) What are essential oils?
   b) Why is the cowpea weevil considered a pest species and what damage does it do to pulse (bean stores) around the world?
   c) Can essential oils be used against cowpea weevils? If so, how?
   d) How could the use of essential oils provide relief to farmers in areas of Africa and Asia?

3) Design an experiment that you think could be used to determine the efficacy of using essential oils to repel cowpea weevils using the remainder of the space below:

DUE NEXT LAB!