Competition Within and Between Species of Parasitoid Wasps

Objectives

1. Describe the life cycle of *Nasonia* and *Melittobia*.
2. Explain the possible interactions between two parasitoid species competing for the same host resource.
3. Design and conduct an experiment to determine the nature of the interaction between these two species when competing for a common host.
4. Relate class research outcomes to the principle of competition exclusion.
5. Discuss the concept of resource partitioning as it relates to the natural history and behavior of these two species.

Introduction

Think of the sparrows darting about in the trees on campus, the robins on the lawn, or the house finches coming to a bird feeder in your yard. The type of place where you will normally find a given bird species is its *habitat* – an inclusive term that includes both the physical and chemical features of the place and the array of other species living in it.

Within this habitat, each species of organism is distinct in terms of its "profession," i.e., the sum of activities and relationships in which it engages to secure and use the resources necessary for its survival and reproduction. This is its *niche*. (If there were no constraints at all on its acquisition and use of resources, each species could expand into its *fundamental niche,* and realize its full potential. In the "real world," however, constraining factors always come into play, so a species occupies its *realized niche*.)

Directly or indirectly, the populations of all species in a habitat associate with one another as a *community*. The structure of this assemblage, in turn, is also shaped by many different factors, such as interactions between climate and topography, and the kinds and amounts of food available. A major influence to be considered is the interaction of the species in that habitat in various mutually helpful or destructive ways.

In even a simple natural community, dozens to hundreds of different species of plants and animals interact with one another. In spite of this diversity, however, we can identify categories of interactions that have different effects on population growth (Table 1).

Most species in a habitat have a *neutral* relationship with one another. For example, a robin that feeds on worms is not affected by a hummingbird that feeds on nectar from flowers, even if the robin and the hummingbird live in the same habitat.

In other cases, for at least part of the life cycle, individuals of two or more species interact to directly affect one another's fate. Generally, one participant clearly benefits, but the effect on the other can be neutral, positive or negative. For example, flocks of insectivorous birds follow large grazing animals in an African savannah. As the animals move through the grasses, they disturb insects that fly up out of the grass. The birds forage on these insects, taking advantage of the disturbance. This type of interaction is called commensalism, where one species benefits and the effect on the other is neutral. In the previous example, the birds benefit by having an easier time finding food, but the large grazers are not impacted by the interaction. In a great many other cases — such as most flowering plants and the insects, birds, bats, and other animals that pollinate them — both parties benefit. This *mutualism* is not only widespread, but often obligatory. One (or sometimes both) species cannot survive without it.

Table 1. Categories Of Direct Interactions Between Species In The Same Community

Name of interaction	**Type of contact**	**Direct effect on species 1**	**Direct effect on species 2**	**Other aspects of the relationship**
Neutral relationship	Two species are linked only indirectly through interactions with other species.	**0**	**0**	Each species has a neutral relationship with most species in its habitat
Commensalism	A relationship that directly helps one species but does not affect the other much, if at all.	+	**0**	Commensalism, mutualism, and parasitism are all cases of symbiosis (‘living together”).
Mutualism	Benefits flow both ways between the interacting species.	+	+	Better viewed as two-way exploitation than as cozy cooperation.
Predation	Predator attacks and feeds upon a series of prey but does not take up residence in or on them.	+	–	Prey generally dies.
Parasitism	Parasite feeds on tissues of one or more hosts, residing in or on them for at least part of their life cycle.	+	–	A host might or might not die as a result of the interaction.
Interspecific competition	Disadvantages flow both ways between species	–	–	Generally less intense than competition between members of the same species.

0 means no direct effect on population growth.
+ means positive effect; – means negative effect.

Predation and *parasitism* are two more interactions where one participant benefits, though in these cases the other party clearly suffers. Defining the line between these categories can be a fuzzy affair. In general, predators feed on other living organisms that they kill outright or mutilate. Parasites feed on tissues of living organisms that they also live on or in, at least for part of their life cycle. Entomologists also recognize *parasitoids*, insects whose larvae live upon and kill what they eat (usually the larvae or pupae of other insect species) (Godfray, 1994).

The final category of contact between species is the only one in which both participants are clearly worse off because of the interaction. *Competition* for required resources is common among animals, and may become especially intense when shared resources become limited.

Intraspecific competition occurs when different individuals of the same species compete for a resource. These interactions can be fierce because the individuals require the same limited resources to survive and reproduce. When different species are vying for the same food, habitat, or some other environmental resource it is called *interspecific* competition. These interactions are typically somewhat less intense. This is because while the requirements of two species might be similar, they can never be as close as they are for individuals of the same species.

Consider, however, the theoretical case of two species that occupy the identical niche. Can such a thing even happen? G. Gause (1934) studied two protist species that both fed on the same bacterial cells. When he combined them in a single culture, one always drove the other to extinction. Many other experiments have since supported “Gause’s Law,” now called *the principle of competitive exclusion.* It states that any two species that use identical resources cannot coexist indefinitely (Harden, 1960).

Many experiments have demonstrated that the more two species in a habitat differ in their resource use, the more likely it is that they can, in fact, coexist (Krebs, 1994). Even two species with a great deal of overlap may live together for some time, although competitive interactions often suppress the growth rate of one or both of them. Over time, an interesting phenomenon called *resource partitioning* may occur. Members of each species may come to specialize in a subdivision of some category of similar resources. For example, if both feed upon apples, one may feed upon small green fruits and the other upon larger, riper ones.

Although they are not particularly closely related to one another, the lives of two parasitoid wasp species, *Melittobia digitata* and *Nasonia vitripennis,* are quite similar. Both species lay their eggs on the pupal stages of host insects. In nature, *Nasonia* use *Neobellieria (=Sarcophaga) bullata*, as well as other related species of flies, as their hosts, while *Melittobia* lay their eggs on the prepupae or pupal stages of solitary wasps and bees. However, in the lab, *Melittobia* will readily accept the same host as *Nasonia*, *Neobellieria bullata*. While *Nasonia* are more choosey about their host, *Melittobia* might be considered as more of a generalist, because they exhibit some flexibility in their host choice. *Melittobia* are about half as large as *Nasonia*, but both are quite small and completely harmless to humans.

Their complete life cycles are relatively short (2-4 weeks at 25^{o} C), and also quite similar (Figure 1). Females lay numerous eggs through the host covering. The eggs hatch to become larvae that consume the host, then change to pupae, and finally molt to a winged adult stage. Adults disperse from the host covering to search for new food resources.

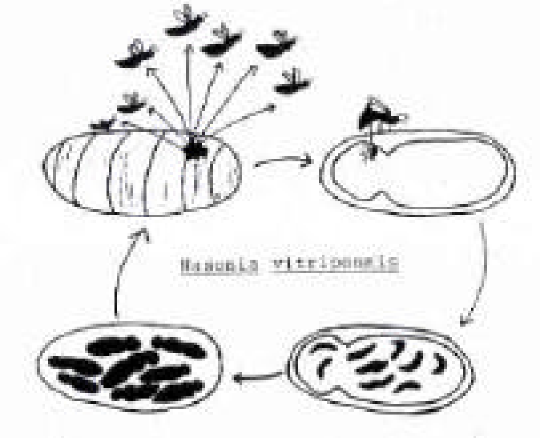


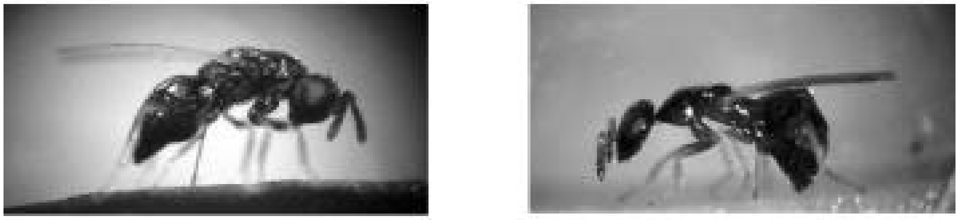
Figure 1. The life cycle of *Nasonia vitripennis;* (drawing by Bethia King). The life cycle of *Melittobia* is the same, though individuals at all stages are smaller.

Adults of both parasitoids are very "user friendly". Although females possess normal wings and can fly, they do not do so readily. However, they are negatively geotactic (i.e., they move up, away from gravity). When a few females from a culture are shaken out onto a horizontal surface and then covered with a glass vial, they will readily climb into the vial and up the sides. One can readily add a host pupa and then plug the vial tightly with cotton. Large numbers of individuals can be efficiently handled in this way.

Before we proceed further with this lab, you'll take a little time to examine your study subjects and learn how to distinguish between the two species, and between males and females within the species.

Distinguishing between *Melittobia* and *Nasonia*:

While *Nasonia* are generally larger than *Melittobia*, you can't always depend on that to distinguish between the species. Some *Nasonia* are as small as *Melittobia*. Therefore, the best way to tell them apart is to practice by looking at them side by side under a dissecting microscope. From the lab bench, obtain a your cultures of *Melittobia* and *Nasonia*, as well as a demonstration vial containing a *Melittobia* male and female. The most reliable characters for determining species are head shape and body shape. *Nasonia* have a distinctly round head and *Melittobia* a flattened and elongated head when viewed from the side (Fig. 2). The thorax and abdomen are about the same thickness in *Nasonia*. In contrast, in *Melittobia*, the thorax is thinner than the abdomen when viewed from the side (Fig. 2).



Nasonia

Melittobia

Figure 2. Side view of females of both species.

Distinguishing between *Melittobia* males and *Nasonia* males is much simplier because *Melittobia* males are amber colored, while *Nasonia* males are black like the females.

Figure 3. **Distinguishing between females and males:** Sexes of *M. digitata.* The female is on the left, male on the right.

Melittobia. *Melittobia* males and females are easy to tell apart. Females have straight dark bodies, straight antennae, and fully-developed wings. Males are amber colored, have branched antennae, and stunted wings (Fig. 3).

Nasonia. Distinguishing between the sexes in *Nasonia* is a little trickier, but you can learn to do it with a little practice. The most reliable difference between the sexes is that males have stunted wings, while females' wings are fully developed (Fig 4).

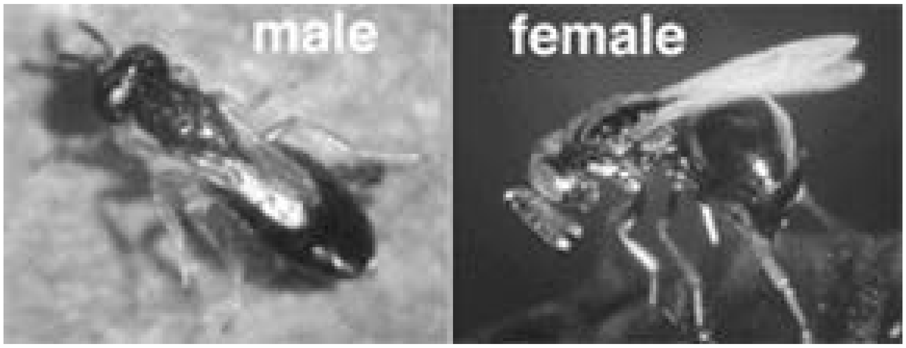


Figure 4. Sexes of *N. vitripennis.* Males have noticeably shorter wings than females.

It's important to note that size is not a reliable indicator of sex in either species.

Methods:

Challenge #1: Design a way to test the interaction between two very similar species in the same habitat

The categories of interactions discussed above can seem quite straightforward when one is simply reading about them. But if you were to observe two unfamiliar animals interacting, how would you decide what "label" to apply? Could you predict the outcome of the interaction? How could you test your prediction?

The two parasitoid wasps presented in this laboratory investigation seem to occupy very similar niches. What would happen if a female of each species found the same host at the same time? How would it compare to the situation when two females of either species found a host simultaneously? How do either of these situations compare to the outcome when only one female of either species encounters a host?

While the situation in nature has not been studied, we can use laboratory trials to make some fairly good predictions. We would need experiments designed to show:

- the reproductive potential for each female in the absence of competition
- whether one species is able to outcompete the other (interspecific competition)
- whether some form of interspecific sharing occurs
- whether two females on a single host (intraspecific competition) produce more or fewer offspring as compared to when they have sole possession of a host
- whether some sort of intraspecific mutualism occurs

Each of these could be approached through a different experimental set-up, and the task of making these observations could be divided among class members. Discuss as a class how you would like to do this.

After you have read the background information and whatever text pages or other material your instructor may indicate, meet with your group to:
- discuss and list the possible experimental combinations that could be set up involving two parasitic wasps, *Melittobia* and *Nasonia*, and a host, *Neobellieria*
- predict what you think might be the outcome for each possible interaction
- identify and list variables that you would manipulate in your experiment
- identify and list variables you would keep constant in your experiment
- what would you measure to find out whether your prediction was true?

Nature of the question	Experimental conditions	Specific predictions

Once you have completed this step, share your information with the class. Then obtain your instructor's approval and proceed to set up your experiment(s).

Challenge #2: Carry out an experiment to test the interaction between two very similar species in the same habitat. To test validity of the class predictions, each group will need to set up cultures for one experimental combination, observe them periodically over the month of the life cycle, then count the total number of adult parasitoids that are produced in each experimental condition.

Results

Class results should be pooled for each of the experimental conditions, allowing firmer conclusions about the nature of the interactions observed. You may wish to use a table like the sample shown her:

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Number of Mothers	**Progeny/ female replicate 1**	**Progeny/ female replicate 2**	**Progeny/ female replicate 3**	**Progeny/ female replicate 4**	**Progeny/ female replicate 5**	**Progeny/ female replicate 6**	**Average progeny/ fem**
Nasonia vitripennis							
1							
2							
Melittobia digitata							
1							
2							
Both *Nasonia vitripennis* and *Melittobia digitata*							
1 N. vitripennis							
1 M. digitata							
2 N. vitripennis							
2 M. digitata							

Data Analysis

After you've collected your data, enter your data in an Excel Spreadsheet to create a class data file. Prepare a graph of the data, showing the mean number of offspring per female for the five different treatments (you'll need two bars for the mixed culture). Add standard error bars to your graph. Using the graph you've just created, answer the following questions.

Conclusions

What, if any, is the effect of interspecific competition on the number of offspring per female for *Melittobia*?

How can you tell?

For *Nasonia*?

Is the number of *Melittobia* offspring per female affected by the presence of a *Nasonia* competitor? How can you tell?

Is the number of *Nasonia* offspring per female affected by the presence of a *Melittobia* female competitor? How can you tell?

Does one species appear to be a stronger competitor? Which one and why?

Which has more of an effect on *Melittobia*, inter- or intraspecific competition?

Why do you think that?

Does interspecific or intraspecific competition appear to have the strongest effect on *Nasonia*? Explain?

Do either species appear to benefit from the presence of another female?

Discussion and Reflection Questions

1. Both of these species are sold commercially. (*Nasonia* are called "jewel wasps" and *Melittobia* are called "WOWBugs.") Imagine you are the laboratory technician facing an ambitious CEO who wants to cut costs and maximize profits. How would you respond to these ideas? What experimental evidence would you present to back up your answers?

   a. Given that they can develop on the same species of host, why can't we just raise them together on the same host?

   b. Setting up cultures costs time and money. If our company's normal rearing protocol is to place one parasitoid female on a single host to establish a culture, wouldn't we do better by using more than one female per culture?

   c. Wouldn't putting two females on a single host result in twice as many offspring produced?

2. Imagine you work for a company that sells these two parasitoid wasps in large numbers to poultry farmers to use to control nuisance flies that breed in chicken manure. You are responsible for rearing cultures of these two parasitoid wasps. Write a memo to your boss with specific recommendations for the optimal rearing conditions that would produce the most

parasitoid adults of each species. Justify your recommendations by citing specific results from the classes' pooled experiment data.

3. "Gause's Law" says that complete competitors cannot coexist. This means that the species that most efficiently uses the contested resource will eventually eliminate the other at that location. Does Gause's Law seem to apply to the interaction between *Nasonia* and *Melittobia*? Why or why not?

4. How might resource partitioning work in the natural world for these two species? To find out more about their natural history and habitats, visit www.wowbugs.com for *Melittobia*, and www.bios.niu/bking/Nasonia.htm or www.rochester.edu/College/BIO/labs/WerrenLab/Nasonia/ for *Nasonia*.

5. Based on the results of your experiment, why might the two species not use the same host in nature?

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