

Examining top-down and bottom up effects on aphid abundance
on *Ligusticum porteri*

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Abstract:

Top-down and bottom-up effects can be seen in tritrophic systems of plants, herbivores and predators. Understanding what factors have a significant impact on herbivores can explain patterns of herbivory in the field. In this study, I report on the aphid *Cavariella aegopodii* on the plant, *Ligusticum porteri* and investigate which effects impact aphid populations. In the observational study, I censused plants weekly in shade and sun light environments to establish patterns of aphid (*Cavariella aegopodii*) and aphid predator abundance. In an experimental study, I applied aphid populations to plants in a variety of light environments as a bioassay of plant quality. I also used sticky stem traps on experimental plants to examine abundance of predators and mutualists among light environments. The observational census demonstrated light was a significant predictor of aphid presence ($\chi^2=3.88$, $P < 0.049$). The presence of a facultative predator (Hemiptera: *Lygus* spp.) was greater in shaded environment ($F = 4.654$, $P < 0.0334$). On experimental plants light also demonstrated a significant effect - lighter environments indicated larger relative growth rates of aphids ($F = 4.714$, $P < 0.0359$). I found that the presence of predators on sticky traps did not vary with light environment. Bottom-up effects can be seen with aphid presence and light environment, while predator presence did not show significant effects on aphid presence. However, abundance of the aphid predator *Lygus* varied with light environment, and this could be a light-influenced top-down effect.

Keywords:

Ligusticum porteri, *Cavariella aegopodii*, *bottom-up effects*, *top-down effects*, *Lygus*, *light environment*

Introduction:

Top-down and bottom-up effects can affect herbivore abundance in an ecosystem (Hairston & Smith, 1960). These effects can be seen in the tritrophic interaction between plants, herbivores and their predators (Moran & Rooney, 1996). Bottom-up control affects herbivore abundance from the level of the plant through quality as a food resource and plant defense, such as chemical mechanisms (Pace, Cole, Carpenter, & Kitchell, 1999). Top-down control of the herbivore can also be seen in its predators. For example Moran and Rooney (1996) found that mantids decreased herbivorous arthropod biomass and found it caused a significant increase in plant biomass. This study and others have found that predation on herbivores can affect plant growth.

Light has the potential to mediate bottom-up and top-down effects on herbivore abundance. It affects bottom-up control, since plants in different light environments may be a different quality to herbivores. A study done by Louda and Rodman (1996) on *Caradmine cordifolia* demonstrates that herbivore presence is increased on specimens not in shade covered environments, and had a significant impact on plant growth and reproduction, which in turn had an effect on *C. cordifolia* distribution. Other studies have also shown that light environment can have an impact on arthropod abundance and diversity (Borkhataria, Collazo, & Groom, 2012; Yi & Moldenke, 2005) If light has an effect on predator and parasite abundance, this could lead to light-specific differences in herbivory. A study by L. Richards (2008) demonstrated that gaps in canopy, introducing more light to the environment, increased lepidopteran larvae (*Zunacetha annulata*) predation which lowered herbivory on its host plant *Hybanthus prunifolius*.

Light environment has an effect on aphid abundance in *Ligusticum porteri* (Apiaceae) (Mooney, Unpublished Data). *L. porteri*, (Oshá) experiences herbivory from the aphid

Cavariella aegopodii (Palmer, 1952), which is a widespread aphid found in temperate regions. *L. porteri* is a common flowering perennial that can be found in forested ravines and aspen groves throughout the Rocky Mountains (Terrell & Fennell, 2009). *L. porteri* has been found in meadow habitat as well (William A. Weber, 1976). Greater number of aphids – feeding mostly on umbels – have been consistently found in open meadows than in shaded aspen understories (Mooney, Unpublished data). Like other aphids, *C. aegopodii* may experience bottom-up and top-down effects that explain this pattern. *C. aegopodii* can be predated on by several other arthropods including green lacewing larvae (Chrysopidae) and ladybird beetles (Coccinellidae) as well as experience parasitism from red spider mites (Acaridae). These organisms together are part of a tritrophic system of plant (*L. porteri*), herbivore (*C. aegopodii*) and predators.

My objective was to examine top-down and bottom-up factors affecting aphid abundance on *L. porteri*. Specifically I wanted to know (1) if light environment has an effect on the abundance or presence of aphids, (2) if light environment has an effect on the abundance or presence of aphid predators, and (3) how light environment influences plant quality to aphid populations. If predators or parasites of *C. aegopodii* are important in the aphid's control, and they show light-specific differences in effect or abundance, then they may partially account for differences in aphid herbivory on *L. porteri* with light environment. Understanding more about the predators and parasites of the aphid can help elucidate the tritrophic system that is *L. porteri*, *C. aegopodii*, and its predators.

Methods:

Observational Study:

I conducted research in sites around the Gothic Townsite at the Rocky Mountain Biological Laboratory in Colorado. For the observational study, I censused *L. porteri* in sun (open meadow) and shade (aspen understory) light environments. I collected this observational data on 10 plants per population, with 5 open meadow and 5 aspen understory populations. I randomly selected points by using plants nearest to 10 random points on a 15 meter transect tape. I collected census data weekly for 6 weeks (June 20th through July 26th). Above each plant, I measured light as a photosynthetically-active radiation (PAR) using a meter (LightScout Quantum Light Sensor, Spectrum Technologies. Plainfield, IL).

I ran three logistic regressions to see if (1) presence of aphids, (2) presence of parasites (red spider mite, Acari: Trombididae), or (3) presence of mutualists (ants, Hymenoptera: Formicidae) was dependent on light. I also performed a linear regressions to determine if hemipteran abundance varied with light level. All analyses were conducted in SAS JMP v. 10 (SAS Institute. Cary, NC).

Experimental Study:

I selected at least 10 plants in two populations in each habitat. I selected plants also using nearest plants on 10 randomly-chosen points along a 15m transect tape. On each plant, I inoculated umbels with 6-10 field collected aphids. All plants had stem traps made with Tanglefoot (Contech Enterprises Inc., Victoria, Canada) around the stem to prevent the access of ants and determine what predators and parasites try to access the plant. I censused plants 2 days after initial inoculation to detect aphid colony establishment, and I re-inoculated plants where there was no establishment. After the second census to assess what aphid colonies had been established, I collected insects from the stem traps and identified under a dissecting scope to order and family when possible. As with observational plants, I took light measurements on all

the plants in the experimental sites.

I used aphid population size to calculate the relative growth rate of each population ($RGR = \frac{\ln P_2 - \ln P_1}{t_2 - t_1}$). I ran a linear regression to analyze aphid relative growth rate and light as well to detect bottom effects from light on aphids. I used a logistic regression to assess if predator presence from sticky traps varied light environment.

Results:

During the study only a few plants had aphids on them (N=7) as well as predators and parasites (red spider mite – Acari:Trombidiformes), and we noted that there were numerous hemipterans, identified to be *Lygus* sp., present. In the observational study, the logistic regression demonstrated light as a significant predictor of aphid presence ($\chi^2=3.88$, $P < 0.049$); more aphids were found on plants in lighter environments (Fig. 2). Also, light was a significant predictor of the presence of ants ($\chi^2 = 4.47$, $P < 0.0345$), as well as *Lygus* abundance ($F = 4.654$, $P < 0.0334$). Ants were more abundant in lighter environments (Fig. 3), however, *Lygus* was more abundant in lower light environments (Fig. 4). For the experimental study, stem sticky traps yielded low predator abundance (N= 19 out of 38 collected). The primary predator identified was the parasitic wasp from the family *Aphidiidae*. Predator presence did not vary with light environment ($\chi^2 = 0.64$, $P = 0.4227$). Aphid relative growth rates decreased with a decrease in light ($F = 4.714$, $P < 0.0359$) (Fig. 1).

Discussion:

I set out to investigate bottom-up and top-down effects on aphids by examining their light environment and predators, and how these factors affected aphid presence and abundance. Evidence for both bottom-up and top-down effects can be seen in the study. Light was shown to affect abundance of aphids in both the observational and experimental parts of the study. From the stem traps, predators did not vary with light environment, however, abundance of the facultative predator *Lygus* was greater on shaded plants. Because very low number of aphids on plants during this study, we could not assess the impacts of these predators on aphids directly. However, patterns of aphid abundance on *L. porteri* appear to be a product of a combination of top-down and bottom-up factors, which could be mediated by mutualistic ants.

The observational study yielded support that light plays a significant role in aphid presence. *C. aegopodii* hosts on many Apiaceae plants, including *L. porteri* (Alford, 2012) and thus quality of plant can be looked at in terms of aphid colonization. Light environment can be affecting *L. porteri* quality in such a way to allow more aphids to colonize the plant in higher light environments. Light is a major bottom-up factor that influences plant quality (Roberts & Paul, 2006). Light plays a role in growth and development, as well as reproduction and defense mechanisms in plants (Roberts & Paul, 2006). Louda and Rodman (1996) present an example where the plant *cardamine cordifolia* experience more herbivory in the sun due to water deficits, affecting the plants ability to actively defend the also increased herbivore abundance. Plants in shade have also reduced rates of photosynthesis, which may influence their quality to insects (Roberts & Paul, 2006). Phloem feeding insects, like aphids, are sensitive changes in phloem sap quality (Bukovinszky, van Veen, Jongema, & Dicke, 2008). For example phloem feeders have been shown to be affected by phloem quality through environmental effects such as elevation (Zehnder & Stodola, 2009) and drought stress (Raupp, Shrewsbury, & Herms, 2010).

The observational study also revealed that ants were more abundant in higher light environments. Aphid-ant mutualisms have been studied extensively, and are part of the

Ligusticum and *Cavariella* system (Mooney, unpublished data). Ants extract honeydew from the aphids through tending, and in turn, protect aphids from potential predators (Styrsky & Eubanks, 2007). Previous research supports the affiliation ants have with light availability (Kersch & Fonseca, 2005). Increased presence of aphids in lighter environments could be due to these mutualisms with ants. It is also pertinent to note that it has been found that ant mutualism can act more as commensalism in shade environments (Kersch & Fonseca, 2005). Shaded plants in that study did not benefit from the ant's presence, so even though ants were located in lower light plants in my study, it could be possible plant quality is not improved, contributing to the lower abundance of aphids in those environments.

The *Lygus*' increased abundance in shadier light environments may not be coincidence. *Lygus* have been known to be a pest on numerous host plants and cause varying degrees of damage (Godfrey, 1966). *Lygus lineolaris* feeds on umbelliferous seed embryos (Berenbaum, 1990) which can affect seed yield. Plant quality has also been diminished on crop plants from *Lygus* (Godfrey, 1966). *Lygus* presence on *Ligusticum* can possibly reduce plant quality for aphids by inducing defenses (Williams III, et al., 2005). *Lygus hesperus* and *Nezara viridula* has been shown to induce cotton (*Gossypium hirsutum*) to release a volatile chemical when feeding and oviposition (Williams III, et al., 2005). Another possibility of reduced aphid presence in the shade light environments is predation on aphids. *Lygus* have been seen to be facultative predator on aphids (Hagler, 2010). Because few aphid colonies (N= 27) were observed overall, we could not assess the impact of *Lygus* on aphid directly. However, the result that *Lygus* is more abundant in light environments that ants and aphids are scarce would be consistent with their potential role as a predator. Their role as a predator has not been extensively researched and could determinate aphid presence in a given light environment. The presence of *Lygus* may also not be tolerated by tending ants. When attacked by ants *Lygus hesperus* has been shown to excrete a volatile chemical that repels ants (Byers, 2006). Taking their recorded defense against ants also points to their role in affecting aphid populations by potentially reducing ant numbers. Further investigation on ant behavior to *Lygus* on aphid infested *Ligusticum* can elucidate their impact on this complex system, especially in the case of shade environments.

Plant quality as mediated by seems to be a factor for aphid populations, and the tending ants may also play a role. *Lygus* may have an impact on *L. porteri* and the aphids, as well as possibly the ants in this system. *Lygus* appear to be a factor worth investigating in future studies regarding *Ligusticum* and its aphids. A study to assess plant quality with the presence/ absence of *Lygus* and using aphids as a measure of plant quality, as well as a study investigating *Lygus* ant interactions could prove to be informative in terms of the extent of damage they may cause. Although bottom-effects predominate this study, top-down effects could use further investigation, especially in light of the apparent complex interactions between the hemipterans, mutualists and *Ligusticum*.

Figures:

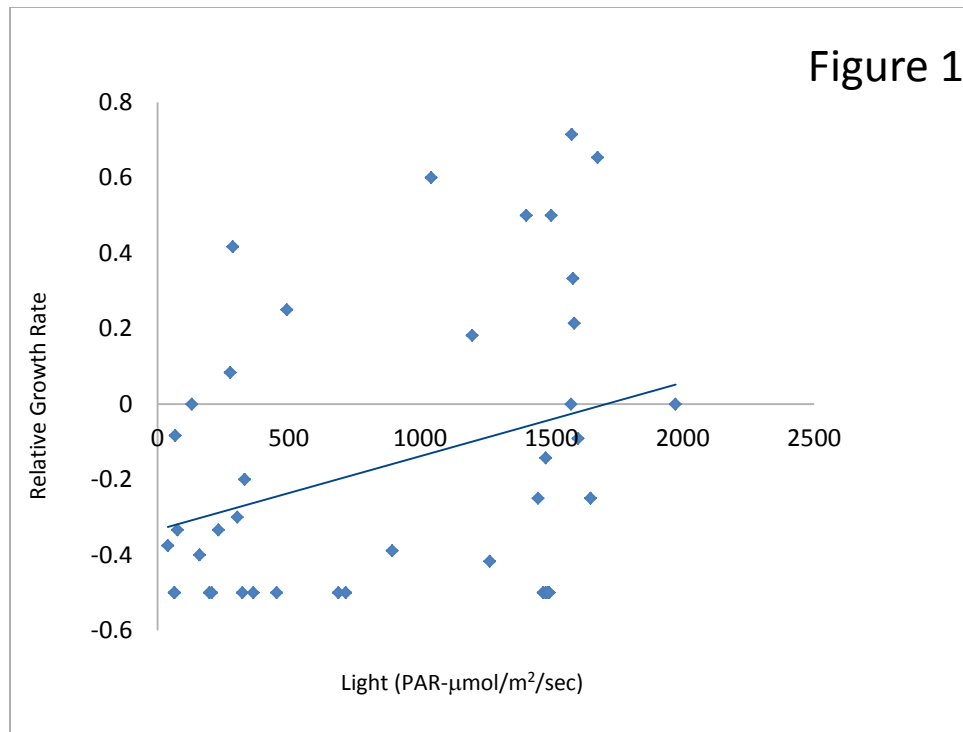


Figure 1. Aphid relative growth rate as a function of light. Aphids were shown to have smaller growth rates in shadier light environments.

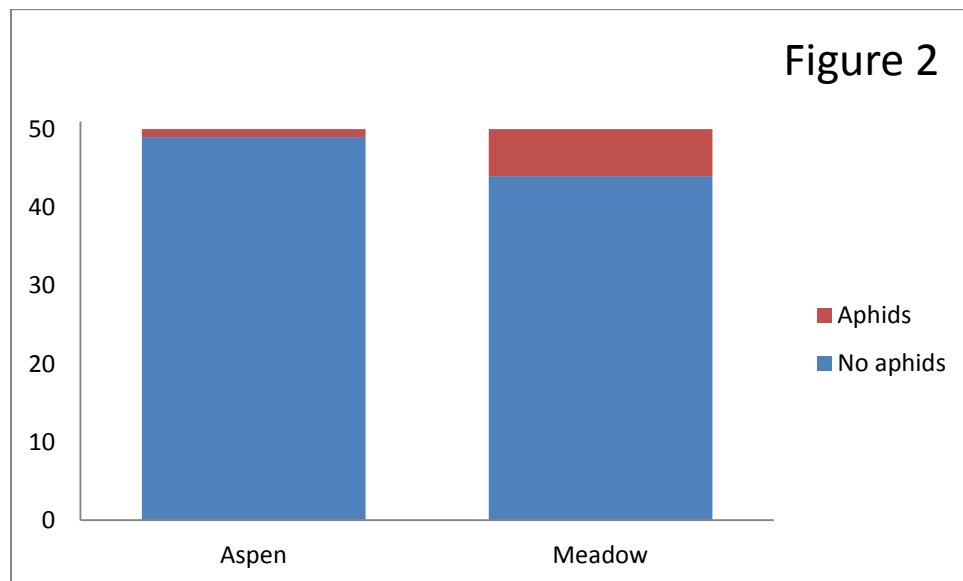


Figure 2. The total amount of plants with aphids present throughout the census period on plants in aspen and meadow habitats which serve as shady and sunnier light environments respectively. More aphids were found on plants in meadow habitat.

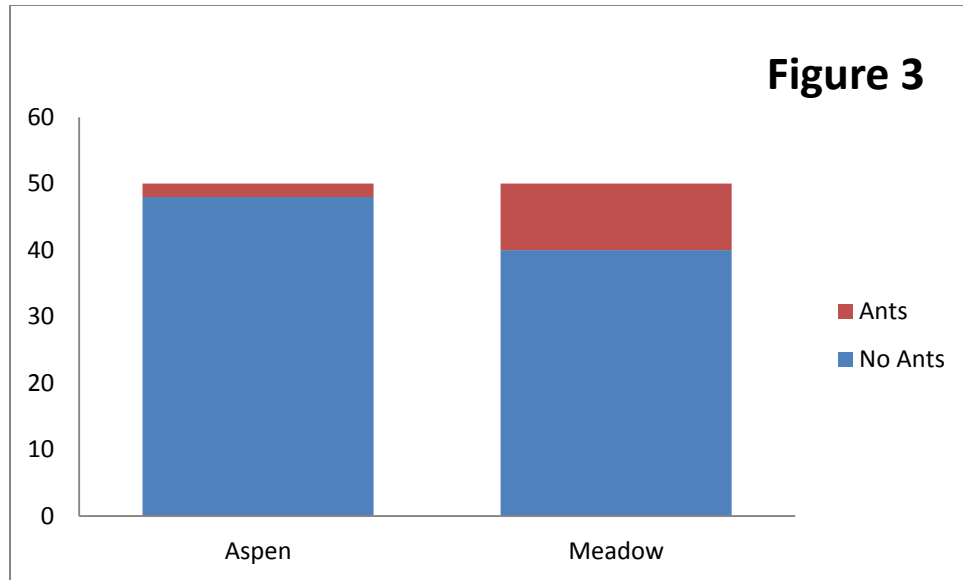


Figure 3. The total number of ants found on plants throughout the census period. More ants were found on Meadow plants.

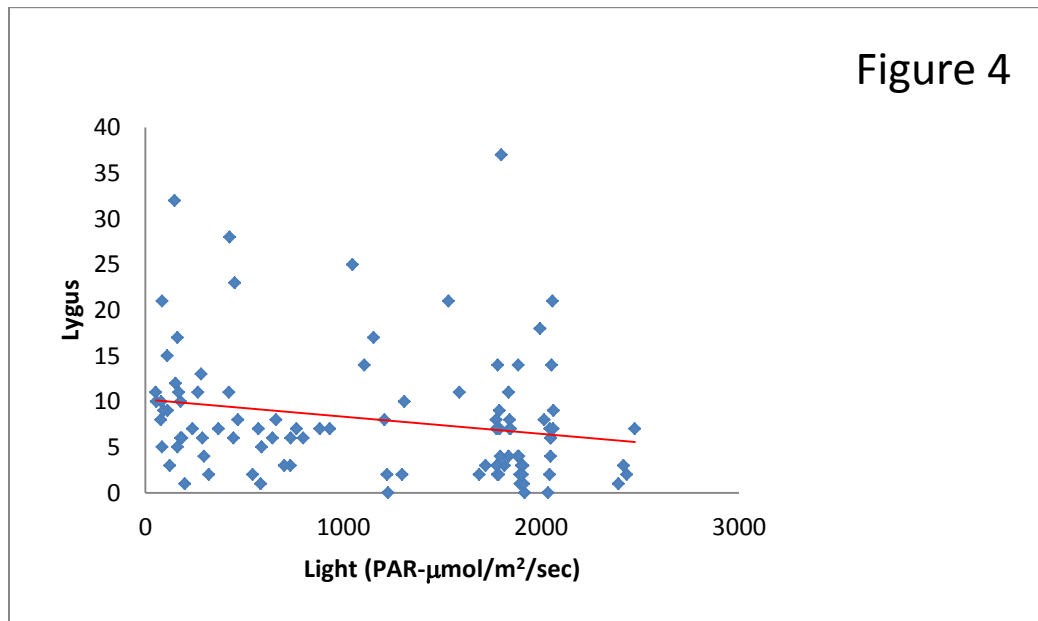


Figure 4. Lygus hemipterans on all the observational plants measured as a function of light measured as photosynthetically-active radiation (PAR). More Lygus were found on plants in shadier environments.

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