Path Analysis of a Forest Food Web

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Quantitative Analysis Center
Summer 2013

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Introduction

- This project applies path analysis to ecological data. Path analysis is a general form of multivariate regression that allows the inclusion of more than one causal model with several dependent variables.
- The ecological data analyzed here consist of food web interactions among carnivores and herbivores that feed on forest trees.
- The carnivores in the food web include predaceous ants and parasitoids, which are hypothesized to kill and consume caterpillars in a density-dependent manner.
- The herbivores include caterpillars, which chew and consume the leaves of trees, and sap-feeding insects, which suck the phloem sap from tree branches. The sap-feeding insects have a mutualistic interaction with ants, providing ants with food in the form of sugary excretion (honeydew) while the sap-feeding insects gain protection in the presence of ants.

The main goal is to identify significant interaction pathways on different tree species.

Methods

Data collection:

- Ecological data were collected in 2012 at three forest sites in Middlesex County, Connecticut.
- Half of the branches were treated with Tanglefoot to control the abundances of ants.
- Ants, caterpillars and sap-feeding insects were sampled from six tree species. Their abundances were determined by counting the number of each type of insects knocked off the branch.
- Caterpillars were brought to the lab for rearing. Parasitism was determined by counting the number of caterpillars from which parasitoids emerged. Parasitoid abundance was measured by counting the number of parasitized caterpillars. Each parasitized caterpillar represented one parasitoid.

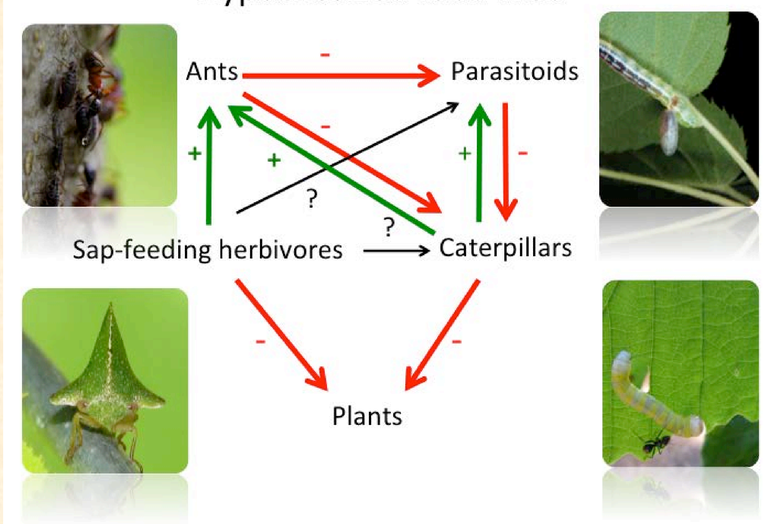
Data analyses:

- Path analysis was run using asymptotic distribution free (ADF) estimation.
- The path analysis quantified the correlations in abundances between interacting groups. In antagonistic interactions, these correlations consist of positive (bottom-up) and negative (top-down) components.
- The analysis shows the net effect of these bottom-up and top-down interactions.
- X^2 tests were used to determine the significance of differences in Tanglefoot treatment for ants.

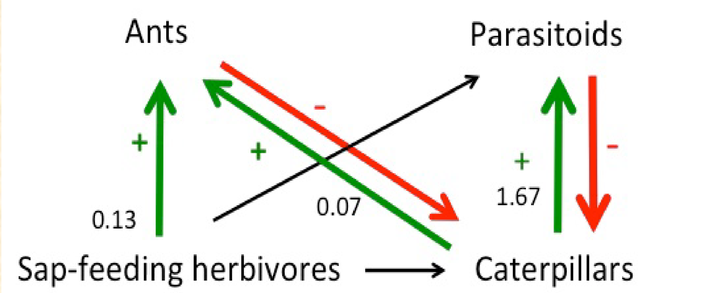
Acknowledgements

I would like to thank my faculty sponsor, Professor Michael Singer, and the Dean of Division III, for the opportunity to be part of this research project. I would also like to thank Professor Manolis Kaparakis, Professor Arielle Selya and Professor Jennifer Rose for their guidance in the statistical analyses. I am also grateful for the data and knowledge shared by fellow researchers in the Singer lab and in the QAC program. Last but not least, thank you Eric Stephen who has been very helpful in assisting the QAC program.

Hypothesized food web



Paths selected for the model



Results

- There is no significance difference between the treated group and untreated group based on difference in chi-square values (X^2 =0.538, d.f.=1). Thus the model is run on all 576 observations.
- The positive component is the increase in abundance of a consumer tracking the abundance of its food (bottom-up interaction). The negative component is the negative impact of a consumer on the abundance of its food (top-down interaction).

Paths	Effects		
	TE	DE	IE
S -> P	0.02	0.02	-
S -> A	0.13*	0.13	-
A -> C	0.07*	0.07	-
S -> C	0.07	0.02	0.05
P -> C	1.67*	1.67	-

S Sap-feeder; **A** Ant; **C** Caterpillar; **P** Parasitoid
TE: Total effect; DE: Direct effect; IE: Indirect effect
*: significant at 5% level
^: significant at 10% level

Estimates for each interaction according to tree species

Paths/ Tree species	Black Cherry			Hickory			Red Maple		
	TE	DE	IE	TE	DE	IE	TE	DE	IE
S -> P	0.11*	0.11	-	0.04*	0.04	-	0.10	0.10	-
S -> A	0.19*	0.19	-	0.40*	0.40	-	0.24	0.24	-
A -> C	0.06	0.06	-	0.60	0.60	-	0.43^	0.43	-
S -> C	-0.01	-0.10	0.09	0.05	0.013	0.038	3.01*	2.72	0.29
P -> C	0.73	0.73	-	0.38	0.38	-	1.91*	1.91	-

Paths/ Tree species	Red Oak			Witch Hazel			White Oak		
	TE	DE	IE	TE	DE	IE	TE	DE	IE
S -> P	-0.01	-0.01	-	-0.13*	-0.13	-	0.00	0.00	-
S -> A	-0.26^	-0.26	-	1.11^	1.11	-	0.05	0.05	-
A -> C	0.08*	0.08	-	0.08	0.08	-	0.09	0.09	-
S -> C	0.42*	0.44	-0.02	-0.96*	-0.85	-0.11	0.13*	0.13	0.00
P -> C	0.71	0.71	-	1.42*	1.42	-	0.09	0.09	-

Conclusions

- Positive interactions outweigh negative interactions.
- There is evidence for density-dependent predation and parasitism at a small scale.
- Interaction strength differs according to tree species.
- Significant paths are between ants and sap-feeders, ants and caterpillars, as well as parasitoids and caterpillars.

Discussion and future research

- Interactions with small values might be due to positive and negative effects cancelling each other.
- The presence of an indirect effect between sap-feeders and caterpillars suggests the presence of a significant mediator. Parasitoids are likely to be the mediator here because the presence of sap-feeders might inhibit the release of volatile organic compounds by trees when caterpillars feed on their leaves. Parasitoids are known to use volatile organic compounds as cues to locate their caterpillar hosts.
- Further research includes running the model on two other tree species, namely the American beech and black birch. Other statistical analyses such as bootstrapping will be used to obtain the estimation of standard errors and residuals for indirect effects.