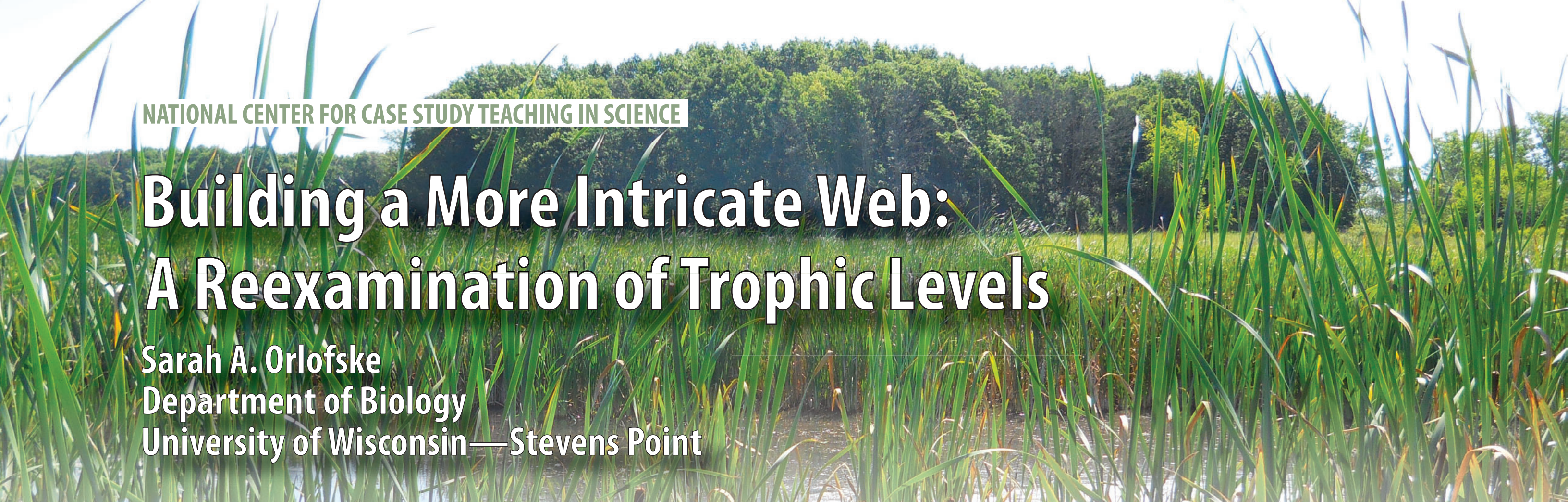

NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Building a More Intricate Web: A Reexamination of Trophic Levels

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Part I – The Research Dilemma

Even though it was a pitiful day, with overcast skies and temperatures barely in the 30s, Arthur and Connie were in the laboratory at the research station of the North-Central Nature Preserves (NCNP) envisioning their summer fieldwork. Last summer Connie had an internship working for NCNP conducting inventories of aquatic invertebrates. Although the work was not what she first expected (long hours in chest waders, blazing sun, and relentless mosquitos), she was nevertheless fascinated by the different species she found and the life cycles that would take an insect from an aquatic larva to a terrestrial and flying adult. They were here today to discuss opportunities to work with NCNP again, but on their own independent project. Arthur was an undergraduate like Connie, but only in his sophomore year and new to research; he was inspired, but didn't know where to start. Connie and Arthur wanted to form a team this summer if they were fortunate enough to get funding for their project.

"Where to begin? Connie, you worked with Dr. Jensen last summer on the invertebrate surveys; what do you think?"

The voice caught both students off guard. They didn't even realize they were daydreaming until Dr. Olson walked into the laboratory. She was a straightforward person who liked to challenge students and Connie was used to being put on the spot.

"Well," responded Connie, "I was thinking about something larger than last summer. There were so many other projects conducted by other researchers that I thought maybe we could learn something more by looking at it all together." Connie recalled the early morning point-count surveys for birds and the day she participated in the electrofishing survey of the streams.

"How about you, Arthur? Connie says that you're interested in species interactions?" Dr. Olson asked.

Arthur's mind was whirling. He knew this meeting was important. The three of them would have to sort out an idea that would form the basis of a summer research proposal that would pay for salaries and supplies. Their ability to do an independent project would depend on the specific research question they would investigate. "It's hard to narrow it down. I guess I would like to study a lot of different aspects, like how different species depend on one another for food or compete for food. Is there a way we can look at that across the different studies other researchers have done like Connie suggested?"

"Hmmm…" Dr. Olson hesitated for a second. "I've had an idea in mind for the past several years that may be just what you're looking for in a research question."

As she spoke she began to draw a diagram on a piece of scrap paper lying on the lab bench. She continued, "I've been reading more and more about how other ecologists have been using food webs to investigate different aspects of environmental change that could be affecting our preserve. Based on previous research, we have plant surveys, insect surveys, amphibian, reptile and bird surveys … and let's not forget fish. Seems like we should have some great preliminary data for building a food web for Clear Lake."

Photo by Sarah A. Orlofske.

Dr. Olson turned the paper around to show a sketch of rectangles with arrows connecting some with others. Taxa names were written in the boxes (Figure 1). "You see we can start with an inventory of the species—those become nodes that represent the organism—and then you two can propose some different methods to measure the species interactions, which become the arrows or links. What do you think about that?"

Connie looked over at Arthur and saw the smile on his face. This would be a way to learn more about all the species in one of her favorite sites on the preserve. But at the same time this sounded like a daunting project. Where would they start and what would they find?

Figure 1. Food web sketch of a simple aquatic community.

Questions

1. Figure 1 represents the drawing Dr. Olson sketched for Connie and Arthur. What are the different components of a food web diagram and what do they represent? What classification is given to the different species based on their connections to one another?

2. Dr. Olson mentioned a list of organisms that have been the subject of previous research studies at Clear Lake. What additional information about these organisms is needed in order to determine their trophic level?

3. What types of methods do ecological researchers use to gain the information needed to build food webs?

4. Imagine that this is your summer research grant proposal. Choose a particular type of organism to investigate in terms of its trophic interactions. Based on your chosen organism and the results of your investigation for Question 3, what possible approaches can you propose for your methods?

Part II – The New Question

"What's bothering you, Connie?" asked Arthur as he approached Connie's table in the library study lounge. It had been almost three weeks since they had submitted their grant proposal for the summer research and Connie was starting to get anxious.

"I don't know, Arthur. I keep thinking that we left something out. Like there's something missing," Connie replied. She had just been thinking; would their literature review be enough to justify their methods and their new research questions to pursue over the summer? Had they provided enough preliminary data by incorporating a food web based on the data already collected? Had they convinced the reviewers that their work was important, novel, but yet feasible?

"You're right. We did leave something out. But not out of the proposal, out of the food web itself," Arthur responded.

"What are you talking about? How did we leave something out of the food web?" Connie looked confused as she turned to her friend.

"I just got a letter from Dr. Olson. The good news is that our project has been funded for the summer! But one of the reviewers included some suggestions and a scientific article to read." Arthur was not one to get excited but he found himself speaking quickly.

"That's awesome! Why didn't you just say that right away? But wait, that doesn't answer the question. What did we leave out?" Connie waited eagerly for the response.

"Parasites. We left out parasites."

"What? How would we put parasites in our food web?" Connie's look of confusion returned.

Background

Read the following article that was recommended to Connie and Arthur by the reviewer of the grant proposal.

- Lafferty, K.D., *et al.* 2008. Parasites in food webs: the ultimate missing links. *Ecology Letters* 11: 533–46.

Questions

1. What are some reasons that parasites have not previously been incorporated into food webs?

2. Where in the food web do parasites fit? How are their interactions with other species represented?

3. Based on Lafferty *et al.* (2008), what steps would you suggest Connie and Arthur take if they wanted to incorporate parasites into their food web as part of their summer research project?

Part III – Building Food Webs

While conducting a literature search and reading more studies on parasites in food webs, Connie and Arthur found a paper, Preston *et al.* (2012), describing a food web including parasites of a pond ecosystem in California. This food web was constructed based on measurements of free-living species and dissections of those free-living species to reveal patterns of parasite infection. Connie and Arthur decided to investigate this paper further as a way to explore how to incorporate parasites into their food web.

Among the species included in the Preston *et al.* (2012) paper are the trematode (flatworm) parasites *Echinostoma trivolvis* and *Ribeiroia ondatrae*. These species, like most trematodes, have complex life cycles involving transitions among several host species. Specifically, *R. ondatrae* infects birds as an adult worm and releases eggs that leave the bird with feces. In the aquatic environment the eggs hatch and infect a snail. Once inside the snail the parasite reproduces asexually producing a free-living infective stage called cercariae, which then infect amphibian larvae. Inside the amphibian, the parasite encysts forming a metacercariae that subsequently infects a bird when the amphibian is eaten (Johnson *et al.,* 2004). Each of these steps represents an interaction between parasite and host where the parasite obtains resources from the host that can be represented in a food web diagram as well as interactions with non-host organisms.

Now you will explore how to develop a food web diagram, incorporate parasites, and investigate some food web properties by examining data from the Preston *et al.* (2012) study. Although the full food web contains 63 species, representing 113 nodes and 1905 links between them, we will examine only a subset of those interactions.

Activity

You will be provided with a worksheet containing photos of representative free-living and parasitic taxa included in the Preston *et al. (*2012) paper describing the ecosystem of Quick Pond in central California. Using Animal Diversity Web (<http://animaldiversity.org/>), field guides, or scientific publications, investigate some ecology of each taxa. Then complete the food web diagram and answer the associated questions.

A. Beginning with the Free-Living Species

1. Consider the life cycle of a given taxon. Do certain taxa undergo an abrupt change of diet or habitat with development? If so how should this be represented in the food web?

2. Determine the types of interactions each of the taxa have with one another at each stage of their life cycle and draw arrows in the direction of energy flow connecting the taxa. (Remember multiple arrows can go to and from each species.)

B. Adding Parasite Life Cycles

1. Start with *Ribeiroia ondatrae*. Based on the information about the life cycle given in the beginning of the background section for Part III, add arrows connecting parasite and hosts as you did for predator-prey interactions for free-living species.

2. Research *Echinostoma trivolvis* and add those connections to the food web.

C. Adding Parasite Interactions with Alternative Hosts and Non-Hosts

Typical hosts are only a part of the story when it comes to putting parasites in food webs. Parasites can infect other species than simply those illustrated in a life cycle and can even become prey for other organisms (Johnson *et al.,* 2010; Orlofske *et al.,* 2012). For example, Orlofske *et al.* (2012) experimentally investigated links between *Ribeiroia ondatrae* and alternative or non-host organisms (Figure 2 below).

1. Using information provided in Figure 2, add arrows connecting *R. ondatrae* to alternative hosts and *R. ondatrae* to its predators.

2. Do you think that *Echinostoma trivolvis* has similar interactions with alternative hosts or predators as *R. ondatrae?* Add in those interactions to your food web diagram. What characteristics might be important in determining whether or not those interactions occur?

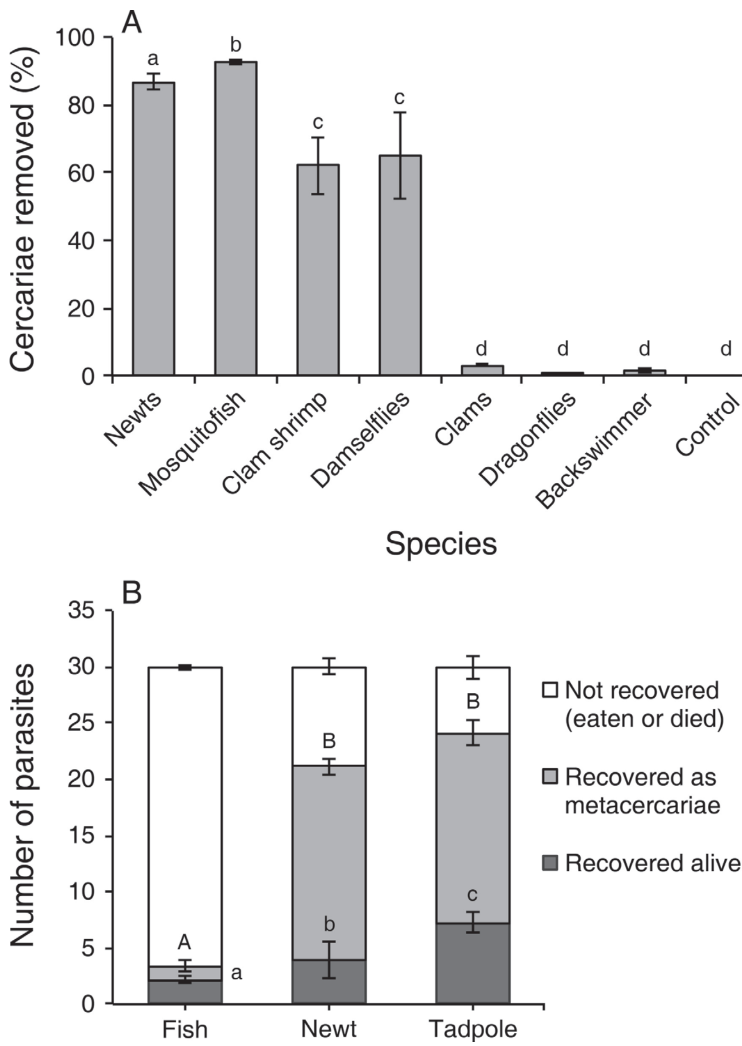

Figure 2. (A) Mean percentage of 30 *Ribeiroia ondatrae* cercariae removed by a single alternative host or predator. (B) Mean number of *R. ondatrae* cercariae that were recovered alive after a 30-minute trial (lower case letters), the average number of cercariae recovered as metacercariae (uppercase letters) from each species, and the number eaten or died. Different letters represent statistically significant differences at $P < 0.05$. Error bars represent ± SE. From Orlofske *et al.,* 2012.

Quick Pond Food Web

reat B lue
eron

reen D arner
Dragonfly

Pacific Chorus

California Newt

Damselfly

Echinostoma trivolvis

Ribeiroia ondatrae

Helisoma sp. snail

Zooplankton

Phytoplankton

Vascular plants

Benthic Algae/Periphyton

Image Credits: Larval dragonfly and larval damselfly by Jessica lofske, used with permission. ll others by Sar A. Orlofske.

Part IV – Analyzing Food Webs

A completed food web diagram can tell you a lot about your ecosystem. Enter your data into the following table and use it to answer the questions below. Links refer to the number of arrows going into or out of a particular species photo (called a node). Trophic levels describe the feeding category of each organism based on the number of feeding steps between it and autotrophs (primary producers). Finally include the classification by diet (e.g., herbivore, etc.). For omnivores (species consuming resources at more than one trophic level), provide a range of values in trophic level representing where that organism can feed.

Table 1. Quick Pond food web properties.

Taxa	*Species Consumed*	*Total Number of Links without Parasites*	*Total Number of Links with Parasites*	*Trophic level*	*Classification*
Benthic Algae/Periphyton					
Vascular Plants					
Phytoplankton					
Zooplankton					
Helisoma sp. snail					
Ribeiroia ondatrae					
Echinostoma trivolvis					
Coengarionidae damselfly					
California Newt					
Pacific Chorus Frog					
Green Darner Dragonfly					
Great Blue Heron					

Questions

1. How do the numbers of interactions compare between a free-living species and a parasitic species? How do the total numbers of interactions compare with and without parasites?

2. According to your drawing and the table, which is the most highly connected species in your food web? Is it free-living or parasitic? How would you describe the influence this species has on the rest of the food web? What might happen to the food web if this species were removed?

3. Does your trophic classification of free-living organisms change based on whether or not parasites are included? Explain with an example from your table. What is the highest trophic level with and without parasites included?

4. The parasites included here have complex life cycles involving several hosts, but free-living species like amphibians have complex life cycles too. How could life stage influence how you made the connections between species?

5. The life cycle of both parasites in this food web requires predation of one host by another in a process known as trophic transmission. Describe the interactions that represent trophic transmission and suggest some potential costs and benefits to the species involved.

6. While this partial food web includes parasites, it is still missing other groups and many nodes are aggregations of numbers of different species. Which groups are missing? Which groups are aggregated? How do you think missing groups and aggregated nodes affect your interpretation of the food web?

References

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