Science from the Source

The conditional benefits of cannibalism for wood frog tadpoles (Lithobates sylvaticus)

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ABSTRACT

Wood frog tadpoles have an incredible ability to rapidly adapt to changing conditions, and when population densities become high tadpoles often become cannibalistic. Cannibalism potentially represents an ideal diet by composition, and should be beneficial to the growth and development of cannibalistic individuals. To test the relative efficacy of cannibalism to growth and development we conducted multiple feeding experiments. Results indicate that cannibalism represents a better alternative to starvation and provides some benefit to development and survival of tadpoles over low quality diets. However, cannibalism can be detrimental to tadpole growth and/or development relative to diets of similar protein content. Additionally, tadpoles raised individually appear to initially avoid consuming the cannibalistic diet, and may continue to do so until they face the risk of starvation. Conversely, when tadpoles were raised in groups providing them with competition, they immediately fed upon the cannibal diet. Our results suggest that competition, rather than dietary quality is likely the driving force behind cannibalistic behaviour unless tadpoles otherwise face the risk of starvation.

INTRODUCTION

Wood frogs are explosive, concurrent breeders capable of producing enormous numbers of eggs each year[1]. Adults often breed in temporary wetlands that develop in the early spring and are devoid of large predatory species[1]. These wetlands are, however, prone to drying and expose tadpoles to the risk of desiccation if they fail to metamorphose prior to the evaporation of the pond[2,3]. As a result of their breeding strategy and pond drying, tadpole densities and competition among these tadpoles may become excessively high[1,2,3]. Competition for food can lead to slower development of tadpoles, decreasing their chance of survival[1,4]. Therefore, tadpoles must be capable of rapidly adapting to improve their competitive success[1,2,3]. Cannibalism represents a potentially ideal diet by composition because all of the nutrients necessary for growth and development should be available in appropriate proportions[5]. Additionally, cannibalism diminishes the degree of competition by reducing population density and may also provide a life raft for tadpoles to survive to metamorphosis where food is limited[4,5]. Our research focused on the efficacy of cannibalism as a diet to determine if tadpoles may adapt this behaviour to exploit a valuable diet or whether it arises out of desperate conditions and a need to improve their competitive success.

METHODS

We conducted three experiments to test the relative effects of a cannibalistic diet on growth and development in wood frog tadpoles. The first experiment simply aimed to compare the cannibal diet (ground up tadpoles) with a high quality (frozen brine shrimp) diet. We raised two groups of tadpoles individually in 1L containers for nine weeks. One group was fed the cannibalistic diet and the other was fed the brine shrimp diet. At the end of each of week

up to five tadpoles were removed from each group and measured for size and development. In our second and third experiments we compared the growth, and development of tadpoles fed a variety of experimental diets. In both experiments we raised groups of tadpoles in 10L aquaria for two weeks. In experiment two we compared tadpoles fed the cannibalistic diet against groups of tadpoles that were starved, fed a high quality (brine shrimp) diet, fed a low quality (corn meal) diet, or a mixed (high + low) diet. In experiment three we similarly compared tadpoles fed the cannibalistic diet against tadpoles fed the high quality diet, low quality diet, or one of three combinations (high + low; high + cannibal; low + cannibal) of these three diets. After the two week test period tadpoles were removed and measured for growth and development. We expected that if cannibalism truly represents an ideal diet then tadpoles fed this diet should grow larger, and develop more rapidly than tadpoles fed the high quality diet.

RESULTS AND DISCUSSION

In our initial experiment we found that tadpoles preferentially avoided eating the cannibalistic diet for approximately two weeks. As a result tadpoles fed the cannibalistic diet developed slower and did not grow as large as those fed the high quality diet (see Fig.1)[6]. When raised in groups, tadpoles did not appear to avoid consuming the cannibalistic diet; however, we observed that the cannibalistic diet still did not appear to result in greater growth or development than the high quality diet.

In the second experiment it appeared as though cannibalism can provide conditional benefits by improving tadpole development over those fed the low quality diet. However, tadpoles fed the cannibalistic diet did not develop as quickly as those fed the high quality diet, and cannibalistic tadpoles did not grow larger than those fed the low quality diet (see Fig.2)[6].

In the final experiment cannibalistic tadpoles exhibited improved survivorship, and faster development over those fed the low quality diet. However, growth of cannibalistic tadpoles did not appear to be improved over those fed the low quality diet. The addition of cannibalistic tissues appeared to have provided similar improvements, and did not appear detrimental to tadpoles in treatments where it was combined with the high quality diet (see Fig.3)[6].

Our results suggest that wood frog tadpoles and potentially other species are not necessarily becoming cannibalistic in order to exploit a profitable food source, but rather in response to competition. Two additional studies further supported this, showing that tadpoles exhibit a competitive response when chemical cues from tadpoles were added to their diet[2] and that competition could elicit a more rapid feeding response upon tadpole tissues[3]. We suggest that this is a response to the crowded conditions that may arise within the temporary wetlands in which these tadpoles develop. Where wetlands can quickly evaporate and tadpole densities rapidly increase it may be necessary for individuals to adapt more aggressive competitive behaviours, which could lead to cannibalism.

Please refer to figures in Jefferson et al. 2014 [6].

RESOURCES

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Q&A WITH DALE M. JEFFERSON

How would you describe your scientific approach?

Our scientific approach begins by maintaining an inquisitive persona and pursuing the questions that intrigue us as we scour the literature and/or listen to the research of our peers, perform an experiment, and analyze our results Once we have an idea or question to explore, we work toward developing a focused experiment that can answer that question in the simplest way possible. We take a conservative approach with our observations and analyses, ensuring accurate measurements and correct assessment of the results.

What is your day-to-day work life like as a researcher in behavioural ecology?

Daily activities change throughout the progression of an experiment or the time of the year. Typically, part of the year is dedicated to office work. This time period may include hours of searching and reading the pertinent scientific literature; developing questions and designing experiments; data analysis; and/or writing documents (e.g. grant proposals, government reports, journal articles, theses, etc.). For graduate students this time may overlap with course work, and for both graduate and professors teaching classes and/or labs may also take place during this time. Often this time period is also used to prepare and submit documents necessary to acquire scientific collection permits and permission from the University ethics office to collect animal specimens.

During field season we typically spend a short time scouting out collection areas for amphibians. Often this may require searching for suitable ponds and then listening for calling frogs to indicate adults are breeding in the area; sometimes this requires late night auditory surveys. Once we have located multiple suitable sampling sites we spend one or more days collecting specimens. Due to the nature of amphibian breeding we have a very short window of opportunity to collect our specimens; our field season therefore tends to be relatively short. During an experiment the day usually begins by taking care of any husbandry requirements, such as feeding animals or cleaning water or tanks. Then we prepare and observe whatever animal behaviour is of interest at the time. This routine can last anywhere from weeks to months. Once behavioural observations are made, work is primarily conducted in the office, analyzing data and preparing reports of the findings in the form of manuscripts or conference presentations.

What is the most fulfilling aspect of working in your research field?

The most fulfilling aspect of working in behavioural ecology is not only developing a better understanding of the focal species and of the natural world, but discovering new questions in the process. At the end of the experiment you are left with the feeling as though you have added a piece of the puzzle. This feeling is often replaced by a much more profound feeling of the enormity of that puzzle as a whole, and how small that piece was you managed to place. This manifests itself in the form of a landslide of questions to pursue. Some may find this tedious or overwhelming, but the discovery of new questions can be as fulfilling if not more so than an answer.

What are the biggest challenges faced by your field of research today?

One of the biggest challenges is in attempting to conduct experiments that balance the degree of control over variables with the relevance of these experiments to natural communities. Lab based studies often strip down the variables to a minimum such that we only tested very specific aspects of an animal's behaviour. However, if we wanted a more natural study we would need to conduct experiments in habitats that more closely reflect natural communities. This too becomes problematic because you lack the control needed to determine if the variable you are interested in is causing the effect you are looking for. Therefore, the challenge is to

produce an experiment that produces viable tangible results while limiting the degree to which it caricaturizes the animal's behaviour.

What advice would you give to high school and undergraduate students interested in behavioural ecology?

I would say to any potential newcomer that the first thing is to have a passion for nature. Understanding and respect for nature is gained through your first hand exposure and observation of it. If you really want to get into any aspect of ecology I suggest you grab one or more field guides and a camera if you have one, and go out and find and identify the species that interest you. Joining biology or naturalist based societies is also a great way to do this and also allows you to network with others that may share your interests and may have a great deal more experience than you. Furthermore take the opportunity to learn from experienced individuals; there are many people out there with lifetimes of experience who can teach you a lot. Be inquisitive, watch animals in nature and when you are observing them start asking yourself the important questions like, "what is this animal doing, and why would it do that?" Be patient and attentive. I have watched many people pass by amazing wildlife because they didn't take the time or the effort to carefully watch for it. This has extensions in research as well; if you are willing to take the time, and do things carefully you will often be rewarded with great results.

The next bit of advice is to read as much as you can. Many great people have come before you and have asked many of your same questions. It is possible that many of your questions have been answered already, and hopefully that will only lead you to explore new questions you had not previously considered. Finally, I strongly encourage students to keep records of their observations and practice their writing. Writing is perhaps the most important technical skill required in science and the only way to become a proficient writer is to practice.