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CourseSource

Lesson

Integrating Community Ecology Into the Study of Parasites: Exploring the Effect of Host Behavior on Parasite Transmission Rates

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Abstract

Organismal life cycles are often presented as a set of facts to memorize in undergraduate biology courses. This approach is cognitively demanding for students and fails to convey how central life cycle diversity is in shaping ecological and evolutionary processes. Understanding the causes and consequences of life cycles is especially important when studying parasites with multiple life cycle stages for passing through diverse hosts. We designed a two-part lab activity to help our students gain a better understanding of the ecological interactions driven by parasite life cycles. Part I is a structured guide to reading a peer-reviewed journal article. Part II is a guided exercise in summarizing and interpreting mock experimental data involving a trematode parasite life cycle. These assignments helped students (1) understand how parasite life cycles shape ecological interactions with their hosts, (2) practice making predictions about species interactions using core ecological principles, and (3) practice quantitative reasoning and graph literacy skills by visualizing and interpreting data. We first used this activity as a self-guided lab exercise for an upper-division undergraduate parasitology class that switched from in-person to asynchronous-remote mid-semester. The stepwise structure of the activity allowed us to pinpoint the links in the chain of biological reasoning where students struggled most to guide target topic reviews in subsequent lectures. Here, we provide a summary of the activity, our experience with the activity, and suggestions for adapting the activity for a synchronous-remote or in-person class.

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Supporting Materials: Supporting Files S1. Parasite Ecology – Part I: Primary Literature Handout; S2. Parasite Ecology – Part II: Data Analysis Handout; S3. Parasite Ecology – Part I: Primary Literature Handout ANSWER KEY; S4. Parasite Ecology – Part II: Data Analysis Handout ANSWER KEY; S5. Parasite Ecology – Excel File for Generating Mock Data; and S6. Parasite Ecology – Modifiable Parasite Life Cycle Diagram

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Learning Goals

Students will:

- Practice reading and summarizing primary scientific literature
- Understand how animal behavior contributes to interactions between species
- Practice quantitative reasoning to infer biological meaning from data
- Appreciate the complexity of parasite life cycles

Learning Objectives

Students will be able to:

- Identify hypotheses in a peer-reviewed article
- Describe the results and methods used to test each hypothesis in a peer-reviewed article
- Summarize the key findings of a peer-reviewed article
- Describe how parasite life cycles can depend on complex trophic interactions
- Summarize experimental data using mean and standard deviation
- Create graphical representations of data and interpret experimental results

INTRODUCTION

During the Spring 2020 semester, instructors teaching lab-based courses faced unique challenges when the COVID-19 pandemic mandated an abrupt transition to distance learning. The shift to online lab activities was especially challenging for topic-specific biology courses lacking an abundance of pre-existing online labs. We encountered this scenario with the parasitology class (BIO 420) that we taught at the University of Montevallo that semester. This course was a combined lab and lecture course that we were both teaching for the first time. One of our primary goals for this course was to develop engaging and interactive lab activities that would go beyond examining prepared microscope slides. We wished to incorporate higher order skills (i.e., application, analysis, and synthesis) to help students understand the eco-evolutionary forces that shape the lives of parasites, rather than focusing solely on the rote memorization of knowledge (1). The pandemic forced us to find creative ways to still facilitate engaging and enriching lab activities, despite the remote setting.

One of the major goals in teaching parasitology is to help students recognize and appreciate the extraordinary diversity and complexity of parasite life cycles. To place the innumerable details of these life cycles into a conceptual framework and move beyond simple memorization, students need to understand the ecological and evolutionary forces that shape these patterns. To move reliably between hosts, parasites tend to evolve strategies that take advantage of routine host behavior, such as passing from the waste of one animal to the drinking water of another animal (fecal-oral route) or infecting a prey species which is then eaten by the next host (trophic transmission; 2). Thus, variation in the local abundance and behavior of host species can have a profound influence on the persistence and abundance of parasite species. To help students engage with such complex information in a meaningful way, we designed activities that focused on quantitative reasoning and exploring the key ecological principles illustrated in these systems. For this activity, students read and discussed a primary scientific journal article using a guided outline (Part I) and analyzed a mock data set to explore how direct and indirect interactions between three different host species influence transmission patterns of a trematode flatworm parasite (Part II) (Figure 1).

There are many approaches to teaching about population ecology and species interactions, ranging on the student engagement spectrum from simple lectures to student-led, open inquiry-based research projects (e.g., 3). The links between species are often best illustrated by observing changes in community structure resulting from a change in one species' density or behavior, so this topic is frequently combined with lessons on experimental design, statistical analysis, and data visualization (see 3-5). The challenge for instructors is to design activities that clearly demonstrate ecological phenomena without allowing students to get sidetracked by the minutia of the methods that were employed. Information-oriented, inquiry-based explorations of natural systems (3), ecological simulation models (6, Virtual Biology Lab), or mock datasets (5) can all be effective forms of active learning. Mock data sets in particular can help students practice critical thinking and quantitative reasoning while exploring the ecological principles that govern community ecology without the distracting "noise" of real data (7). The purpose of such activities is not for students to generate novel information, but to use the tools of scientific reasoning to arrive at a better understanding of pre-existing information (8). While open inquiry is often viewed as the "gold standard" approach for teaching students the practice of science, alternate approaches such as structured or guided inquiry using previously collected or simulated data result in similar student outcomes and attitudes when the goal is helping students master concepts (7, 9).

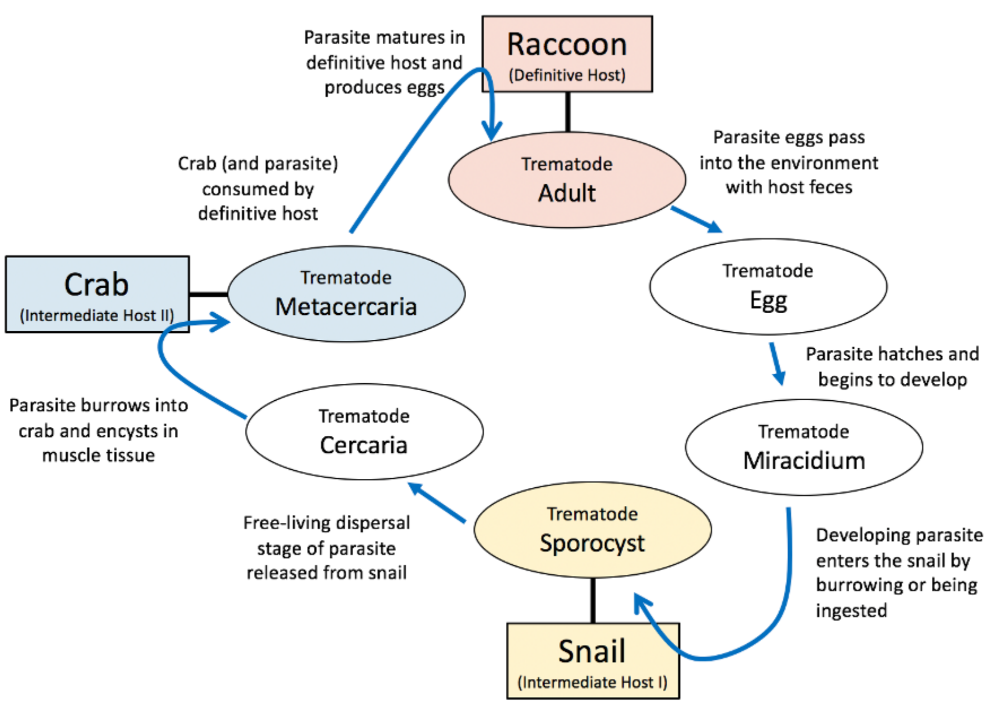

Figure 1. Example of a trematode flat worm life cycle showing transitions through a horn snail, a fiddler crab, and a raccoon. Colored shapes indicate life cycle stages that occur inside a host. Stages in white occur in the surrounding environment (Figure drawn by WH Ryan).

To facilitate student understanding of the role of host population dynamics on parasite transmission, we designed a two-part activity using mock data for an imagined experiment based on trematode flatworm transmission through three animal hosts in a coastal salt marsh community (Figure 1). For Part I, students engaged with an assigned article from the primary scientific literature (we used 10). Undergraduates often struggle to extract useful information from peer-reviewed publications (the primary means of communicating new scientific information) because they lack both background expertise and familiarity with the structure and rhetorical style common in scientific articles (11). There are many resources that instructors can use to help students become effective readers of the primary literature, ranging from compilations of expert advice (e.g., 12) to evidence-based pedagogical systems (e.g., C.R.E.A.T.E.; 13). Given the restrictions of an asynchronous remote class format, we sought to create a self-guided exercise that would allow a student to gain similar insights without the benefit of in-class discussion. We gave a brief introduction to the purpose and structure of academic articles, then had students complete a guided reading activity (Supporting File S1. Parasite Ecology – Part I: Primary Literature Handout). The introductory material is applicable to any article, while the assignment portion is tailored for a specific paper (10). However, this document could be easily adapted for any paper that reports the results of an experiment. We used this activity as an opportunity to preview the concepts involved in the data visualization activity and to practice reading and interpreting graphical representations of data.

For Part II of the activity, we generated a mock dataset for a hypothetical experiment set in a well-characterized food web in a California coastal salt marsh (14). Students often struggle to envision the dynamic relationships between species that are represented by static food web or community interaction diagrams. In general ecology courses, concepts like trophic cascades and predator-prey population cycles require students to develop intuition about how changes in population density or trophic behavior in one species might propagate through a food chain to influence the populations of interacting species. Developing intuition about dynamic systems is particularly important in parasite ecology, where variables of interest, such as the prevalence of a parasite in a population or the per-capita infection risk, depend on the population density and behavior of multiple host organisms. To help students develop this form of thinking, we designed an imaginary experiment to measure the effect of host density on interactions among three parasitic trematode flatworm hosts (horn snails, fiddler crabs, and raccoons) (Figure 1). The activity handout (Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout) provides students with a summary of the relevant natural history of the system, the details of the experimental design, and the raw data. The instructions then lead them through calculating and graphing parasite prevalence and transmission rates for each host species under each experimental condition. Students then answer a series of questions assessing their ability to interpret and contextualize the patterns they found. Finally, they are asked to describe additional, unstudied factors which could influence parasite abundance in this system. In the end, students arrive at a comprehensive understanding of how a small change in the system (e.g., variation in fiddler crab density) influences parasite abundance across all hosts.

The structure of this project allowed students to practice several core scientific skills and closely mirrors the investigative process a professional researcher uses to collect new information. Our students gained conceptual understanding of direct and indirect species interactions, trophic ecology, and parasite biology with this activity. Students also practiced scholarship skills in reading, interpreting, and discussing primary literature, as well as technical skills in calculating basic summary statistics and converting raw data into interpretable graphs. Importantly, this project provided an opportunity for students to practice building logical arguments using quantitative reasoning based on evidence to make predictions about the dynamics of a biological system. The stepwise structure of this assignment also allowed us to clearly identify key points in the chain of reasoning where students struggled, which allowed us to tailor more efficient follow up discussions to clarify these points.

While these assignments were first used as home-based activities for remote learning students working individually, they could easily be modified for use as in-person and/or group activities. Here we report the details of the project as it was used for a 16 person, upper-level undergraduate parasitology course, but we also discuss suggestions for how to modify this activity for a variety of course types (introductory biology, general ecology, etc.) and classroom settings.

Intended Audience

This lesson was originally designed for advanced biology undergraduates at a small, liberal arts university, but could be modified for biology students at any level and in any undergraduate setting.

Required Learning Time

This project was originally assigned as two separate take-home lab assignments. The literature assignment (Part I) required approximately two hours of student effort, including engaging in an asynchronous, Canvas-based discussion of the assigned research article. The data analysis assignment (Part II) took students approximately 30 – 60 minutes, depending on the student's comfort level with making and interpreting basic graphs.

Prerequisite Student Knowledge

This activity can be completed without specialized knowledge about either parasites or ecology, although this project was originally paired with a short lecture about the effects of parasites on host behavior drawn from chapter six of Loker and Hofkin (2). For Part I, students should understand the purpose and structure of primary scientific articles and should have received guidance on how to read these articles effectively. For Part II, students should be comfortable calculating means and standard deviations from raw data and constructing basic bar graphs either by hand or in a computer program (e.g., Microsoft Excel [15], R statistical software [16]). For both activities, basic instructions are included in the example assignment handouts (Supporting File S1. Parasite Ecology – Part I: Primary Literature Handout, Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout).

Prerequisite Teacher Knowledge

Instructors should be familiar with core ecology concepts such as food webs and parasite life cycles, as well as with basic terminology and concepts used to describe the interaction of parasites with hosts (e.g., intermediate host versus definitive host). Specifically, it would be helpful to be familiar with trematode life cycles characterized by multiple modes of transmission and development across multiple hosts, as well as examples of parasite-mediated changes in host behavior (e.g., parasite infections leading to increased risk-taking behavior in systems with trophic transmission).

Instructors should also be familiar with basic concepts of experimental design used in field ecology (e.g., predator exclusion cages) to help students visualize how data were collected. Particularly for Part I, instructors should be comfortable helping students read and digest primary scientific research articles. A guide to reading scientific papers is provided in Supporting File S1. Parasite Ecology – Part I: Primary Literature Handout, and a variety of additional, free resources are available online).

SCIENTIFIC TEACHING THEMES

Active Learning

In Part I of the lesson, students prepared for and engaged in an online message-board discussion about a paper with their peers. In Part II of the lesson, students practiced hands-on data synthesis and interpretation skills. Student learning was enhanced by asynchronous feedback from their peers and the instructors. In an in-person setting, these activities could further promote peer-to-peer engagement and collective problem solving.

Assessment

Part I included 9 short answer questions to guide students in extracting meaning from a primary journal article. To prepare students for a discussion with their peers, the questions were designed to ensure that students understood (1) the study system, (2) the goals of the study, (3) the methods used, (4) the evidence provided by the results, and (5) the biological conclusions drawn by the author. Completing this assignment required a range of skills including finding information in the text, reading comprehension, graph literacy, and synthesizing information well enough to make predictions about the outcome of a hypothetical scenario. Student responses were graded on completion and factual correctness (Answer key provided as Supporting File S3. Parasite Ecology – Part I: Primary Literature Handout ANSWER KEY). Due to the remote education setting, we organized the discussion on an asynchronous, virtual message board in Canvas. We used a "muddiest point" approach (17, 18) to stimulate discussion by asking students to identify a specific method, result, or conclusion in the paper that confused them. Students earned points for posting initial questions and responding to their peer's posts. Instructors assigned points for completion, but also screened posts to ensure relevance and adherence to course conduct guidelines (e.g., ensuring no harassing behavior was displayed online).

Part II included four guided tasks to produce graphs followed by six short answer questions that varied in the degree of creative thinking required to answer. The primary skills assessed through this assignment are graph literacy, mathematical reasoning, and the interpretation of biological meaning from data. Graph-based responses were graded using a rubric that assigned points for giving the correct answer and for constructing a figure with all of the requested elements (a model of the required elements for each graph is included in the assignment handout, Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout). Short answer questions were compared to a key that identified the essential information for a complete answer. The answer key with an example rubric for evaluating graphs is included as a supporting file (Supporting File S4. Parasite Ecology – Part II: Data Analysis Handout ANSWER KEY)

In order to not double penalize students who made errors in the graphing portion, students were given full credit for a correct interpretation of an incorrect graph, although this was rare. For the final question, students were asked to extend their understanding of the topic by proposing two additional factors that could influence parasite transmission rates in the system. After the assignments were graded and returned, we gave a short, recorded summary discussing common errors and encouraged students to discuss the parts of the activity they found challenging during video call-based office hours.

Inclusive Teaching

Many of the case studies used to illustrate the principles of parasitology involve human health and well-being and provide a wealth of opportunities to model respectful and inclusive ways of discussing the diverse lives and experiences of humans around the world. For example, lecture material in the ecology and evolution unit of this course included discussions of human diseases (e.g., hookworm, malaria) and ecological issues (e.g., amphibian loss to chytrid fungus) that disproportionately affect people living in tropical regions and the Global South (19). In discussing these topics, we were careful to counteract harmful and pervasive stereotypes that associate parasite risk with the behaviors and cultural markers of certain groups of people, and not to invoke colonialist assumptions about the economic development and public health infrastructure of regions affected by these ecological problems and diseases (20). Wherever possible, we also focused on research of scientists living in the regions most affected by the subject of their study.

Due to the inherent intertwining of human experiences with health- and environment-related topics in parasitology, there are ample opportunities in this kind of course for engaging students with activities that will allow them to reflect critically on the intersections of social equity, public health, and their own assumptions through a socio-scientific issues framework (21, 22). For example, the link between hookworm infection, anemia, and impaired cognitive development is often illustrated in parasitology textbooks through the story of Charles Stiles' 1902 announcement of the discovery of the "germ of laziness" in the American Southeast and subsequent public health initiatives funded by John D. Rockefeller (e.g., 2, page 360). While this narrative conveys real historical events and biology, the commonly used structure of the story tacitly reinforces harmful stereotypes about the populations that were affected. It also ignores important historical context where public messaging around this biological discovery was used to support and spread racist and classist ideologies in public health and popular culture (23). Teaching such material can be made more inclusive by integrating an explicit discussion of the social context in which the scientific discoveries were made, and the role scientific information and subsequent interpretation play in constructing both public policy and public narratives (see 21, 22).

LESSON PLAN

Pre-class preparation

Prior to this activity, students should learn about the role of trophic transfer among hosts in parasite life cycles. For example, our students had read and attended lectures about chapters three and six in Loker and Hofkin (2), which focus on parasite life cycle diversity and ecological relationships between parasites and hosts, respectively. For general biology or general ecology courses, treatments of these subjects in a chapter on species interactions (e.g., Chapter 12 in 24) would provide an adequate primer for the activity. In addition, students should be introduced to examples of peer-reviewed literature and the role that such journal articles play in the modern scientific process. In our class, students had been introduced to these topics through previous case studies and examples in lecture.

To prepare for this activity, the instructor should set clear dates and times for each part of the activity, especially where asynchronous discussion board posts are involved. The instructor also has the option of generating new mock data for Part II. We have provided a simple Excel worksheet that can be used to generate pseudo-random data with the desired properties to support the intended results (Supporting File S5. Parasite Ecology – Excel File for Generating Mock Data). Students can use either a calculator and paper or statistical software to analyze the data and make graphs. We have included an annotated example of a graph and the Excel functions for calculating mean and standard deviation at the end of the handout (Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout). Depending on the level of student experience with making graphs in Excel or other software, it may be useful to demonstrate the basic features of the program, including how to add correct error bars to column charts. We have also included a modifiable slide version of the life cycle diagram used in the assignment (Supporting File S6. Parasite Ecology – Modifiable Parasite Life Cycle Diagram) to promote flexible use of this assignment structure for other parasites with different life cycles.

Progression through the lesson

<u>(1) Lesson Introduction</u>

Because this portion of our course was taught remotely and asynchronously, there were few opportunities to engage in live group discussion with the students. Thus, the goals of the activity were introduced as written instructions for each self-guided assignment (see supporting files).

<u>(2) Part I: Reading and Discussing the Primary Literature</u>

The Part I assignment document (Supporting File S1. Parasite Ecology – Part I: Primary Literature Handout) was distributed after the associated lecture. Students had one week to read the paper, answer the assignment questions, and post an initial question about the paper on our learning management system (Canvas) message board. All students were then required to respond to at least one peer's question within four days. To foster useful interactions through an asynchronous discussion board, it is useful to give students specific instructions to generate pithy comments (25). We asked students to post specific examples of background, methods, or results that they did not understand to encourage peer-to-peer problem solving and learning through teaching. The instructors engaged sparingly in the discussion, only to ensure that every comment got a response and to clarify confusing information. However, the small class size allowed us to give detailed and individual feedback on each student's written responses to the assignment through the learning management system. In a synchronous remote or face-to-face format, pairing the individual activity with a facilitated group discussion would help students get the most value out of their reading.

<u>(3) Part II: Data Analysis and Presentation</u>

The Part II assignment document (Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout) was distributed one week after the paper discussion, and after students had received instructor feedback. Again, due to the nature of our course, we had to use written instructions to convey the activity goals to the students. Students were given four days to complete the activity, including one scheduled lab period. We were available to answer questions and assist students through email and/or video calling to avoid student disengagement due to confusion.

<u>(4) Lesson synthesis</u>

Students were given thorough written feedback on their work alongside scoring results using the key and rubric described above (Supporting File S4. Parasite Ecology – Part II: Data Analysis Handout ANSWER KEY). We also discussed common misunderstandings and errors on the assignment in a subsequent recorded lecture. However, in an ideal situation, we would have been able to engage the students in a synchronous discussion of their findings and help them connect their results to broader themes in parasite ecology and species interactions.

TEACHING DISCUSSION

Outcomes

Our students benefited from this activity in a number of ways. First, students gained experience with primary scientific literature and were better able to connect their work in Part II with the process of real scientific discovery. Second, students were able to effectively explain abstract concepts like trophic interactions and describe the biological importance of parasite life cycle complexity after working through an applied example involving these concepts. Finally, students gained valuable practice in key scientific skills, including summarizing raw data and interpreting biological patterns.

As instructors, we also benefitted from this activity in a number of ways. The structure of the assignment allowed us to pinpoint the areas of scientific reasoning where students had the most trouble. In Part I, we were able to distinguish where students struggled with complex vocabulary or unfamiliar techniques versus where students struggled to understand important biological concepts. In Part II, we observed several key points that students found challenging. For example, most students were able to follow the instructions to make the graphs, but some struggled to interpret the meaning of their findings. Other students were able to explain the biological meaning of the graphs but struggled to apply that information to make predictions about other scenarios. Lastly, some students were unable to recognize when they had made a graphing error that made it impossible to infer biological meaning from their results. Each of these outcomes provides an opportunity for an instructor to design targeted follow up instruction and guidance to address specific gaps in knowledge and skills.

We did not gather student opinions on this specific assignment, but saw evidence of the lesson's efficacy in student performance on subsequent assignments. Nearly all students in the class were able to demonstrate the kind of ecological reasoning practiced in this activity in short-answer responses to a weekly review assessment and a targeted question on the subsequent exam. In future semesters, we will try to use a synchronous discussion period instead of an asynchronous message board activity to discuss the paper in Part I. We think that the students who struggled to interpret patterns from their graphs and make predictions about alternate experimental scenarios would benefit from seeing such quantitative and biological reasoning modelled by other students and the instructor.

Adapting this Activity for Synchronous Remote and/or In-Person Classes

This activity worked well as a two-part, self-directed project. However, both Parts I and II could be adapted as a highly interactive classroom activity.

<u>Part I</u>

Part I could be enhanced with a facilitated discussion of the journal article after the students have read it and have attempted to answer the assigned questions on their own. To best support the learning goals in Part II, the discussion should focus on (1) defining the parasite life cycle and species interaction web to understand how these processes interact, (2) describing the experimental design that led to the data underlying each result, and (3) clarifying how the paper's conclusions are supported by the evidence. Finally, students should be encouraged to practice making predictions based on the conclusions from the paper.

For smaller class sizes (e.g., < 30 students), a synchronous session related to Part I could be operated as a jigsaw activity (26). Each small group could focus on one of the three goals above for 10 – 15 minutes. Students could then shuffle into new groups and spent a few minutes reporting on the findings for each goal. Then, they could work together to make predictions about how the system would respond to a perturbation (e.g., "How would terminal host parasite load change if there were fewer intermediate hosts at the site?"). Each group would then report out their reasoning and conclusions.

For larger classes, an instructor-led discussion revisiting the most challenging assignment questions based on student's written answers would be useful.

<u>Part II</u>

Part II would be effective as a small group project. Groups of 2-4 students could work together to analyze the data and create graphs. Then, depending on the goals of the course, this assignment could be extended by asking each group to make predictions about a different kind of perturbation to the system (e.g., What would happen to parasite transmission rates to raccoons if fiddler crabs started being removed at high rates by humans?). Alternatively, students could be asked to design a follow-up experiment to test a question that they have about the system. In either case, students could briefly present their ideas to the class as a culminating activity.

SUPPORTING MATERIALS

- Supporting File S1. Parasite Ecology – Part I: Primary Literature Handout
- Supporting File S2. Parasite Ecology – Part II: Data Analysis Handout
- Supporting File S3. Parasite Ecology – Part I: Primary Literature Handout ANSWER KEY
- Supporting File S4. Parasite Ecology – Part II: Data Analysis Handout ANSWER KEY
- Supporting File S5. Parasite Ecology – Excel File for Generating Mock Data
- Supporting File S6. Parasite Ecology – Modifiable Parasite Life Cycle Diagram

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Table 1. Lesson Plan Timeline.

Activity	Description	Estimated Time	Notes
Pre-activity preparation			
Generate new mock data	Use provided Excel file to generate new data sets (optional)	5 minutes	Supporting File S5. Parasite Ecology – Excel File for Generating Mock Data
Establish clear deadlines for students	Students need a timeline for turning in handouts and preparing for the paper discussion		
Part I Literature Discussion (week 1)			
Introduce peer-reviewed literature		Variable	Self-guided introduction available in Supporting File S1. Parasite Ecology – Part I Primary Literature Handout
Assign reading and Part I handout	Students should read Morton (10) (or other assigned paper) and answer Part I handout questions	2 hours at home	
Facilitate paper discussion	This can take place on asynchronous message boards, synchronously online, or in person.	Depends on instructional mode	Asynchronous: 10-15 minutes over 4 days Synchronous: 20-30 minutes
Part II Data Analysis (week 2)			
Assign Part II handout	Work can be self-guided in a remote setting or assigned as a group project in an in person setting	1 hour	Supporting File S2. Parasite Ecology – Part II Data Analysis Handout
Provide feedback to students	Give either written or verbal comments		