INQUIRY & INVESTIGATION

Crayfish Behavior: Observing Arthropods to Learn about Science & Scientific Inquiry

NABT BioClub RECOMMENDATION

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Abstract

This is a set of animal behavior investigations in which students will practice scientific inquiry as they observe crayfish, ask questions, and discuss territoriality, social interactions, and other behaviors. In doing this, they hone their skills of observation, learn to record and analyze data, control for variables, write hypotheses, make tentative conclusions, and then design and carry out original experiments. This set of activities and experiments is designed for middle school through high school life science or biology classrooms.

Key Words: *Crayfish; animal behavior; inquiry; laboratory work.*

As biology teachers, we understand how important it is for students to become engaged first-hand with nature. Although bringing students to fields, woodlands, and wetlands to observe, explore, and wonder may be the preferable way to stimulate curiosity and practice scientific inquiry, field excursions are not always practical or possible.

As an alternative, I have found it useful to study creatures that can easily be maintained in a laboratory setting. Organisms in the local ecosystem that can be captured readily, such as mice, snakes, fish, and various arthropods, make some of the best study subjects because their behavior is easily observable and relatively simple to understand (please see safety note below). Crayfish are exceptionally good study organisms. They are somewhat familiar to most students, and their size makes observation easy. Their active, territorial, and aggressive behavior provides an abundance of observation opportunities, and their claws add drama that students appreciate. Crayfish are very common in nearly every area of the United States, but if it is impossible to collect specimens, they can be ordered from biological supply houses or even local fishing bait stores.

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The crayfish behavior investigations described here are adaptations of those I have frequently used in middle school and high school biology classes. They require very little equipment and can be used in any school setting from grades 5 through 12.

Although this study takes no sophisticated equipment, it does require imagination, ingenuity, and creative scheduling. In the beginning you will need several class sessions to set up the original investigations and model the kinds of inquiry that students will later do more independently. After the introductory class sessions, each week of the study will require several observation sessions of 10–15 minutes and at least one class session for debriefing and discussion. Continue this for as long as you feel that new lessons are being learned about crayfish, about environmental issues, and about scientific principles and processes.

Safety note: There are always safety and ethical issues associated with any laboratory investigation that uses living organisms in the classroom. Start by reading the NABT's position statement on the use of animals in biology classes and follow the link given for the "Principles and Guidelines for the Use of Animals in Precollege Education" provided by the National Research Council (http://www.nabt.org/websites/institution/index.php?p=97). In addition, your state or government will likely have rules and laws about using animals in classrooms. For example, in Ohio, the DNR Division of Wildlife has a very useful "Guide to Using Animals in the Classroom and for Collection," available at http://www.dnr.state.oh.us/Portals/9/pdf/pub009.pdf, that gives necessary information about the ethical treatment of animals and the collection permit process, and useful information on laboratory procedures.

○ Background

Crayfish (Astacidea), like other arthropods, have many reasons for moving about, including foraging for food, competing for space, searching for a mate, avoiding parasites, and escaping predators. However, movement is always risky and often costly. Optimal foraging theory is a conceptual framework that scientists use to think about the behavior of prey species (McCleery, 1978; Sephans & Krebs, 1986; Lima & Dill, 1990; Abrahams & Cartar, 2000). According to this theory, animal decisions about the risks of predation are assumed to represent a balance between the costs and benefits of behaviors. Recent studies have suggested that risk of exposure and predation can influence an animal's behavior when foraging for food or engaging in reproduction

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(Wellborn, 2000). Crayfish survival behaviors that are related to shelter, nutrition, the need for protection during a molt, and reproduction compete with each other and with the need for cover and safety.

Scientists also study the social behaviors of crayfish, examining how individuals compete with each other for space, food, and opportunities to mate and reproduce. Body position and the movement of chelae (Belanger & Moore, 2006), antennae, or swimmerets may be indicators of a complex social organization called "dominance hierarchy" (Copp, 1986; Drerup, 2003) or even territoriality. Dominance hierarchies can be simple (one animal over another), linear, or more complex. Territoriality may be related to dominance in that an animal, although not necessarily bigger or stronger, may exhibit aggression to an intruder.

A crayfish placed in a new environment such as an arena in a classroom will look for shelter and structure. To minimize movement and exposure, it may spend its time near relative safety and as close as possible to available food. If cover is limited, it may defend this space from other crayfish, an action called "territorial behavior," in which the defended space defines the territory. The boundaries may coincide with physical markers or they may be marked chemically and be, therefore, very real but invisible to the human observer.

Water is the best solvent in nature, and it carries many chemicals released by aquatic animals and plants. Crayfish exude various chemicals into the water, depending on the type of behavior they are engaged in, whether agonistic (Bergman et al., 2005), social (Bergman & Moore, 2005a, b), mating (Little, 1975; Stebbing et al., 2003), or the behavior of the vulnerable molting stage. This provides stimuli for other crayfish as well as for predators and parasites (Richmond & Lasenby, 2006). There is also convincing evidence that crayfish locate food by chemical odors in the water (Moore & Grills, 1999).

○ Materials & Setup

The study involves placing several crayfish into a test arena, controlling for variables, and observing behaviors. The arena should be large enough to give the crayfish freedom of movement and for a number of crayfish to establish their own personal space. Although a glass aquarium makes a convenient arena, it may not be large enough to maintain a number of crayfish and avoid overcrowding. A rule of thumb is to allow for at least one square foot of space for each adult crayfish. A shallow plastic tub is also a possible container, although it is a disadvantage for students to only be able to observe from above.

The best solution for an arena is to build one out of clear plastic (Plexiglass®) and a glue specifically made for it. Making your own arena allows for 15–20 cm side walls that will both contain the crayfish and permit easy observation. (The same arena can be used later for numerous behavior activities and experiments with different animals.) Aquarium gravel makes a nice substrate. Small physical orientation markers like stones, waterlogged sticks, or other small objects should be placed in the arena. Earthenware pot trays with a small section of the rim chipped away work well as shelters, as do piles of flat stones or brick shards. It is important to bubble air into the water using an aquarium air stone. Put a couple larger rocks in the arena on which crayfish can climb to the surface of the water. If they lift their tails and gills into the air, there is not enough oxygen in the water and you should increase water circulation and the amount of air bubbled out of the air stones.

A clear cover can help limit evaporation and keep foreign objects from falling in. The arena cover should have drilled holes for adequate ventilation. The plastic must be clear to permit detailed observations. Students can easily draw, with a permanent marker, a grid on the cover on which to record data. However, if your classroom is relatively humid, you may prefer to eliminate the cover of the arena and thus make close observation easier. Place the arena on a table that is low enough that students can comfortably see inside for extended periods of time.

Crayfish should be marked for identification by placing a small colored mark on the thorax using a permanent marker with a fine point. Small dots or other small marks will work. Crayfish can be fed sinking tropical fish pellets, chopped-up night crawlers (*Lumbricus* spp.), and occasional vegetables like carrots, beans, and peas. They also like crab cakes and shrimp pellets. Be careful not to overfeed them, and remove uneaten food before it begins to foul the water.

It's important to remind students that crayfish are often nocturnal and become more active at night. Consequently, during any experiment or observations, it is wise to dim the lights in the room and be as quiet as possible. Students should stand or sit close enough to see but far enough away that they do not disturb the crayfish. Remind them never to tap on the side of the arena or the glass of an aquarium, because water conducts sound very well and the residents can be disturbed or even harmed.

Materials

- 6–10 or more male and female crayfish
- Observation arena equipped as described above
- Small plastic containers with covers to isolate crayfish (provide air, shelter, water, and food)
- Suitable crayfish food (see above)
- Stopwatch or clock with second hand
- Turkey baster or other method of transferring water from one container to another and for removing uneaten food, etc.

○ Procedures & Teacher Notes

As an introduction, discover what students already know about crayfish – physical characteristics, habitat, and whether they have had any personal experiences with them. Then have your students visit the Crayfish Corner (http://www.mackers.com/crayfish/) and the Crayfish Home Page (http://crayfish.byu.edu/). Students should discover information such as how to identify the species of their specimens, the natural history of their particular animals, anatomy and physiology, how to tell sex and age, and how to care for crayfish in captivity. They should also learn about the role of crayfish in their ecosystems: What are their habitat needs? What do they eat? What eats them? Also engage them in a discussion of where in their own community these creatures might live. Have students use the Web sites listed as well as other online resources and print journals to explore existing crayfish research. Remind students that this kind of preliminary reading takes much of a scientist's time and that reading and learning from others is a necessary part of being a scientist.

The investigations should be introduced by discussing predator–prey relationships, the niches of different kinds of animals, and the behaviors of various predators and parasites. Remind students that a high population of a species of animals at the bottom of the food chain supports the nutritional needs of a large variety of other creatures. Different animals have different niches, some being scavengers, predators, herbivores, and so on. Ask them what niche they think crayfish inhabit and what evidence they might have for their assertions. Have them look at and observe a large crayfish and try to relate structure to function and lifestyle. Try to get students to ask a lot of questions about structures and movements. Relate what they observe to assertions about what a crayfish might do to defend itself, escape predators, be aware of its surroundings, or find food. Let them touch the carapace and feel the exoskeleton. Then show them a very young specimen and let them observe again. How can an animal with an external skeleton grow, move, and breathe?

Important preparation for students is discussion about the particular challenges and advantages of living a completely aquatic life. Life in water is very different from life in air, and it presents a whole set of

advantages and disadvantages. The food chain in rivers and streams is based in woody material and the microscopic and macroscopic life forms that move up the food web. Water carries sounds and chemical markers better than air. How might the ability to test for different chemicals in water, and perhaps deposit chemicals into the water in which they live, benefit a crayfish? When crayfish exude chemicals into their water – either intentionally or for physiological reasons – what risks are they taking? What other animals might be able to sense these chemicals and take advantage of this? Have students figure out where crayfish fit in the food web of the stream or pond from which the crayfish came. Would the place of crayfish in the food web be different in a different lake, pond, or marsh?

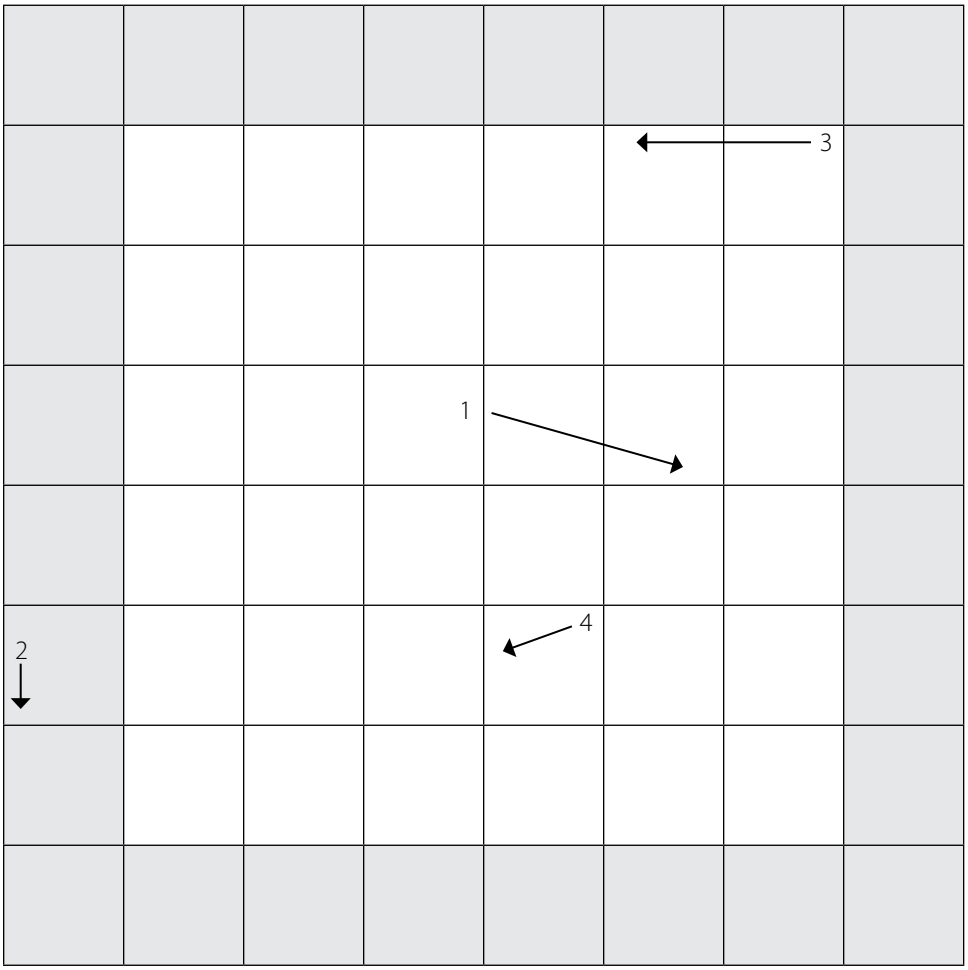
Let students' curiosity drive the inquiry, helping them determine how to discover the answers to their questions. Discussing optimal foraging theory before the investigation gives students a framework for reference and a theory to test. On the other hand, it may come across as giving some of "the answers" away or promote the impression that scientists set out to prove theories (a common misconception to begin with), so you may prefer to introduce the theory later. Either way, students should be able to explain why animals, when foraging for food or searching for a mate, need to do it efficiently. The energy expended in obtaining food must be less than that gained from food, and meanwhile the animal must minimize the risk of exposure to predators. Time and distance away from cover increase the risk of becoming lunch. Ask students if they think these behaviors are learned or inherited and what evidence they have for their opinion.

Table 1. Sample data chart for timed crayfish observations.

Time Interval (in seconds)	Observations of Crayfish Behavior Keyed to Time Interval
1. 0–30	
2. 31–60	
3. 61–90	[Events should be recorded at the appropriate time interval]
4. 91–120	
5. 121–150	[Continue the table for the correct number of time intervals]

Note: Time intervals are provided as examples. You might choose different time intervals.

Table 2. Sample recording grid for timed crayfish observations. The grid corresponds to the arena area. The numbers represent the crayfish and their location at the corresponding time interval. The arrows represent the direction of crayfish movement at the time interval.



Note: Numbers and arrows on this chart are examples of how you might record your data.

Discuss why it is important in any investigation to control for variables such as sex, age, health, scents in the test arena, and presence or absence of shelter and food. Also discuss why it is important to conduct several trials with different crayfish. As part of the preparation, also discuss the ethical issues related to the treatment of living things in laboratories and in the wild. Students invariably agree that school investigations should never be hazardous to animals in any way. I have very seldom had to deal with crayfish abuse.

After this discussion, students should be ready to do the investigations described below. The goal is to have them do a few guided inquiries like those given here to get a feel for the animals and their behaviors and then to design their own investigations and experiments. Have them work in small groups with individuals assigned certain tasks. For example, the groups could designate a timer, "go-fer," crayfish handler, and reporter. All students should take and record observations. Discuss why it is important, in any scientific experiment, to take as many observations as possible (see Table 1). Students will probably need help in learning the differences between observations, inferences, and conclusions, as well as in learning to record observations. Discuss the need for a control in any experiment and consider establishing a different arena with a control group of animals. Discuss possible ways to use checklists and data tables to record positions, postures, and orientations at timed intervals for repeated trials (see Table 2). Some students may find it useful to use video recordings to study and communicate what they observe.

○ The Investigations

(A) Crayfish, a New Space, & Observing First Encounters

Some of the most interesting behaviors happen when crayfish find themselves in a new space and in the presence of others they have not encountered before. For this first investigation, prepare the testing arena but do not provide food or shelter.

1. Using small plastic containers, isolate 4 or 5 marked crayfish from each other for at least 24 hours.
2. After the isolation period, place all the crayfish in the test arena and immediately begin taking observations. When the designated timer calls "time" (every 30 seconds), the recorder marks the individual position on the grid (Table 2) using an arrow to note the direction the crayfish is facing at the time and consecutive numbers that correspond to timed intervals. Participants should record observations as they wait between time intervals. Pay special attention to when animals come in contact with each other (see Table 1). Look for subtle as well as not-so-subtle behaviors: movement and positioning of chelae, stance, orientation, etc. Although the more time intervals the better, a 15-minute testing time should be sufficient for this first investigation.
3. Establish a classification scheme for observed behaviors. Be sure that students record body movement, posture, and positions of chelae.
4. Encounters between crayfish will vary in intensity, depending on certain observable behaviors. Have students record "win and loss" tallies for individuals. Have groups discuss the encounters they observe and what evidence they have that the behavior observed is agonistic. What evidence do they have that there are "winners and losers?" Are these descriptions appropriate for all observed encounters? Discuss whether there is a dominance hierarchy among these crayfish and, if so, how long it took to become established. What evidence do groups have for their assertions? Is the hierarchy simply linear or is it more complex? Where on the hierarchy does each crayfish belong?
5. Discuss and test other variables the students are interested in. For example, repeat the experiment with females only, with females and males, and with same-age or mixed-age individuals. Do size or other physical characteristics make a difference? Remember to discuss the need for evidence in making any tentative claims and what constitutes evidence in each case.

(B) Territoriality & Personal Space

In part A, students tested crayfish behavior when animals first encountered each other. This next set of investigations is designed to test other variables associated with crayfish behavior. Before beginning, place food and water in the arena.

1. Place some physical space markers, such as small stones, sticks, and other small objects (too small to function as shelters) in the arena. Place 5 or 6 marked male crayfish and the same number of shelters into the arena. For a period of 1 week, record observations and discuss any data that can serve as evidence for establishment of personal space or territoriality. What behaviors classified in part A are observed during the week of acclimation? Where do encounters take place? Do you observe any different behaviors? Modify your behavior classifications according to what you see.
2. Place another marked male crayfish (but not another shelter) into the arena. Observe any interactions and record any behaviors of the crayfish. Be sure to keep in mind any tentative findings about dominance hierarchy in part A.
3. Repeat, using different crayfish that represent different positions on the hierarchy.
4. Discuss the nature of the encounters, their relationship to space, and hierarchy assertions.
5. Write hypotheses about your crayfish's behaviors and design other experiments to test your hypotheses. Try to test only one variable at a time and control for confounding variables as carefully as you can.

(C) Behavior in Response to a Molting Crayfish – A Water Transplant Investigation

As discussed above, crayfish are most vulnerable to predation and even cannibalism when molting their exoskeletons. This investigation is designed to examine whether a crayfish can sense and respond to a molting individual without seeing or hearing it.

1. Remove all the crayfish from the arena, except for 1 or 2 that you know have recently molted and are therefore not likely to molt again soon. Put the crayfish that you removed in separate holding containers during this inquiry.
2. Wait until one of the crayfish in the holding containers begins to molt.
3. Using a turkey baster or something similar, transfer some water from the container with the molting crayfish into the test arena.
4. Observe and record. (Have students look for the meral spread response – when the test crayfish raise their claws in a particular way.)

Students should be able to brainstorm other hypotheses to test. In making any changes to the study, make sure that students discuss other possible variables that might affect their results.

○ Assessments of Student Learning

Assessments should always be closely related to the goals and objectives for student learning. As stated above, students will learn about crayfish species specifically, and animal behavior in general. They also should learn about the process of scientific inquiry, including skills of observing and recording, representing data in charts and graphs, the importance of using averages (means), and how to analyze data using mathematics. In addition, a spirit of inquiry, curiosity, asking good questions, and making predictions are important lessons to learn. Students also gain experience in designing and carrying out their own investigations and experiments, necessary components of a standards-based curriculum. Although all of these performances and habits of mind are important learning outcomes, they are not easily measured and assessed.

Although there are a variety of creative assessment strategies that could be used, perhaps the most effective and formative way to measure student learning is through an individual or group lab report that follows a typical scientific publication format, with an introduction, literature review, methods, data analysis, conclusions, and suggestions for further study. For an example of an assessment sheet, see Table 3. Have your students organize an animal behavior conference where individuals or groups of students present their findings either as Power Point® presentations or in poster sessions. This could be done during the school day, or it could be organized as an evening event with parents and community members invited.

Table 3. Crayfish behavior report: sample lab report assessment rubric.

In the spaces provided, rate your lab report using X+ for excellent, X for good, and IP for "in process." Be sure to use the comment spaces when you wish to explain something. Use NA for criteria that do not apply.			
Section of Report	**Self Evaluation**	**Peer Evaluation**	**Teacher Evaluation**
Introduction • I included a central research question(s) • I briefly explained how this topic is important to us • I clearly explained what I did and briefly told what I learned that I didn't know before Comments			
Literature Review I included relevant sources • that helped me understand my own study • that helped me see a need for my study • that helped me with my inquiry methodology Comments			
Procedure or methods • I explained what I did and why I did it • I was especially careful to explain how my methods are related to my research questions Comments			
Data collected • I included all the data and laboratory notes • I included observations keyed to time intervals • My data are displayed in appropriate, readable form • All charts and diagrams are clearly labeled Comments			
Data analysis • I included all charts and graphs of my data • My charts and graphs help teach my reader • I labeled all charts and graphs, diagrams and drawings needed to show my reader what the data can tell us Comments			
Conclusions • I clearly stated my conclusions • I explained how the data became evidence for conclusions • I put findings in the context of other scientific studies • I made suggestions for further study Comments			
Writing performance • I used clear, easy-to-understand language • I followed all the rules of grammar • I wrote in complete sentences (except in data section) • I edited my work and checked my spelling Comments			
Overall Rating			

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