How To Make a Field Trip a Hands-On Investigative Laboratory: Learning About Marine Invertebrates

PATRICIA A. BURROWES

For many years I have been taking my Zoology students (sophomores in college) to the beach to observe and learn about marine invertebrates in a coral reef. Although we generally had a good time, and students actually saw a diversity of animals in their natural habitat, I returned disappointed. I felt that the students did not employ the time effectively. They chose to play in the water or sunbathe rather than focus on the assignment.

I had been applying the recommendations of the American Association for the Advancement of Science (AAAS, 1990) and the National Research Council (1999) in my classroom so why not in a field trip? Research has shown that when students are given the opportunity to ask their own questions and design their own experiments, they become more interested in learning the answers (Foote & FitzPatrick, 2004). So, I decided to change this field experience in Zoology from a passive one (student learns from what teacher shows) to an active one (student learns from what student discovers).

As a graduate student I participated in a six-week training course sponsored by the Organization of Tropical Studies in Costa Rica, where we learned tropical biology by conducting our own experiments in the field. The entire scientific process from observation to documenting results, took place within an eight-hour work day, so I assumed I could follow a similar model with my undergraduate students. In this article I will describe an effective method to do a field trip to the beach and get your students to make observations about marine animals, come up with a testable question, design an experiment, use equipment to collect data, analyze their results, draw conclusions, and write a brief one-page report–all in seven hours! In addition they get a chance to test their knowledge on taxonomy and integrate concepts on major evolutionary trends of the animals observed. Although this is a beach field trip to study marine invertebrates, I recommend this strategy for other field trips regardless of the ecosystem or organism of interest.

Academic Background & Field Trip Educational Goals

This field trip takes place at about three quarters into the semester, when we have studied basic principles of the systematics, anatomy, physiology, ecology, and behavior of the major invertebrate groups. In the lab component of the course, students have had the opportunity to manipulate and dissect preserved specimens representative of Porifera, Cnidaria, Platyhelminthes, Nemerteans, Nematoda, Rotifera, Mollusca, Onychophora, Annelida, Arthropoda, Equinodermata, and Hemichordata. In addition, they have viewed microscope slides of asexual reproduction, gametes, and developmental stages of many of these organisms when discussing topics related to animal reproduction and development. Thus, the goal of this field trip is to give students the opportunity to:

1. construct upon the knowledge gained in the class/lab by observing these organisms in their natural environment
2. classify the animals observed by identifying key taxonomic characters that seemed to work when applied to models or preserved specimens in the lab
3. raise questions about the life of these organisms in their natural environment
4. formulate a testable hypothesis that may answer one of these questions
5. perform the corresponding research

Field Trip Preparation

Students are advised beforehand to pack a snack and a lunch, and bring snorkeling gear (at least a mask and snorkel), bathing suit, rubber sandals or beach shoes that can be used to walk under water, sun screen, hats, and clothing that can get wet in case they need extra protection from the sun. As equipment we prepare five big plastic boxes full of basic field gear that includes:

extra skin diving equipment (masks, snorkels, and fins)
rubber and cloth gloves
calipers
rulers
calculators
folding tables
clipboard
pencils
indelible ink markers
flagging tape
coral reef life field guides
1 m^2 quadrants (made from wood or PVC)
100 m plastic measuring tapes
nylon rope
buoyant bulbs that (when attached to string and tied down to the substrate) serve to mark areas
submersible lanterns
plastic trays
mesh nets

PATRICIA A. BURROWES is Associated Professor, Department of Biology, University of Puerto Rico, San Juan, Puerto Rico; e-mail: paburrowes@uprrp.edu.

A handout that describes the field trip activities, with the specific time-table for the day, is given in class a week before the field trip, and we discuss all the procedures including the safety guidelines.

Field Trip Site

One of the secrets for the success of this field activity is the selection of the ideal site for students of different swimming proficiencies. However, the strategy described herein may be applied to any other ecosystem, or even to a visit to a museum. The place we go is Playa Azul beach located in the town of Luquillo, approximately 80 km from our University campus in San Juan, Puerto Rico. This is a Caribbean barrier reef with all the typical components: a white sandy beach, followed by a sea grass (*Thalassia*) lagoon with shallow waters (50 cm – 1 m deep) for an extension of approximately 500 m, that reaches a reef flat followed by a reef crest. Beyond the reef crest where the waves break, there is a nice coral reef front characterized by excellent visibility and a great diversity of marine invertebrates and fish. In the sea grass lagoon, there are patches of bare sand and patches of rock with star and cerebrum corals where fish and marine invertebrates are also abundant. Students that cannot swim are not afraid to go into the ocean because they can stand in water at waist-height most of the time, and thus, cooperate with the team by submerging only their heads.

Description of Field Trip: Agenda & Methods

7:30 AM Leave University campus by bus.

8:15-9:00 AM Arrive on beach site, help unload equipment, get settled at beach site, establish four-member cooperative teams.

9:00-10:00 AM **25 Questions Exercise**

Students get in the water with skin-diving gear to observe the marine fauna, and must come up with at least 25 questions on anything that stirs up their curiosity. One of the team members (note-taker) carries a clipboard to write down all the questions that the others dictate. Examples: *Why do we find starfish only under rocks? Why are sea fans purple? What do sea cucumbers eat? Do conks prefer sea grass or coral habitat? How many fire worms are there in the corals? What do feather worms eat? Why do some fish species travel in groups? Why are anemones always clumped on rocks?* etc. The purpose of this exercise is to stimulate observation, enhance curiosity, and come up with an ample list of questions in order to select one that may be investigated later.

10:00-10:30 AM **Visit animal display**

While student teams are making their observations and formulating questions, the staff (professor and two teaching assistants [upper undergraduate or graduate students], for a group of 32 students) prepare an animal display, by collecting a diverse array of 10 invertebrate specimens and displaying them in water-filled trays. Students visit the display and complete Table 1, which requires identification of all animals to phylum or class and integration of some evolutionary-physiology concepts that we have been discussing in class. Sea water is dripped into the trays every 10 minutes, and live animals are returned to the sea, once the exercise is finished (See Figure 1). The purpose of this exercise is to review and apply concepts and facts learned in class, to the observation of live animals in their environment.

10:30-11:30 AM **Dry up, snack time, and discuss questions**

Students have the task of examining their questions and choosing one that they may be able to investigate and answer in the next three hours. With the help of graduate or undergraduate teaching assistants, I mingle between the groups, and help them achieve this task. Mostly, I find that students have difficulty formulating a proximate cause question that they can study in the given time frame. For example if a group of students wonders, *How many fire worms are there in Luquillo?*, I lead them to ask, *What is the density of fire worms in the Luquillo coral reefs?* This can be estimated

Table 1. Observe all the animals displayed, identify them to phylum and class; then apply the knowledge gained in your Zoology course to comment on the type of body cavity, digestive, circulatory, and reproductive system that these animals have. (*Partially filled as an example*).

Tray #	Common name	Filum/Class	Body cavity	Digestive cavity	Circulatory system	Reproduction
1	Sea urchin	Equinoderm/Echinoidea	True coelom, Enterocoelous	Complete- mouth anus.	Modified –water vascular system	Sexual, separate sexes, indirect development with bilateral larvae
2	Feather worm	Annelida/Polycaheta	True coelom, squisocoelo	Complete- mouth anus. Tentacles around mouth to pick up organic matter.	Closed	Sexual, separate sexes, no clitellum, external fertilization.
3						
4						
5-10						

by establishing several $1m^2$ quadrates in coral patches, and counting worms systematically. Another group may wish to investigate *Why sea anemones are always clumped on rocks*. In this case, I explain that their question may be hard to address in one day, since the answer may be dependent on light, water currents, nutrient availability, substrate quality, predation pressure, etc., which are too many variables to manipulate in a short experiment. Then, I help them modify their question until it may decide to test the hypothesis that sea anemones have a clumped vs. random distribution within coral reefs, by establishing a 100 m transect and mapping their occurrence. Although these students may not generate enough data to achieve statistical significance in this brief experience, they are applying the scientific method to yield a set of results that may suggest something about the life style of these anemones.

Figure 1. Student visiting the animal display trays to observe, identify, and answer questions about the animals in order to complete Table 1.

Figure 2. Group of students working on its research project. The work required measuring total length of sea cucumbers along a transect, to determine if size was correlated to distance from the shore line.

11:30 AM-Noon **Decide on field methods, select equipment**

Students agree on field methods for their particular questions, assign their roles, plan sampling times, pick up the necessary equipment and go back into the water to do their research (Figure 2).

Noon-2:00 PM **Data collection**

2:00-4:00 PM **Dry up, eat lunch, analyze data, write up report**

Students gather on the beach under shade, and with the aide of field guides, rulers, and calculators, they summarize their results in graphs and/or tables in a serious attempt to show how their data agree or disagree with their hypotheses. Finally, they complete a one-page report that follows scientific format (Figure 3), and hand it in by 4:00 PM.

4:00-4:30 PM **Put away equipment and help load up the bus**

5:15 PM **Arrive on campus**

Results on Student Learning

While the outcome on the animal display questions (Table 1) may vary in accuracy depending on individual student's ability to recall knowledge, the results on the field research reports tend to be surprisingly good for all groups. With a little help from the staff, students are able to formulate proximate cause questions and corresponding testable hypotheses. In the results section, they summarize their data by using means with ranges for measurements on body sizes, and drawing graphs or tables when appropriate. Because these reports are hand-written in the field, simple bar or trend-line graphs are considered sufficient. Conclusions were concise but straight forward, suggesting that the students understood the meaning of their results. This confirms research findings that when students are allowed to question themselves about biological systems and design their own experiments, they become more motivated and perform better (Sundberg & Moncada, 1994; Burrowes, 2003; Dinan, 2005; Rutledge, 2005). Reports are carefully graded and annotated to provide feedback on their performance as researchers. As with any other evaluation item, students are invited to discuss their report grades and my comments during my office hours. Often students express their desire to go back to the field and continue their investigations. Thus, there is a great potential for turning this activity into a sequential field trip.

The activity described herein promotes hypothesis testing and emphasizes development of scientific process skills through experimental design and the application of field research methods. In addition, it provides students an opportunity to integrate concepts learned in class and to practice communication skills by completing a brief laboratory report. Listed below are other testable questions that have been successfully investigated by my students:

- Does the size of sea cucumbers vary with (a) depth? (b) microhabitat? (c) distance from shore?
- How do brittle stars respond to light? Are brittle stars negatively phototactic?

- Is the occurrence of brittle stars associated to size of rocks?
- How does fish diversity vary between microhabitats: sea grass, coral rocks, or coral reef?
- How do morpho-species diversity indexes compare between mollusks, annelids, and equinoderms within coral reefs?
- How many species of Gastropods occur in this ecosystem?
- Are the different species of sea urchins (black, red, or white) associated with different microhabitats, or do they occur together?

Figure 3.
One page scientific report form for Research Project.

Group Members: ______________________________
____

1. Question to Investigate:

2. Hypothesis:

3. Methods:

4. Summary of observations and/or data collected (include graphs or tables here):

5. Conclusions:

6. If you had the opportunity to repeat this experiment with unlimited time, what would you do differently?

Results on Students Perception

In order to assess students' perception on (1) the field trip in general, (2) the knowledge they had gained, and (3) the effectiveness of their cooperative groups, I developed a short evaluation form (Table 2). Results summarized in this Table are averaged from three different groups that have passed through this experience. It is evident that the majority of the students perceive that the field trip was well organized and that the time allocated for the activities was enough to get them done. In addition, students were generally satisfied with the performance of team members in their cooperative groups. However, most importantly, students expressed that they enjoyed doing research and that the activities and resources available (25 questions and a simple report guideline), helped them think critically about science and apply the scientific method. This short easily-answered evaluation form was very effective in getting immediate feedback from students at the end of the field trip. Open-ended questions have not worked well for me in the past because students are too tired to provide meaningful answers. A week later, when I return their graded reports in class, we take time to discuss the results of their evaluation forms, and students usually express freely what they enjoyed most or less, and provide suggestions on how to enhance the activity.

Acknowledgments

I am thankful to our Zoology technician, Omar Pérez , for helping us put together the equipment for all the field trips, and to Juan Diego Daza, Carlos Andrés Rodríguez, Antonio Súarez, Bernice Acevedo, and Pamela Casillas, who served as enthusiastic teaching assistants. Funding for this initiative came from an NSF-CCLI A& I Grant to P. A. Burrowes and G. M. Nazario (DUE 0309922).

References

American Association for the Advancement of Science. (1990). *The Liberal Art of Science: Agenda for Action*. Washington, DC: AAAS.

Burrowes, P. A. (2003). A student-centered approach to teaching general biology that really works: Lord's constructivist model put to a test. *The American Biology Teacher, 65*(7), 491–502.

Dinan, F. J. (2005). Laboratory-based case studies: closer to the real world. *Journal of College Science Teaching, 35*(2), 27–29.

Table 2. Field Trip Evaluation Form. Rank the following statements marking the appropriate box according to the way you perceived today's activity at the beach. Scale (1-4) where: *1* = I disagree completely; *2* = I somewhat disagree; *3* = I agree; and *4* = I strongly agree. *(Filled with the averaged results of 3 different groups of students, n=96)*

STATEMENT	1	2	3	4
1. The field trip was well organized.			8 %	92 %
2. The time allotted for each activity was adequate.		2 %	11%	87 %
3. The 25-question exercise helped me make detailed observations.		2 %	10 %	88%
4. The animal display exercise helped me assess my taxonomic knowledge and my ability to apply concepts of comparative anatomy across taxa.		3 %	14 %	83%
5. Having to evaluate our questions and select one that we could investigate made me think critically about research.			6%	94%
6. I enjoyed designing and doing a real experiment in the field.			5%	95%
7. The guidelines in the research report helped me apply the scientific method to my project.				100%
8. All members in my group contributed equally to the achievements of today's work.		1%	8%	91%

Foote, L. C. & FitzPatrick, K. A. (2004). Introduction to biological investigations: A first year experience in experimental design and scientific communication. *Journal of College Science Teaching, 34*(3), 35–40.

National Research Council. (1999). *Transforming Undergraduate Education in Science, Math, Engineering and Technology*. Executive Summary. Washington, DC: National Academy Press.

Rutledge, M. L. (2005). Making the nature of science relevant: Effectiveness of an activity that stresses critical thinking skills *The American Biology Teacher, 67*(6), 329–333.

Sundberg, M. D. & Moncada, M. D. (1994). Creating effective investigative laboratories for undergraduates. *BioScience, 44*(10), 698–704.