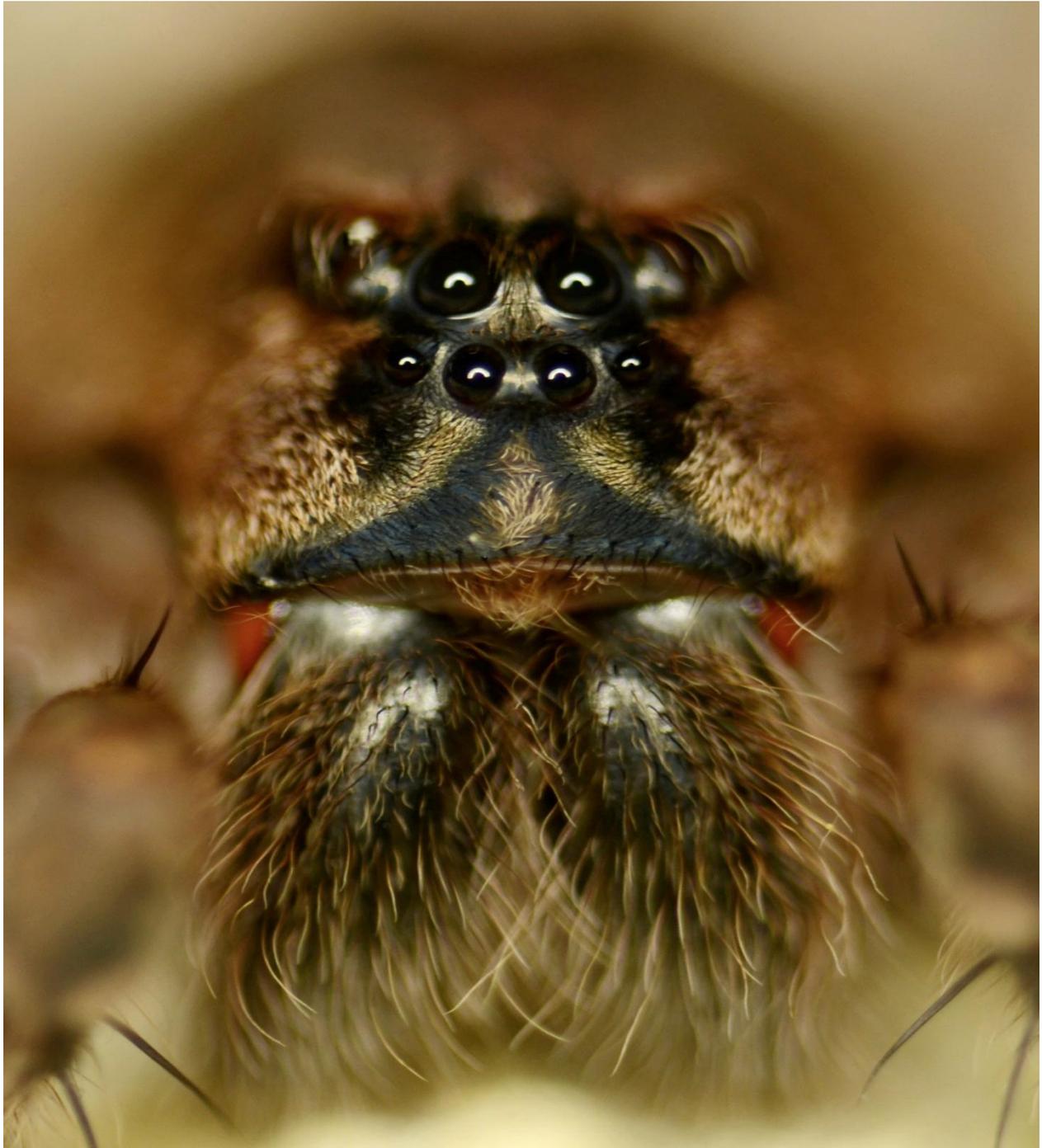


# **Bioscene**

**Journal of College Biology Teaching**



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# Bioscene

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# Bioscene: Journal of College Biology Teaching

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The objectives of ACUBE are:

1. To further the teaching of the biological sciences at the college and other levels of educational experience;
2. To bring to light common problems involving biological curricula at the college level and by the free interchange of ideas; endeavor to resolve these problems;
3. To encourage active participation in biological research by teachers and students in the belief that such participation is an invaluable adjunct to effective teaching; and
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## ARTICLES

### Field Research Studying Whales in an Undergraduate Animal Behavior Laboratory

R. David MacLaren<sup>a,b,\*</sup>, Dianna Schulte<sup>b</sup>, and Jen Kennedy<sup>b</sup>

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**Abstract:** This work describes a new field research laboratory in an undergraduate animal behavior course involving the study of whale behavior, ecology and conservation in partnership with a non-profit research organization – the Blue Ocean Society for Marine Conservation (BOS). The project involves two weeks of training and five weekend trips on whale watch vessels to the Jeffreys Ledge region of the Gulf of Maine to collect behavioral data, and to track and individually identify humpback and fin whales as well as document the presence and behavior of other marine mammals and seabirds. Students learn to use an ethogram of whale behaviors as well as methodology related to individual identification in the field. Students work with BOS scientists, using the BOS field research protocol described herein. In conjunction with the project, students keep a journal, pass data collection and ethogram proficiency tests, and complete data sheets associated with each trip. The project has been very successful, providing students with exposure to multiple scientific skills, and emphasizing competencies over content. We hope it may serve to inspire the development of similar partnerships and/or quantitative field studies in other more practical species.

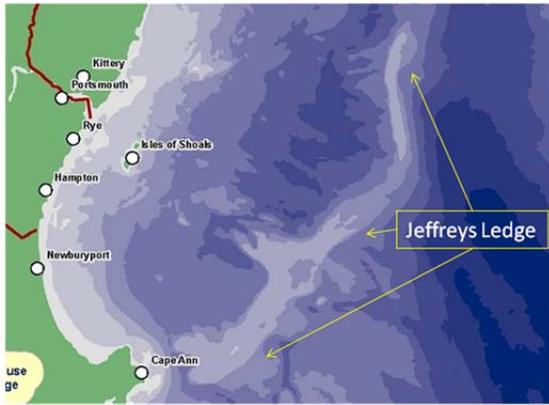
**Key words:** behavior, marine biology, field research, whales, conservation, community outreach

#### INTRODUCTION

A key goal of undergraduate coursework in animal behavior involves providing students opportunities to engage in descriptive and quantitative data collection and analysis in the form of controlled laboratory studies and field data collection. The latter can be difficult to incorporate into a traditional undergraduate course given the logistics associated with planning field experiences and the oftentimes poor quality and quantity of data collected. This article describes a laboratory studying whale behavior, ecology and conservation in the Gulf of Maine (GOM) as part of an undergraduate advanced animal behavior course offered within the Department of Biology at Merrimack College in North Andover, MA.

The laboratory involves collaborating with a non-profit organization, the Blue Ocean Society for Marine Conservation (BOS), in marine mammal research and education. Established in Portsmouth, NH, in 2001, BOS's mission is to conserve the marine environment through education and research in New England. From May through October, BOS naturalists work aboard four commercial whale watch vessels collecting behavioral and physical data on whale, dolphin, and seabird populations in the GOM while educating passengers about marine mammal ecology and conservation.

The BOS/Merrimack relationship began with a regional scan of internships available for college biology majors conducted by Merrimack Associate Professor Dr. R. David MacLaren in November, 2008. MacLaren met with BOS cofounders Dianna Schulte and Jennifer Kennedy soon thereafter, leading to the establishment of a partnership in research and education in January 2009. As part of the collaboration, BOS provides competitive internship opportunities to qualified Merrimack students. BOS's 14 years of research offer a wealth of opportunities for students to engage in the analysis of complex behavioral and environmental datasets, while the field work provides opportunities to engage in unique and exciting research experiences. At the tail end of a successful summer collaborating with BOS in whale research and public education in 2009, Dr. MacLaren began developing the animal behavior course with a lab component inspired largely by the BOS partnership. BOS was very receptive to the idea, seeing it as an opportunity to further their educational mission, draw more interest to their internship program, and acquire additional resources in the form of undergraduate assistants as well as technology for data collection and analysis (e.g. access to greater computational power, geographic information systems and statistical software, digital SLR cameras, and handheld GPS units provided by the College).



**Fig. 1.** Jeffreys Ledge, a seasonal feeding area for numerous species of endangered marine mammals and the region where Blue Ocean Society naturalists travel most frequently to study whales given its proximity to the ports of Rye Harbor, NH, Hampton Beach, NH, and Newburyport, MA. Jeffreys, a productive fishing ground, is a rocky underwater ledge approximately 30 miles long and 5-6 mi wide. The water above the ledge is 150-200 ft. deep, whereas the surrounding water can be as much as 400-600 ft.

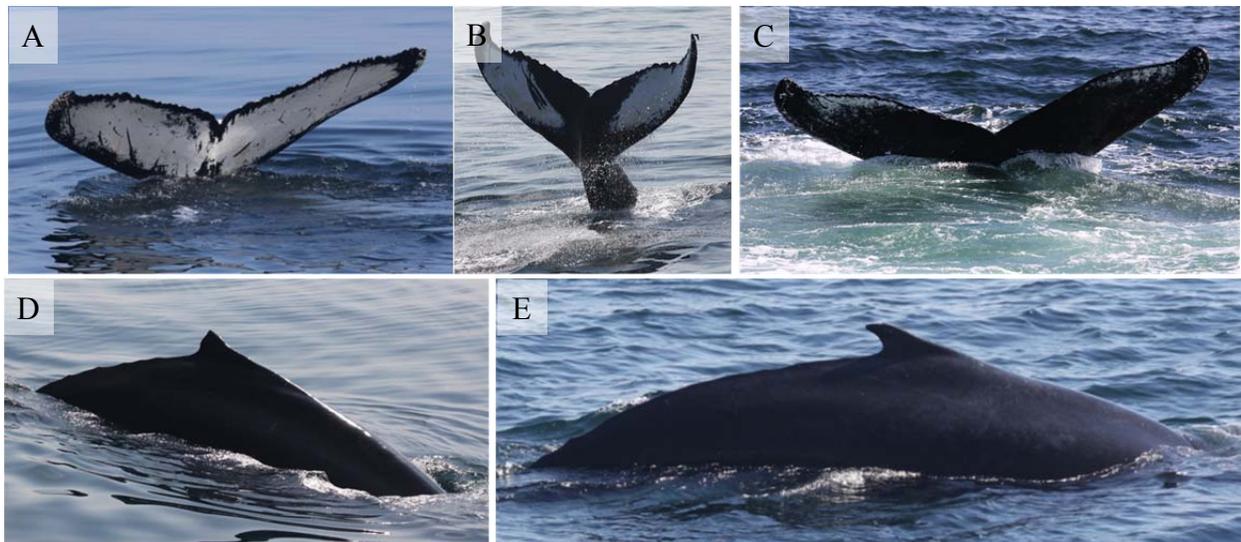
Jeffreys Ledge (a biodiverse and productive fishing ground in the GOM) is BOS's principal study area, given its proximity to the ports of Rye Harbor, NH, Hampton Beach, NH, and Newburyport, MA. Jeffreys is a rocky ledge, similar to an underwater mountain range, approximately 30 miles long and 5-6 miles wide (Figure 1). Due to its unique topography, the ledge is a productive marine ecosystem and major seasonal feeding area for numerous endangered marine mammals including fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), North Atlantic right whales

(*Eubalaena glacialis*), and Atlantic white-sided dolphin (*Lagenorhynchus acutus*) among several other species.

### Incorporating field research into coursework in animal behavior

The animal behavior course met at Merrimack College for three 50-min lectures and one 2.5-hr lab per week for 15 weeks. The lab was divided into two half-semester projects designed to introduce students to careful observation in nature and controlled laboratory experimentation. The laboratory addressing the former is the focus of this paper, introducing students to marine mammal behavior, life history, ecology, and conservation in the region. Students learned to use an ethogram of whale behaviors, methodology related to individual identification and the BOS field research protocol. Upon completion of data collection and ethogram proficiency tests, students collected behavioral data, tracked, and individually identified humpback and fin whales among other marine species in collaboration with BOS scientists on five trips aboard local whale watch vessels. Additionally, they kept journals, completed data sheets for each trip, and were actively engaged in public education as described below.

Although all students entering the course were junior/senior biology majors having taken a common core sequence of Biology I & II, Ecology, and Genetics, they had virtually no exposure to the study of animal behavior – a required course for Merrimack's concentration in "Ecology and Environment" and an open elective for all Biology majors. Moreover, despite Merrimack's geographic location, several students had never been on a whale watch before, or even spent time on the ocean.



**Fig. 2.** Humpback whales (*M. novaeangliae*) possess markings on the ventral surface of their tail flukes used to identify individuals. Flukes vary from all white (T1) to all black (T5) and change little over the course of an individual's lifetime, serving as whale "fingerprints." All identified humpbacks are given permanent names used by all research organizations studying them world-wide. A) Filament's T1 fluke; B) Chromosome's T3 fluke; C) Ivey's T5 fluke; D) Filament's dorsal fin; and E) Flicker's dorsal fin.

The goals of this paper are to describe the whale project, provide student feedback about the course, and reflect on how this laboratory may be used as a model for the development of similar field-based experiences.

### Whale research: A brief history

Marine mammals serve as keystone species in fragile marine ecosystems, inspiring greater environmental appreciation and awareness. With many species near extinction in the mid-1900s, early cetologists launched field studies, finding it was possible to repeatedly locate and recognize individual whales (e.g. Katona *et al.*, 1979; Whitehead and Payne, 1981; reviewed in Hammond *et al.* 1990; Figures 2 and 3). Photo identification and data on resightings of individuals provided valuable information on population parameters, among other life history traits (Hammond *et al.*, 1990). Individual identification thus paved the way for modern whale behavioral studies (Payne *et al.*, 1983) and is now common practice in studies of animal behavior.

Although the threats have changed over time (reviewed by Whitehead *et al.*, 2000), conservation persists as the principal thrust of whale research. As some risks to whales have diminished since the worldwide ban on commercial whaling in 1986, new threats have emerged including entanglement in fishing gear, disturbance by and/or collision with boats, pollution, and climate change. Conservation concerns and the ability to recognize individual animals have ushered in a new era of field research that includes an increasing number of studies emphasizing long-term monitoring of known individuals to assess cetacean sociality and the selective forces that shape patterns of whale communication, life history, behavior, and ecology. Moreover, cetacean behavioral research compares favorably in quantity and sophistication with those of terrestrial mammals such as ungulates and primates (Whitehead and Dufault, 1999), revealing a number of parallels between whale societies and those of

terrestrial mammals (Conner *et al.*, 1992; Smolker *et al.*, 1992; Weilgart *et al.*, 1996).

### PROCEDURE

Two laboratory manuals were developed by Dr. R. David MacLaren in collaboration with BOS cofounders Dianna Schulte and Jennifer Kennedy. The first is a 43 page document, “Whale Behavior and Ecology Lab Handbook,” which includes BOS background information; policies, procedures, meetings and deadlines for course field trips; a project overview; description of a typical whale watch; and information regarding the ecology and species typically observed on Jeffreys Ledge. The second manual, “Guide to Whale Data Recording and Sequencing,” describes the research protocol used for data collection including the ethogram used for behavioral sequencing.

Week 1a. On-campus lab meeting--whale project introduction: The first laboratory involved reviewing whale behaviors, data collection, educational approaches, schedules, and general policies described in the lab handbook. Students viewed videos of whales exhibiting the behaviors to be learned in the ethogram and practiced behavioral sequencing. Students also learned techniques used to distinguish among different whale species in the field and how to identify individuals.

### The Ethogram

Forty years of whale behavioral studies in the GOM have provided a greater understanding of the function of over eighty discrete behaviors exhibited by our study species, leading to the development of an ethogram—a comprehensive list of well-defined behaviors that whales exhibit at the water’s surface. In mastering the ethogram, students learned to distinguish between short-duration behavioral displays (e.g. breaches or breaths) and long-duration behaviors (e.g. “logging” and associations between individuals) (Altmann, 1974). The behaviors described in our ethogram represent humpback



**Fig. 3.** Sample fin whale (*B. physalus*) dorsal fin and chevron photos used for individual identification: A) dorsal fin of whale #9820; B) dorsal fin of whale #0613; C) Chevron of whale #0720; and D) Chevron pattern of whale #0613.

whales, but some are also seen in other species. To record behaviors quickly and efficiently, behavior codes are used to describe specific activities. Table 1 contains sample behaviors and codes found in the whale ethogram. Students were asked to memorize the codes for the most common behaviors observed in the field.

### Individual Identification

Individual identification is another important aspect of long-term field studies. It is therefore critical that students learn techniques used for identifying individuals *within* species—specifically humpback and fin whales. Humpbacks can be individually identified using distinctive color patterns on the ventral surfaces of their flukes, marks on the fluke’s trailing edge, dorsal fin shape, and scars (Katona *et al.*, 1979; Figure 2). Fin whales are identified using back pigmentation patterns (the chevron), dorsal fin shape, and scars (Figure 3). The best photographs of identifiable individuals from each encounter are compared with a catalog of existing photo-identification records to determine the identity of all whales observed. Students were asked to identify individuals encountered in the field using a catalog provided by BOS.

**Week 1b. First weekend on the water:** Week 1 culminated in the first of five 5-hr weekend whale watch trips departing from an affiliated whale watch company on the New Hampshire coastline. The College paid a fee of \$15-20 per student per trip to the whale watch companies. No fees were paid to BOS scientists as they were compensated by the

whale watch companies for serving as naturalists hosting the trips. Students did not collect data on their first trip, using it as an opportunity to familiarize themselves with the boat, see whales for the first time, and observe others collecting data.

**Week 2a. On-campus lab meeting #2:** Students took a proficiency exam in week two, assessing their grasp of the material in the handbook, competency in behavioral sequencing using the ethogram, and ability to identify individuals using an abbreviated photo catalog of named whales. The meeting also provided time to address student questions and concerns before collecting data the following weekend.

**Week 2b. Second weekend on the water:** At the end of week 2, students began the first of four weeks of data collection in collaboration with BOS scientists aboard commercial whale watch vessels. The following protocol was typically used:

1. Passengers boarded 15-25 minutes before departure and received safety announcements from the captain and an introduction of the crew.
2. The naturalist invited passengers to check out the posters and displays and to look for marine life on the way to Jeffreys Ledge. Students used this time to look for whales and marine debris or to talk with passengers about whales and marine ecology etc.
3. Once we got within 5-10 miles from potential sightings, the naturalist gave an introduction speech on the Gulf of Maine, whales in general, and the species we might see that day.

**Table 1.** Sample codes and descriptions of behaviors exhibited by humpback and other large whale species included in the ethogram used for behavioral sequencing (see methods for further explanation).

| Code  | Description  |
|---|--|
| FLU (fluke)   | Bringing the tail flukes into the air at the beginning of a dive so that the ventral pigmented surface (humpbacks) would be visible from behind the animal.  |
| LTA (lob tail)  | Slapping the tail ventral surface down on the water after an even arc of the tail stock (as opposed to the sporadic uneven motion of a tail breach).   |
| BUSLP (belly up flipper slap)   | Pectoral flipper is brought into the air and dorsal side is slapped onto the surface. BUSLP’s may take place from both flippers simultaneously if the whale is on its back. If both flippers are slapped down at exactly the same time, it is recorded as a DBLBUSLP (double belly up flipper slap). |
| S (spout)   | Animal exhales, followed by inhaling. Blowholes are above the surface and a misty column is formed.  |
| BRSB (spinning head breach)   | The highest and most spectacular of all breaches; animal comes 2/3 to all of the way out of the water, while spinning up to 360 degrees. Generally, one flipper is held close to the side, while the other is outstretched. Animal usually falls on its side or back.                                |
| SND (sounding dive)   | Animal arches its back tightly and appears to be taking a deep dive, but does not bring flukes into air. Animal may or may not actually be diving.   |
| VBRL (vertical lunge)   | Animal’s body is perpendicular as it breaks the water (often up to the eyes). Evidence of feeding is seen. Whale usually sinks vertically as well.   |
| BLC (feeding bubble cloud)  | Large circular patch (10-13m diameter) of fine bubbles appears. Animal surfaces after 5-20 seconds of bubbles appearing, with mouth open, or with mouth closed but filtering.  |
| *LOG (logging)  | Animal is stationary at the surface, breathing at regular intervals, and appears to be in a resting state.   |
| *CTB (close to boat)  | A social behavior. Animal is directly orienting its behavior to the vessel, usually in a curious manner.   |
| *NURSE  | Calf makes one or more shallow dives directly in the vicinity of its mother’s tailstock area as the mother continues moving along at the surface.  |
| * <u>continuous</u> behaviors and should be recorded with a <i>start and end time</i> . |  |

4. We spotted marine species and the naturalist gave a commentary on the species' natural history and its identification, and its life history (if it was a whale that was recognized from past whale watches). Students collected detailed data and helped the naturalist with photo identification.
5. During the return trip, the naturalist and interns again brought around displays (whale bone, baleen, plankton sample, whale sounds) and answered passenger questions.
6. As we docked, the naturalist gave a wrap-up summary of what happened on the trip.

Students were responsible for collecting detailed data pertaining to the animals observed and answering passenger questions about whales and the local marine environment. The amount of detail in the data collected depended on the species observed. At minimum, a trip summary sheet was completed recording physical data such as weather conditions and tides (Figure 4). A behavioral sequencing sheet was also completed for all humpback, fin and right whale sightings. The field protocol was taught to students as described below.

Student materials required for data collection included a handheld GPS, pen, digital watch, trip summary sheet, and sequencing sheets all attached to a clipboard. Of particular importance was that students be able to hold the clipboard, write and note the time all at once. As soon as the boat left the harbor, students began logging the time and position (latitude and longitude) every 10 minutes to record the boat's track line throughout the trip. Students logged animal sightings onto the trip summary sheet as described in Table 2.

### Behavioral Sequencing

Behavioral sequencing, a method of data collection used in animal field studies, provides a chronological record of behaviors along with notes on individual identification, position, and other

significant activities in the area. Sequencing allows analysis of many subtle aspects of animal behavior and provides a general record of activity patterns for studying population dynamics. Students assign one column of the behavioral sequencing sheet to each whale in the immediate vicinity. The whale's name or dorsal fin description is written at the top of the column. The whale's behavior is documented in sequence using the behavioral codes in the ethogram along with the time, to the second, it occurred. It is important for students to quickly distinguish the dorsal fin of each whale in the group (Figures 2 and 3) before attempting to record the whales' behavior to ensure proper identification of individuals sequenced simultaneously in separate columns. Each line on the sequence sheet represents one point in time. Thus, each successive behavior gets recorded on a new line. Only behaviors that occur simultaneously are written on the same line. The goal is to recreate the exact sequence of behaviors from the information recorded on the data sheet.

Students occasionally encountered continuous behaviors as well (e.g. LOG, NURSE, Table 1). A whale might do other things during the course of the continuous behavior. For example, a whale can be "logging" for 10 minutes, but take a breath every minute. When a continuous behavior began, students wrote "Start LOG" (or whatever behavior it was doing) and the time followed by "End LOG" and the time when the behavior ended. If/when students became confused or missed behaviors, they were instructed to write "MISS" in the column at the time where there was a lapse in data collection. Otherwise someone looking at the data later on would mistakenly assume nothing had happened during that time interval.

### Documenting Associations

We emphasized to students the importance of recognizing and recording "who is with whom" (i.e.

**Table 2.** Students logged animal sightings into the trip summary sheet (MacLaren *et al.*, 2012) as described below.

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**Animal Sightings:** The largest section of the trip summary data sheet is the area to record all mammal and fish sightings. Refer to the sample sheet (MacLaren *et al.*, 2012).

**Time:** Write the hour and minutes of the first time we see a whale (or seal, shark, tuna, etc.). Below that, in the same box, write the time when we leave that animal.

**Location:** Write the Latitude and Longitude, in decimal degrees, which correspond with the first sighting time. Below that write the latitude and longitude that correspond to the time when we leave the animal.

**Sp. #/A:** Species/number/Association. Write the species code (e.g. humpback = Mn for *Megaptera novaeangliae*) and how many are in the area or traveling together. If there is more than 1 animal, note if they are associated or not (A=associated, N=not associated). (e.g. Mn/3/A = 3 humpbacks associated; Mn/3/N= 3 humpbacks not associated)

**ID:** Write the name of the humpback or finback, if known. If it is unknown, identification will be determined after the trip using the catalog back in the lab.

**Behavior:** Summarize the major and minor behaviors of each sighting by using behavior codes from the ethogram.

**Photos:** Write the digital image numbers of all shots taken so that each photo can be associated with the correct behavioral data taken on each whale.

**Buoys:** Record the number buoys of each type seen within a 1-mile radius of sighting.

**Birds:** Circle codes for the major bird species in the area.

**WW Vessels:** Circle the vessels that are at the same sighting. If one of the boats is arriving or leaving, please indicate by noting "POW-leaving 12:32" or "POW-arriving 11:45". This helps BOS link sightings of the same whales, and gives them a better idea how many non-identifiable whales are really out there.

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associations/changes in group structure) in the field as a critical aspect of the study of social behavior. Association is defined as the state of being within 1.5 body lengths of each other and coordinating behaviors (e.g. diving, surfacing together). Students were instructed to document associations as follows:

**JOIN** (MacLaren *et al.*, 2012): When two or more whales associate, a horizontal line is drawn connecting the columns in which those whales are listed. The time they joined is recorded in the left margin next to that line. If the whales are associated upon initial approach, a horizontal line connecting their names is drawn immediately.

**SPLIT** (MacLaren *et al.*, 2012): If a whale leaves a group, a horizontal line with a diagonal slash is drawn between that whale's column and the column(s) of the other whale(s) in the group, noting the time in the left margin.

**OFF** (MacLaren *et al.*, 2012): When an animal leaves the vicinity, the boat leaves the animal, or the student is no longer recording the animal's behavior, "OFF" is written directly below the last behavior recorded for that animal followed by the time and location (lat/long).

#### **Documenting Other Activity in the Area**

Often, when sequencing whales, we see other activity that is too far away to sequence effectively. When this happened, students were instructed to record the species, number of animals, position, time, behaviors (if known) and photos taken on the trip summary sheet. Lastly, students were asked to record any information that may be significant to the whales' behavior in the left margin of the sequencing sheet including birds and their concentration, bait patches, tuna, sharks, sunfish, nets/buoys, and boat activity.

**On-campus lab meetings, weeks 3-5:** Beginning in week 3, students were assigned relevant primary literature to improve their general knowledge and presentation of information to passengers. The purposes of these weekly meetings were to provide students opportunities to ask questions, discuss the trip(s), and address the weekly readings, requiring no more than 30-60 min of lab time. Students also kept journals to log their hours at sea, summarize each trip, record their ideas for improvements in data collection, and reflect on their experience. Journals were reviewed weekly, beginning week 3.

**Weekends 3-5 on the water:** Students continued field data collection and public education as described above.

#### **Assessment of student learning**

Learning assessment was conducted by the course designer and instructor and included a whale data collection, behavioral sequencing and ethogram proficiency test; species identification and humpback whale fluke matching quiz; accurate and organized completion of four trip summary and behavioral sequencing sheets; five whale journal entries; several

short essay questions pertaining to the whale project built into the first lecture exam; and attendance and participation in laboratory meetings and whale watches.

#### **ASSESSMENT**

Student evaluations of the Animal Behavior laboratory were positive, rating it highly overall (3.86 out of 4). Specifically, they found the labs to be well-organized/prepared (4.0), and the instructor's teaching effective (4.0). They also indicated the course challenged them to think critically (3.43), lab assessment techniques accurately reflected course material (3.71), and grading practices were fair (3.57). Student comments regarding the lab included the following:

*"[The instructor] is so enthusiastic about the subject and took time on weekends to take us whale watching...really got us involved with animal behavior"*

*"One of the best labs I have taken at Merrimack"*

*"This was by far one of, if not the best lab experience I've had at Merrimack"*

At the end of the semester, students were required to write a "credo statement"—a 3-4 page document in which students explain, in their own words and from their own perspective, what they perceive to be the value of being knowledgeable about animal behavior and its interdisciplinary significance. We asked that they be introspective and address the skills and experiences that were of greatest value to them as a biology student. Lastly, we asked them to provide their opinion of whether they felt Animal Behavior is a course all undergraduate Biology majors should take and why they felt that way. We attached the learning goals for the course (Table 3) to the credo to be used as a guide for the type of understanding we were attempting to achieve. Like the standard course evaluations, the credo statements were positive. Student reflection on the whale laboratory included the following:

*"I found the lab especially beneficial in that it taught me how to conduct research, design an experiment and sharpen my scientific writing skills."*

*"Despite being wary and almost opposed to the thought of going on whale watches every weekend, I found in the end that it allowed me to gain very important research and communication skills. Although I may never record data on a whale watching trip again, the skills I acquired can transfer over to any aspect of data collecting."*

*"The lab made me appreciate how much effort actually goes into behavioral data collection. If I was simply told how to collect data on whales, I would never have appreciated how complicated it gets."*

*"I am an environmental science major and this course has helped me see the potential I could pursue in the field. It has given me practical knowledge about how the study of behavior is undertaken."*

**Table 3.** Expected learning outcomes for the Animal Behavior course.

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After completion of the course students will:

1. Have a broad knowledge and understanding of animal behavior.
2. See the information presented and discussed in this course not as a collection of facts, but as an ongoing research effort.
3. Be able to read and understand primary literature articles in the field of animal behavior.
4. Learn and appreciate many of the analytical and technical skills used in the collection of data presented in this course.
5. Gain experience conducting behavioral field studies and laboratory studies (experimental design).
6. Identify proximate and ultimate questions and hypotheses to explain observed behaviors.
7. Be able to discuss the evolution of different reproductive strategies (male and female) and mating strategies (e.g., monogamy, polygyny)
8. Understand the evolution of animal signals, why they evolve, and how they are used to communicate.
9. Learn and/or sharpen your critical thinking skills.
10. Become a better science writer/critic.

---

*“It is because of the whale lab that I realize that I belong in the field. Office work, sitting behind a desk or working in a chemistry lab do not suit me. It was being out there that made the greatest impact”.*

*“Animal Behavior provided me with an understanding of how experimental design is so critical in the field of ethology.”*

*“Gaining field experience whale watching has already played a significant role in obtaining an internship at the end of the semester.”*

### DISCUSSION

In our efforts to analyze BOS data for publication and raise awareness of marine environmental issues, we recognize the valuable contribution Animal Behavior students made in support of BOS’s mission. Additionally, two students continued their research after the course was over and presented at regional and national conferences. Furthermore, Animal Behavior has served as an excellent intern recruitment tool for BOS. Word spread quickly through the Department of Biology at Merrimack beginning in fall 2009 when the course was first offered, producing eight Merrimack student BOS internship applicants in the past two summer research seasons (2010 and 2011).

BOS’s mission, in addition to research, is to increase awareness of marine conservation issues through education/public outreach; to help the public understand and appreciate the diversity of life in the oceans and to realize the need to protect these creatures and their habitat. To this end, BOS strives to make the whale watches as informative as possible by addressing passenger questions and incorporating hands-on activities, exhibits, and visual aids. Animal Behavior students assumed the majority of this responsibility, benefiting from ample opportunities to share their newly-acquired knowledge and practice oral communication skills through passenger education. BOS’s mission of environmental awareness and appreciation of nature clearly resonated with students. The whale project thus went beyond the study of animal behavior as students experienced a clear shift in their attitudes towards marine conservation while recognizing the naïveté of the general public regarding such issues—perhaps the

most important and unique objectives the course has to offer. Moreover, the experience gave them an appreciation for the rigor, complexity, and level of detail involved in field research.

Offered on a two-year cycle, Fall 2011 enrollment in Animal Behavior was over three times that of the initial offering (from 8 to 28 students). Improvements for 2011 included providing students with the option of expanding the project from a six-week field experience to a full semester project involving significant data entry and analysis. All of the data collected are added to the BOS database, which students can “mine” for noteworthy, statistically testable relationships/trends. Engaging students in an examination of complex behavioral and environmental data culminating in a written report of their findings provided a more comprehensive laboratory experience, involving them in the process of science from field observation and hypothesis generation to data analysis and conclusions. Several students in the 2011 class chose this option (over an alternative fish behavior project) leading to the completion of a pair of quality lab reports that may evolve into senior theses.

For geographically constrained educators interested in developing a similar lab experience, the individual identification and behavioral sequencing work may be done on a smaller scale using videos of whales in the wild, especially in dry labs where several computers are available. Alternatively, this kind of study may be applied to numerous more ‘practical’ species where an ethogram of discrete behaviors can be constructed (e.g. squirrels). To understand behavior, students must first spend time familiarizing themselves with the species to identify the range of behaviors typically observed, thus generating a species-typical catalog of behaviors (or becoming familiar with an existing ethogram). Constructing a useful ethogram requires observing animals, taking careful notes, and making sense of the observed behaviors. Students end up with an annotated catalogue of behavioral patterns grouped in a coherent fashion that describe what a given species does in a given environment. Project objectives may include becoming more aware of biases present in making observations and collecting data; practicing

formal methods of behavioral observation; practicing the skill of defining and categorizing observations in an objective manner; considering different strategies for collecting data; practicing the conversion of observations into objective, quantitative information; and developing and comparing ethograms. Exercises like the whale project or a campus squirrel study make it clear to students that in order for behavior (or any observation for that matter) to be scientifically analyzed, it must first be objectively quantified, but it cannot be quantified without first being explicitly defined. Such projects thus instruct students to practice turning casual subjective observations of animal behavior (be it whales on Jeffreys Ledge or squirrels on campus) into objective, quantitative data. Methods such as developing a time budget may then be applied to express patterns in behaviors observed through the observational techniques. In the case of squirrels for example, the time budget may reflect the amount or proportion of time an individual spends engaged in different behaviors (e.g., feeding, resting), performing different classes of behavior (e.g., resting versus movement) and/or located in specific parts of the environment (e.g., canopy, ground, nest cavity).

In conclusion, the whale laboratory or similar quantitative field study of animal behavior is a good model for how to provide students with exposure to multiple scientific skills (e.g. experience handling complex datasets, oral communication/public education, observational and data recording skills, practice in following a research protocol, working as a research team, multitasking in data collection etc.) that emphasize competencies over content. The whale project in particular is all the more valuable given its community service component along with student recognition of the importance of *accurate* data collection given their direct contribution to BOS's research efforts. The whale project exemplifies how partnering with an area non-profit research organization may enrich/enhance field laboratory experiences. We hope that the partnership described herein may inspire the development of similar college laboratory and non-profit field research collaborations in the future.

#### ACKNOWLEDGEMENTS

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# Experimental analysis of cell function using cytoplasmic streaming

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**Abstract:** This laboratory exercise investigates the phenomenon of cytoplasmic streaming in the fresh water alga *Nitella*. Students use the fungal toxin cytochalasin D, an inhibitor of actin polymerization, to investigate the mechanism of streaming. Students use simple statistical methods to analyze their data. Typical student data are provided.

**Key words:** Cytoplasmic streaming, cytochalasin, student t-test.

## INTRODUCTION

The development of effective laboratory exercises for large first-year university classes can be a challenging task. We describe here a simple laboratory class that requires students to observe cell structure and to analyze some aspects of cell function. The exercise demonstrates the basic principles of experimental technique and analysis of data.

We have run this experiment for 10 years in our first-year cell biology class using standard laboratory equipment. It can easily be completed in 3 hours by very inexperienced students but also provides interest for students with some previous knowledge of biology. In our classes, groups of 14-16 students are led by a demonstrator (teaching assistant) who is typically a graduate student in a biology discipline.

Cytoplasmic streaming is a phenomenon seen in many large eukaryotic cells in which cytoplasmic particles, such as cellular metabolites, are transported continuously along the cytoskeleton, thus maintaining an even distribution of cytoplasmic contents (Lodish *et al.*, 2008). Some freshwater algae such as *Chara* and *Nitella* consist of a branching array of elongated cells (internodal cells) connected at nodes (Casanova, 2009). The process of cytoplasmic streaming can be readily observed in the internodal cells using a light microscope (Wessells *et al.*, 1971; Bradley, 1973). Since the cells are elongated and the cytoskeleton is formed of parallel actin bundles running longitudinally, particles stream in a linear manner along the cell. Consequently, the rate of streaming can easily be measured using an eye-piece micrometer and a stopwatch.

The motive force for cytoplasmic streaming is provided by an interaction between the actin cytoskeleton and myosin-coated endoplasmic organelles (Shimmen & Yokota, 2004). The mechanism of streaming can be studied using cytochalasins. Cytochalasins are fungal products that bind to the plus end of actin filaments, block the interaction between myosin and actin and thus block cytoplasmic streaming (Wessells *et al.*, 1971;

Bradley, 1973; Collings, Wasteneys & Williamson, 1995).

In this class, students measure the rate of streaming in cells of *Nitella* and determine the effect of cytochalasin D on streaming. Students analyze their findings using simple statistical analyzes and discuss the importance of controls.

## Learning Objectives

After completing the exercises presented in this paper, students should be able to:

1. Describe the process of cytoplasmic streaming.
2. Measure the rate of cytoplasmic streaming in the alga *Nitella*.
3. Explain the mechanism of cytoplasmic streaming.
4. Understand the principles of experimental design, the use of appropriate controls and analysis of data.
5. Use simple statistical methods to analyze experimental results.

## MATERIALS AND METHODS

Students work in pairs; two pairs form a group of four.

### Materials

Each student needs the following personal protective equipment:

- Enclosed footwear
- Safety glasses
- A laboratory coat
- Disposable gloves
- Material Safety Data Sheets (MSDS) for dimethyl sulfoxide (DMSO) and cytochalasin D

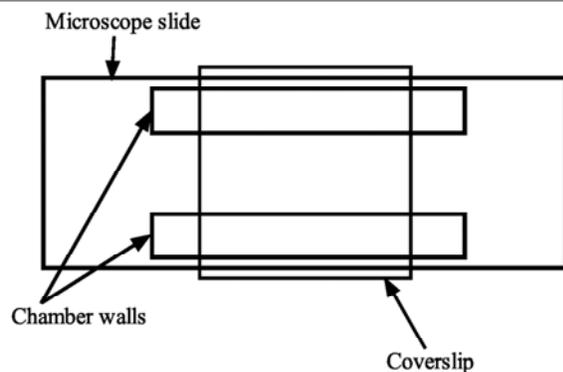
Each pair of students need:

- a compound binocular microscope with an eyepiece micrometer;
- a stop-watch;
- a modified microscope slide made by cutting 0.5cm x 2.5cm sections of a standard microscope slide and gluing them onto another slide to create sidewalls (Figure 1);

- a sample of *Nitella* in pond water; *Nitella* is commonly found in freshwater streams and ponds (Casanova, 2009);
- disposable plastic transfer pipettes.

The supervisors need:

- disposable gloves for handling DMSO and cytochalasin D;
- a solution of 200 $\mu$ M cytochalasin D in 2% DMSO kept on ice;
- a 2% solution of DMSO, kept on ice;
- a micro-pipette suitable for dispensing 50 $\mu$ L.



**Fig. 1.** Diagrammatic representation of the modified microscope slide.

### Initial measurement of cytoplasmic streaming

*For each pair of students:*

A sample of the fresh water alga *Nitella*, containing at least 5 internodal cells, was removed from pond water and placed between the sidewalls of the modified microscope slide. A coverslip was placed over the sample and the chamber filled with pond water (about 300 $\mu$ L filled the chamber). The cells were left for several minutes until streaming resumed.

The cells were observed for the appearance of cytoplasmic streaming with a light microscope, using a 10x objective. One eyepiece was fitted with an eyepiece micrometer. The time taken (in seconds) for a particle to move the length of the micrometer scale (approximately 1mm) was measured 5 times in 5 different cells. Following a discussion on the possibility of cell size affecting the rate of streaming, students selected cells of varying lengths to study and measured the length of each cell using the eyepiece micrometer.

It is important in these experiments that the microscope light is turned off between measurements. In some cases, the rate of cytoplasmic streaming increased slightly as the experiment proceeded. It is most likely that this is attributable to a warming of the incubation fluid by the microscope light. We have not found this to impact significantly on the results obtained, but it can lead to confusion for some students.

### Effect of cytochalasin D

Before starting this part of the experiment, teaching staff and students discussed the importance of controls and what would constitute a suitable control when testing the solution of cytochalasin D used in this experiment.

The addition of cytochalasin D was used to study the mechanism of streaming. Cytochalasin D was dissolved in dimethyl sulfoxide (DMSO) to make a 10 mM solution (5mg cytochalasin D in 1ml DMSO). The stock solution was stored at  $-20^{\circ}\text{C}$ . The stock solution was diluted with pond water to make a 200 $\mu$ M working solution.

DMSO may readily penetrate skin and so it is essential that gloves are worn when handling the DMSO or the solution of cytochalasin D in DMSO. Only the experienced teaching assistants are permitted to handle the working solution of DMSO to further reduce any potential risk. Technical staff prepared the working solutions of DMSO and cytochalasin D before the class and these were given to the teaching assistants.

*For one pair of students/group:*

A 50 $\mu$ L aliquot of 200 $\mu$ M cytochalasin D was added to the chamber by the teaching assistants and mixed by gently pipetting up and down (giving a final concentration of cytochalasin D of approximately 30 $\mu$ M). Cytoplasmic streaming was sequentially measured in each of the five cells at 5 minute intervals after the addition of cytochalasin D. After being treated with the drug for 15 minutes, the cells were washed extensively with several changes of deionised water by using absorbent paper to draw the liquid out from underneath the coverslip and then replacing with deionised water. The chamber was then refilled with pond water. Cytoplasmic streaming in the cells was measured in each cell at 5-10 minute intervals for a further 60 minutes.

*For the second pair of students/group:*

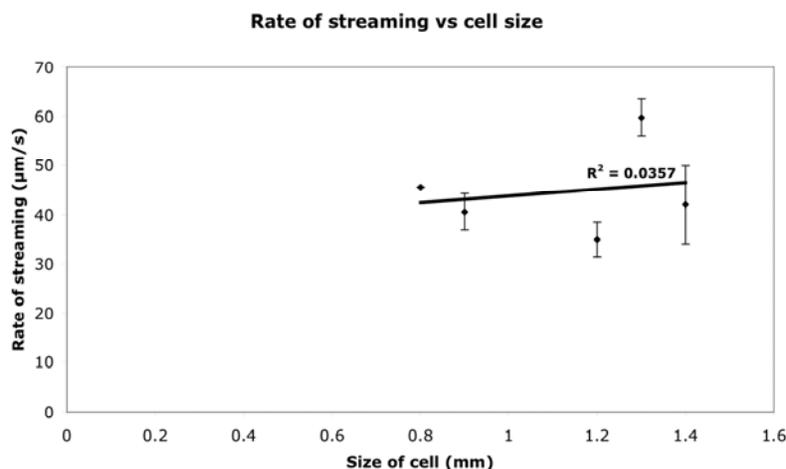
The above procedure was performed in a separate group of cells using 50 $\mu$ L of 2% DMSO in place of the cytochalasin D solution. The results from this pair of students formed the control for the experiment.

Each group then had two sets of data: an experimental group of cells which had been exposed to cytochalasin D and a control group of cells which had been treated in an identical way except that the DMSO solution contained no cytochalasin D.

*Analysis of data:*

The rates of streaming (in  $\mu\text{m/s}$ ) were calculated and statistical analysis of the data was performed. The means and standard deviations were calculated for each time-point. Student's t-tests were used for analysis and differences were considered significant when  $p < 0.05$ .

The class coordinator collected multiple sets of results from each session. These were used in a post-lab workshop to demonstrate consistency in the effect



**Fig. 2.** Rate of cytoplasmic streaming versus cell size (length of cell) in *Nitella*. Results for each cell are presented as mean $\pm$ S.D. The horizontal line is a linear regression of the means; the slope is not significantly different from 0 ( $R^2 = 0.0357$ ).

of the cytochalasin D on the rate of streaming. There were typically 40-50 different groups each year and the findings were consistent in the vast majority of these.

## RESULTS

### The results presented here are representative student results.

#### *Effect of cell size on rate of streaming:*

There was no consistent difference in the rate of streaming in cells of different lengths from 0.8 to 1.4 mm. (Figure 2). These findings indicate that there is no need for students to find similarly sized cells to carry out this experiment.

#### *Effect of addition of cytochalasin D on the rate of streaming:*

The rates of cytoplasmic streaming were measured in 5 different cells of *Nitella* before the addition of cytochalasin D or DMSO and then at 5-minute intervals after the addition of cytochalasin D or DMSO. The cells were washed at  $t=15$  minutes and the rates of streaming were measured subsequently at 5-10 minute intervals (Figure 3).

In cells treated with cytochalasin D, the rate of cytoplasmic streaming was reduced substantially (Figure 3). At 15 minutes after the addition of cytochalasin D, Student's t-test analysis demonstrated there was a significant decrease in the rate of streaming ( $p < 0.01$ ) compared with the rate before the addition of cytochalasin D. The cells were washed 15 minutes after the addition of cytochalasin D. The rate of streaming did not change initially but, by 30 minutes after the cytochalasin D was washed from the cells (45 minutes after cytochalasin D was originally added), the rate of streaming had increased and reached a rate similar to the original rate ( $p > 0.1$ ).

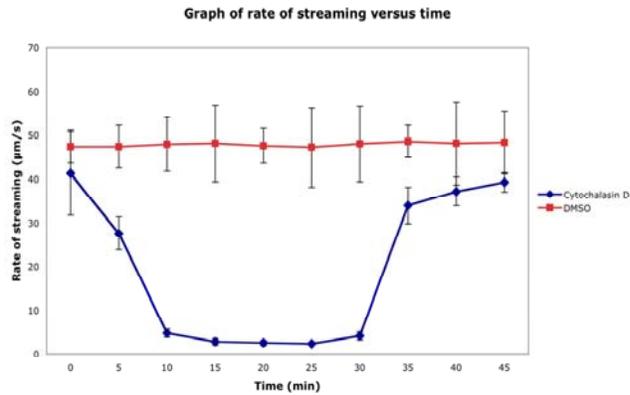
In cells treated with DMSO there was little change in the rate of streaming over the course of the experiment from time = 0 when the incubation was first set up, through the addition of DMSO, the washing out of the DMSO, to the end of the

experiment. Student's t-test analysis showed that the rate of streaming did not significantly vary throughout the experiment; specifically, such analysis showed there was no significant difference ( $p > 0.1$ ) in the rate of streaming 15 minutes after the addition of DMSO at a time when cytochalasin D had had a major effect, or at the end of the experiment (45 minutes after addition of DMSO and 30 minutes after DMSO had been washed out of the system, during which time cytochalasin D-treated cells had recovered).

These results demonstrate clearly that cytochalasin D inhibits cytoplasmic streaming in *Nitella* and that DMSO, the solvent for cytochalasin D, has no effect. The results shown here are from one typical student experiment. In many cases, cytochalasin D completely blocked streaming and the recovery from blocking was more rapid than that shown here. It is, however, routine for students to get qualitatively consistent results from group to group and from year to year.

## DISCUSSION

This experiment provides a simple and technically undemanding way of meeting the Learning Objectives set out earlier in this paper. First year students find it relatively easy to see cytoplasmic streaming occurring and to measure its rate. The class can be structured in a number of ways depending upon the abilities of the students. If the aim of the class is to allow students to observe and measure the rate of cytoplasmic streaming, then very detailed instructions of all steps to be performed can be given. Alternatively, if the aim is also for students to explore experimental design, teaching assistants can lead small group discussions to allow students to shape the experiment. For example, questioning whether cell size affects the rate of streaming requires cells of different sizes to be measured. A discussion of the importance of sample size for statistical analysis requires students to consider the



**Fig. 3.** Rate of cytoplasmic streaming versus time for cells of *Nitella* treated with cytochalasin D or DMSO.

number of cells to be measured. Consideration of appropriate controls can be explored. Students can also determine whether the length of time that the preparation has been set up has any effect upon the rate of streaming and they can analyze their findings using a variety of statistical techniques. We routinely use Student's t test to analyze the results but we have also used non-parametric tests such as the Mann-Whitney U test which enables us to discuss the important difference between parametric and non-parametric tests.

In the above account, we have used cytochalasin D dissolved in DMSO as the effector with an equivalent solution of DMSO as the experimental control. Other cytochalasins (e.g. cytochalasin B) also interfere with actin-myosin interaction while some (e.g. cytochalasin C) have little or no effect (Foissner & Wasteneys, 2007). This option for variability has permitted us to alter the protocol slightly from year to year to avoid the direct passing on of data and discussion from students who have previously completed the unit. This is a common occurrence in our experience, especially between students in student residences. In some years we have changed the alga being studied (*Nitella/Chara*), used cytochalasin B instead of cytochalasin D or used a solution of cytochalasin C, an agent which does not affect the rate of cytoplasmic streaming, in DMSO in place of DMSO.

The use of cytochalasin C in place of DMSO raises the question of whether it is an appropriate control and, if not, what controls should be used. In comparing the effect of cytochalasin D dissolved in DMSO with cytochalasin C dissolved in DMSO, students found that cytochalasin D + DMSO inhibited cytoplasmic streaming while cytochalasin C + DMSO did not. In the ensuing class discussion, nearly all students agreed that they demonstrated that cytochalasin D inhibited cytoplasmic streaming whereas cytochalasin C did not. When they reached this conclusion, we asked the students if they thought that the experiment was adequately controlled. Most thought it was. However, an equally valid interpretation of the data is that DMSO inhibits

cytoplasmic streaming but the inhibitory effect is blocked by cytochalasin C but not by cytochalasin D. Therefore, cytochalasin C + DMSO is not an adequate control. We found this to be an effective way of showing students the importance of controls.

#### ACKNOWLEDGEMENTS

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# In Darwin's Footsteps: An On and Off-Campus Approach to Teaching Evolutionary Theory and Animal Behavior

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**Abstract:** The study of evolutionary theory and fieldwork in animal behavior is enriched when students leave the classroom so they may test their abilities to think and act like scientists. This article describes a course on evolutionary theory and animal behavior that blended on campus learning with field experience in the United States and in Ecuador and the Galápagos Islands. The on-campus portion of the course covered Darwin's life and travels, evolutionary theory, natural history of the Galápagos Islands, and field ecology techniques. The travel component was a two-week excursion where the students studied the ecology of the islands directly. Unlike other courses described in the literature, this one was offered to science and non-science majors alike, demonstrating the benefits of offering these kinds of learning experiences to a wide variety of undergraduates. Logistics with regard to planning for the course are discussed in detail, as are important elements to consider when taking students to South America. Considering the many benefits to students and faculty alike, this is an innovative and highly stimulating way to teach science.

**Key words:** Galápagos Islands, travel course, field biology, evolution, student research

## INTRODUCTION

The year 2009 was a banner year for all things related to Charles Darwin. It was a celebration of the 200<sup>th</sup> anniversary of his birth and the 150<sup>th</sup> anniversary of the publication of *On Origin of Species*. Academic institutions worldwide honored these two events in a variety of ways, one of which was to emphasize courses on Charles Darwin and evolutionary theory. At Elmira College, a course was developed for science majors and non-majors on evolution and field biology that went beyond the classroom to include study in the place that inspired Darwin's masterwork. This article describes this learning experience and offers insight into developing similar courses. We begin by examining the overall benefits of designing and implementing travel courses; later, we discuss the specific details that went into our course, demonstrating its feasibility.

Courses in the biological sciences involving travel impart far more information to students than those that offer only classroom instruction (Bodycott and Walker, 2000; Drummond, 2001; McLaughlin and Johnson, 2006; Stanitski and Fuelhart, 2006; Zervanos and McLaughlin, 2003). This seems to be especially true when one takes a constructivist approach to learning about science. It is imperative for learners to interpret information, which requires making meaningful connections between concepts and ideas (Wubbels and Girgus, 1997). However, traditional classroom experiences in the biological sciences often provide few opportunities for such interpretation and concomitant deeper scientific insight (McLaughlin and Johnson, 2006). In contrast, direct experience with different cultures and biomes

enables students to contextualize concepts in a meaningful, "hands-on/minds-on" way (McLaughlin and Johnson, 2006). This may be of particular importance for non-science majors who may otherwise shy away from science coursework. Moreover, these experiences do not need to involve protracted stays abroad. Rather, shorter-term travel courses (i.e., six or fewer weeks) can be highly effective in promoting scientific knowledge (McLaughlin and Johnson, 2006; Zervanos and McLaughlin, 2003).

Generally speaking, there are additional benefits to extending instruction to foreign nations. Adults and students alike find the ability to learn abroad to be highly valuable (Marcum and Roochnik, 2001). These experiences expose individuals to different cultures, which broaden their horizons. Moreover, such experiences may help students build their resumés while enabling them to develop and hone interpersonal and intrapersonal skills that are crucial in our increasingly global society (Ornstein and Nelson, 2006). Thus, travel courses may assist students to become more cognizant of the world at large, which is one overarching goal of undergraduate education (Stanitski and Fuelhart, 2003). As for the instructors, a travel course that is carefully planned and delivered can be very enriching and invigorating (Bodycott and Walker, 2000; Drummond, 2001). Teaching in another part of the world can be inspiring to your own teaching and scholarship.

Considering the benefits of travel courses to students and faculty alike, and more specifically with regard to teaching in the sciences, going to the Galápagos Islands and retracing part of Darwin's

journey is an excellent way to inspire one to learn about Darwin’s life, evolutionary theory, and the natural world. In the archipelago’s extraordinary mix of geology, ecology, and animal life, students are able to observe, ask questions, and apply the scientific method in an authentic fashion. However, this optimal learning experience poses particular challenges in its design and implementation. The sections that follow review these challenges and how they were overcome.

**COURSE DESCRIPTION AND PLANNING**

“In Darwin’s Footsteps: Evolutionary Theory in the Galápagos Islands and Ecuador” was a 6-week, 6-credit course for science majors as well as non-science majors offered in April-May 2009. There were no prerequisites for this course, so non-science majors were evaluated in the same way the science majors were. Elmira College has a unique academic calendar into which is built a 6-week semester that is devoted to interdisciplinary and travel courses. Faculty are responsible for teaching six credit hours during this term, either alone or through team-teaching a travel course, and students take a total of six credits of coursework. For students, taking a single 6-credit course occupies all their time, especially when travel is involved; the same is true for faculty. For this course, we met in a combined lecture/lab for three hours per day for 16 days while on campus, and approximately 12 hours per day for the 14 days we were off campus. This justifies making such travel courses six credits. The formal objectives of the course are found in Table 1. In terms of instruction, the first three weeks were spent on campus, followed by two weeks abroad, primarily in the Galápagos Islands. The final week was spent back on campus. Despite the fact that this course was only six weeks long, nine months were spent in its development. During that time three major facets had to be managed simultaneously: curriculum planning, trip logistics, and student recruitment and preparation.

*Curriculum planning and student evaluation:* As with all new course offerings at an undergraduate institution, it is important to receive administrative

support for your plans. Therefore, a month was spent honing the curriculum in concert with the travel plans to present to faculty and administrators for their approval. Because this course was taught by faculty from two different departments, course approval had to be obtained from both departments and divisions. Documentation included the syllabus, learning objectives, method of evaluation, topics covered, justification for off-campus offering and 6-credit course designation, and preliminary itinerary. Final approval came from the Faculty Course Approval Committee. Afterward, the Office of the Associate Dean of Academic Affairs was instrumental in coordinating submission of required student paperwork for travel. Once approval was obtained, we finalized activities and materials for three weeks of on-campus instruction, which laid the foundation for what was to come in the Galápagos Islands and the manner in which student learning would be evaluated.

Each course meeting whether on campus or abroad was a combination of lecture and laboratory. The first week of class was devoted to studying Darwin, evolution, and Galápagos Islands geology and ecology. Texts used were *The Voyage of the Beagle* (Darwin, 1887) and *The Beak of the Finch* (Weiner, 1995). Week two began with an exam based on the first week’s instruction (Table 1). What followed was practice proposing hypotheses, designing experiments, and testing questions in animal behavior using the scientific method. During this period of instruction we used *Measuring Behaviour* (Martin and Bateson, 2007) as our primary source. In addition, we spent time observing local fauna to practice essential data collection skills. The week culminated with student presentations about the geology and ecology of the Galápagos Islands. Content and delivery of presentations were evaluated. Students spent the third week on campus investigating the literature for animals they had the possibility of observing in the Galápagos Islands. They then chose one aspect of behavior for a particular species and wrote and revised research proposals. Their final research paper was 25% of

**Table 1.** Learning objectives and their evaluation: “In Darwin’s Footsteps.”

| Learning Objective                       | Description   | Evaluation   |
|--|---|--|
| Evolutionary Theory                      | Identify and explain the main tenets of evolutionary theory and its value as a foundation for biology.  | In-class multiple-choice and short answer exam                         |
| Darwin and Evolution                     | Describe Darwin’s development of evolutionary theory through his work in the Galápagos Islands.   | In-class multiple-choice and short answer exam                         |
| Natural History of the Galápagos Islands | Describe the natural history of the Galápagos Islands and the major flora and fauna.  | Two presentations and daily field journal entries                      |
| The Scientific Method                    | Apply the scientific method in designing and implementing experiments in animal behavior, including a small-scale field observation in the Galápagos Islands. | Daily field journal entries and final research paper with presentation |
| Professional Presentation Skills         | Present results of research in a professional manner.   | Three in-class oral presentations                                      |

**Table 2.** Considerations for finding the right tour.

|                               |  |
|-------------------------------|--|
| The Role of the Travel Agency | <ul style="list-style-type: none"><li>• Length of time in operation</li><li>• Length of time providing tours to the area in which you are interested</li><li>• Variety of tours with all costs indicated</li><li>• Flexibility with regard to time that deposit for the tour must be in</li><li>• Pictures of accommodations</li><li>• Customer feedback available</li></ul>   |
| The Role of the Travel Agent  | <ul style="list-style-type: none"><li>• Attention to your academic needs</li><li>• Familiarity with the vicissitudes of travel from USA to Ecuador/Galápagos Islands</li><li>• Ability to help you plan a careful budget for the travel with different numbers of students</li><li>• Willingness to explore a variety of options for accommodations, flights and in-country tours.</li><li>• Knowledge of all fees (e.g., tips and gratuities, park admissions, etc.)</li><li>• Ability to find guides that are able to work with students</li></ul> |

their course grade. Once abroad, students each kept a journal of field notes and were instructed to record information on all animals they came across, especially those that they had chosen as their final project's focus. Because these notes were vital to complete their project and were graded, daily feedback was provided to help them hone their observation and data collection skills. Finally, upon our return to campus, students completed a paper modeled after scholarly articles based on their hypotheses and the data they collected. Each section of this paper (Introduction, Method, Results, Discussion, Literature Cited) was evaluated for its content and clarity.

*Trip logistics:* Neither of the instructors had been to South America. Therefore, it was necessary to work with a highly experienced travel agency in Quito, which enabled us to create the best possible tour for our educational purposes. Additionally, it made it much easier to negotiate the pitfalls of travel. The Internet was an invaluable search tool. However, it is easy to become overwhelmed with the seemingly endless amounts of information to sift through to find an agency that is trustworthy. Table 2 provides a list of questions that are important to consider when evaluating travel agencies and their services. A key factor for us was flexibility with regard to making a deposit for the trip; many companies require that the money be ready within 48 hours of booking a tour. For students, this may not be enough time to settle one's finances and provide the down payment.

The most important asset in planning the tour of the Galápagos Islands was having an experienced travel agent who understood that we were not planning a vacation; rather, this was an academic experience. Our travel agent described key details about weather, flight schedules, national park fees, traveling from Ecuador to the Galápagos Islands, securing guides, personal budgeting for the trip, and currency issues. A travel agent's help with choosing the options for accommodations is extremely important, as where you stay directly affects what and how much can be done and seen. Hotels are

available on some of the islands, but this limits access to the diversity of field sites and research experiences. To maximize the opportunities for observing flora and fauna on a variety of islands, staying on a boat is the best choice. A seasoned travel agent will be able to suggest the best quality boat in your price range for your group. Our agent found us a cost-effective, budget-class boat that served us very well for the eight days we toured the archipelago.

*Student recruitment and preparation:*

Recruitment for this course began at the earliest point during the fall semester of the academic year in which we offered the course; it was limited to the undergraduates at our institution. Registration was open to all matriculated students; however, we had mostly juniors, with a few seniors and sophomores. Of these 14 students, only four were non-science majors. Given the expense of this kind of trip, it was important to advertise it at this time to give interested students ample time to work out their finances and place a deposit for the course. Because of the small size of the boat we chose, only 14 students could be accommodated. This definitely worked in our favor, as it created a sense of urgency for students to act before it was too late.

Enrollment in the course was contingent upon submission of a completed application packet, a copy of a valid passport, a deposit for the course (and, eventually, full payment for it), and participation in an interview with both instructors. The pre-class interview was vital as a screening mechanism; field-work in an isolated area requires good health, judgment, positive attitude, flexibility, and independence. In other words, field courses demand emotional intelligence (Ornstein and Nelson, 2006), and it behooves instructors planning on taking students abroad to evaluate the students on factors such as experience with foreign travel, managing stress, coping with adversity, etc. A list of questions that were posed to students can be found in Table 3. The interview also gave us an opportunity to convey information about course requirements and expectations so that students did not equate this

**Table 3.** Questions to ask students in a pre-trip interview.

|                              |  |
|------------------------------|--|
| Travel History               | <ul style="list-style-type: none"> <li>• What is your travel experience to date?</li> <li>• In terms of foreign travel, what countries have you visited and for how long?</li> <li>• What's the longest flight you've ever been on and what was that like for you?</li> <li>• What is flying like for you? Do you have any fear of it?</li> <li>• Have you ever lived in tight quarters? What has that been like?</li> </ul>   |
| Motivation to Try New Things | <ul style="list-style-type: none"> <li>• How well do you like sleeping in unfamiliar places?</li> <li>• How well do you like eating different foods?</li> </ul>  |
| Self-Awareness               | <ul style="list-style-type: none"> <li>• How would you describe yourself as a student? How would others like your friends and professors describe you?</li> <li>• How would you describe yourself as a person? How would your friends describe you as a person?</li> <li>• What would you say is your "comfort zone?" How willing are you to leave it?</li> <li>• What kinds of things about others irritate you?</li> <li>• What sorts of things stress you out?</li> <li>• What kind of a roommate would you say you are? What kind of a roommate are you when you travel?</li> <li>• What kinds of roommates would you travel best with?</li> </ul> |
| Coping                       | <ul style="list-style-type: none"> <li>• What do you do to cope with stress?</li> <li>• How do you help others cope with stress?</li> <li>• What do you do when someone has done something to offend you?</li> <li>• What do you do when you have roommate problems?</li> <li>• How do you function when you have not had enough sleep?</li> <li>• How do you cope when you are separated from friends and family?</li> <li>• How do you cope with feelings of loneliness?</li> </ul>  |
| Health History               | <ul style="list-style-type: none"> <li>• What are the recent immunizations you have had?</li> <li>• What special health concerns do you have?</li> <li>• What dietary restrictions do you have?</li> <li>• Do you have any problems with regard to breathing?</li> <li>• What medications are you taking and for which conditions?</li> <li>• What allergies do you have?</li> <li>• Are you prone to sunburn or sun poisoning?</li> <li>• Do you get seasick?</li> <li>• Do you have any problems with stamina, heat, or walking distances for periods of time?</li> </ul>  |

experience with a vacation, but rather expected a rigorous science course. Fortunately, all students successfully met basic requirements for this course. However, severe physical and behavioral health issues would have precluded students from participating in this course. The Office of Academic Affairs requires a health screening to be completed at the campus Health Center before students receive travel clearance.

### **EXCURSION AND FIELD WORK ABROAD**

We arrived in Quito very late during the first day of the trip. It was the start of the rainy season. Therefore, rather than depart for the Galápagos Islands immediately and run the risk of being stuck at the airport due to weather related delays, a full day touring Quito and the western Andes was recommended by our travel agent. This was an excellent idea; it gave students the opportunity to experience the culture and ecology of part of Ecuador, allowing a comparison with the Galápagos Islands. Highlights of the day tour included standing on the equator, visiting one of only two inhabited calderas in the world, touring beautiful cathedrals and churches, and sampling the local delicacy, cuy (guinea pig).

The following day, we departed for the Galápagos Islands. The National Park services oversee all tours to the islands, but this does not mean that all itineraries are identical. Our port of arrival in the Galápagos Islands was Baltra; however, we soon took the ferry across to the central island Santa Cruz where we boarded a bus for the southern town of Puerto Ayora. This ride is an excellent way to facilitate a discussion of the vegetation zones of the islands, as it takes individuals through most of them. As soon as the luggage was loaded onto the boat and introductions were exchanged between our group, the boat's crew, and the guide, we immediately embarked on an excursion during which we scrambled through a lava tube, and observed giant tortoises and a variety of finch species.

Every day on the islands felt like three: multiple activities and excursions were planned from sunup to sundown. A typical day started with a pre-breakfast hike, followed by another hike or snorkel. Often the boat would move to another location while we had lunch, and the afternoon was spent either on land or snorkeling once again. Evenings were spent writing up field notes and planning for the next day. Given this pace, we now understand why most of the tours offered were only eight days long.

It did not seem possible, but each day on the islands was more extraordinary than the previous one. This is because the opportunity to observe animals in close proximity is unparalleled, despite the constraint of needing to stay on a well-defined path with a naturalist guide present at all times. Mating and nesting behavior of seabirds were easily observed on many islands and included blue-footed boobies, waved albatross, and frigate birds. Land and marine iguanas were abundant, as well as the smaller lava lizards. The diversity of finch species was outstanding, but required a more careful eye to observe at times. In the water, highlights included snorkeling with penguins, sea lions, green sea turtles, hawksbill sea turtles, large stingrays, and countless, colorful reef fish. We are grateful for seeing all of this magnificent wildlife; however, the giant tortoises, which are emblematic of the islands, truly brought us back to the time of Darwin's journey. The tortoises were mainly found in places like the Giant Tortoise Breeding Center on Isla Isabella or the Charles Darwin Research Center on Santa Cruz. The students learned a great deal about natural history of tortoises at these sites, and the conservation efforts that surround the preservation of these magnificent animals.

Field guides and, to a greater extent, our naturalist gave us a good idea of what flora and fauna we would be seeing with each excursion. Even so, field observations of animals tended to be serendipitous. Despite having to stay on predetermined trails and having limited time at any one site, students were successful during data collection because they had designed their research proposals with this in mind. Moreover, these circumstances helped our students cultivate the skills of field researchers, instilling in them the need to be

resourceful and flexible, which they were. Student project topics for the 2009 class are in Table 4. As can be seen, science majors' projects were very similar to those designed by non-science majors.

Species that were not chosen for observation but were observable and abundant enough to have made good study subjects included: Nazca boobies (*Sula granti*), Galápagos mockingbirds (*Nesomimus parvulus*), magnificent frigatebirds (*Fregata magnificens*), great frigatebirds (*F. minor*), brown pelicans (*Pelecanus occidentalis*), large-ground finch (*Geospiza magnirostris*), and the cactus finch, (*Geospiza scandens*). Tropical fish species also are excellent possible research subjects.

After our 8-day tour of the Galápagos Islands, we returned to Quito, stayed the night, and returned to campus the following day. Students spent the final week writing and revising their research papers and presenting their results to the class. As a group, they also created a Power Point and video presentation that was open to the campus community that highlighted their adventure and shared their research.

#### COURSE OUTCOMES

By the end of the course all students completed an original research study based on a testable hypothesis that involved fieldwork. Science majors and non-science majors alike developed and demonstrated skills in field biology and critical thinking. Moreover, they were able to integrate elements of evolutionary theory in a meaningful way into their projects, thereby demonstrating an understanding of and an appreciation for Darwin's contributions to science.

Every student who participated in this course found it necessary to modify his or her original research proposal in some way. For example, an

**Table 4.** Projects conducted during the course, "In Darwin's Footsteps" in the Galápagos Islands, spring 2009.

| Project Title   | Student major              |
|---|----------------------------|
| Galápagos sea lion ( <i>Zalophus wollebacki</i> ) colony size on rocky vs. sandy shores                           | Sociology and Anthropology |
| Galápagos tortoise ( <i>Geochelone</i> spp.) feeding on vegetation of different heights                           | Biology                    |
| Mother-pup interactions in Galápagos sea lions ( <i>Z. wollebacki</i> )   | Biology                    |
| Blue-footed booby ( <i>Sula nebouxii</i> ) and waved albatross ( <i>Phoebastria irrorata</i> ) courtship patterns | Sociology and Anthropology |
| Galápagos penguin ( <i>Spheniscus mendiculus</i> ) and Galápagos sea lion ( <i>Z. wollebacki</i> ) distributions  | Biochemistry               |
| Lava lizard ( <i>Microlophus</i> spp.) head bobbing behavior  | Biology                    |
| Galápagos penguin ( <i>S. mendiculus</i> ) locomotion frequency   | Biology                    |
| Sally Lightfoot crab ( <i>Grapsus grapsus</i> ) locomotion  | Business Administration    |
| Basking site choice in marine iguana ( <i>Amblyrhynchus cristatus</i> )   | Biology                    |
| Blue-footed booby ( <i>S. nebouxii</i> ) diving angle   | Biology                    |
| Galápagos sea lion ( <i>Z. wollebacki</i> ) vocalizations   | Psychology                 |
| Color variation in Sally Lightfoot crabs ( <i>G. grapsus</i> )  | Biology                    |
| Basking behavior in marine ( <i>Amblyrhynchus cristatus</i> ) vs. land iguanas ( <i>Conolophus subcristatus</i> ) | Biochemistry               |
| Lava lizard ( <i>Microlophus</i> spp.) vigilance in habitats with varying levels of vegetation                    | Biology                    |

important aspect of the students' proposals was recognizing that their research was contingent on a number of factors (e.g., weather, opportunity to observe that particular animal, breeding season constraints, etc.), and was subject to change. Case in point: one student wanted to compare behavior of two seabirds, specifically the red-footed booby and the blue-footed booby. However, after we arrived in the Galápagos Islands, we learned that the island where the red-footed booby resides was not on our itinerary. Moreover, they are not very abundant even in that habitat. Thus, conducting research in the field in this course gave the students a genuine taste of scientific fieldwork in animal behavior that cultivated in them an appreciation of the need to be flexible as researchers and that helped them figure out how to recover when things do not go as planned. This piece of learning went above and beyond the formal course objectives, and it proved to be particularly beneficial for the science majors' career development.

Happily, all participants in this course said it was the experience of a lifetime. In both formal and informal evaluations, students expressed gratitude for the opportunity to study science in this unique setting and were proud of the work they did. They recognized how arduous field work often is and gained a new respect for it. As such, all students remarked, "I can't believe how much I've learned."

## DISCUSSION

Clearly, travel courses such as this have many payoffs, some of which may not even be anticipated. However, they require much planning (McLaughlin and Johnson, 2006; Stanitski and Fuelhart, 2003; Zervanos and McLaughlin, 2003). Often, the instructor is the person who has ultimate responsibility for every aspect of the course from the planning to its delivery at home and abroad. This is why coordination among the administration of your institution, your department, and the agencies that are helping arrange your trip logistics is essential. Moreover, given the many details that come with even a shorter-term travel course, it is necessary to begin the planning process as much as a year in advance of its delivery. Therefore, it is unwise to wait until the beginning of the academic year to start planning.

If your field site is as remote as the Galápagos Islands, the benefit of having two faculty members is great; therefore, team-teaching is recommended. This becomes most apparent in the case of an emergency, but on a day-to-day basis, it is very helpful to share all responsibilities, especially managing students around the clock while abroad. In short, a collaboration between colleagues that is balanced reduces the effort and stress involved in planning and executing a travel course. As we have found, similar philosophy of teaching and compatible

personalities are the essential components to making this team-teaching approach work.

In terms of students, we found that fieldwork conducted abroad combined with a project far surpassed any reading materials or classroom lecture in terms of conveying scientific concepts and applying research methods. This echoes the findings of others (e.g., McLaughlin and Johnson, 2006; Zervanos and McLaughlin, 2003). We discovered that having students keep a journal of field notes was an excellent way to teach them techniques of data collection used by professional biologists (Stanitski and Fuelhart, 2003). Additionally, it helped students preserve their experiences not only for the purposes of a research project, but potentially for the rest of their lives. Finally, the tight quarters, nearly constant activity, and research setbacks that occurred proved to be useful for challenging students' coping abilities. This was an added and somewhat unexpected benefit of this course. Consequently, this learning experience gave them a very real sense of the rigors of field research in graduate school and beyond. However, not only did the science majors reap the benefits of this course; the non-science majors were truly grateful for the experience as well. One does not need to plan a course such as this one solely for science majors, which is what other authors have suggested (see McLaughlin and Johnson, 2006; Stanitski and Fuelhart, 2003; Zervanos and McLaughlin, 2003). In fact, this course illustrates how well science can be delivered to individuals who may have been avoiding the sciences. In fact, half of the non-science majors performed as well as or better than the science majors on their papers, exams, and projects. Multiple factors (e.g., writing ability, study habits) influenced the final grades earned by the non-science majors. In addition, future offerings of this course should include an assessment of the application of experimental design for both science majors and non-science majors. This can easily be accomplished with a modified version of the EDAT (Experimental Design Ability Test) (Sirum and Humburg, 2011).

In summary, creating and teaching "In Darwin's Footsteps" was a highly satisfying and stimulating experience. The course exceeded our expectations and those of our students; each day was better than the one before it. Learning science in this breathtaking environment was worth all the effort, so much so that we will offer this course again. We encourage other faculty to think of doing the same.

## ACKNOWLEDGMENTS

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## INNOVATIONS

### Using Stable Isotopes of Carbon and Nitrogen to Evaluate Trophic Interactions in Aquatic Environments

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**Abstract:** This paper describes a series of laboratory exercises for upper level biology courses, independent research and/or honors programs. Students sampled fish from a local water body with the assistance of a local fish and wildlife agency. Tissue samples from collected fish were utilized to obtain estimates of the stable isotopes  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ . An open-source mass balance model was utilized to estimate fish diets from isotope values. Isotopes were also used to measure trophic position (TP) and evaluate dietary niche overlap between native and introduced species. It was found that  $\delta^{15}\text{N}$  concentrations increased with each trophic level starting with benthic algae (lowest) to omnivores, then primary carnivores and ultimately piscivores (highest). Estimates of  $\delta^{13}\text{C}$  suggested all collected taxa utilized littoral habitats for feeding purposes. Native chain pickerel (*Esox niger*) had the highest  $\delta^{15}\text{N}$  and TP estimates at 14.4 and 4.11, respectively. Nonnative largemouth bass (*Micropterus salmoides*)  $\delta^{15}\text{N}$  and TP estimates were 13.56 and 3.86, respectively. Model estimates suggested that chain pickerel and largemouth bass diets were partitioned: pickerel consumed only fish and bass consumed principally invertebrates with some intermittent fish contributions. This lab helped integrate multiple disciplines, provide practical experience, and encourage critical-thinking skills while educating students about trophic ecology.

**Key Words:** Stable isotopes, trophic position, dietary niche, nonnative species

#### INTRODUCTION

Current pedagogical theory suggests an active-inquiry based approach to teaching can provide students with essential skills such as observation, hypothesizing, experimentation, analysis and synthesis (National Science Foundation, 1996; National Research Council, 2000). Often, inquiry-based laboratory exercises are theory-based experimentation, rather than practical application of scientific understanding. Many students interested in environmental biology disciplines will eventually accept applied field-based positions where descriptive research is most commonly used. In field-based disciplines such as ecology, conservation biology, environmental biology, limnology, fisheries, and marine and wildlife biology, students often graduate deficient in necessary skills needed to compete in their fields (Millenbah and Millspaugh, 2003). These skills could include sampling techniques, data management, data analysis, statistics, oral and written communication mastery, inquiry and critical thinking. Particularly, the ability to integrate these skills into a single approach has been cited as a major shortcoming in contemporary college graduates (Millenbah and Millspaugh, 2003). A balance between experimental inquiry-based learning and applied/descriptive-based approaches

should be considered to provide students more experiences appropriate to their future careers. In particular, an integration of multiple disciplines into one project, as would be common in real-life working scenarios, should be encouraged.

In this paper we describe a series of laboratory exercises for upper-level biology, independent research and/or honors courses. The exercise involves students collecting fish taxa from a local pond, fixing tissue samples, managing large data sets, and reconstructing the local food web through the utilization of carbon and nitrogen isotopes and an open-source isotope model. Students are allowed to focus on particular components of the food web such as trophic structure, feeding behavior, resource partitioning and the potential for competition. At the end of the lab sequence students are familiar with common fish sampling methods, fish identification and ecology, the chemistry of carbon and nitrogen isotopes in the environment, data management, basic statistics, ecological modeling, and applied fishery biology. Students also prepare a term paper regarding their research and present it orally to their class. Methods presented here can be adapted to local conditions, budgets and other limitations. The concepts presented here can also be applied to other

aquatic species as well as to organisms in terrestrial environments.

### Isotope Ecology

Students were first educated on the concepts of food web and isotope ecology. Ratios of the stable isotopes of carbon  $^{13}\text{C}/^{12}\text{C}$  and nitrogen  $^{15}\text{N}/^{14}\text{N}$  can be used to estimate organism diet and trophic position (Cabana and Rasmussen, 1996; Vander Zanden and Rasmussen, 1999; Vander Zanden et al., 1999; Vander Zanden et al., 2000; Fry 2006). These isotopes exist in the environment at relatively predictable ratios:  $^{12}\text{C}$  exists at about 98.9% while  $^{13}\text{C}$  is approximately 1.1% and  $^{14}\text{N}$  is 99.6% while  $^{15}\text{N}$  is about 0.4% (Fry 2006). The lighter isotope  $^{14}\text{N}$  is more readily processed through organic tissue while the heavier isotope  $^{15}\text{N}$  tends to bio-accumulate (Vander Zanden and Rasmussen, 1999). When compared to a two-point normalized standard curve,  $\delta^{13}\text{C}/\delta^{12}\text{C}$  in muscle tissue is similar to that of the prey consumed. The ratio of  $\delta^{15}\text{N}/\delta^{14}\text{N}$  becomes enriched with  $\delta^{15}\text{N}$  from prey to predator at a rate of approximately 3-4‰ (DeNiro and Epstein, 1981; Cabana and Rasmussen, 1994; Vander Zanden and Rasmussen, 1999). Since these ratios represent carbon and nitrogen accumulation in muscle tissue,  $\delta^{13}\text{C}/\delta^{12}\text{C}$  and  $\delta^{15}\text{N}/\delta^{14}\text{N}$  represent a time-integrated estimate of organism diet (Fry 2006; Christensen and Moore, 2009). Plants and algae fractionate carbon differently from each other, and are expressed through the food web differently, indicating various potential sources of carbon and spatial feeding locations of predators (Vander Zanden and Rasmussen, 1999). For example, pelagic algae (phytoplankton) and benthic algae (periphyton) in lakes fractionate carbon differently, leading to spatial food web differentiation in lakes (Vander Zanden and Rasmussen, 1999). However, nitrogen fractionation is relatively constant and indicates trophic position (Vander Zanden and Rasmussen, 1999). Therefore, when used together, nitrogen and carbon isotopes can give a time-integrated, spatial and trophic estimate of feeding behavior, energy flow and food web dynamics. A fish that is  $\delta^{13}\text{C}$  depleted in a lake, for example, would likely be feeding in pelagic (open water) while a  $\delta^{13}\text{C}$  enriched fish would likely be feeding in littoral (near shore) habitats (Vander Zanden and Rasmussen, 1999). A fish that is  $\delta^{15}\text{N}$  enriched is likely a top-predator, consuming other fish species while a fish with low  $\delta^{15}\text{N}$  is likely consuming zooplankton or is an omnivore (Vander Zanden and Rasmussen, 1999).

A number of mass-balance isotope mixing models have been developed to assist researchers in estimating potential diet sources using stable isotopes. We used an open-source model provided by the Environmental Protection Agency (EPA) (Phillips and Gregg, 2003). Values of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  were inputted for both predator and potential prey sources. The model then used an algorithmic approach to

estimate a range of diet possibilities that sum to the isotopic signature of the predator. The model can estimate a range (0-100%) of diet possibilities for up to 10 prey sources for each predator. However, previous knowledge of potential diet possibilities must exist so inappropriate comparisons are not made.

### METHODS

This exercise required four 3-hour lab periods to complete. However, the labs can be adjusted to meet faculty and student needs or any possible limitations. Students were first given material to read regarding the ecology of the common fish species found in Pequot Pond, Westfield, MA. They also read material regarding lake and fishery management, invasive species and food web dynamics. Students were then encouraged to make well defined objectives. Some objectives included: create an isotopic map depicting possible feeding relationships among fish species, determine the trophic position of fish and invertebrates, use the multiple-source mixing model to estimate diets of largemouth bass (*Micropterus salmoides*) and chain pickerel (*Esox niger*), measure the level of resource partitioning between largemouth bass (an introduced species) and chain pickerel (a native species).

#### Lab One: Fish Sampling

During lab one, students collected fish taxa from Pequot Pond with the Massachusetts Department of Fish and Wildlife (MDFW). Arrangements were made with MDFW several weeks in advance. Fish were collected using an electrofishing john boat fitted with a 5000 watt generator. Electricity was applied to the water causing galvanotaxis (forced swimming) in fish. Students then netted the fish as they swam towards the boat. Because we are a small teaching university, funds were not available for expensive field sampling equipment such as electrofishing boats. However, state fish and wildlife agencies, if asked, are often willing to assist colleges and universities with field trips. This provided students with exposure to working professionals and real-world sampling techniques. Also, the MDFW utilized their own collection permits and sampling authority. If we had conducted the sampling ourselves, we would have been required to apply for a collection permit through the MDFW well in advance. Since fish are vertebrates, it was necessary to request authorization through our institution's animal care-use committee.

Other sampling methodologies could also be applied that would not require the assistance of fish and wildlife agencies, as long as the proper permits were acquired. These methods include gillnets, beach seines, cast nets and/or minnow traps. Each of these methods can be effective for a variety of near shore (littoral) lake, river and stream fish species. It may also be possible to focus on macroinvertebrate

collections that include species from different trophic levels and that are spatially distributed throughout a lake or pond. Using macroinvertebrates would eliminate the need for collection permits and IACUC authorization.

Once netted using the electrofishing technique, fish were placed in a live-well where they recovered quickly. Four fish of each species and of similar lengths were removed from the live well for further analysis. The rest of the fish were identified by students and released back into the pond.

Fish selected for isotopic analysis were pithed and a small muscle sample the size of a quarter (1-4 g wet-weight) was removed from the left dorsal side of the fish just anterior to the dorsal fin (Christensen and Moore, 2009). These tissue samples were rinsed with distilled water and then placed separately in small plastic vials, labeled and frozen (Christensen and Moore, 2009). Tissue samples were collected within an hour after fish were captured.

Macroinvertebrates were collected throughout the littoral zone of the pond using D-style invertebrate nets. We had four invertebrate sampling locations that included vegetated, organic muck, sand and gravel zones. These locations were indicative of the different habitat types common to the littoral region of Pequot Pond. Sampling effort in each of these regions was approximately 30 minutes. Each macroinvertebrate species was identified and then stored in small labeled plastic vials and frozen. We attempted to collect 1-4 g (wet weight) for each invertebrate species. Due to their small size, multiple invertebrate samples were collected for each vial. The entire invertebrate was used for analysis.

### Lab Two: Tissue Preparation

During the next lab, all the fish and macroinvertebrate samples were thawed. All skin from fish was removed while the entire macroinvertebrate was used (Christensen and Moore 2009). Samples were then re-rinsed and placed in a drying oven for 48 hr at 75°C (Christensen and Moore, 2009). Once the samples were dried, a mortar and pestle were used to homogenize each individual sample separately until it reached a floury consistency. Due to their small size, macroinvertebrates were pooled to ensure adequate dry weight (at least 1 mg). Samples were labeled in small air tight vials and shipped to the Washington State University (WSU), Biology Department, Isotope Core Laboratory for processing. We contacted the WSU Isotope Core Laboratory at the beginning of the semester to set up a billing account and then contacted them again several days in advance before sending the samples.

At the WSU Isotope Core Laboratory stable isotope analysis of  $^{13}\text{C}$  and  $^{15}\text{N}$  was performed for each sample using a continuous flow isotope ratio mass spectrophotometer (Delta Plus XP, Thermofinnigan, Bremen; Brenna et al., 1997). Delta

notation ( $\delta$ ) was utilized to express the deviation of  $^{13}\text{C}$  and  $^{15}\text{N}$  from a standard material utilized in the lab. The international standards Vienna Pee Dee Belemite (VPDB) for  $^{13}\text{C}$  and atmospheric nitrogen for  $^{15}\text{N}$  were used. All values were expressed in parts per thousand (‰) utilizing the following equation where R equals  $\delta^{13}\text{C}/\delta^{12}\text{C}$  or  $\delta^{15}\text{N}/\delta^{14}\text{N}$  :

$$\delta^{13}\text{C} \text{ or } \delta^{15}\text{N} = (R_{\text{sample}} / R_{\text{standard}} - 1) * 1000$$

The WSU Isotope Core Laboratory performed all of the analysis and sent a Microsoft Excel file with the results. The file was easy to understand and manage. The cost per sample, which included both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  together, was \$8.20 and the delay from shipping to return was about three weeks. While we waited for the samples to be returned, students worked on other, non-related exercises regarding aquatic biology. This time could also be utilized to further educate students about isotopic analysis and trophic ecology. Due to a limited budget we pooled fish and invertebrate samples of the same species. Although this is a fundamental problem in scientific investigation because no standard error could be determined and any useful statistical analysis was greatly reduced, the results still provided students with a useful picture of trophic interaction. A laboratory fee or allotted departmental budget could eliminate this shortcoming and pay for more isotope lab analyses.

### Labs Three and Four: Data Analysis and Modeling

The trophic position was calculated for each fish species and invertebrate species sampled following the method described in Table 1 (Vander Zanden et al., 2000). This method is unique in that it not only determines the appropriate trophic level, but also considers variation within each level (Vander Zanden et al., 2000).

We used the model IsoSource (Phillips and Gregg, 2003) to determine the range of possible diet proportions (0-100%) from our data (Figure 1). IsoSource is an algorithmic mass-balance model that uses the mixture of prey (source) isotopic signatures to determine all possible diet combinations that sum to the isotopic signature of the predator (consumer). Trophic fractionation needs to be accounted for by subtracting 3-4‰ from the  $\delta^{15}\text{N}$  of the predator (Phillips and Gregg, 2003). The output is simply an

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**Table 1.** Formulae used in the calculation of the trophic position with largemouth bass and chain pickerel as examples (Vander Zanden, 1999). The  $\delta^{15}\text{N}$  baseline was the lowest recorded primary heterotroph in our samples, which was the common freshwater snail ( $\delta^{15}\text{N} = 7.24$  ‰).

---

$$\text{TP}_{\text{fish}} = [(\delta^{15}\text{N}_{\text{fish}} - \delta^{15}\text{N}_{\text{baseline}})/3.4] + 2$$

$$\text{TP}_{\text{largemouth bass}} = [(13.56 - 7.24)/3.4] + 2 = 3.86$$

$$\text{TP}_{\text{chain pickerel}} = [(14.4 - 7.24)/3.4] + 2 = 4.11$$


---

The screenshot shows the IsoSource software window with the following data:

|                 |               | ISOTOPES |       |  |  |
|-----------------|---------------|----------|-------|--|--|
|                 |               | d13C     | d15N  |  |  |
| <b>Mixtures</b> |               | -25.36   | 9.46  |  |  |
| <b>SOURCES</b>  | Golden shiner | -25.48   | 11.68 |  |  |
|                 | Yellow perch  | -25.23   | 12.93 |  |  |
|                 | Pumpkinseed   | -24.56   | 10.81 |  |  |
|                 | Bluegill      | -25.10   | 11.26 |  |  |
|                 | Crayfish      | -26.71   | 7.75  |  |  |
|                 | Damselfly     | -24.99   | 8.12  |  |  |
|                 | Dragonfly     | -23.77   | 8.35  |  |  |
|                 |               |          |       |  |  |

**Fig. 1.** Example of the multiple source mixing model IsoSource. The display illustrates potential sources (prey) of largemouth bass in Pequot Pond, MA. The mixtures represent the  $\delta^{13}\text{C}$  and adjusted  $\delta^{15}\text{N}$  of the largemouth bass. The  $\delta^{15}\text{N}$  was adjusted down by 3.5 ‰ to account for fractionation (Phillips and Gregg 2003). The range of results was presented in 1% increments with an error tolerance of 10%, the minimum allowed

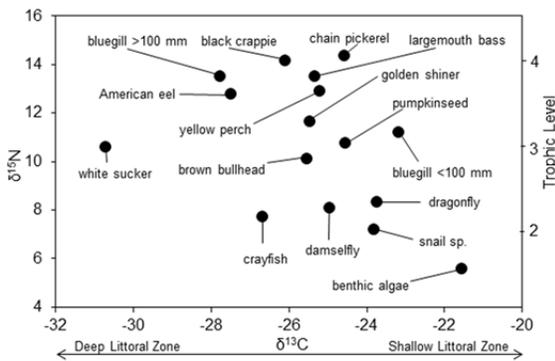
estimate and the entire range of possibilities should be presented since multiple combinations may have the same probability of occurrence (Phillips and Gregg, 2003). The model is open-sourced and can be accessed through the Environmental Protection Agency website (U.S. EPA, 2012).

We plotted the adjusted predator isotopic signature and the signatures of all possible prey. Since trophic fractionation was subtracted from the predator, all valid prey signatures should be located around the predator (Phillips and Gregg, 2003). We then created mixing-polygons around the predator to indicate all possible prey sources. All the sources should be within the polygon. When the predator signature is nearest the line connecting two prey sources a “constrained solution” exists (Phillips and Gregg, 2003). IsoSource output will display a bell-

shaped curve indicating that the two prey sources contribute most to the predator diet. A predator signature more toward the middle of the polygon suggests a “diffuse” contribution of prey (Phillips and Gregg, 2003). Model output for a diffuse solution would consist of incomplete curves. Because muscle turnover rates in most fishes can be relatively slow, isotopic estimates were indicative of late summer feeding behavior (MacAvoy et al., 2001).

## RESULTS AND DISCUSSION

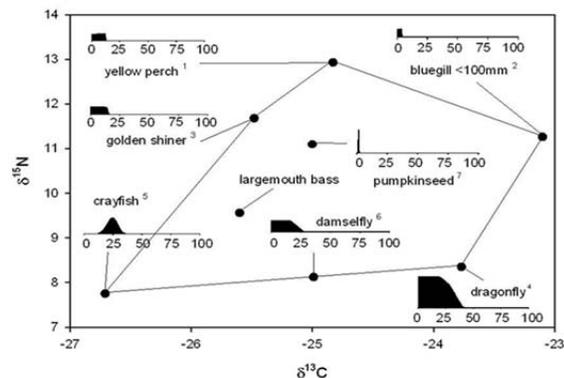
Students analyzed data based on their defined objectives. For example, trophic and spatial position was determined for all sampled fish and invertebrate species (Table 2 and Figure 2). We found in Pequot Pond that chain pickerel had the highest trophic position estimate, suggesting a piscivorous (eats other



**Fig. 2.** Late summer isotopic signatures and trophic position of fishes, invertebrates and benthic algae in Pequot Pond, MA. Stable isotope estimates for bluegill > 100mm were unusually high suggesting sample contamination.

fish) diet. The brown bullhead (*Ameiurus nebulosus*) and white sucker (*Catostomus commersonii*) had the lowest trophic position estimates, suggesting omnivory. The white sucker, bluegill (*Lepomis macrochirus*) and American eel (*Anguilla rostrata*) had depleted  $\delta^{13}\text{C}$  values, indicating deeper littoral habitat utilization than other fish species. Invertebrates all had lower trophic positions than fish. The common snail was the lowest recorded heterotroph. Benthic algae, the base of the food web had the lowest  $\delta^{15}\text{N}$  estimate.

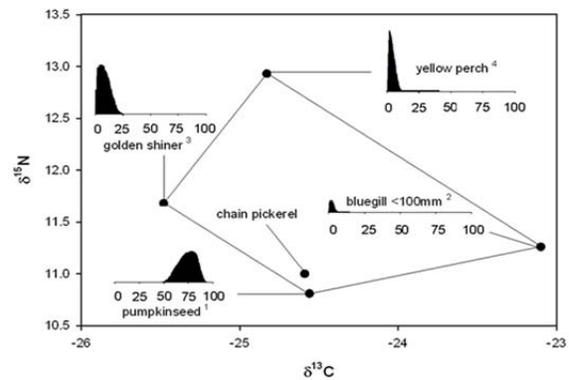
IsoSource model outputs suggested some diet overlap between introduced largemouth bass and native chain pickerel. However, there appeared to be some distinct diet partitioning between the two species. Crayfish were the principal diet constituent for largemouth bass while chain pickerel diet was



**Fig. 3.** Mixing polygon that depicts the most probable diet composition of largemouth bass based on outputs from the model IsoSource. Bell-shaped curves depict the most probable diet contribution while incomplete curves represent a more intermittent diet contribution. Diet contributions were: 1. yellow perch 0-16%; 2. bluegill <100mm 0-2%; 3. golden shiner 0-12%; 4. dragonfly 0-43%; 5. crayfish 13-35%; 6. damselfly 0-27%; 7. pumpkinseed 0-5%. Largemouth bass  $\delta^{15}\text{N}$  signatures were adjusted down by 3.5 ‰ to account for trophic fractionation (Phillips and Gregg 2003).

primarily pumpkinseed (*Lepomis gibbosus*) (Figures 3 and 4). These results suggested resource partitioning between a native and introduced predatory fish in Pequot Pond. Largemouth bass diets also consisted of more invertebrates while chain pickerel diet estimates were entirely other fish species. These estimates are consistent with current scientific understanding for these two species (Hartel et al., 2002; Wydoski and Whitney, 2003).

Students could also use these data to explore management implications of nonnative species, quantify energy flow through food webs, and predict potential shifts due to disturbances. Hypotheses for future research could also be explored. Students used these data and results to complete a paper and oral presentation that explored potential impacts of



**Fig. 4.** Mixing polygon that depicts the most probable diet composition of chain pickerel based on outputs from the model IsoSource. Bell-shaped curves depict the most probable diet contribution while incomplete curves represent a more intermittent diet contribution. Diet contributions were: 1. pumpkinseed 48-96%; 2. bluegill <100mm 0-15%; 3. golden shiner 0-25%; 4. yellow perch 0-41%. Chain pickerel  $\delta^{15}\text{N}$  signatures were adjusted down by 3.5 ‰ to account for trophic fractionation (Phillips and Gregg 2003).

nonnative fish introductions to a local food web. Students further hypothesized regarding management techniques that could minimize nonnative fish influence on food web dynamics.

Working with MDFW personnel was particularly rewarding in that several students made contacts that may become beneficial in their careers. Also, interacting with working professionals gave students an opportunity to learn about the practical, real-world perspective of biological work. After completing the lab series students felt confident they could develop similar projects that would address food web dynamics in other systems. In particular, students developed an appreciation of the multi-disciplinary approach often used in biology and the importance of critical thinking skills.

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## EDITORIAL

### Is Online Instruction Really Ready for Prime Time?

*“Fifty years from now, there will be only 10 institutions in the whole world that deliver higher education.”*

*-- Sebastian Thrun*

I have to admit it – I’m a technophile. I love to live on the bleeding edge of technology, at least as far as computers are concerned. The last time I checked, I had three electronic devices in my backpack: a laptop, a netbook and an Android tablet. Of course, there is also the Android phone that I keep with me day and night. I actually maintain a file server in my home network. I speak Windows, Linux (partial to OpenSuse), and Android fluently. Suffice it to say that I’m certainly not a Luddite.

Late one night I was reading an issue of *Wired*, a magazine that we techies like to keep up on. It is a very edgy, entertaining magazine that has timely articles on new technology and its effects on culture and institutions. On this particular night, I found an article by Steven Leckart which extolled the virtues of an online course, CS221: Introduction to Artificial Intelligence, offered by the “Stanford Education Experiment” (Leckart, 2012). This is part of a suite of three computer science courses that are offered online for free to anyone. Those who are not actually enrolled at Stanford get a “statement of accomplishment” rather than a grade and college credit. According to Sebastian Thrun, one of the instructors for Mr. Leckart’s course, over 20,000 students signed up for the course, took the midterm examination, and were turning in weekly assignments. The course is a mixture of audio/video filmed in Dr. Thrun’s guest house (!) with HTML overlays that are used in a manner similar to traditional presentation software – just a little fancier.

The real goal of the experiment was to see if it could attract and retain students. There really was no intent to determine the efficacy of this form of online instruction. Having satisfied himself that there is a market for this type of online instruction, Dr. Thrun has since left Stanford and formed a for-profit startup called Udacity (Thrun, 2012). He and several cohorts are gearing up to make polished university-level education that will be available via the internet around the globe. The *Wired* article mentions his plans to improve the quality of Udacity’s online instruction: *“Behind every Udacity class will be a production team, not unlike a film crew. The professor will become an actor-producer. Which makes Thrun the studio head.”* According to Thrun, in fifty years there will only be ten institutions that deliver higher education, presumably online, and his company aims to be one of them.

I can imagine college administrators drooling over the thought of collecting tuition from 20,000 students for a single class which requires no infrastructure other than high-speed broadband and a bank of servers. I have also dipped my toe in the green water of online/hybrid instruction. It is because of my experiences related to online courses that I am not embracing it wholeheartedly. I have several concerns about the emergence of online instruction as a panacea in higher education. First and foremost, online instruction tends to limit student/instructor interaction. Universities have tried numerous ways to induce online class interaction that mimics that which occurs face-to-face, but the truth is that direct, “chat-style,” interaction rarely occurs unless students are required to do so in order to earn credit toward their grade. In addition, the typed word simply does not come across in the same way that conversations do because of the absence of visual and other contextual clues. This becomes a problem for many online instructors because their online communication style is often interpreted by students as aloof or even antagonistic. This is a huge disadvantage of online instruction.

In addition, I am very concerned about the way colleges and universities currently support the development of online courses. As mentioned above, Dr. Thrun is adopting a film or television studio-style production for the recording of his online content because he has concluded from his experiences that this is the minimum investment necessary to make a quality product. This implies that there will be a true production studio and staff. Of course, these things require money – in some cases, lots of money. It is estimated that the budgets for one- to two-hour television features is in the range of \$100,000 to \$500,000. Each polished forty minute educational program produced by PBS (i.e., *Nature*) or The Discovery Channel costs millions to tens of millions of dollars to produce. So far at my university, the standard compensation carrot used for development of a fifteen hour online course is either \$1,000 in a research account or a single course release. Occasionally, in the past, we have also been offered internal competitive grants of up to \$15,000 to develop courses, but those grants dried up several years ago. I believe that in this case the adage, “You get what you pay for,” applies. It appears that higher education institutions aren’t interested in paying for

much. This will result in poor overall quality of the resulting online courses.

I have encountered a number of other problems unique to online courses that really need to be addressed before all higher education instruction moves online or to a hybrid format. They are:

1. The impression of college students that online courses are easier and require less time.<sup>1</sup>
2. There is also a belief by some administrators that the amount of time and effort necessary to offer an online course by instructors is less than for traditional classes, even though most who have taught online courses believe that the opposite is the case. This, coupled with the fact that online courses do not require classroom resources, leads to the creation of online sections that are much larger than normal “face-to-face” sections.
3. Despite the above, many other students simply do not like online instruction (and they say so!).
4. There is quite a bit of academic misconduct related to online assessment, especially when conducting traditional types of exams online.
5. In practice, there is a considerable lack of oversight related to quality and standards of online courses. For example, online courses are often overlooked in the peer review process and, because student evaluations are much harder to mandate in online courses, they are often either sporadically completed by students or not performed at all.

In summary, many “visionaries” see a new model of online instruction in higher education on the horizon, a type of instruction that will revolutionize higher education. In spite of my love of technology, I simply do not agree. Curmudgeon that I am, I see an imperfect technique in its current form, one that will require large investments of time and money up front to do right. I do not see this happening anytime soon in our current academic environment.

One last thing – the author of the *Wired* article, while he claimed that he worked extremely hard in the course, didn’t do as well as he hoped. He got an F.

Respectfully Submitted,  
James W. Clack  
Editor-in-Chief, *Bioscene*

#### ACKNOWLEDGEMENTS

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<sup>1</sup> I have preliminary evidence to suggest that grades are significantly higher in online courses at my institution.

# ***Bioscene: Journal of College Biology Teaching***

## **Submission Guidelines**

### I. Submissions to *Bioscene*

*Bioscene: Journal of College Biology Teaching* is a refereed quarterly publication of the Association of College and University Biology Educators (ACUBE). Submissions should reflect the interests of the membership of ACUBE. Appropriate submissions include:

- **Articles:** Course and curriculum development, innovative and workable teaching strategies that include **some type of assessment** of the impact of those strategies on student learning.
- **Innovations:** Laboratory and field studies that work, innovative and money-saving techniques for the lab or classroom. These do not ordinarily include assessment of the techniques' effectiveness on student learning.
- **Perspectives:** Reflections on general topics that include philosophical discussion of biology teaching and other topical aspects of pedagogy as it relates to biology.
- **Reviews:** Web site, software, and book reviews
- **Information:** Technological advice, professional school advice, and funding sources
- **Letters to the Editor:** Letters should deal with pedagogical issues facing college and university biology educators

### II. Preparation of Articles, Innovations and Perspectives

Submissions can vary in length, but articles should be between 1500 and 4000 words in length. This includes references, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. Topics designated as acceptable as articles are described above. The formats for all submissions are as follows:

- A. **Abstract:** The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.
- B. **Manuscript Text:** The introduction to the manuscript begins on the second page. No subheading is needed for this section. This supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. Articles describing some type of research should be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted. Articles describing a laboratory or class exercise that works should be broken into sections following the introduction as procedure, assessment, and discussion.

Acknowledgment of any financial support or personal contributions should be made at the end of the body in an Acknowledgement section, with financial acknowledgements preceding personal acknowledgements. Disclaimers and endorsements (government, corporate, etc.) will be deleted by the editor.

A variety of writing styles can be used depending upon the type of article. Active voice is encouraged whenever possible. Past tense is recommended for descriptions of events that occurred in the past such as methods, observations, and data collection. Present tense can be used for your conclusions and accepted facts. Because *Bioscene* has readers from a variety of biological specialties, authors should avoid extremely technical language and define all specialized terms. Also, gimmicks such as capitalization, underlining, italics, or boldface are discouraged. All weights and measures should be recorded in the SI (metric) system.

In- text citations should be done in the following manner:

Single Author:

"... when fruit flies were reared on media of sugar, tomatoes, and grapes" (Jaenike, 1986).

Two Authors:

"... assay was performed as described previously (Roffner & Danzig, 2004).

Multiple Authors:

“...similar results have been reported previously (Baehr *et al.*, 1999).

- C. References: References cited within the text should be included alphabetically by the author's last name at the end of the manuscript text with an appropriate subheading. All listed references must be cited in the text and come from published materials in the literature or the Internet. The following examples indicate *Bioscene's* style format for articles, books, book chapters, and web sites:

(1) Articles-

(a) Single author:

DEBURH, L.E. 1991. Using *Lemna* to study geometric population growth. *American Biology Teacher* 53(4): 229-32.

(b) Multi-authored:

GREEN, H., GOLDBERG, B., SHWARTZ, M., AND D. BROWN. 1968. The synthesis of collagen during the development of *Xenopus laevis*. *Dev. Biol.* 18: 391-400.

(2) Books-

BOSSEL, H. 1994. *Modeling and Simulation*. A.K. Peters, London. 504p.

(3) Book chapters-

GLASE, J.C. AND M. ZIMMERMAN. 1991. Population ecology: experiments with Protistans. In Beiwenger, J.M. 1993. *Experiments to Teach Ecology*. Ecological Society of America, Washington, D.C. 170p.

(4) Web sites-

MCKELVEY, S. 1995. Malthusian Growth Model. Accessed from <http://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html> on 25 Nov 2005.

Note that for references with more than five authors, note the first five authors followed by *et al.*

D. Tables

Tables should be submitted as individual electronic files. Placement of tables should be indicated within the body of the manuscript. All tables should be accompanied by a descriptive legend using the following format:

**Table 1.** A comparison of student pre-test and post-test scores in a non-majors' biology class.

E. Figures

Figures should be submitted as individual electronic files, either high-quality TIFF or JPEG, with a resolution of at least 300 dpi. Placement of figures should be indicated within the body of the manuscript. Figures include both graphs and images. All figures should be accompanied by a descriptive legend using the following format:

**Fig. 1.** Polytene chromosomes of *Drosophila melanogaster*.

### III. Letters to the Editor

Letters should be brief (400 words or less) and direct. Letters may be edited for length, clarity, and style. Authors must include institution address, contact phone number, and a signature.

### IV. Other Submissions

Reviews and informational submissions may be edited for clarity, length, general interest, and timeliness. Guidelines for citations and references are the same for articles described above.

### V. Manuscript Submissions

All manuscripts are to be sent to the editor electronically. Emails should include information such as the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each

author's name should be accompanied by complete postal and email addresses, as well as telephone and FAX numbers. Email will be the primary method of communication with the editors of *Bioscene*.

Communicating authors will receive confirmation of the submission within three days. Manuscripts should be submitted either as a Microsoft Word or RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and for revisions. A single-email is required to submit electronically, as the review process is not blind unless requested by an author. If the article has a number of high resolution graphics, separate emails to the editor may be required.

## VI. Editorial Review and Acceptance

For manuscripts to be sent out for review, at least one author has either joined ACUBE or agreed to page charges. Charges will be the membership fee at the time of submission per page. Once the authors' membership or page charge status has been cleared, the manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board. Authors' names will be withheld from the reviewers. The associate editors will examine the article for compliance with the guidelines stated above. If the manuscript is not in compliance or the authors have not agreed to the page cost provisions stated above, manuscripts will be returned to authors until compliance is met or the page cost conditions have been met.

Reviewers will examine the submission for:

- **Suitability:** The manuscript relates to teaching biology at the college and university level.
- **Coherence:** The manuscript is well-written with a minimum of typographical errors, spelling and grammatical errors, with the information presented in an organized and thoughtful manner.
- **Novelty:** The manuscript presents new information of interest for college and university biology educators or examines well-known aspects of biology and biology education, such as model organisms or experimental protocols, in a new way.

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. Further revisions should be made within six months if called for. Manuscripts requiring revision that are submitted after six months will be treated as a new submission. Should manuscripts requiring revision be resubmitted without corrections, the associate editors will return the article until the requested revisions have been made. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. . Time from acceptance to publication may take between twelve and eighteen months.

## VII. Revision Checklist

Manuscripts will be returned to authors for not following through on the following:

- A. Send a copy of the revised article back to the associate editor, along with an email stating how reviewers' concerns were addressed.
- B. Make sure that references are formatted appropriately.
- C. Make sure that recommended changes have been made.
- D. Figures and legends sent separately, but placement in manuscript should be clearly delimited.

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