An Ecosystem Experience

Students Apply Math, Modeling, and Sampling to Gather Authentic Data on a Nesting Coastal Seabird

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The elegant tern is the most abundant coastal seabird in southern California during spring and summer, May to July, typically nesting at three coastal mainland sites. They then move northward into central and northern California, and occasionally into Oregon and Washington, with their fledged young to feed in productive temperate waters. The juveniles learn to forage but are still being fed by their parents. Scientists study this shallow (upper 0.5 m [1.6 ft.]) plunge-diving tern because it is a reliable indicator of surface-occurring fish species (Horn and Whitcombe 2015) and of oceanographic conditions, especially sea surface temperature (Velarde et al. 2015). The nesting colonies of this highly social seabird fluctuate markedly in size both among nesting sites and years. Because of these fluctuations and the tern's value as an indicator species, seabird researchers have recorded nest counts at the sites as an initial measure of productivity (i.e., number of eggs laid) for the last three decades.

The shallow depressions (nest scrapes) built by the birds remain for several weeks after the chicks have fledged and the birds migrated northward. Thus, the tightly spaced nests (Figure 1) can be counted well after the birds have left, avoiding any disturbance to the colony. This important nest-counting activity is easily accomplished, and, as we show in this article, it is one that can involve middle school students, giving them the opportunity to help gather authentic scientific data.

Our project was a three-part enrichment experience to expand upon classroom lessons on ecosystems. The project was focused at the Bolsa Chica Ecological Reserve, a protected coastal wetland where the tern nests on a small island within the reserve. All students were encouraged to apply, with the final group of 30 drawn from the school's population of 725 seventh-graders. Participating students were selected in early May based on their applications, which included a statement of interest, grades, and a record of behavior. Selected students were a mix of males and females of varying academic abilities representative of the school's 92% low socioeconomic population. Field trips for the selected students took place during the school day after the ecosystem lessons had been completed for all students.

First wetland visit: Enrichment of ecological terms

The first field trip took place in May of students' seventh-grade year to deepen classroom lessons about ecosystems. This wetland visit coincided with the start of the breeding period for the elegant tern. Students were chaperoned by two middle school science teachers and a local college professor. We focused our observations primarily on birds, and students worked in pairs during the four-hour visit. The college professor was introduced, and he gave advice on the use of binoculars and spotting scopes, which were on loan from his university laboratory. Using these instruments made viewing the birds identifiable, especially the terns that were nesting about 500 m (1,640 ft.) away on the protected island (Figure 2).The college professor generously provided Rite-in-the-Rain waterproof notebooks for each student so that they could use a common tool of aquatic field biologists because of the risk of being dropped into water. During their time at the wetland, students paired up to share a set of binoculars (Figure 3) and used spotting scopes to identify birds with help from field guides and tips from their teachers and the professor. The field guides were borrowed from instructors and the local library. Students were instructed to record in the notebooks a list of the birds they saw and encouraged to practice their use of ecological terms, such as *predator*, *prey*, *consumer*, *producer*, *decomposer*, *herbivore*, and *carnivore*.

The wetland is bordered by a dry coastal scrub habitat to the east and the Pacific Ocean to the west. Walking on the path through the public-use area of the wetland provided frequent opportunities to show students the interconnectedness of these three different environments. The hike was important because most students had never been to a wetland or any other

CONTENT AREA

Life science/ecology

GRADE LEVEL

7–8

BIG IDEA/UNIT

Understanding ecosystems and gathering authentic field data

ESSENTIAL PRE-EXISTING KNOWLEDGE

Ecosystems terms: predator, prey, herbivore, carnivore, decomposer, consumer, and consumer

TIME REQUIRED

Two full-day field trips and a one-hour classroom activity

COST

Bus transportation and substitute teacher fees for two days

SAFETY

Appropriate clothing, sunscreen, shoes, and life jackets

natural ecosystem. Although no coyotes were observed, students were informed of the threats posed by coyotes to the eggs and chicks of nesting seabirds. A large floating barrier used by the California Department of Fish and Wildlife to deter coyotes from swimming out to the seabird colony generated numerous questions, and a discussion ensued as we walked along. Another predator we discussed was the peregrine falcon, which targets both juvenile and adult seabirds during the breeding season. Students were also informed of other wetland predators such as raccoons, skunks, gopher snakes, and rattlesnakes.

Nest count modeling: Applying math and random sampling

The objective of the second trip to the wetland was to have students gather authentic nest-number data for the elegant tern. An interesting natural history note about the elegant tern is that this colonial species breeds in dense clusters, with the nests forming a hexagonal pattern. Hexagonal packing means that a nest is adjacent to six other nests, with reported distances between elegant tern nests of about 31 cm (12.2 in.) (Collins and Taylor 2008). This tight nesting habit and consistent distance between nests allow the number of nests in a cluster to be estimated by averaging the number of nests per square meter.

Before returning to the wetland, students in the project worked through a nest-count simulation model after school. Round coffee filters were used to represent individual nests within a cluster. The method applied to estimate the number of nests within a cluster is relatively simple: First, meter tapes are used to "square off" the usually irregular-shaped clusters into common geometric shapes (square, rectangle, or triangle) so that the area (m^2) can be obtained and the boundaries noted. Then, a 1 m^2 (10.7 ft^2) quadrat made of ½ in. PVC pipe is randomly placed three times within the cluster (Figure 4) and the average nests/m^2 calculated. Finally, the total number of nests in the cluster is determined by multiplying the average number of nests/m^2 by the area of the cluster. This method has become the technique preferred by elegant tern researchers, and it was essential for students to understand if they were to obtain authentic data on nest counts at the wetland. The use of sampling quadrats can be easily implemented at all levels of learning on school grounds. For example, sampling quadrats

FIGURE 1: Elegant tern nest depressions

A cluster of elegant tern nest depressions after the chicks have hatched and the adults and fledged chicks have flown from the island.

FIGURE 2: Nesting elegant terns

Elegant tern adults and chicks at the nesting colony.

can be used to measure biodiversity, quantify invasive plants, or record changes over time, such as species composition or abundance (see Resources). Even tabletops within a classroom could be used to represent a sampling area with small quadrats of 100 cm^2 (15.5 in^2) to establish a foundation for conducting a sampling effort (Dobson, Woller-Skar, and Green 2017).

Students practiced measuring the area of common geometric shapes before working through the simulation model. Measuring square area was fairly straightforward for students, as this was a math standard they learned earlier in the year. We also explained that each cluster would be randomly sampled three times using the quadrat. Random sampling was a new concept for students. They learned that it helps prevent bias and that most scientific fieldwork involves random sampling. Going through a hypothetical example in the classroom by modeling how to measure a cluster and how to calculate the average nest number within the cluster proved to be vital for establishing a sound procedural footing.

Outside on the school grounds, a mock colony of three clusters was set up for students to practice using the coffee filters as substitutes for nests. Initially, students had difficulty squaring off the individual clusters as we purposely placed some nests just outside the tightly packed clusters, as found in nature. Working in three teams for the simulation, students had to discuss and argue how and in what shape the cluster should be measured to calculate area. To place the quadrat randomly within a cluster, students were shown how to throw a landscape flag (5 cm × 5 cm [2 in. × 2 in.] flag on a 30 cm [12 in.] metal wire) into the colony that would then mark the center of the quadrat, a common practice of scientists engaged in similar kinds of random sampling.

FIGURE 3: Students using binoculars

Students making observations using binoculars and recording field notes.

FIGURE 4: Nest cluster modeling with quadrat

Using modeling to learn how to estimate the number of elegant tern nests with a 1 m × 1 m (3.3 ft. × 3.3 ft.) PVC quadrat.

An even more challenging task was to have students obtain an accurate count of the nests within the quadrat. Although this effort may seem to be an intuitive task, it is a crucial step for students to learn if they are to collect accurate, reliable, and repeatable data. Nearly every time a quadrat is placed with the landscape flag marking its center, some nests will only be partially within the quadrat at the edges. Students were instructed to count only those nests that were 50% or more within the quadrat. This requirement led each group to discuss which nests along the border of the quadrat should be included during a count. Students practiced using the quadrat to sample the simulated clusters three times, as this procedure would be the method used to gather authentic data at the wetland tern colony.

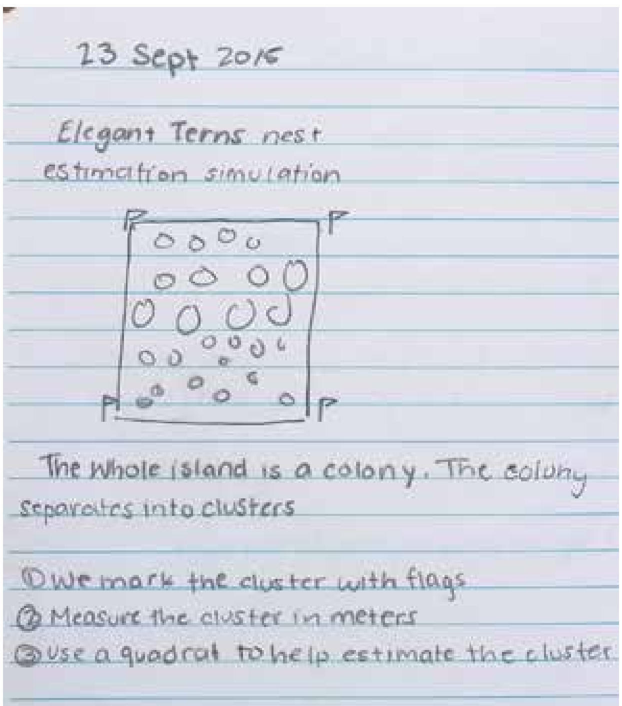
Second wetland visit: Gathering authentic data

The second field trip took place in September, at the start of students' eighth-grade year, and well after the elegant tern chicks had fledged. Nest depressions remain for weeks after the birds migrate north because the bird's guano acts to harden the nest site area (Figure 1). As a result, nest counts could be made without disturbing the chicks. Local California Department of Fish and Wildlife officials granted us permission to take students into the restricted area of the wetland ecological reserve. Canoes were used to transport adults, students, and equipment to the nesting island approximately 200 m (656 ft.) away. To ensure safety, all personnel wore life jackets while in the canoes, everyone wore old shoes, and only the adults paddled.

One teacher supervised students on the island until the remaining students were transported by the other teacher, college professor, and an adult volunteer. After a short overview of the day's objectives and instructions, we separated into four groups, with one adult leading each group to one of the clusters previously marked with a flag by the college professor. Students were instructed to respect all parts of the wetland and the island. The island is barren and void of nearly everything except scrub plants, sand, and small rocks. The adults facilitated the procedures needed to gather the desired nesting data rather than leading students through the work. Students were reminded to use their waterproof field notebooks to reflect on the methods used during the nest-count simulation performed at their school (Figure 5). Working together, students first measured and outlined the cluster and then diagrammed it in their notebook. Students took turns throwing the landscape flag to place the quadrat randomly within the cluster to obtain the three samples. Once the adult leader had approved the cluster configuration and nest count, students recorded the number of nests within each quadrat and used calculators to determine the total number of nests in the cluster.

After each group finished gathering data from the clusters, students and adult leaders held a short debriefing before leaving the island. After returning to school, each group presented its data so that everyone had all the information obtained from the four clusters. Students were instructed to write the summary of their experience of gathering these nest-number data. These data were compiled with other research estimates to arrive at a total nest number of 5,878 for the 2015 wetland colony. This total count has been added to a nest-number database stretching back 30 years, which serves as valuable information on colony dynamics of the elegant tern for seabird researchers and fish and wildlife managers (e.g., Velarde et al. 2015).

FIGURE 5: Student field notebook showing nest estimation procedure used during modeling activity



Conclusions

This collaborative effort was valuable on many levels. First and foremost, the objectives of the project were to provide a field experience for students to complement their classroom understanding of ecosystems, interact with professional biologists, and contribute to local research by gathering authentic data. Introducing our students to the use of quadrats was a learning extension of previously taught classroom lessons on ecosystems. Students had little difficulty with the math needed to gather the data for this project, as we practiced necessary math standards that they had mastered in seventh grade. Modeling and simulating the use of the quadrat at the school campus was invaluable, as this exercise saved time and eliminated the need for instructions at the ecological reserve.

Teachers may wish to design or adapt a quadrat lesson that can be completed in the classroom. Sampling using convenient small markers (beans or plastic beads) and quadrats may be an effective and engaging means for students to understand how sampling portions of a population reveals estimated information of the entire population (Dobson, Woller-Skar, and Green 2017; see Resources).

Students could configure a square meter sample plot and then randomly place predetermined numbers of markers within the plot. A 10 cm × 10 cm (3.9 in. × 3.9 in.) quadrat made from bendable drinking straws would be an appropriately sized quadrat to use in this 1 m × 1 m (3.3 ft. × 3.3 ft.) plot. Simulations where there are equal numbers of each variant (e.g., coloration of individuals) in the population could be set up using five colors and randomly distributing 20 of each color. Working through the simulation, students could test whether their sampling techniques match the actual population they placed within the sample plot by calculating percentages. The next step would be to take students out onto their campus grounds to use 1 m^2 quadrats (10.7 ft^2) made of PVC piping and to estimate the number of invasive species (e.g., dandelions) in the schoolyard (see Resources).

This project was a three-part enrichment experience coordinated and carried out by two teachers, a college professor, and a California Department of Fish and Wildlife biologist at the Bolsa Chica Ecological Reserve. Our team came together conveniently in part because one of the teachers (JWC) and the biologist were former graduate students of the professor. Their long personal and professional acquaintance facilitated the project. In our study, we took students into a protected ecological reserve where they could collect authentic data. Although planning and implementing an activity such as this can be arduous, we encourage other educators to investigate ways to engage their students in authentic research by connecting with science professionals. We suggest that educators rekindle relations with past professors, network at professional meetings, and become involved within environmental organizations in their vicinity. ●

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RESOURCES

Environmental inquiry—*ei.cornell.edu/ecology/invspec/plotsample.html*

M&M quadrat sampling—*www.cpalms.org/Public/PreviewResourcePV/Preview/128604*

Schoolyard quadrats—*http://smile.oregonstate.edu/lesson/schoolyard-quadrats*

Staying Local: Investigating the Schoolyard—*www.classroomscience.org/staying-local-investigating-the-schoolyard*

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standard

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics
www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics

Performance Expectation

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Developing and Using Models	Students worked through a nest-count simulation model at their campus to learn how to estimate nest-count data. They applied this technique in the field to measure nesting clusters, calculate nests per cluster, and tabulate total nests for the clusters investigated.
Disciplinary Core Idea	
LS2.A: Interdependent Relationships in Ecosystems Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.	Students made observations in the field about the elegant tern population and learned the specifics of their interactions with biotic and abiotic factors.
Crosscutting Concept	
Patterns	Students used the distinct hexagonal nesting pattern of the elegant tern to calculate total nests.

Connections to the *Common Core State Standards* (NGAC and CCSSO 2010)

Mathematics

CCSS.Math.Content.6.SP.B.5. Summarize numerical data sets in relation to their context.

CCSS.Math.Content.MP.4. Model with mathematics.