# Enhancing Statistical Skills in Undergraduate Ecology: A Multi-Week Laboratory Project Investigating Bird Feeding Preferences


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## Quantitative Skills in Undergraduate Biology

- Statistical skills are essential in modern biology:
  - Biological research
  - Graduate school
  - Scientific careers
- Yet most undergraduate biology students enter with little statistical background
- National initiatives emphasize the need for quantitative skills in undergraduate science education:
  - "Biology majors headed for research careers need to be educated in a more quantitative manner."[1]
  - "There is an increasing need for students in the biological sciences to build a strong foundation in quantitative approaches to data analyses…Statistical analysis is poorly integrated into undergraduate biology course work."[2]
  - "In undergraduate biology majors as diverse as wildlife biology and neuroscience, educators have called for greater emphasis on quantitative skills, notably the use and interpretation of statistical tests."[3]
  - "Separation…between biological knowledge and quantitative skill sets often causes students to view these two fields as disconnected."[1] "As a consequence, they do not learn how to correctly apply their mathematical knowledge to solve a scientific problem."[3]
- To address these needs, we developed a multi-week laboratory investigation for ***Ecology and Adaptation (BIOL 131 - 74 students)*** at Radford University, VA

## Introducing Statistics in Ecology

- Why use statistics?
- What are null and alternative hypotheses?
- What are independent (IV) vs. dependent (DV) variables?
- What are categorical vs. numerical variables?
- Designing ecological experiments (sample size, repeatability, independence)
- Common statistical tests and scientific graphing

| IV | DV | Statistical Test | Graph |
|---|---|---|---|
| Numerical | Numerical | Regression (predict DV from IV) or correlation (co-vary) | Scatter plot |
| Categorical | Numerical (means) | *t*-test (2 groups) or ANOVA (more than 2 groups) | Bar chart of means & standard errors |
| Categorical | Categorical (%'s or totals) | Chi-square ($X^2$) test | Bar chart of %'s or totals |
| Numerical | Categorical | Uncommon | --------- |

## Research Questions

- Do bird species (e.g., Northern Cardinals vs. Blue Jays) differ in seed preference? (millet, sunflower, thistle, suet)
- Do bird species (e.g., Northern Cardinals vs. Blue Jays) differ in feeding location? (hanging vs. ground feeders)


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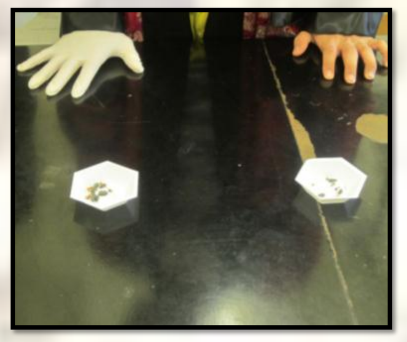
## Learning About Local Birds

- **Identifying common bird species:** Students learn 15 common bird species
- **Discussing ecological literature:** Students read and discuss a scientific article[4] considering positive and negative effects of supplementary bird feeding.
- **Comparing bird structure and function:** Students examine preserved specimens from the *Radford University Natural History Museum* and consider :
  - How do our local bird species differ in body size, beak size, beak shape?
  - How might these physical differences affect their feeding habits?
- **Comparing supplementary wild bird foods:** Students examine 4 common foods offered in bird feeders (sunflower, suet, millet, thistle) and consider :
  - How do food sources differ in accessibility (e.g., seed size)?
  - How do food sources differ in fat content? (calculating mg fat per seed)
  - How might this affect bird feeding preferences?



## Quantifying Bird Feeding Behaviors

- Three hanging bird feeders, each filled with sunflower, thistle, and millet seeds
- Two hanging feeders, each filled with suet cakes
- Students collect data (outside of class) in small groups for eight 30 minute sessions. For each feeding observation, the following information is recorded:
  - Bird species, feeding location, and type of seed selected
  - Other observations (competitive interactions, weather influences, etc.)

Observer(s): ______________________ Date (D/M/Y): __________

Beginning Time: __________ Ending Time: __________ Temperature (°F): __________

General Weather Conditions (describe): ______________________

| Bird Species | HANGING FEEDERS | | | | GROUND |
|---|---|---|---|---|---|
| | Sunflower | Thistle | Millet | Suet | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

*Other observations. (Use the space below to describe any other observations / trends you noticed for particular species, interactions between species , feeding behaviors, feeding locations, other cool stuff):*

## References & Supplemental Information


1. National Research Council. (2003) *BIO 2010: Transforming Undergraduate Education for Future Research Biologists.* Washington, D.C.: National Academy Press.
2. Metz, A.M. (2008) Teaching statistics in biology: Using inquiry-based learning to strengthen understanding of statistical analysis in biology laboratory courses. *CBE Life Sciences Education, 7*, 317-326.
3. Goldstein, J., & Flynn, D.F.B. (2011). Integrating active learning & quantitative skills into undergraduate introductory biology curricula. *The American Biology Teacher, 73* (8), 454-461.
4. Jones, D.N., & Reynolds, S.J. (2008). Feeding birds in our towns and cities: A global research opportunity. *Journal of Avian Biology 39*: 265-271.
5. "All About Birds: The Cornell Lab of Ornithology" (www.allaboutbirds.org/) and "Animal Diversity Web: University of Michigan Museum of Zoology" (www.animaldiversity.ummz.umich.edu/)

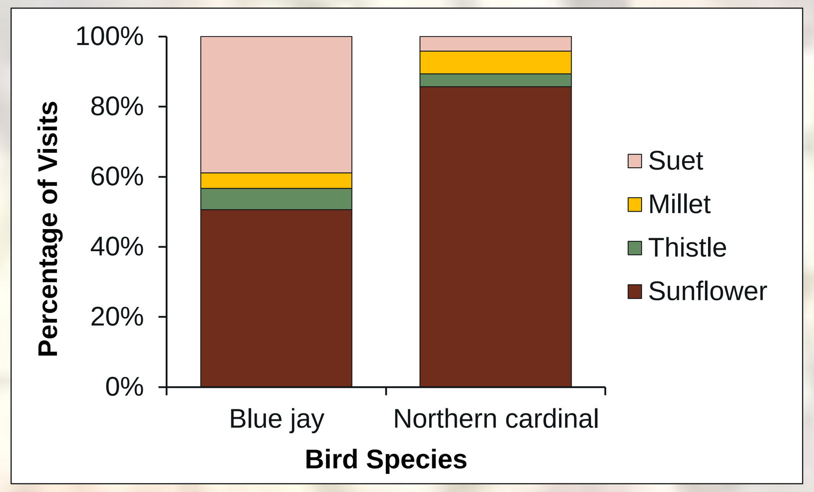

6. Funded by NSF: Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) Program Grant. SUMS4BIO: Strengthening Undergraduate Mathematics and Statistics Education for Biologists

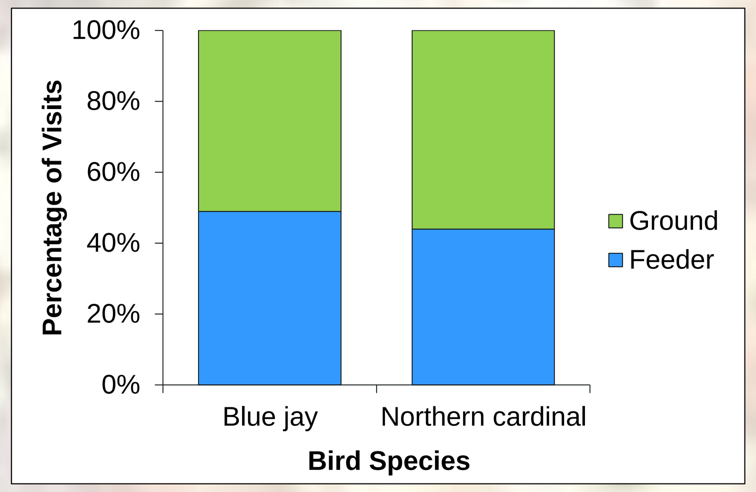

## Exploratory and Statistical Data Analysis

- From the large class data set ($n$ = 7,046!), each group chose two bird species for detailed comparison

| Bird Species | Sunflower | Thistle | Millet | Suet | Ground |
|---|---|---|---|---|---|
| American crow | 10 | 1 | 6 | 7 | 77 |
| American goldfinch | 250 | 360 | 98 | 40 | 106 |
| American robin | 14 | 6 | 15 | 9 | 155 |
| Black-capped chickadee | 157 | 77 | 94 | 29 | 170 |
| Blue jay | 125 | 15 | 11 | 96 | 258 |
| Dark-eyed junco | 32 | 41 | 51 | 5 | 378 |
| European starling | 4 | 2 | 4 | 2 | 18 |
| Hairy woodpecker | 39 | 3 | 8 | 86 | 7 |
| House finch | 365 | 186 | 92 | 46 | 434 |
| Mourning dove | 40 | 31 | 13 | 5 | 454 |
| Northern cardinal | 185 | 8 | 14 | 9 | 275 |
| Red-bellied woodpecker | 20 | 2 | 5 | 51 | 4 |
| Sparrow | 241 | 55 | 209 | 7 | 732 |
| Tufted titmouse | 229 | 39 | 47 | 20 | 87 |
| White-breasted nuthatch | 125 | 6 | 2 | 106 | 36 |

- Students defined research questions, hypotheses, and experimental variables
- Students determined appropriate graph type to display their data




- Students determined and conducted appropriate statistical analysis

- $X^2_{calculated}$ = 84.49
- $X^2_{critical}$ = 7.81
- Reject $H_o$

$$X^2 = \sum \frac{(\text{Observed Value} - \text{Expected Value})^2}{(\text{Expected Value})}$$

- $X^2_{calculated}$ = 2.42
- $X^2_{critical}$ = 3.84
- Accept $H_o$

## Interpreting Data Using Bird Natural History

- Students compiled written descriptions of their two bird species using two reliable online resources[5]. Some information gathered:
  - Physical description and life span
  - Geographic range, habitat, feeding habitats, behavior
  - Reproduction
  - Threats and conservation status
- Making connections between science and math: Students used natural history information to provide plausible explanations for observed trends in data
- E.g.,: *"Blue jays have bills that are useful for a wide variety of food. In the wild they are typically observed eating seeds and eggs. This trend is also reflected in our data: blue jays preferred sunflower seeds and suet – a soft food that is high in fat, similar to eggs. After running a Chi-Square Test, we conclude that blue jays and cardinals have different food preferences ($X^2$ = 84.49, $p < 0.05$)."*

## Learning Outcomes & Future Directions

- The importance and use of statistics in biology
- How to create and interpret scientific graphs
- How to select, use, and correctly interpret a statistical test
- How to use statistics to assess confidence in biological trends
- Possibly re-evaluate this experimental design and analysis in two new courses: *Math for Biologists (MATH 119)* and *Statistics for Biologists (STAT 219)*[6]
- Use this lab as a model for developing stronger statistical bases for laboratory research projects in this and other biology courses[6]