**Testing hypotheses about behavioral interactions between cats, coyotes, and birds at carcasses.**

**Student Instructions – Each QUESTION is worth 1 point**

**Overview -** In this activity, you will play the role of a field biologist quantifying and explaining animal behavior using the scientific method (observation – hypothesis – prediction – test). (For details on the method see <https://www.sciencemadesimple.com/scientific_method.html>.) This exercise contains a series of photos of scavengers at deer carcasses. You will form hypotheses about the behavioral interactions in the photos. After you form a hypothesis (or >1 competing hypotheses if you can think of more than one), you will make predictions that could be used to test your hypothesis or to discriminate between competing hypotheses. Depending on the level of detail that your instructor wishes to implement, you may also gain experience graphing and analyzing data in Excel. If your instructor assigns work in Excel it is highlighted in green. Much of the information in this document is also in the “Notes” section of your Powerpoint (or pdf, if you are using the pdf version of this exercise instead of the Powerpoint).

**Slides 2a, b -** Review the terms on these slides. You may refer back to this slide to answer questions.

**Slide 3**  - BACKGROUND - In Oregon and Washington from 2011 – 2017, scientists placed 89 road-kill deer carcasses into remote locations during cold months of the year, and monitored them using game cameras. In terms of cats, 8 of the 89 carcasses were visited by cougars and 4 were visited by bobcats. These photos show a few of the cat visitations. Note that in the photos, the carcass is either fully apparent (left photo), buried in snow (upper right photo), or buried in pine needles (lower right photo).

QUESTION 1 - What type of ecological interaction do you think best explains the cats’ tendency to bury a carcass after encountering a dead animal - (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism? State your answer in the form of a working hypothesis, i.e. “Our hypothesis is that cats bury a carcass in order to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. This represents a form of (choose one option from a-e).”

QUESTION 2 - Describe one testable prediction you would make that would allow you to further examine your hypothesis. State it as follows: “If cats bury carcasses in order to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, then we predict that we could measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and it would show \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.”

**Slide 4 -** BACKGROUND - We occasionally captured scenes between coyotes and bobcats like those shown here.

QUESTION 3. What type of ecological interaction do you think is happening in these photos - (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism? Explain your answer.

QUESTION 4. Describe one testable prediction you would make that would allow you to either examine your hypothesized interaction from Question 3. State it as follows: “If cats and coyotes exhibit (choose one option from a-e) at a carcass, then we predict that we could measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and it would show \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.”

**Slide 5 -** BACKGROUND. Even though cougars appeared at 9% of carcasses, and coyotes appeared at 66% of carcasses, coyotes and cougars never once appeared in the same photograph together.

QUESTION 5. This cougar has buried a carcass in pine needles. List TWO hypotheses for why coyotes often appeared in photos at carcasses guarded by bobcats, but never at carcasses guarded by cougars. How would you discriminate between your hypotheses? Answer the question in the form of “I would predict that if \_\_\_(hypothesis A)\_\_ is correct, then \_\_\_\_(result X) \_\_ should occur.” Alternatively, try to make a statement of this form: “If \_\_(result X) occurs, then this would be sufficient to eliminate (hypothesis A) as a possible explanation.” Make sure that your prediction is something that you realistically could test by gathering data.

**Slide 6 -** BACKGROUND. Birds comprise a major component of the scavenging community at carcasses in the study area. The photo on the left shows a golden eagle, which is a very common scavenger. The photo on the right shows a coyote visiting the same carcass.

QUESTION 6. If you had to guess, would you imagine that golden eagles drive coyotes from carcasses, coyotes drive golden eagles from carcasses, or that the outcome can vary?

**Slide 7 -** BACKGROUND. Golden eagles do not back down to coyotes, as seen in the three carcasses pictured here. What sort of competition does this look like to you? As a side note, our cameras never captured a single photograph of a bird of any species in the same frame as a bobcat or cougar, suggesting that cats pose a greater danger to eagles than coyotes do. Our cameras also never captured a photo of cats, dogs, or birds actually making contact with one another, suggesting that although a lot of aggressive posturing happens, there is seldom any contact or injuries inflicted on animals.

**Slide 8 -** BACKGROUND. Corvids (ravens and magpies) are other common avian scavengers. Here is a photo of a golden eagle with ravens. Game cameras did not register the sorts of aggressive posturing between eagles and ravens that we commonly saw between cats and coyotes and between eagles and coyotes.

QUESTION 7. What type of ecological interaction do you think is happening in this photo - (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism? State your answer in the form of a working hypothesis, i.e. “Our hypothesis is that eagles and corvids exhibit (choose one option from a-e) at a carcass.” If you think there is more than one possibility (i.e. the photos do not clearly document the exact option between a-e), then state your answer in terms of two alternative (competing) working hypotheses, i.e. “One hypothesis is that eagles and corvids exhibit (choose one option from a-e) at a carcass. An alternative hypothesis is that they exhibit (choose one option from a-e) at a carcass.”

QUESTION 8. Describe one testable prediction you would make that would allow you to either examine your lone hypothesis (if you described just one) or to discriminate between your competing hypotheses (if you described more than one hypothesis) in Question 7. State it as follows: “If eagles and corvids exhibit (choose one option from a-e) at a carcass, then we predict that we could measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and it would show \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.”

**Slide 9 -** BACKGROUND. Do the photos shown above make you more confident or less confident in the type of ecological interaction you chose in the previous question? To answer this question, you will need to observe carefully each photo. Note the time stamps on the photos and on the photo in the previous slide.

QUESTION 9. Do your observations modify whether your would choose (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism (f) none of the above? After you form a hypothesis for which of the possibilities listed in a-e you think is happening, write a statement of the form: “My hypothesis is that \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is happening. To test my hypothesis, I would predict \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. (Make sure your prediction is testable!)

**Slide 10 -** BACKGROUND. Here is what scientists did to test the hypothesis that COMMENSALISM is happening at a carcass. They believed that ravens may benefit from having eagles open a carcass, while eagles may be neither helped nor harmed by the presence of ravens (because there is more meat to go around than an eagle can eat). To test whether corvids may benefit from raptors opening a carcass, they put out two kinds of carcasses. Half (N = 5) were “pre-opened” using a hatchet, and the other half (N = 5) were fully intact. They then measured where on a carcass ravens and magpies fed before and after a raptor arrived. Because birds could choose to change locations on a carcass at least once every minute, they examined photos > 1 minute apart and tallied where on the carcass corvids were seen to be feeding in each photo. They were particularly interested to see if corvids shifted from feeding at the eyes and anus to feeding on meat after a raptor visited a closed carcass. They predicted that they would shift toward meat after a raptor visited a carcass, and that no similar change would occur at pre-opened carcasses.

RESULTS & ANALYSIS. The five closed carcasses were visited by 5 ravens and 3 magpies. The five pre-opened carcasses were visited by 4 ravens and 2 magpies. Data on their foraging locations on a carcass are in the Excel file, in the tab labeled “Feeding Locations.” You may analyze the data in that tab by using the link to the Mann-Whitney U test, or, if your instructor did not assign this statistical test, proceed to the next slide.

**Slide 11 -** QUESTION 10. Do the quantitative data shown in Slide 11 (and tested statistically in Excel, if the statistical test was assigned) support your hypothesis for whether the interactions between corvids and raptors is (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism (f) none of the above? Explain your answer.

**Slide 12 -** In summary, corvids appear to benefit after a raptor opens a carcass.

QUESTION 11. If the raptor has no reciprocal benefit, then is this a case of (a) amensalism, (b) commensalism, or (c) mutualism?

Is there anything more to these interactions than we have seen so far? Does the raptor get anything out of the deal? Go to the Excel data sheet and open the “Hours to Bird Appearance” tab. Follow the directions in the tab, which are also described in the Notes section of the next slide.

**Slide 13 -** BACKGROUND. There was an interesting pattern for when corvids and raptors showed up at a carcass. You can see the pattern by making a figure in Excel.

INSTRUCTION (GRAPH). Open the Excel data set, if you have not already done so, and click on the tab labeled “Hours to Bird Appearance.” Select all of the data in the rows under “corvid” and “raptor.” Then plot an X-Y scatterplot by choosing “Insert” – “Charts” and “Scatterplot,” which has the icon shown in the slide beneath “Bird Arrival Times.” What do you notice? Sometimes patterns emerge more cleanly when you use log-transformed data. Repeat using the data in the columns under ln(corvid) and ln(raptor).

QUESTION 12. If you did a graph, it should show that the arrival times of corvids and raptors coincide at carcasses, with corvids usually arriving first. If you were not assigned the Excel portion of the assignment, then simply accept that as true. List up to four reasons why the arrivals of corvids and raptors should coincide at carcasses. Please describe at least two. If you were assigned the plots and regression analyses in Excel, then conduct a regression analysis on your log-transformed data. Turn in a copy of your plot and report your R-squared and P values. (Note that in Excel E-15 means “times 10-15.) A P of < 0.05 is considered significant.

QUESTION 13. Describe an experiment you could do to either support or to eliminate from consideration one of the possible reasons you listed in Question 12.

**Slide 14 -** TYPES OF SCIENTIFIC EXPERIMENTS. So far, the data described about arrival times at carcasses has been observational. That means the investigators just observed birds arriving at carcasses without doing anything to try to directly manipulate their behavior. One shortcoming of observational studies is that they are not controlled, and so their results may be subject to a variety of different plausible interpretations, making it difficult to pinpoint an exact understanding of what is happening. As you probably know, you can narrow things down to a more precise understanding by conducting a controlled experiment, which is sometimes referred to as an experimental study (as opposed to an observational study). In a controlled experiment, one variable is manipulated to differ between a control treatment and an experimental treatment.

BACKGROUND. See Slide 14, which describes how control and experimental treatments were created in a Synthetic Carcass study.

RESULTS. Control treatments did not attract birds. Nor did a single raptor show up at the experimental treatments when just the decoys and playbacks were present. However, corvids showed up at 13 of 16 experimental treatments, and raptors showed up at 8 of 16 experimental treatments either when the live corvids were present or within 3 minutes of their departure. Moreover, there was an association between when corvids flew in circles above a synthetic carcass and when raptors arrived.

INSTRUCTION (GRAPH). To examine the relationship between corvid circling and raptor arrival, open the tab titled “Synthetic Carcasses” in the Excel® data sheet, and follow the directions at the top of the page.

INSTRUCTION (STATISTICS). Run a regression using the instructions in the “Regression Instructions” tab in the Excel file.

QUESTION 14 – A P value below 0.05 indicates that there is a statistically significant relationship between when corvids circled and when raptors arrived. The R2 value shows the proportion of the variation in raptor arrival time at the carcasses that can be explained by when corvids circled. If you were assigned the statistics in Excel, then what were your P value and R2 value when the outlier was present? When the outlier was not included? Turn in your graph.

**Slide 15 -** SUMMARY – If you made a graph and ran statistics, you will have seen that the arrival times of corvids and raptors at carcasses are highly correlated. (If you did not, then take our word for it.) This was true both for the observational data and the experimental data, especially when the outlier was removed. So, not only do corvids benefit when raptors open a carcass, but raptors may benefit from corvids by using them to locate carcasses.

QUESTION 15 - At this point, how would you classify the overall interaction between raptors and corvids - (a) interference competition; (b) exploitative competition; (c) mutualism; (d) commensalism; (e) amensalism (f) none of the above? Explain why you chose your answer. Does your answer differ from your original hypothesis? If so, then this is one example of how scientific inquiry can help to form a more accurate view of the natural world.

**Slide 16 –** See slide for definitions.

**Slide 17** – See slide for definitions.

**Slide 18** – Describes an experiment to test whether corvids may signal the location of carrion.

**Slide 19** – QUESTION 16 - Do the results shown in Slide 19 suggest that ravens use signals to recruit raptors to cut carcasses open for them? (See slides 16 & 17 for definitions of cues and signals.) Explain your answer.

**Slide 20 -** DISCUSSION - In this study, we discovered that individuals from one species use individuals from a different species (heterospecifics) to gain information about their environment, i.e. the location of carrion. More often in nature, one species uses other individuals of the same species (conspecifics) to gather information about their environment.

QUESTION 17 - Why do you think it is more common for species to use social information from conspecifics than heterospecifics (underlined words defined Slide 2b)? (Choose all that apply) (a) For many species, individuals tend to be around conspecifics more often than heterospecifics; (b) conspecifics have a greater overlap in resource needs than heterospecifics, so information from a conspecific may be more likely to be relevant to survival; (c) individuals may be better able to interpret behaviors or signals of conspecifics than heterospecifics – e.g. vocal calls or pheromonal signals.

QUESTION 18 – Describe an instance you used cues from other humans to gain information about your environment.

QUESTION 19 - Now, try to think of and describe a case where you used cues (or signals) from another species to gain information about your environment.

**Slide 21 -** DISCUSSION - Although use of heterospecific information by scavengers is not commonly documented in North America, it has been commonly observed in Africa. Jackals, hyenas, other vulture species, and even humans have been known to use circling vultures to find carcasses. In a study by O’Connell et al., Hadza Bushmen were found to get about 15% of their total meat intake by weight from carrion. They were guided by scavengers to the carrion in 4/11 of the instances in which they fed on carrion (see table). So, even some contemporary humans use heterospecifics to scavenge, and since the Hadza Bushmen live the sort of hunter-gatherer lifestyle that humans evolved under, the practice of using heterospecifics to locate meat has probably been common throughout the history of humans.

QUESTION 20 – What proportion of their total meat intake do Hadza get by being guided by scavengers to carrion? Show your calculation.

**Slides 22 + –** Behind the scenes of the science. This section is designed to provide a sense of how science gets “made,” which may not often be evident from textbooks or scientific publications.