**Answer Sheet: Testing hypotheses about behavioral interactions between cats, coyotes, and birds at carcasses**

From Orr, M.R. et al. (2019). Heterospecific information supports a foraging mutualism between corvids and raptors. Animal Behaviour 153:105-113. <https://doi.org/10.1016/j.anbehav.2019.05.007>

*We recommend that you do not share the above citation with students until after they have completed the exercise, or they will not be viewing the system from a naïve perspective, which could circumvent their sense of scientific discovery.*

Each question is worth 1 point if you choose to grade this assignment. You could assign only certain questions for points. Answers associated with optional Excel exercises are highlighted in green.

**Question 1 –** Hypothesis statement about carcass burying

There is no exact correct answer here, although it should probably have something to do with concealing the resource visually or reducing olfactory evidence of its presence. Cats like cougars, jaguars, and leopards also commonly carry prey into trees to prevent other animals from stealing it. This represents a form of exploitative competition because it allows the cat to use up the resource before another animal can access it.

**Question 2 –** Testable prediction about carcass burying

If carcasses are buried to conceal them from competing then we predict that we could measure differences in discovery time between buried and unburied carcasses, and buried carcasses should take longer for scavengers to discover.

**Question 3 –** Hypothesis about bobcat-coyote interactions

Our hypothesis is that bobcats and coyotes exhibit interference competition at a carcass because there is a direct interaction and one species appears to be limiting the other from getting access to the resources.

**Question 4 –** Testable prediction about bobcat-coyote interactions

There is room for creativity here. Here are some possible answers: If cats and coyotes exhibit interference competition at a carcass, then we predict that

* we could measure competitive outcomes with different numbers of coyotes present and it would show that coyotes require large numbers to drive away bobcats.
* we could measure coyote feeding rates on a carcass, and it would show that they have higher feeding rates when bobcats are absent than when they are present.
* we could measure rates that coyotes return to check a carcass guarded by a bobcat, and it would show that they attempt to feed only after the cat has left (e.g. during daylight hours, when cats may be dormant).

**Question 5 –** Two hypotheses for why coyotes appear in photos with bobcats but not cougars.

* Coyotes will challenge bobcats at a carcass to see if they can chase one off, but cougars are too big and dangerous to mess around with. The risk of death from cougars exceeds any possible foraging benefit.
* Coyotes tend to frequent habitats occupied by bobcats more often than habitats occupied by cougars.
* Coyotes tend to be active during times of day that overlap more with bobcats than cougars.
* Cougars consume carcasses faster than bobcats, so there is less time for coyotes to discover a carcass guarded by a cougar than one guarded by a bobcat.

**Question 6** – Who do you think wins between coyotes and golden eagles?

No right answer, but after viewing slide 7 it looks like eagles can hold their own against coyotes.

**Question 7** – 1-2 hypotheses about ecological interactions between eagles and corvids.

It is difficult to predict what is going on here, so students could probably justifiably choose interference competition, exploitative competition, or amensalism. As the exercise eventually shows, none of these is correct.

**Question 8**  - Testable prediction about ecological interactions between eagles and corvids.

Lots of answers are possible because lots of answers were possible in Question 7. Again, no right answer at this point.

**Question 9 –** Revised hypothesis statement and test statement about corvid-raptor interactions.

Ideally, students should be able to see that ravens get a better opportunity to feed after an eagle opens a carcass to feed itself. This would be a benefit to the ravens, with no obvious cost to the raptor (+/0, commensalism), although a student may also wish to argue that the raptor could be losing food to the ravens, which would make it perhaps some sort of form of foraging parasitism or competition (+/-). Students could come up with a variety of possible approaches to test their ideas; the main point of asking for a test is to help them to engage more actively with the test described in subsequent slides than they would if they were not asked to think about it in advance.

Man-Whitney U test, if assigned in Excel:

The *U*-value is 0. The critical value of *U* at *p* < .01 is 6. Therefore, the result is significant at *p* < .01.

The *Z*-Score is 3.03384. The *p*-value is .00122. The result is significant at *p* < .01.

**Question 10** – Do the quantitative data in Slide 11 support your hypothesis from Question 9? Explain.

Corvids feed more on meat after raptors arrive at a closed carcass, which you can tell because in every case with a solid line and triangle, feeding on meat went way up after raptors arrived. In contrast, at pre-opened carcasses, the dotted lines connected to circles stayed level, indicating no change in where birds fed, except in one case. In general, the quantitative data support the impression from the photographs in slides 8 & 9.

**Question 11 –** If the raptor has no reciprocal benefit, then is this(a~~) amensalism~~, (b) commensalism, or (c) ~~mutualism~~?

**Question 12** - Reasons for why the arrivals of corvids and raptors should coincide at carcasses. (2 minimum)

* Raptors use clusters of corvids as an indication that carrion is somewhere nearby.
* Raptors and corvids tend to occur in high densities in some areas and low densities in others, so when a carcass is placed out they either all tend to arrive quickly in a high density area or slowly in a low density area, creating a correlation in arrival times.
* Ravens are known to follow wolves in hopes of scavenging kills. If they associate with golden eagles for similar reasons, then the birds may already be pre-associated even before a carcass is discovered, causing associations when they appear on camera.
* If raptors are shy about descending to a carcass with a game camera beside it (or any carcass, given the possible danger from bobcats or mountain lions), they may wait around until a corvid finds the carcass and demonstrates that it is safe to approach the carcass, then only descend into camera range after the corvid has foraged.

Scatterplot and regression analysis, if assigned in Excel - From the regression analysis: R2 = 0.65, P = 3.7 x 10-15. The scatterplots show both the transformed and untransformed data, although the students were only asked for a scatterplot of the transformed data.

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**Question 13 -** Experiment to either support or to eliminate one of the possible reasons you listed in Question 12.

Lots of possible answers here, depending on the answer to Question 12. Again, this is mainly to get students to engage and take an interest in the study that was done to eliminate some of the possible explanations in Question 12.

**OPTIONAL Question 14 –** *Regression with outlier included* - P value: 0.12 R2 value: 0.23 *Regression with outlier excluded* - P value: 8.2E-6 R2 value: 0.98

**OPTIONAL** DRAW A ROUGH SKETCH OF THE GRAPH YOU MADE FOR CORVID CIRCLING vs. RAPTOR ARRIVAL:

**Question 15 –** How would you classify the overall raptor-corvid interaction? Explain your answer.

Corvids appear to benefit from raptors opening a carcass, and raptors appear to benefit by using corvids to locate a carcass, so it looks like it could be classified as a mutualism (+/+).

**Question 16 -** Do the results in Slide 19 suggest ravens use signals to recruit raptors to cut carcasses open for them? Explain.

No, because if they signaled raptors to come and cut a carcass open for them, then raptors would arrive sooner after ravens at closed carcasses (where the cutting services are needed) than at open carcasses (where ravens already can access flesh). If anything, raptors actually arrived later at closed carcasses (although the difference is not statistically significant).

**Question 17**  - List the letters that apply: All seem plausible

**Questions 18** **& 19** – Which do you use more often, conspecific or heterospecific social information (circle one).

If anyone answers anything other than conspecific then they may be too reclusive and own too many pets. 😊

**Question 20 –** What proportion of their meat did the Hadza get in this study by being guided by scavengers?

15% of meat from carrion x 4/11 of carrion guided by heterospecifics = 0.15 x 0.36 = 5.4%.

**We recommend that you peruse the section “Behind the Scenes of the Science” either with your students or with your students split in groups. You might discuss with them whether any of this information changed their perception of science, or whether it would change their mindset if they pursued a research project.**