Exploring KT Extinction Patterns

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Overview: Students will be introduced to a data set about mollusk genera that survived and did not survive the KT extinction event. They will formulate hypotheses regarding extinction patterns and mechanisms and analyze the data for evidence relevant to those hypotheses.

Instruction level: AP high school, intro level undergrad biology

Curricular materials:

- This instructor's guide
- The extinction data set [Excel spreadsheet]
  Link: https://evolution.berkeley.edu/ktpatterns//1609-kt-bivalve-data-patterns.xls
- Instructor background reading [PDF]
  Link: https://evolution.berkeley.edu/ktpatterns/1609-kt-teacher-background.pdf
- Associated slide set [Powerpoint slides]
  Link: https://evolution.berkeley.edu/ktpatterns/1609-kt-slide-set-patterns.pptx
- Map of geographic provinces [PDF]
  Link: https://evolution.berkeley.edu/ktpatterns/1609-kt-geo-map-extinction-patterns.pdf

Learning outcomes/objectives:

Extinction and evolution

- Students will be familiar with the trigger of the KT mass extinction, as well as several hypotheses regarding the kill mechanism of the extinction.
- Students will understand the idea of extinction bias.
- Students will recognize extinction as a macroevolutionary pattern.

Data literacy and process of science

- Students will understand that a hypothesis is tested by figuring out what expectations are generated by the hypothesis and making observations to find out whether those expectations are borne out.
- Students will understand that we can test causal hypotheses about past events by studying data available today.
- Students will be able to examine a large dataset and select appropriate data for analysis to test a given hypothesis.
- Students will be able to read and interpret a graph in relation to a hypothesis.
- Students will understand that data generally exhibit variability and may include confounding factors.
- Students will understand that science is ongoing and that investigating one scientific question frequently leads to additional questions to be investigated.
- Students will understand that scientists look for patterns in their observations and data.
- Students will understand that raw data must be analyzed and interpreted before we can tell whether a scientific idea is likely to be accurate or inaccurate.
- Students will understand that analysis of data usually involves putting data into a more easily accessible format (visualization, tabulation, or quantification of qualitative data).

Duration: Ideally 2-3 hours in lab or classroom.

Requirements:
Classroom: <30 students (but modification for a large lecture course are described below)
Technology: one computer per student group (e.g., 10 for a class of 30), projector, internet access
Software: graphing/statistical package (e.g., the free program MYSTAT)

Prerequisite knowledge: Students should have some familiarity with the software package that will be used. They will need to be able to use it to calculate simple descriptive statistics and construct graphs (e.g., pie charts, bar graphs, etc.). If you wish to incorporate simple statistical tests such as t-tests and chi-squared tests, students should also be familiar with these.

Instructor background: Instructors should be familiar with the KT extinction and its potential mechanisms, mollusk biology, and basic statistics. See the *Teacher background* document for an introduction to the data set and topics that students will be investigating.

Description of activity:

1) Pre-lab reading and preparation: Before lab, have students read *Asteroids and Dinosaurs* (http://undsci.berkeley.edu/article/alvarez_01). Depending on students' background and reading level, you may also want to have them read one of the following review articles:

- Kring, D. A. (2007). The Chicxulub impact event and its environmental consequences at the Cretaceous-Tertiary boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 255: 4-21.
- Schulte, P., Alegret, L., Arenillas, I., Arz, J. A., Barton, P. J., Bown, P. R., … Willumsen, S. (2010). The Chicxulub asteroid impact and mass extinction at the Cretaceous-Paleogene boundary. *Science.* 327: 1214-1218.

Divide students into groups and ask each group to prepare a 2-minute slide presentation on one of the following potential environmental effects of the KT asteroid impact: global darkness, ocean acidification, ozone destruction, climate change, wildfires, acid rain, and food web collapse. Student presentations should briefly explain what the effect is, how the impact caused the effect, and how it might have affected life on Earth.

2) Introduction to extinction (15 minutes): Introduce the topic of mass extinction (you may wish to use relevant slides from The Exploring KT Extinction Patterns slide set) and have students give their presentations.

3) Class discussion/brainstorm (10 minutes): Lead the class in a discussion and group brainstorm about organismal traits that may have protected species or made them vulnerable during the KT mass extinction. List student ideas on the board. Ask students to be explicit about why one might expect each factor to impact extinction risk. Make sure to distinguish traits that are specific to one of the kill mechanisms that students researched and traits that might be universally protective or endangering. Make sure that students recognize that the factors they've come up with are not mutually exclusive and that multiple factors may affect extinction risk.

Choose two of the traits to illustrate the difference between hypotheses and expectations. Hypotheses are proposed explanations for phenomena. Hypotheses generate expectations regarding what we might observe if the hypothesis were true or false. In science, sometimes hypotheses come first, and other times observations come first and suggest a hypothesis. For example, a scientist might first hypothesize that food chain collapse was a major kill mechanism during the KT mass extinction, reason that if this were true, we might expect to see higher rates of extinction among organisms further up the food chain (e.g., carnivores) than among primary producers (e.g., photosynthesizers), and then start collecting this data. Other times, observations come before hypotheses. For example, a scientist might notice that, among the group she is studying, tropical species were more likely to go extinct during the KT mass extinction and, based on that, hypothesize that global cooling played a role in the extinction.

Lead a discussion that encourages students to illustrate the difference between hypotheses and expectations using some of the other ideas that came up in the brainstorm.

4) Mollusk and data set introduction (10 minutes): Introduce students to basic mollusk biology and the data set that they will use to test some ideas about the KT Extinction. The Exploring KT Extinction Patterns slide set includes several slides you may wish use for this introduction. Briefly explain the columns of the dataset; this may give students new ideas about hypotheses they might test and patterns they might look for. If you have access to mollusk shells, pass them around to give students an idea of the variety of taxa included in the data set. Some data are missing from the data set and students will have to figure out if this is a problem for their analyses and what to do about it.

5) Small group work (60 minutes): Ask students to divide into groups of two to four. Each group should devise a hypothesis that they could test using the data set. The hypothesis might be relevant to the KT extinction kill mechanism (e.g., direct local effects of the asteroid impact were a major kill mechanism) or to extinction risk in general (e.g., over time, lineages accumulate more and more adaptations that protect them against extinction). The Teacher Background Information document lists a wide variety of hypotheses and expectations that might be investigated using this data set. You may wish to seed some of these ideas during the earlier class discussion/brainstorm. Groups should get their hypothesis approved by the instructor (simply to ensure that it is an explanatory hypothesis that can be investigated with the available data) and then use the data set and graphing software to attempt to test it. Depending on your students' background knowledge, you may or may not wish to have them perform statistical tests of their hypotheses (e.g., chi-square tests and t-tests). The most important patterns in the data can be observed in simple graphs.

Ultimately, students will be asked to give a 5-minute presentation to the class on their hypothesis, analysis, and interpretation. They should create a few slides to facilitate the presentation. Emphasize that in their presentations, students should interpret their results in relationship to extinction patterns and mechanisms (not just report a statistic or show a graph), identify potential problems with analyses, and explain further questions or investigations the findings inspired. A grading rubric for this presentation is provided below. You may wish to provide this rubric to students to help them shape their presentations.

5) Student presentations (20-30 minutes): Ask groups to report back to the class on their investigations. Encourage students to be explicit about the mode of action of their hypotheses, interpret their results, identify problems with their analyses, and explain further questions or investigations that the findings inspired. Note that there are going to be many potential problems with student analyses--in particular the facts that many of the variables they are investigating are correlated with one another, that sample sizes for genera with particular characteristics are likely to be small, and that students may not be able to appropriately evaluate statistical significance with the tools at their disposal. That's fine. Emphasize to students that they are engaging in data exploration and in the initial investigation and formulation of

hypotheses. Appropriate follow-up would include more advanced statistical analyses that correct for correlated variables.

6) Wrap-up discussion (15 minutes): Engage students in a wrap-up discussion that connects the topic of extinction to macroevolution and that connects their investigations to the process of science. A few slides that may be useful during this discussion are included in the slide set. You may wish to address the following points about extinction and the nature and process of science:

- The most important factor in determining survival is breadth of geographic range. This is consistent with the hypothesis that a broad, global change (such as climate change) contributed to the K-T mass extinction. In that situation, we might expect genera with widespread geographic ranges to be more likely to occupy a safe harbor than genera with narrow ranges.
- Hypotheses are proposed explanations for phenomena. Hypotheses generate expectations regarding what we might observe if the hypothesis were true or false – and these expectations can be compared to what we actually observe in order to test the hypotheses.
- We can test hypotheses about processes that occurred long ago and that we cannot directly observe.

Modifications: This activity was designed to be implemented in smaller classrooms or in laboratory or discussion sections. However, it can work in a large lecture course with the modifications that follow:

- Complete steps 2, 3, and 4 (introduction, class discussion, data set introduction) in class.
- Ask individual students or student groups to complete step 5 (small group work) outside of class as homework.
- Instead of developing short presentations, student groups should write up their investigation and submit a short paper (<2 pages) summarizing these results. Student write-ups should include the same basic elements that a presentation would.
- Complete step 6 (wrap-up discussion) in lecture on the day that the homework is turned in.

Assessment resources: Student work may be assessed by grading presentations (or write-ups if this portion is assigned as homework). A potential grading rubric is as follows:

Hypothesis explanation	Did the student formulate an explicit hypothesis relating to extinction patterns? Is the hypothesis explanatory? Did the student explain how the hypothesis generates the expectations that it does?	20
Analysis	Did the student use the available data to perform an analysis that relates to the hypothesis? Is the analysis a reasonable way to investigate the validity of the hypothesis?	30
Interpretation	Does the student explain whether the analysis supports or casts doubt on the hypothesis? Is this interpretation logical?	10
Limitations	Does the student describe potential limitations of their analysis? Is the explanation logical?	20
Next steps	Does the student list other lines of evidence that would be useful in evaluating the validity of the hypothesis? Does the student propose related questions for investigation?	20

		Total	100

Supporting Materials:

Teacher background document that accompanies this lesson

Case studies and readers on extinction:

- How to survive a mass extinction: The work of David Jablonski (https://evolution.berkeley.edu/how-to-survive-a-mass-extinction/)
  Through detailed analysis of patterns in the fossil record, scientist David Jablonski reconstructs the rules that helped dictate who lived and died in past mass extinctions. This research profile describes his surprising discoveries and their disturbing implications for the biodiversity crisis today.
- Evo in the news: A species' unwelcome inheritance - extinction risk (https://evolution.berkeley.edu/evo-news/a-species-unwelcome-inheritance-extinction-risk/)
  Even as the world loses species at an unprecedented rate, conservationists are struggling to save them. But where should they focus their efforts? This news brief from September 2009 describes new research suggesting that evolutionary history is an important factor in determining which species are at the gravest risk of extinction.
- Ancient fossils and modern climate change: The work of Jennifer McElwain (https://evolution.berkeley.edu/ancient-fossils-and-modern-climate-change/)
  Wondering how global warming will affect our planet? Scientist Jennifer McElwain studies the fossil record in order to learn more about extinction, how global warming has affected life on Earth in the past, and how it might affect life on Earth in the future.