SCIENTIFIC DATA, SOURCES OF VARIATION, AND SIGNIFICANCE OF POPULATION CHANGES FROM WOLF REINTRODUCTION IN YELLOWSTONE NATIONAL PARK

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ABSTRACT

Biological question:

- How has wolf reintroduction into the Greater Yellowstone Ecosystem (GYE) affected animals and plant at all tropic levels?
    - Helps students understand and apply the concept of trophic cascades and food webs

Statistical content:

- Graphical and tabular observational data from scientific literature
    - Animal & plant density and diversity measures
    - Population census measurements over time
- Descriptive statistics with measures of variation
- Understand measures of variation and their relevance
- Identify and account for sources of variation

What students do:

- Read tables and graphs of scientific data

Student active approaches:

- Peer learning: either groups or in pairs
- Use of student response systems (SRS, i.e clickers)

Skills:

- Distinguish observational versus experimental research/data
- Understand the difference between correlation and causation
- Interpret descriptive statistics
- Understand measures of variation and their relevance
- Identify and account for sources of variation
- Interpret data, evaluate possible explanations from the data; make conclusions

Assessable outcomes:

- SRS questions

BACKGROUND

In 1995 grey wolves were re-introduced into their natural and historical habitat in Yellowstone National Park (YNP) after being absent from this ecosystem for 70 years. The reintroduction was controversial

and debates about it ranges from local residents and ranchers, conservation groups, and hunters-- all the way up to the U.S. Congress. Reintroduction was only approved by Congress after computer simulations showed that reintroduction of a few wolves would have only a modest effect elk, moose, and other prey species. Reintroduction also was only possible with the provision of funds to reimburse ranchers who suffered livestock losses at the hands (paws? jaws?) of wolves.
During the 70 years that wolves were absent in the GYE, elk populations expanded to unsustainable levels and those populations over-consumed plant (especially aspen and willow trees) resources preventing recruitment of young saplings to adulthood. Over this period of time 92% of aspen forests were lost from YNP and a cascade of events slowly and affected the density and diversity of many other organisms including bear, beaver, coyotes, songbirds. We were largely unaware of the accumulation of these almost imperceptible changes until well after the wolves were reintroduced and natural restoration processes were documented.

We use ecological data sets of density, diversity, and population sizes in various organisms found in a riparian habitat. The table contains two sets of measurements (one historical the other contemporary) each taken years apart; the intervening years include a period of biologically significant change that alters significantly the density of some species but not others. In this specific scenario the two data sets are collected before and after wolf re-introduction in the GYE, and the data reflect (sometimes surprising) changes in size, density and diversity in a surprising array of animals after wolf reintroduction.

Since the re-introduction, elk have accounted for 92% of wolf kills in part because of their excess availability. Consequently, populations of elk declined from about 18,000 to ecologically sustainable levels of about 6,000 in YNP. This reduced herbivory on willows and aspen; therefore, recruitment of these tree species increased 0% in 1998 to 25% - 87% in 2011, allowing the natural recovery and restoration of willows and aspen to begin. Beaver numbers are increasing because of availability of aspen and willows as a food source as materials for constructing lodges and dams. Songbird diversity and density increased because of increased availability of nesting and foraging habitat in willows and aspen. Bear numbers increased because wolves are the top predator in the ecosystem and bears make a living scavenging and stealing wolf kills (no wolves means nothing to steal). Coyotes are competitors with wolves and are considerably smaller (wolves are commonly 120 lbs; coyotes, 40 lbs.). Experience from Canada and the upper Midwest in the United States where wolves have always been present tells us that wolves do not tolerate coyotes in or near their territories. Two years after wolf reintroduction, coyote population sizes were down more than 50% in YNP. Other species that could be included in the data sets are species for which the population size, density, and diversity changed, but not significantly so: birds of prey and insects.

Source information:

- WJ Ripple and RL Beschta (2012) Trophic cascades in Yellowstone: the first 15 years after wolf reintroduction. *Biological Conservation*, 145: 205-213.
- LM Baril et al. (2011) Songbird Response to Increased Willow (*Salix* spp.) Growth in Yellowstone's

Northern Range. *Ecological Applications*, 21: 2283-2296.
- LM Baril et al. (2009) Willow-Bird Relationships on Yellowstone's Northern Range. *Yellowstone Science*,
  17: 19-26.
- M Hebblewhite et al. (2005) Human Activity Mediates a Trophic Cascade Caused by Wolves. *Ecology*,
  86: 2135-2144.
- DW Smith, RO Peterson, and DB Houston (2003) Yellowstone after Wolves. *Bioscience*, 53: 330-340.
- National Park Service: http://www.nps.gov/yell/naturescience/mammals.htm

Faculty Notes

Objective:

Teaching experience has revealed that students typically consider any change or variation in data a significant source of data. One cause of this error is that students often only conceive of one or limited sources of variation and often assume that this source is relevant, failing to see any source of error or natural randomness in real data. Our objective is to give students experience with scientific data and to help students make predictions (hypotheses), account for all sources of variation, and recognize significant from insignificant changes in statistics. Biologically this information provides a way to recognize trophic cascades.

Audience: Adaptable for college level Introductory Biology or Ecology classes.

Suggestions on using the exercise:

- Prior to engaging in this exercise, students should be familiar with the concepts of: population, community, community interactions (predation, parasitism, commensalism, mutualism, & competition), niche, and trophic levels. This can be the topics of previous lectures or given as homework or a pre-lecture activity.
- In class engage the students and capture their interest by providing background information on the wolf reintroduction.
- Group discussion: provide a list of other organisms found in GYE (wolf, elk, beaver, bear, coyote, song birds, birds of prey, insects, willows, aspen as a core group; can also add in others as you think the students can handle: grasses, rabbits, moose, bison—whatever you want). Ask students to get into pairs or groups and make a food web of the organisms provided. Discuss food webs and trophic levels as concepts and the strengths and weaknesses of food webs as representations of community interactions. Show how to arrange a food web by trophic level after clicker questions to help them seen how presenting the data can make some information more accessible.
  - Tip: Clicker questions on the food webs can be used for student engagement (see resources below)
  - Tip: Keep the number of organisms in the food web to a manageable level.

- Group discussion: provide a short list or organisms (wolf, elk, beaver, bear, coyote, song birds, birds of prey, insects, willows, aspen) ask students to use their knowledge of community interactions to predict what the population size/density will do in response to wolf reintroduction into YNP: will it go up, down, or stay the same? Have the students include write down *why* they think the organism will respond in that way (i.e. predation, commensalism, mutualism, competition, etc.).
- Present population density data from before wolf reintroduction only. Ask students pair up and when presented with the historical data only they should come up with at least 4 sources or variation, i.e. reasons why the contemporary measurements could be different from the historical ones. They can hypothesize about how large of a difference each of the sources could contribute. After the students are finished the instructor solicits responses and presents them so the entire class can see, and leads a discussion about the effects of each source. The students then pair up again and come up with strategies to control or minimize each undesirable source of variation.
- Present scientific data in tabular and/or graphical formats (see resources below) to show how the community has responded to wolf reintroduction (this can be done one by one or all together). With the students, analyze each one to illustrate top-down trophic cascades. Discuss which population densities changes significantly and those that did not? How do we what is significant statistically and biologically? Talk about means and measures of variance seen in the data tables. Discuss the observational nature of these data; compare to experimental data. Discuss causation/correlation for the significant and nonsignificant density changes—what are the sources of variation? Teach how top-down tropic cascades are different from bottom-up trophic cascades.
    - Tip: some of the tables are too complex for display in class and as a teaching tool. Glean the relevant data from the tables and simply into your own table to present to your class (see example below)
    - Tip: in some cases original data sources can be downloaded as powerpoint slides for teaching purposes directly from the publisher.

Additional resources to consider for use and adapt to your style and class:

Food web clicker questions:

- At what trophic level are song birds found?
- What other organisms are found in this trophic level?
- If a rabbit consumes 1000 calories of grass, how much of that 1000 calories will be available to a hawk if it consumes the rabbit?

Trophic cascade clicker questions:

- Using your foodweb diagram, predict which population change would result in reduced songbird populations under a top-down trophic cascade? (answers could include "increasing hawk population" (right answer), "decreasing hawk population", increasing elk population", "decreasing elk population"
- Using your food web diagram. If bottom-up control explains the size of songbird populations in your riparian habitats, which graph best illustrates the critical population interactions? (answers are in graphical format with songbirds on the Y-axis and another organism (i.e birds of prey, or aspen, or willows or elk) on the other. The trend line should be simple and can be flat, positive correlated or negatively correlated. The correct answer would show either willows or aspen on the X axis and a positive trend line).

Example of (overly) simplified data table for presentation in class:

Measure	1994	Current data
Elk density (#/site^2)	9	2
Hawks (#sighted/hr/site)	4.3	3.8
Insect abundance (#/m^2)	34	39
Willow stem density (#/m^2)	6	12.5
Songbird diversity	1.3	5
Songbird abundance	3.4	9.5

Online data:

The National Park Service website: http://www.nps.gov/yell/naturescience/mammals.htm

Published scientific data:

NOTICE: Generally terms of use allow non-commercial educational use as long as credit, citation and copyright are displayed with the resources.

For the three following figures:

William J. Ripple , Robert L. Beschta

Trophic cascades in Yellowstone: The first 15 years after wolf reintroduction

Biological Conservation Volume 145, Issue 1 2012 205 - 213

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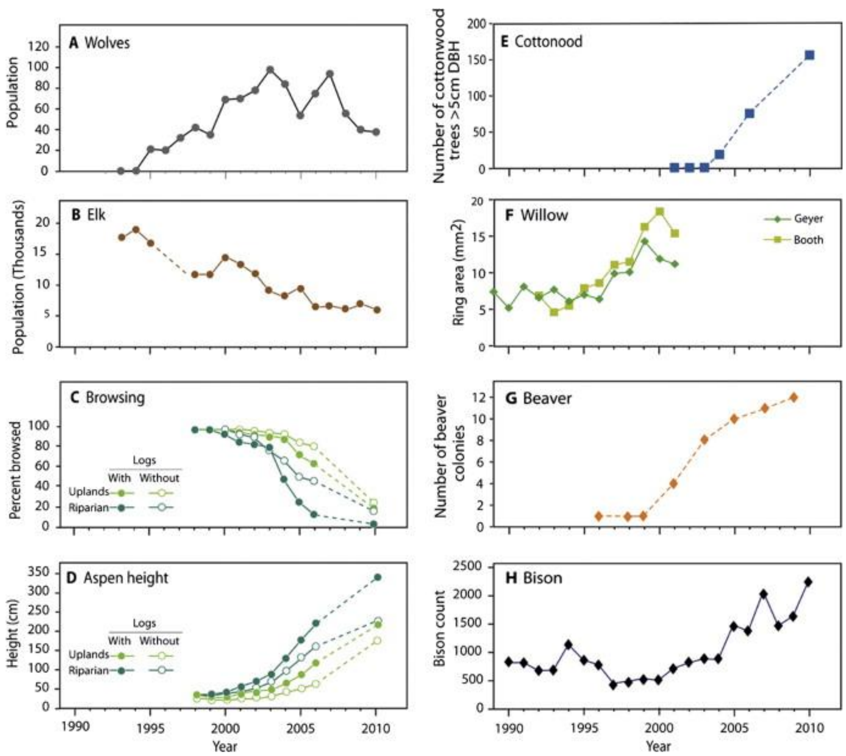
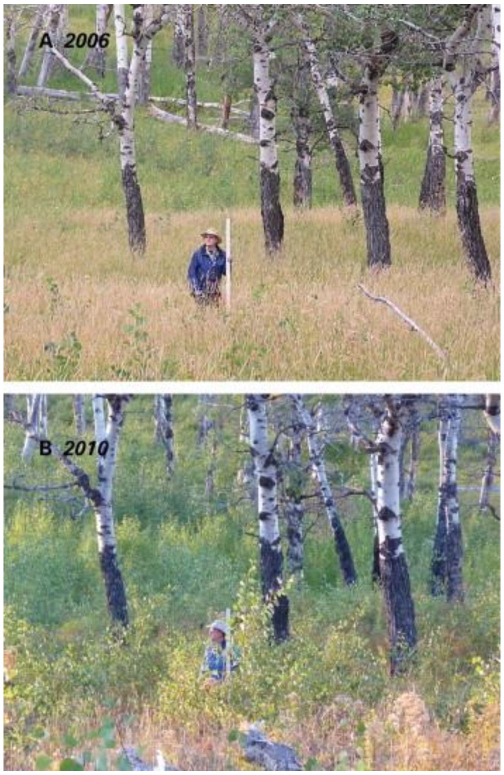
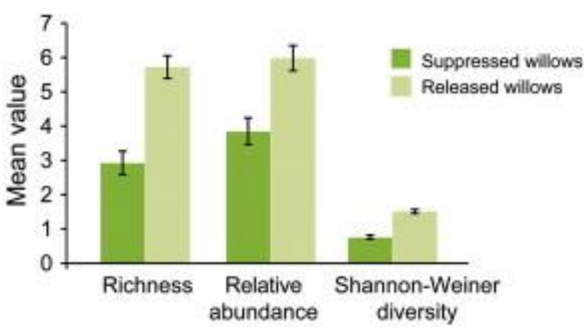
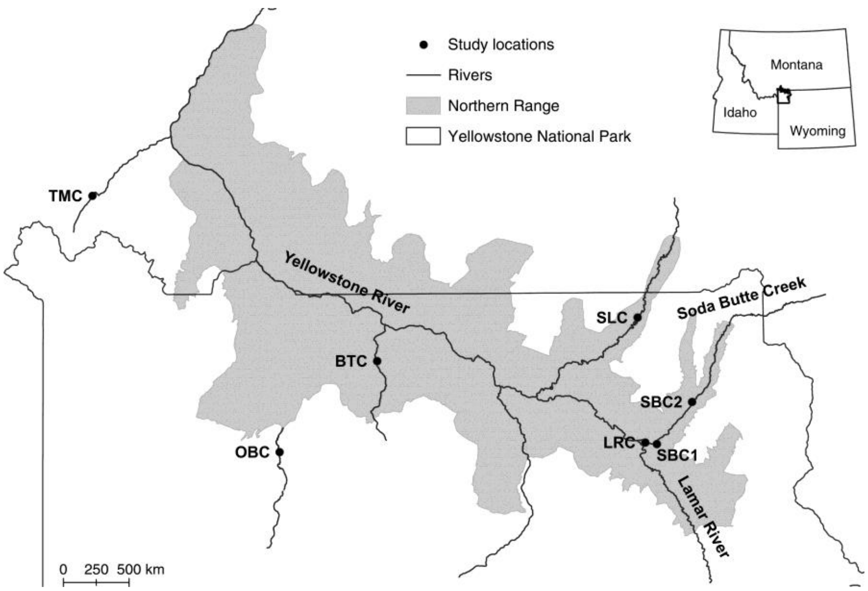


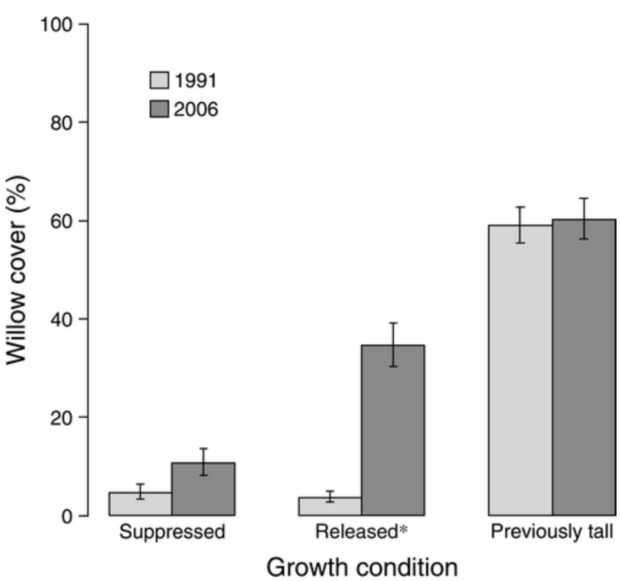

A 2006
B 2010

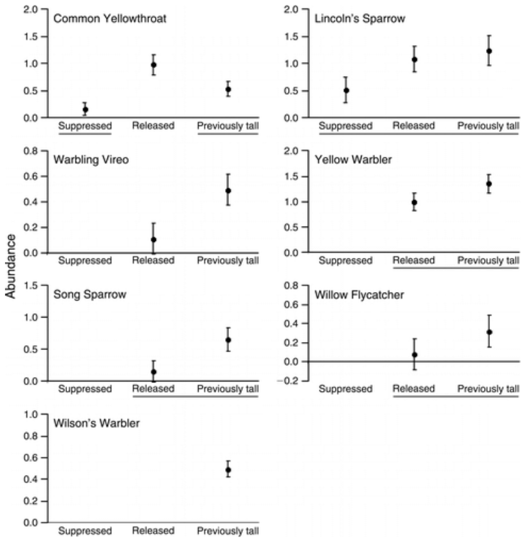

Mean value
7
6
5
4
3
2
1
0
Suppressed willows
Released willows
Richness
Relative abundance
Shannon-Weiner diversity

For the following 5 data figures and tables:

Lisa M. Baril, Andrew J Hansen, Roy Renkin, and Rick Lawrence
Songbird response to increased willow (*Salix* spp.) growth in Yellowstone's northern range
Ecological Applications Volume 21, Issue 6 2011 2283 - 2296







Structural characteristics	Suppressed ($n = 23$)	Released ($n = 21$)	Previously tall ($n = 23$)	$F_{2,64}$	P	Differences†
Height (cm)	61.55 ± 19.03	143.08 ± 18.34	179.71 ± 19.91	15.08	<0.001	S, R, Pt
CV in height (cm)	0.37 ± 0.04	0.39 ± 0.04	0.39 ± 0.04	0.11	0.895	S, R, Pt
Horizontal cover (%)	9.61 ± 3.15	21.42 ± 3.29	60.39 ± 3.15	76.75	<0.001	S, R, Pt
Frequency (%)	26.53 ± 3.95	30.48 ± 4.13	73.48 ± 3.95	31.34	<0.001	S, R, Pt
Foliage height diversity	0.45 ± 0.12	1.39 ± 0.12	1.69 ± 0.13	29.37	<0.001	S, R, Pt
Patch size	1.05 ± 2.06	2.95 ± 2.15	12.49 ± 2.05	11.31	0.001	S, R, Pt
0–50 cm (%)	59.74 ± 3.65	69.20 ± 3.81	68.42 ± 3.65	14.33	0.246	S, R, Pt
50–100 cm (%)	20.29 ± 3.83	53.16 ± 4.01	63.85 ± 3.83	34.91	<0.001	S, R, Pt
100–150 cm (%)	NA	36.59 ± 4.90	51.16 ± 4.69	4.61‡	0.038	R, Pt
150–200 cm (%)	NA	24.88 ± 5.05	34.98 ± 4.83	3.92‡	0.054	R, Pt

Notes: CV is the coefficient of variation. The number of point count locations is signified by n, derived from measurements taken in the 40 m radius circular sample plots. NA stands for not applicable.

† Underlines indicate nonsignificant differences ($P > 0.05$) between growth conditions (S, suppressed; R, released; Pt, previously tall).

‡ For these two tests, df = 1, 42.

Bird characteristics	Suppressed ($n = 23$)	Released ($n = 21$)	Previously tall ($n = 23$)	$F_{2,64}$	P	Differences†
Richness	2.93 ± 0.34	5.72 ± 0.33	7.52 ± 0.34	48.04	<0.001	S, R, Pt
Relative abundance	3.85 ± 0.39	5.98 ± 0.37	6.46 ± 0.41	14.64	<0.001	S, R, Pt
Shannon-Weiner diversity	0.76 ± 0.06	1.51 ± 0.06	1.78 ± 0.07	62.46	<0.001	S, R, Pt

Note: The number of point count locations is signified by n, derived from measurements taken in the 40 m radius circular sample plots.

† Underlines indicate nonsignificant differences ($P > 0.05$) between growth conditions (S, suppressed; R, released; Pt, previously tall).

For the following data figure:

Mark Hebblewhite, et al.
Human activity mediates a trophic cascade caused by wolves
Ecology Volume 86, Issue 8 2005 2135 - 2144