Test of Mediation Example: Effects of Drought on Animal Communities

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This module presents an additional example of a mediation model. In this study, the authors looked at animal community changes over several years spanning from before a drought until after. Very clear study with interesting and somewhat unanticipated results:

Prugh LR, Deguines N, Grinath JB, Suding KN, Bean WT, Stafford R, Brashares JS. (2018) Ecological winners and losers of extreme drought in California. *Nature Climate Change*, Aug 20:1.

An appropriate general citation for mediation testing is

Grace, J.B. (2006) *Structural Equation Modeling and Natural Systems.* Cambridge University Press.

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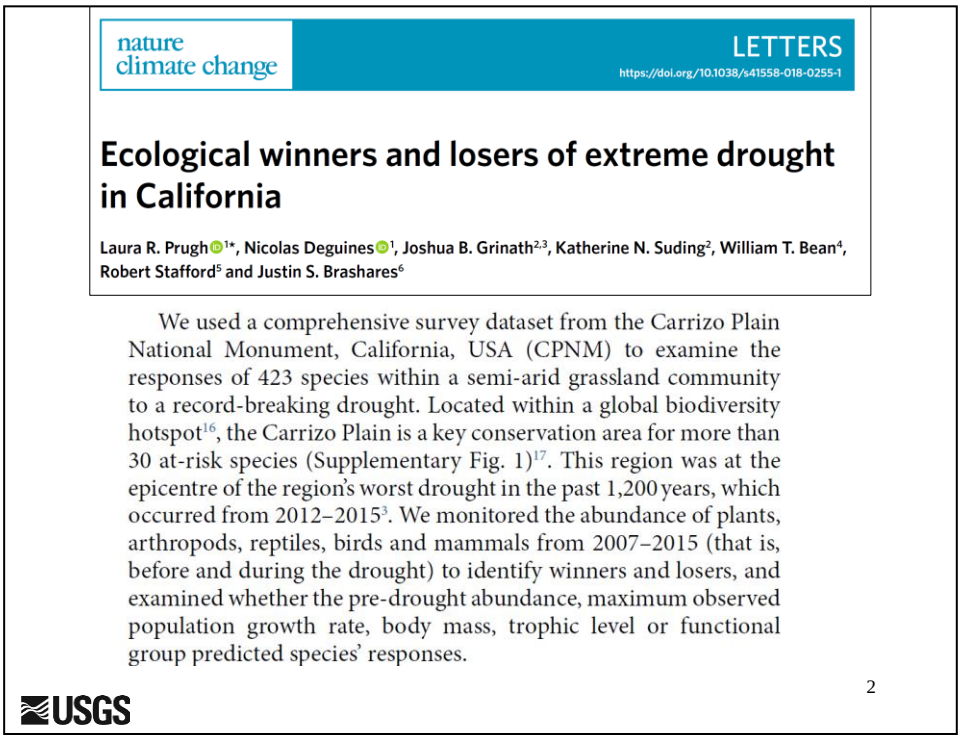
Source: https://www.usgs.gov/centers/wetland-and-aquatic-research-center/science/quantitative-analysis-using-structural-equation



nature climate change

LETTERS

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Ecological winners and losers of extreme drought in California

Laura R. Prugh[1*], Nicolas Deguines[1], Joshua B. Grinath[2,3], Katherine N. Suding[2], William T. Bean[4], Robert Stafford[5] and Justin S. Brashares[6]

We used a comprehensive survey dataset from the Carrizo Plain National Monument, California, USA (CPNM) to examine the responses of 423 species within a semi-arid grassland community to a record-breaking drought. Located within a global biodiversity hotspot[16], the Carrizo Plain is a key conservation area for more than 30 at-risk species (Supplementary Fig. 1)[17]. This region was at the epicentre of the region's worst drought in the past 1,200 years, which occurred from 2012–2015[3]. We monitored the abundance of plants, arthropods, reptiles, birds and mammals from 2007–2015 (that is, before and during the drought) to identify winners and losers, and examined whether the pre-drought abundance, maximum observed population growth rate, body mass, trophic level or functional group predicted species' responses.

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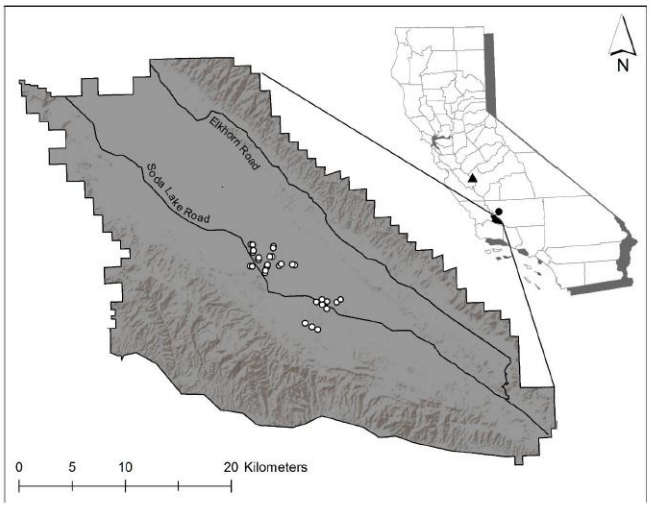
Note that the presentation of results in this illustration is focused on the conceptual content of the topic and original study. No attempt is made to validate or criticize the authors' choices of how to measure concepts of interest or to handle data complexities.

Study Area



Supplementary Fig. 1 | Carrizo Plain National Monument, California (35.19° N, 119.9° W). Long-term study plots are shown as white dots. Spotlight surveys and Christmas bird counts were conducted along Soda Lake Road and Elkhorn Road. Locations of the Lokern (black circle) and Ciervo-Panoche (black triangle) supplemental feeding trials for giant kangaroo rats are shown on the California map inset.

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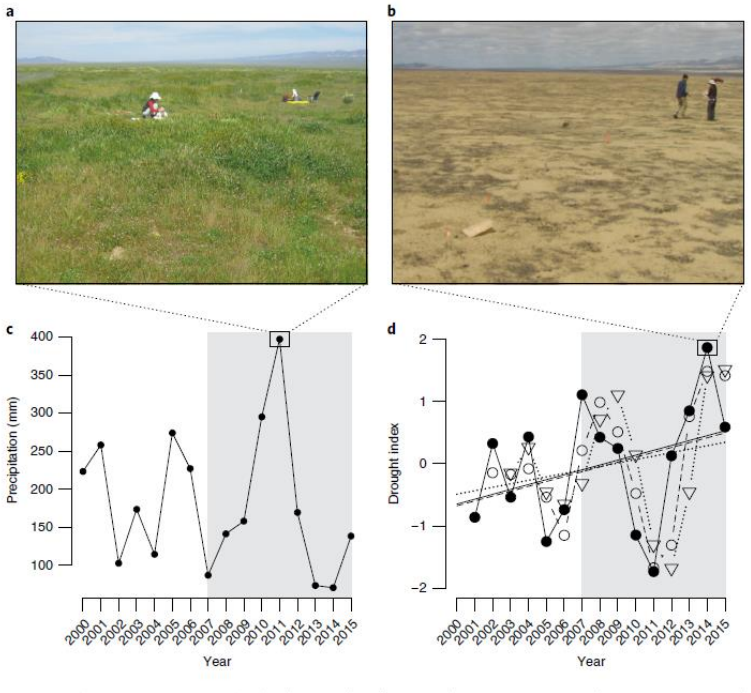
Before and During the Drought



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Additional conditions were measured with an interest in understanding variations in community recovery.

Some of the Main Findings

"Abundant species more likely to lose and rare species more likely to win. Strengths and slopes of these negative density dependent drought responses were remarkably consistent across taxonomic groups."

"In addition, there was a spike in the number of rare species during the last year of the drought: 27 of the 87 species (31%) that occurred during one year only were present in 2015—far more than expected by chance (binomial test $P < 0.001$)."

"These findings support the role of drought as a disturbance agent that opens niche space by stressing dominant species and allowing competitively inferior species to increase in abundance."

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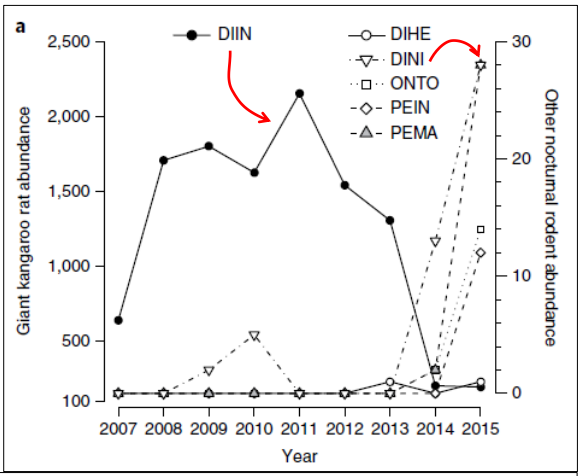
"We further tested this competitive release hypothesis by assessing the response of nocturnal rodents to drought."

Giant kangaroo rat (DIIN) greatly outnumbered other rodent species before drought.

Dominance weakened as drought ensued: four species colonized during drought and abundance of short-nosed kangaroo rat (DINI) increased fivefold (Fig. 3a).



DIIN, *D. ingens* (giant kangaroo rat); DIHE, *D. heermanni* (Heerman's kangaroo rat); DINI, *D. nitratoides brevinasus* (short-nosed kangaroo rat); ONTO, *Onychomys torridus tularensis* (southern grasshopper mouse); PEIN, *Perognathus inornatus* (San Joaquin pocket mouse); PEMA, *Peromyscus maniculatus* (deer mouse).

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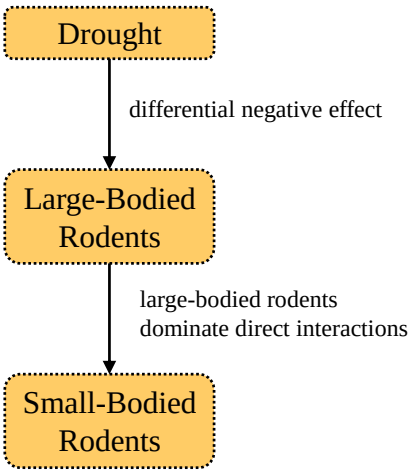
Time series of nocturnal rodent abundance, measured as the total number of unique individuals captured during spring and summer mark–recapture sessions on 30 1 ha plots.

A video about kangaroo rats can be seen at:

https://www.youtube.com/watch?v=wkJLHnYy_G0

Do the Data Support Mediation Hypothesis?

Full-Mediation Hypothesis



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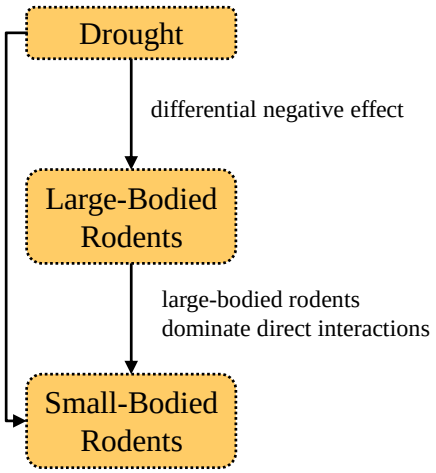
Do the Data Support Mediation Hypothesis? (cont.)

Partial-Mediation Hypothesis

drought affects small-bodied rodents independent of competitive release



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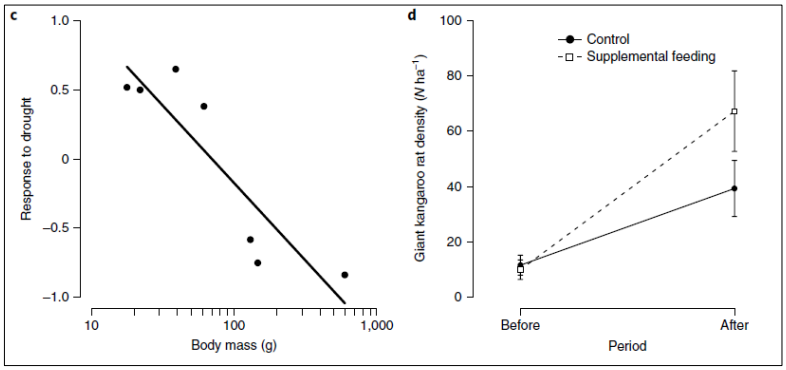
Supporting Information.



c. Larger bodied rodents were losers and smaller-bodied rodents were winners in response to drought.

d. Effect of supplemental feeding on giant kangaroo rat density.

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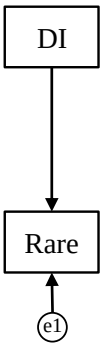
Lavaan code for net response of rare rodents to drought.




```
######### TEST OF MEDIATION ##########
# Response of rare rodent abundance (Rare)
# to drought (DIndex = drought index)

## Net Effect Model
  # net effect
    net <- 'Rare ~ DIndex'

    # Fit model
    net.fit <- sem(net, data=sem.dat)

    # Output results
    summary(net.fit, standardized=T,rsq=T)
```

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Lavaan results.

```
  Model Fit Test Statistic (Chi-square)  0.000
  Degrees of freedom                        0
  P-value                                1.000
```

```
               Est  Std.err  Z-value  P(>|z|)   Std.all
Regressions:
Rare ~
    DIndex  0.203    0.023    8.844    0.000   0.474

R-Square:
                 Estimate
    Rare            0.225
```

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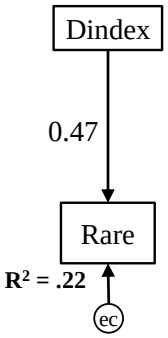
Results indicate a significant net effect.

Graphical summary of net relationship.



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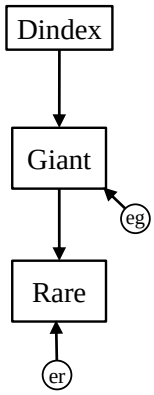
Here is a graphical summary of the net effect.

Mediation Hypotheses

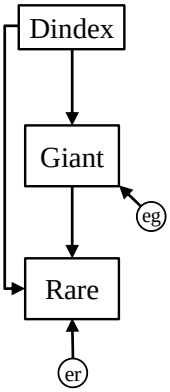
Some Possible Outcomes.

complete mediation



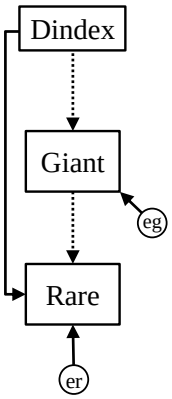

```
'Rare ~ Giant
 Giant ~ Dindex'
```

partial mediation




```
'Rare ~ Giant + Dindex
 Giant ~ Dindex'
```

no mediation




```
'Rare ~ 0*Giant + Dindex
 Giant ~ 0*Dindex'
```

When we think about the possible findings in a test of mediation, there are three types of models possible.

The lavaan code for each model is below the graphs.

We can use AICc to compare the the models.

```
aictab(list(comp.mod.fit, partial.mod.fit,
nomed.mod.fit), c("Complete", "Partial", "None"))
```

```
Model selection based on AICc :

          K   AICc Delta_AICc AICcWt Cum.Wt      LL
Partial   5 811.31       0.00   0.86   0.86 -400.53
Complete  4 814.94       3.63   0.14   1.00 -403.38
None      3 974.51     163.20   0.00   1.00 -484.20
```

Results support partial mediation hypothesis

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We can go further and create an AICc table, including the computation of model weights. You can refer to the module on “Model Evaluation” for more detail on this procedure.

A succinct treatment of model comparison using AIC tables can be found at

http://www.unc.edu/courses/2006spring/ecol/145/001/docs/lectures/lecture17.htm

AICc leads to same conclusions as AIC.

Results for Partial Mediation Model

```
                   Estimate  Std.err  Z-value  P(>|z|)   Std.all
 Giant ~
    DIndex           -0.590    0.046  -12.707    0.000   -0.634
  Rare ~
    Giant            -0.223    0.032   -6.938    0.000   -0.469
    DIndex            0.072    0.030    2.405    0.016    0.163

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv
Std.all
   .Giant             0.623    0.057   10.954    0.000    0.598
   .Rare              0.155    0.014   10.954    0.000    0.656

R-Square:
                   Estimate
    Giant             0.402
    Rare              0.344
```

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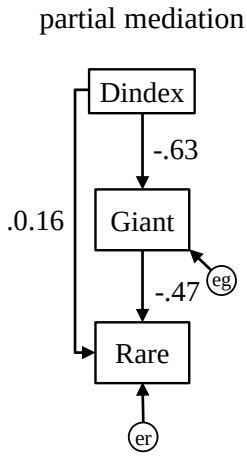
Calculating the magnitude of the standardized indirect effect.



Standardized total effect of Dindex on Rare:
= -0.63 * -0.47 = +0.30

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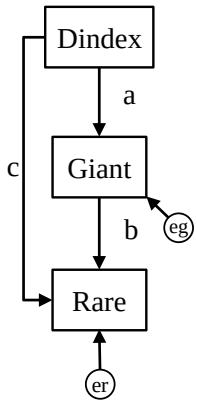
Simple to compute the indirect effect in the linear Gaussian case, just mutiply the path coefficients along the path.

For more complex models, we might use queries to quantify indirect effects.

We can compute indirect and total effects within lavaan




```
### Compute indirect and total effects
### We will use partial mediation model
partial <- 'Giant ~ a*DIndex
            Rare ~  b*Giant + c*DIndex

            direct   := c
            indirect := a*b
            total    := c + (a*b)
           '

# Fit the model
partial.fit <- sem(partial, data=sem.dat)

# Extract results
summary(partial.fit,standardized=T,rsq=T)
```

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Here we see that if we label the parameters, we can then define different quantities in the model syntax.

Results

```
                   Estimate  Std.err  Z-value  P(>|z|)   Std.all
 Giant ~
    DIndex     (a)   -0.590    0.046  -12.707    0.000   -0.634
  Rare ~
    Giant      (b)   -0.223    0.032   -6.938    0.000   -0.469
    DIndex     (c)    0.072    0.030    2.405    0.016    0.163

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.all
   .Giant             0.623    0.057   10.954    0.000    0.598
   .Rare              0.155    0.014   10.954    0.000    0.656

R-Square:
                   Estimate
    Giant              0.402
    Rare               0.344

Defined Parameters:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.all
    direct             0.072    0.030    2.405    0.016    0.163
    indirect           0.132    0.022    6.090    0.000    0.298
    total              0.203    0.025    8.033    0.000    0.460
```

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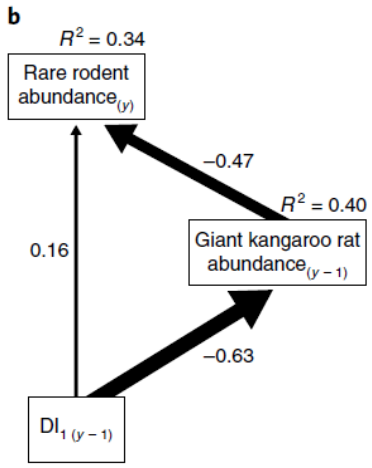
Now, we get full information about defined quantities. Here we can see that if you add the direct and indirect effect, you get the total effect.

Published Results



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The figure is from the published paper.