Causal Modeling Principles

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In this module I revisit causal modeling principles in a little more depth, now that we have a few models under our belts.

An appropriate general citation for this material is

Grace, J.B., Scheiner, S.M., Schoolmaster, D.R. Jr. in press. Structural equation modeling: building and evaluating causal models. Chapter 8 In: Fox, G.A., Negrete-Yanlelevich, S., and Sosa, V.J. (eds.) *Ecological Statistics: From Principles to Applications*. Oxford University Press.

An additional important reference for the topic of causal modeling is

Pearl, J. (2009) Causality (2nd Edition). Cambridge University Press

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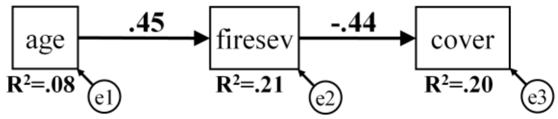
material can be sent to sem@usgs.gov.

How we can throw around the word "causal"?

causal linkages versus causal estimates.

Let's consider this snippet from our fire-effects SEM.



"How strongly can we defend the contention that this is a causal hypothesis (linkage are cause-effect)?"

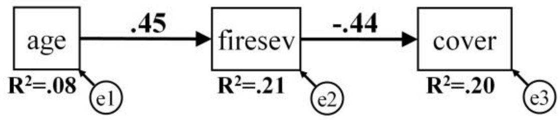
- Time sequence is good:
  Age before fire → severity of fire → recovery from fire.

- Temporal logic is irreversible (arrows can't go the other way).

There is a very important distinction to make between causal linkages and causal estimates.

Establishing that links are causal and that manipulations of one variable lead to responses in the other can be difficult.

Causal linkages versus causal estimates (continued).



A second question, "How strongly can we defend the parameter estimates as unbiased causal predictions?"

This one is much harder.
A strong causal prediction would be that any individual plot in a hypothetical population of plots would increase in fire severity by 0.45 if we increased stand age by one unit.

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There are a whole additional set of issues surrounding whether parameter estimates are pure causal effects.

In ecology we don't usually require our quantities to be exact in order to declare our model results a useful approximation. However, in some other fields (e.g., medical trials) people can be sticklers about the coefficients. We ignore that these are standardized coefficients for the moment, though we really should be dealing with unstandardized estimates to be more careful.

There is skepticism about causal modeling from some quarters.

Caution is OK, *but* we should not be afraid to do science!

How far down the rabbit hole does this debate go?
Even in controlled experiments we cannot know for sure how individuals assigned to one treatment group would have behaved had they been in the other treatment group. For example, we might ask

"If Ms. X had been given the drug, would she have then survived?"

At a certain level, this counterfactual cannot be answered with certainty.

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If you read widely enough, you will find some very deep debates about causal modeling here and there. These are usually not from scientists, but from some statisticians who are concerned that our causal estimates may not be perfect.

Bottom line: we should not be cavalier about the limits of interpretation.

Generally, with SEM we are evaluating causal hypotheses. Building confidence about causal conclusions requires persistent investigation.

Therefore, we might say,

"Our model results support the conclusion that X affects Y through Z."

Best not to speak as if by doing SEM we automatically have causal conclusions.

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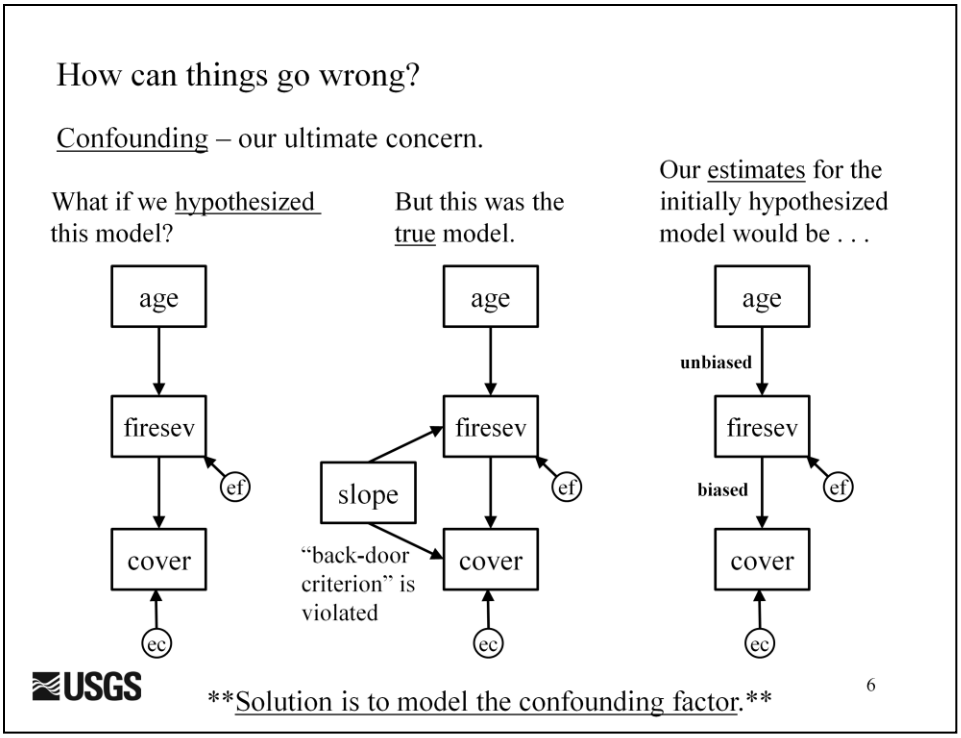
Understanding of the issues brings with it a respect for the need to pursue a causal understanding seriously. It also brings with it an understanding of the need to clarify our dependence on assumptions.



Confounding is one of the big issues.

There are other issues as well, such as whether causes are reversible and whether each individual in the population is equally affected by a causal influence. There is a deep literature here and I would suggest another reference that is a bit more accessible than Pearl.

Berzuini, Dawid, Bernardinelli (eds) (2012) *Causality*. John Wiley & Sons.