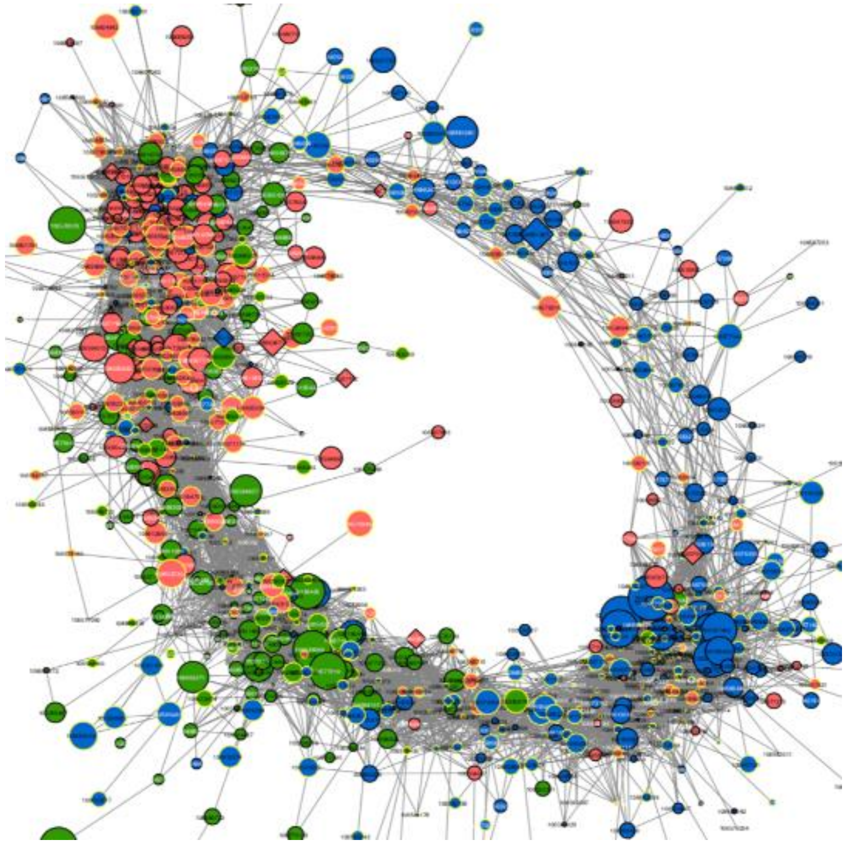
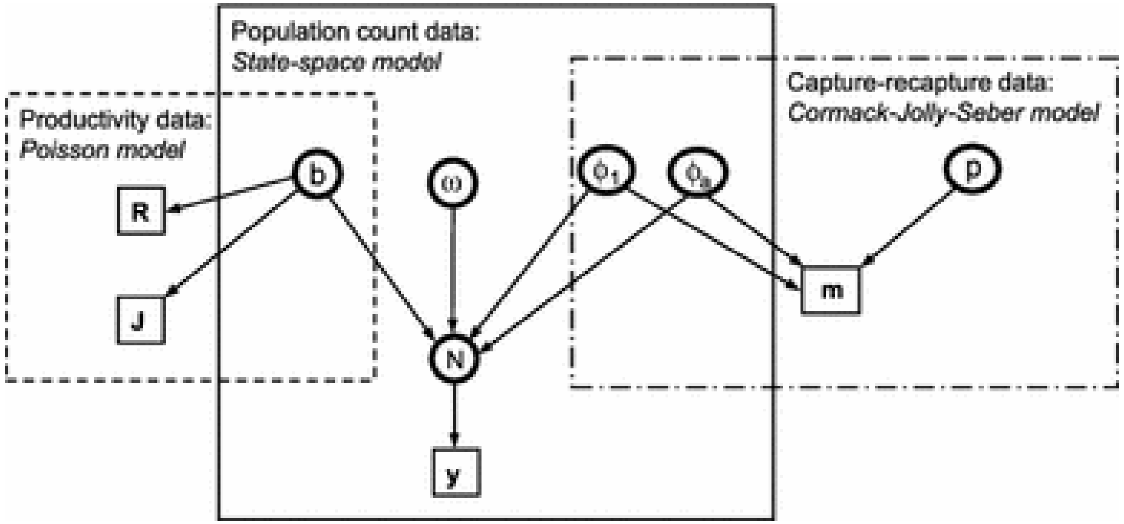
Cross-lags or dynamic SEMs, Bayesian inference & conclusions

TV Riecke





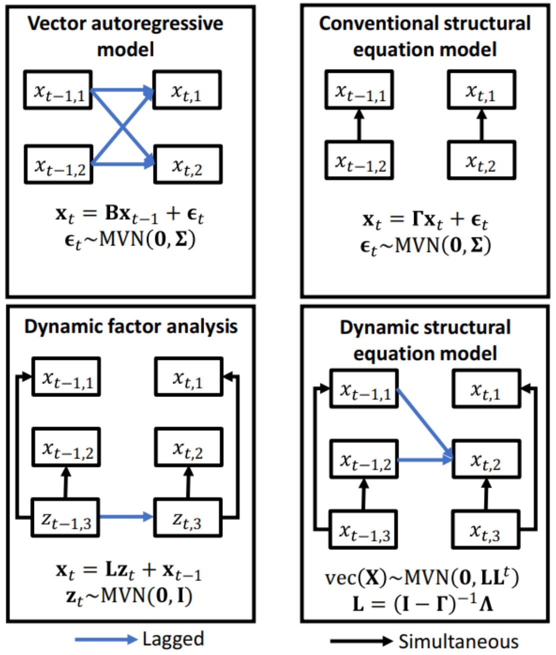
Cross-lags or dynamic SEMs

Received: 31 July 2023 | Accepted: 3 January 2024
DOI: 10.1111/2041-210X.14289
Methods in Ecology and Evolution

RESEARCH ARTICLE

Dynamic structural equation models synthesize ecosystem dynamics constrained by ecological mechanisms

James T. Thorson[1] | Alexander G. Andrews III[2] | Timothy E. Essington[3] | Scott I. Large[4]

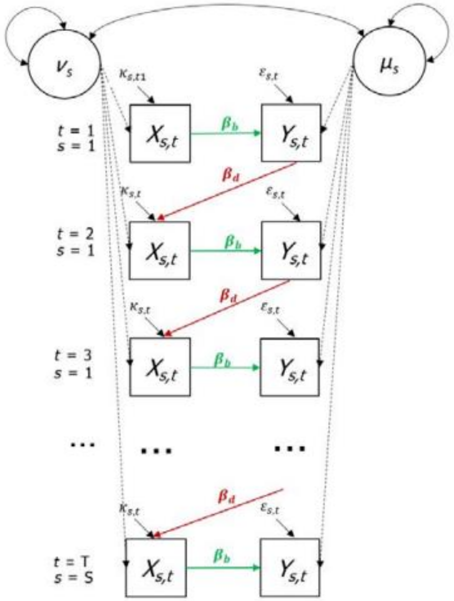


Received: 6 October 2020 | Accepted: 21 July 2021
DOI: 10.1111/1365-2656.13572
Journal of Animal Ecology

RESEARCH METHODS GUIDE

Cross-lags and the unbiased estimation of life-history and demographic parameters

Martijn van de Pol[1] | Lyanne Brouwer[2,3]



Thorson et al. **(2024)** *MEE*

Van de Pol & Brouwer **(2021)** *JAnE*

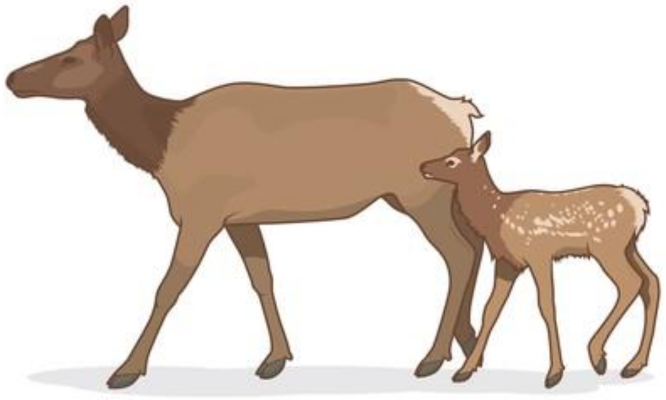
Two examples

1. Life-history trade-offs
    - Based on an *in revision* manuscript

2. Density-dependence and environmental heterogeneity
    - Based on our work with ducks

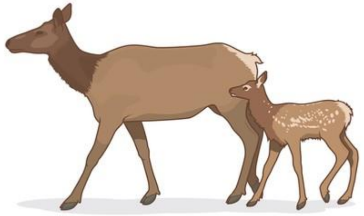
Life-history trade-off example

Reproductive success (ρ) $\rho_{it} \xrightarrow{-} \phi_{it}$ Survival (φ)

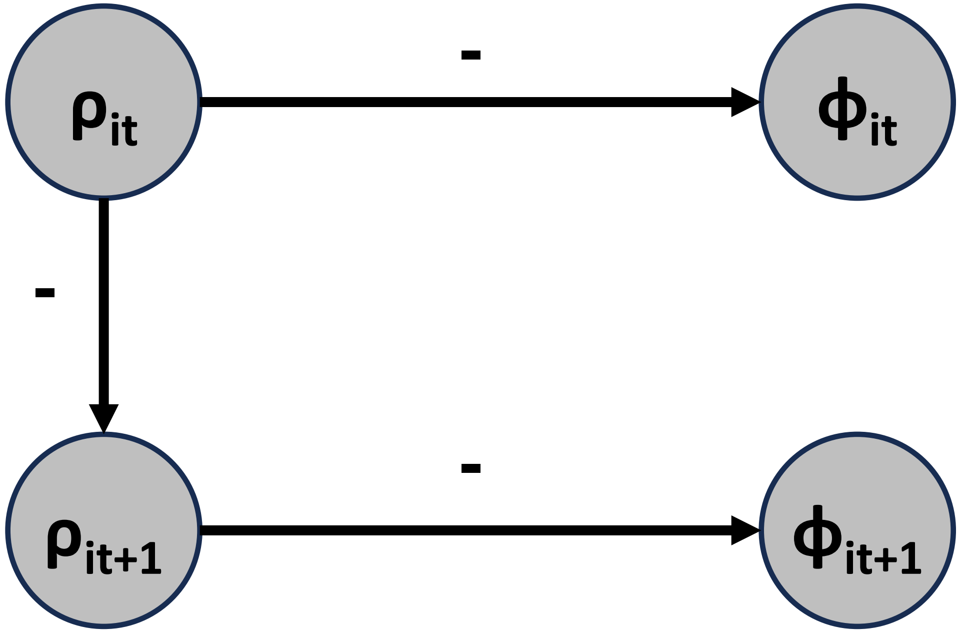


https://github.com/thomasriecke/SEM_workshop/R_scripts/Lecture6_scripts/Lecture6c_lavaan_v_blavaan.R

Life-history trade-off example



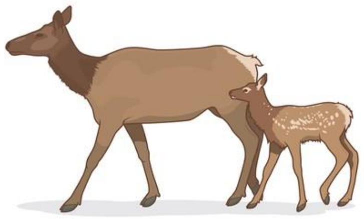
Reproductive success (ρ)

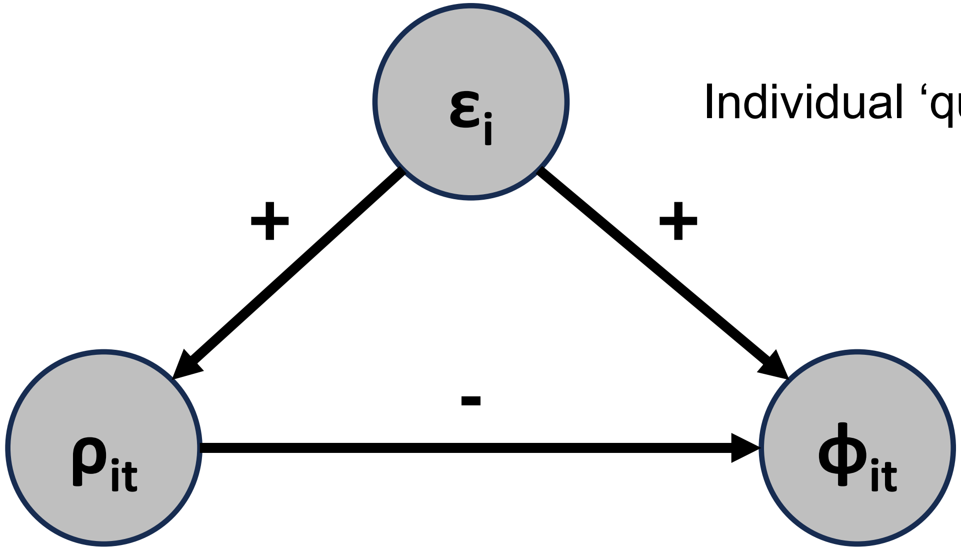


Survival (φ)

Negative effect of increased reproductive investment in t+1

There’s a twist… individuals are… different!

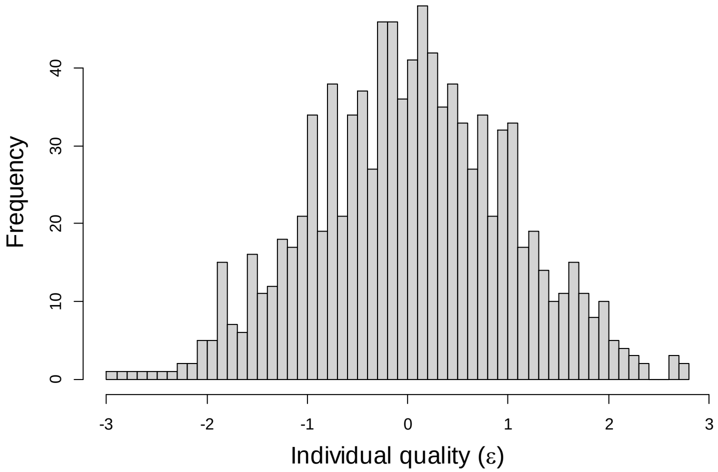




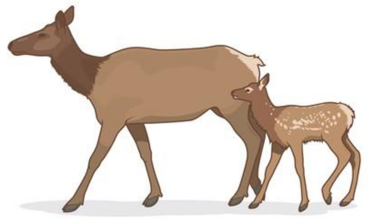
Individual ‘quality’ (ε)

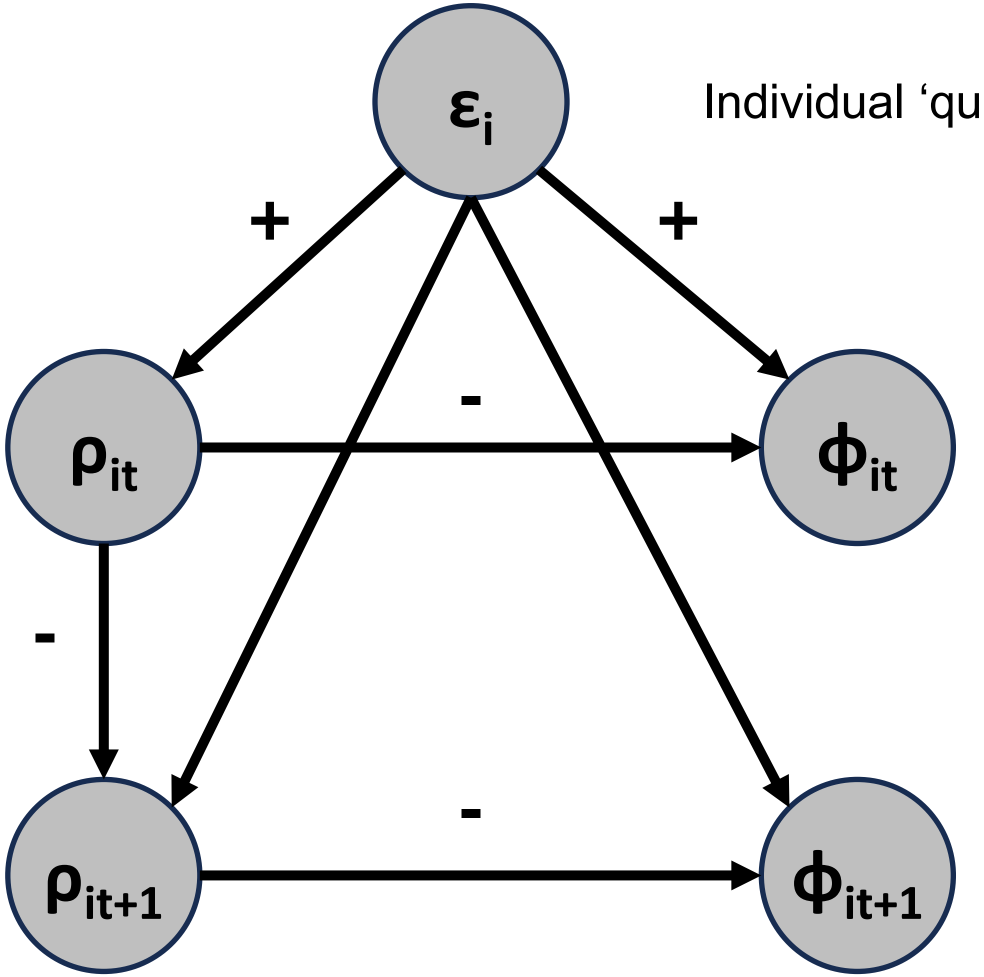
Reproductive success (ρ)

Survival (φ)



The full model



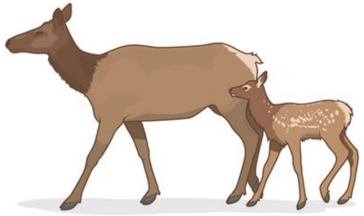


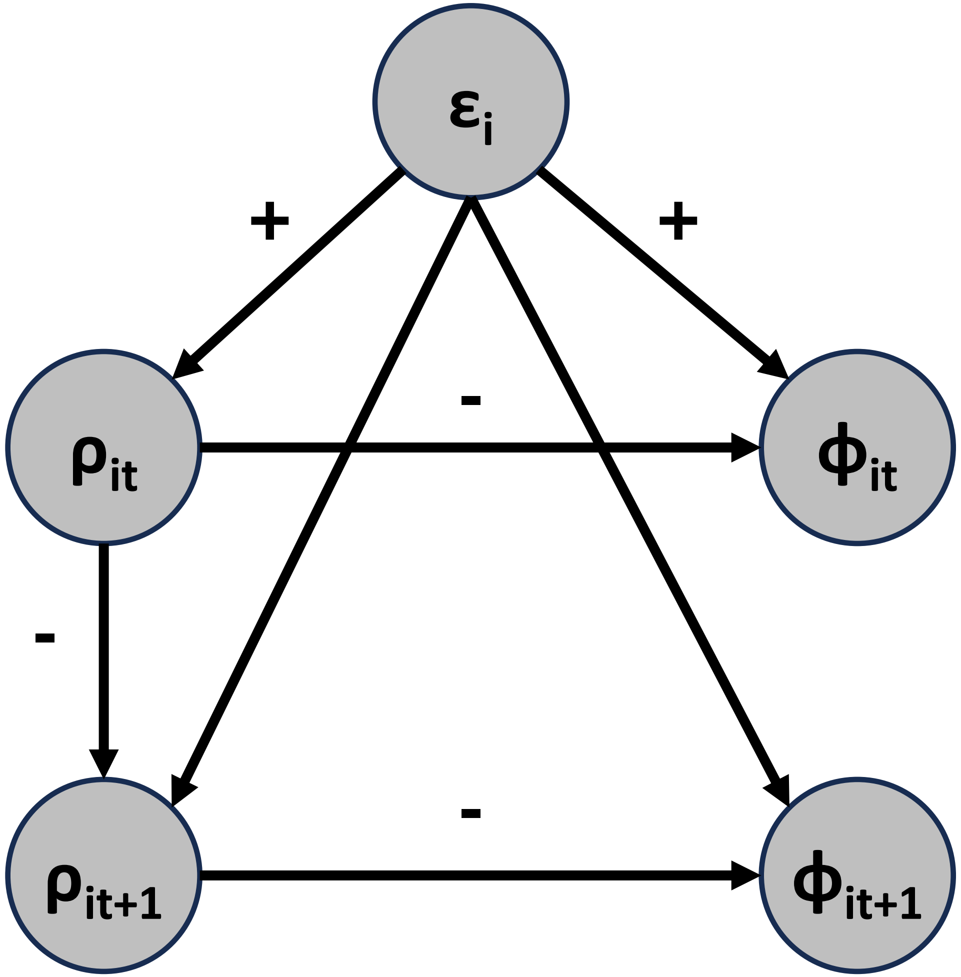
Individual ‘quality’ (ε)

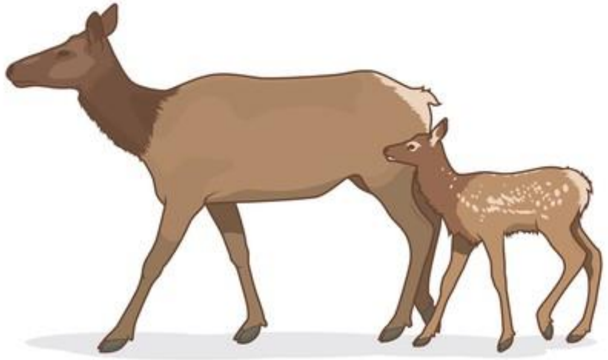
Reproductive success (ρ)

Survival (φ)

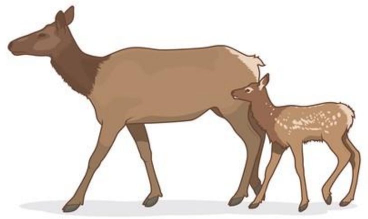
The full model

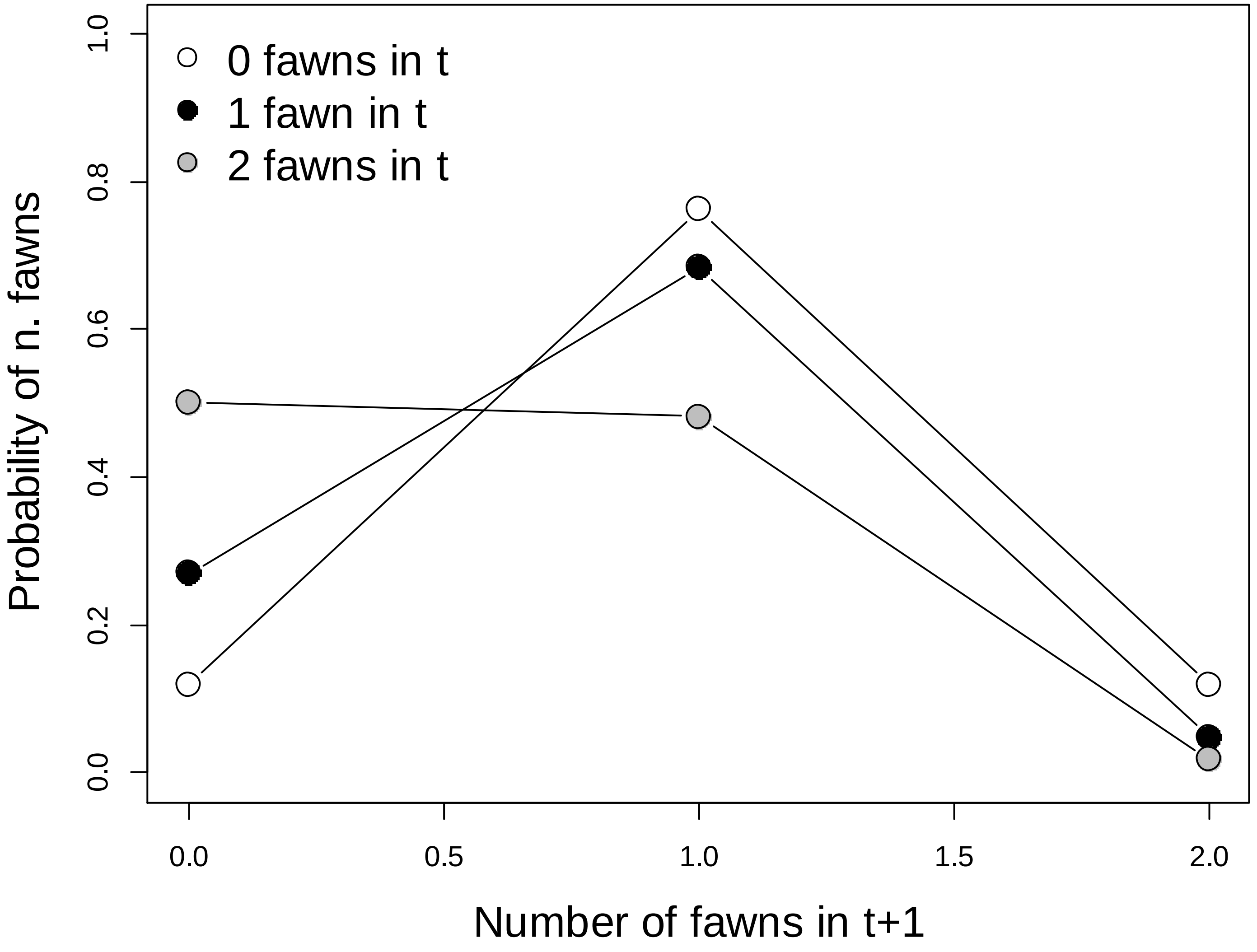


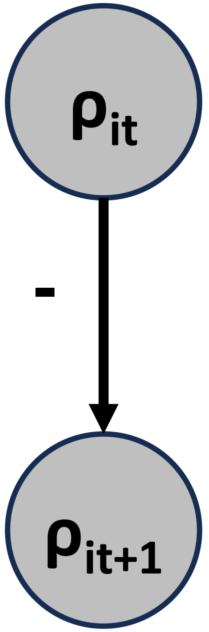




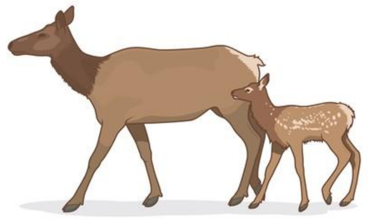
What is our true carry-over effect of reproduction?

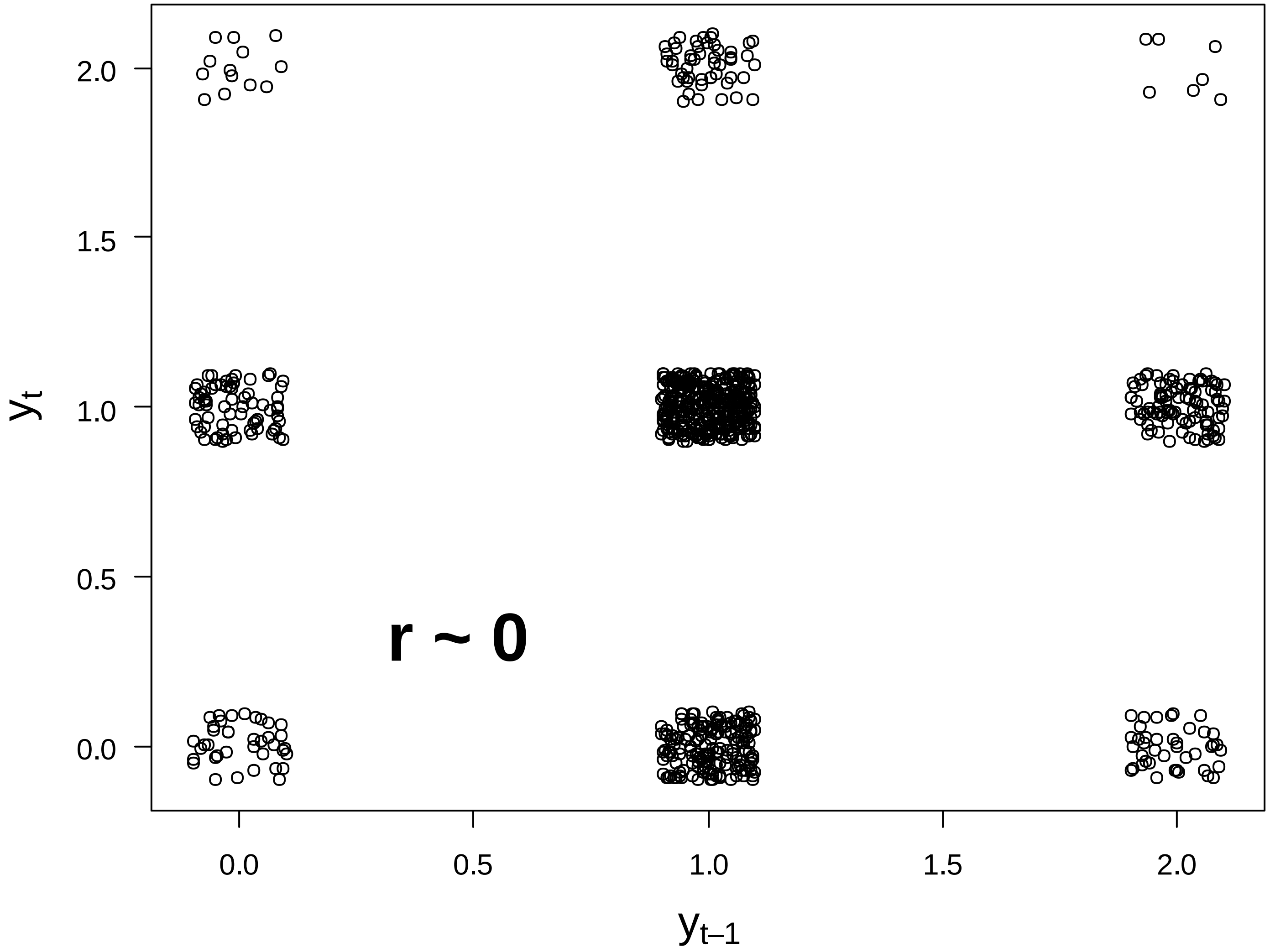


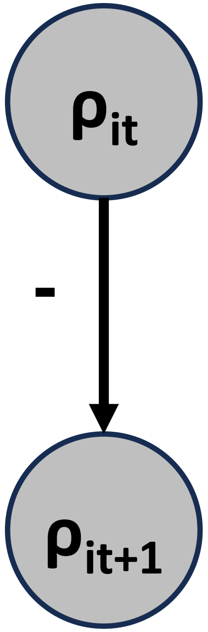




What is our observed carry-over effect of reproduction?

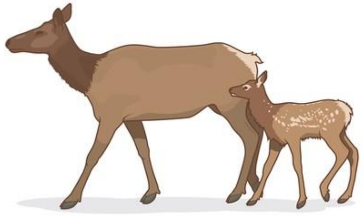


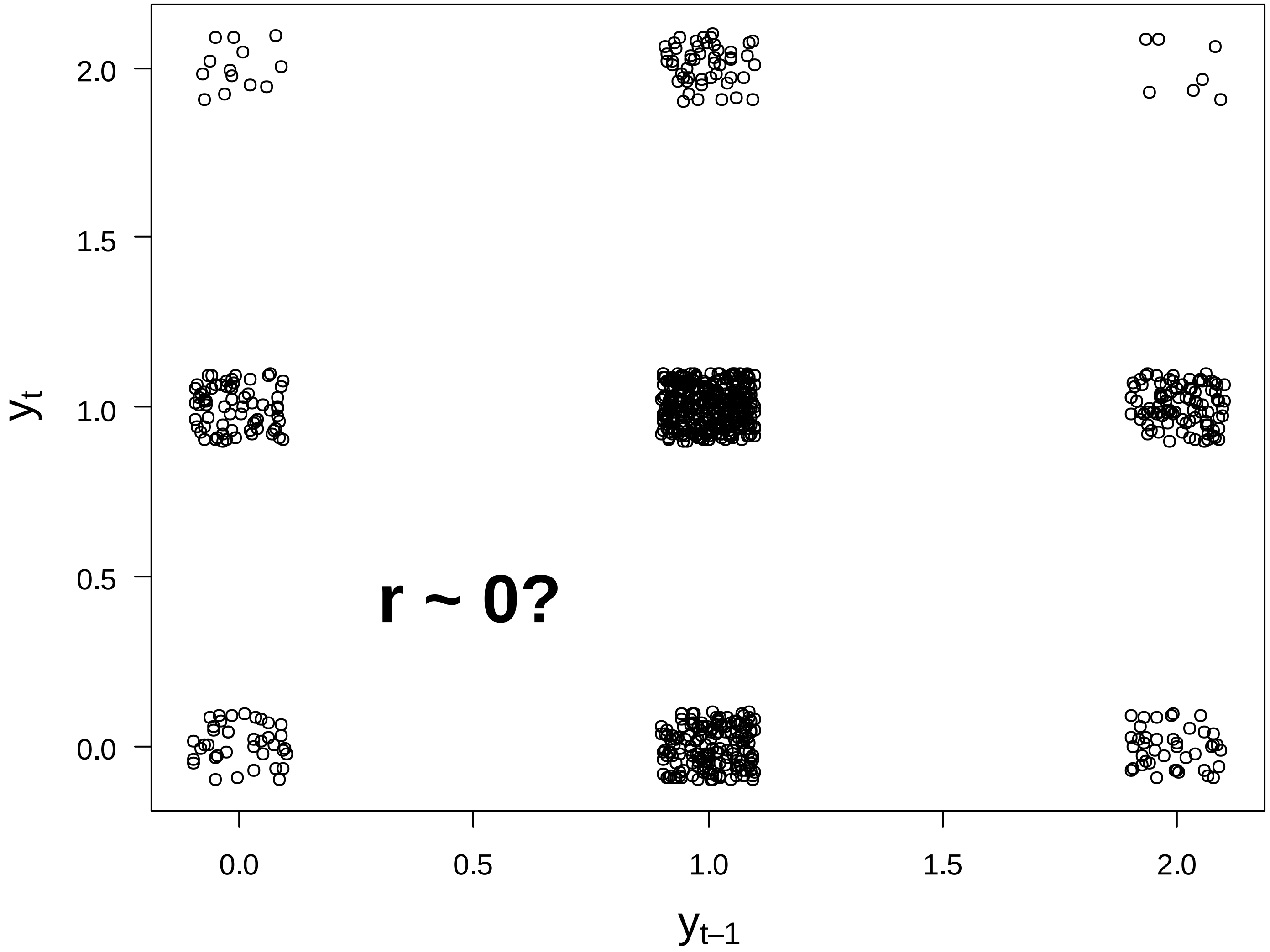


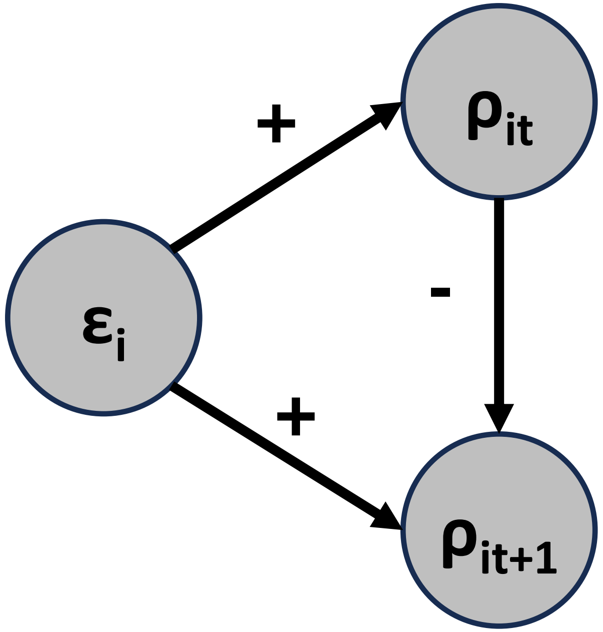


What's happening?

High-quality females have more offspring, more often

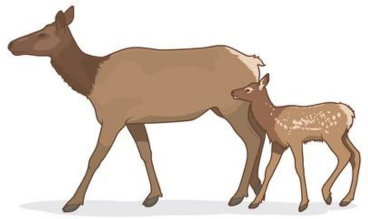


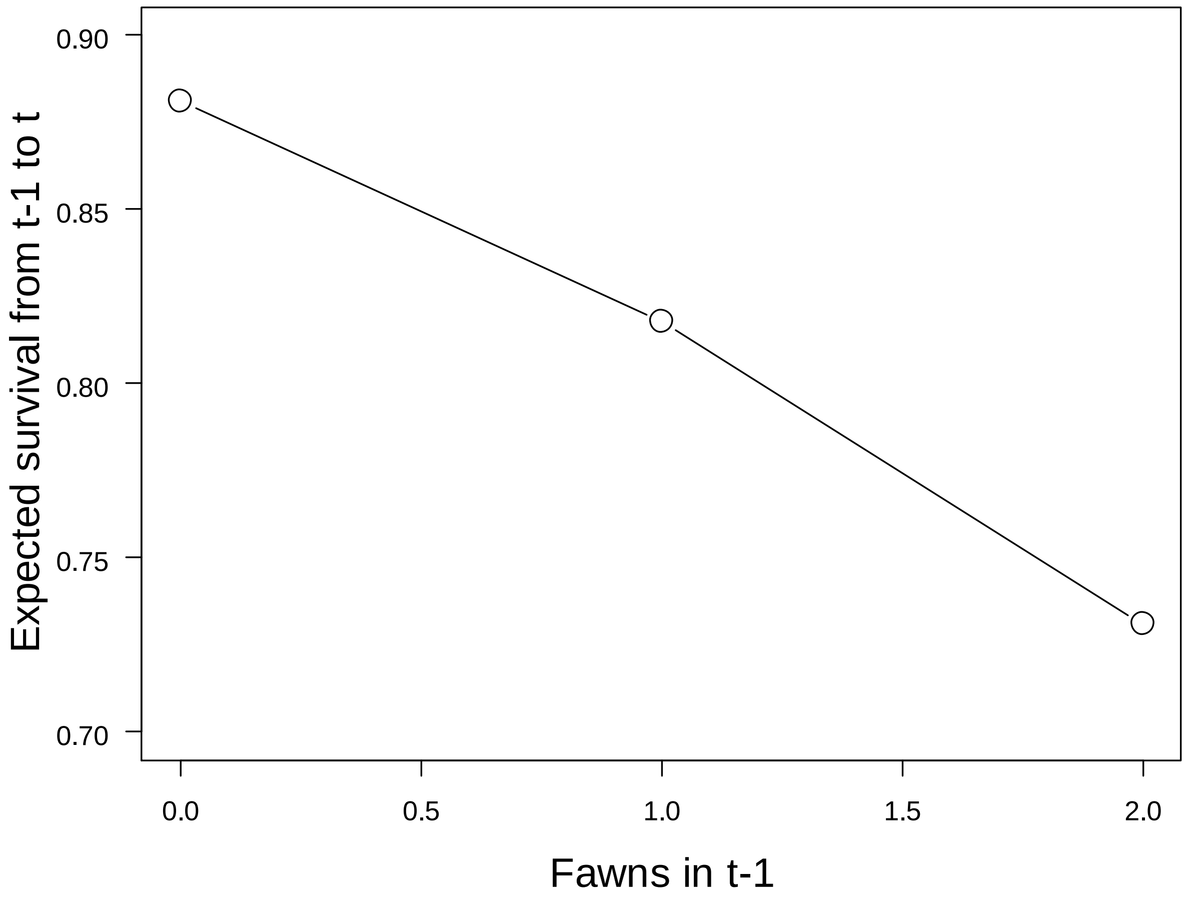


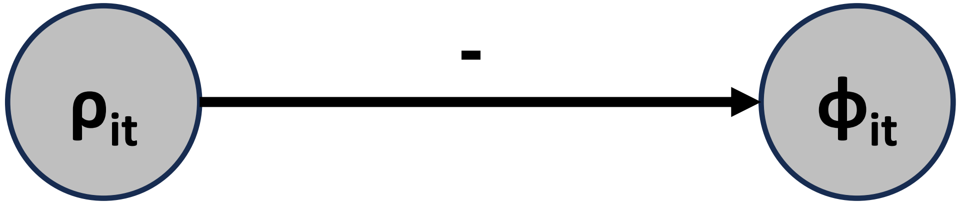


This ‘disguises’ trade-offs

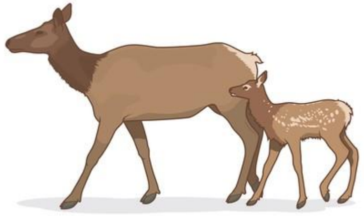
What is our true effect of reproduction on survival?

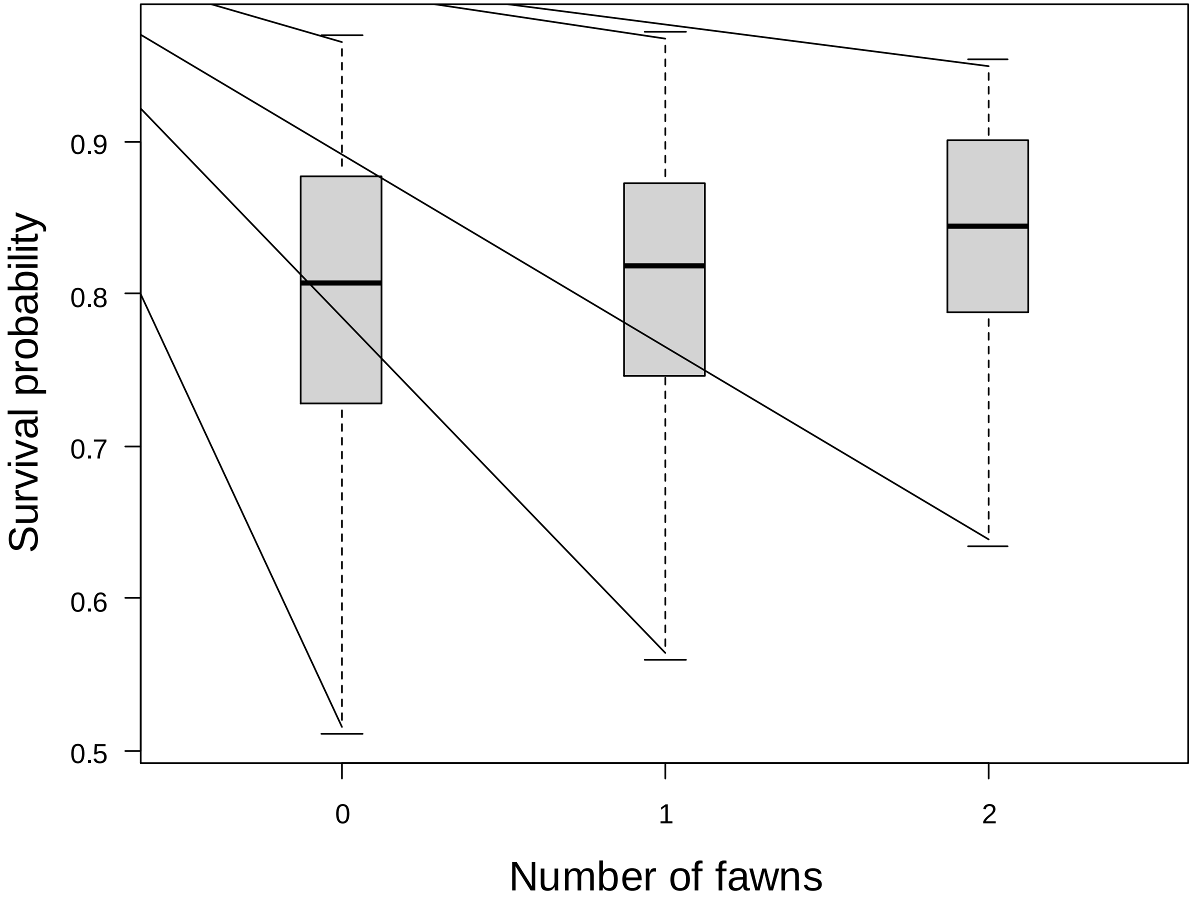


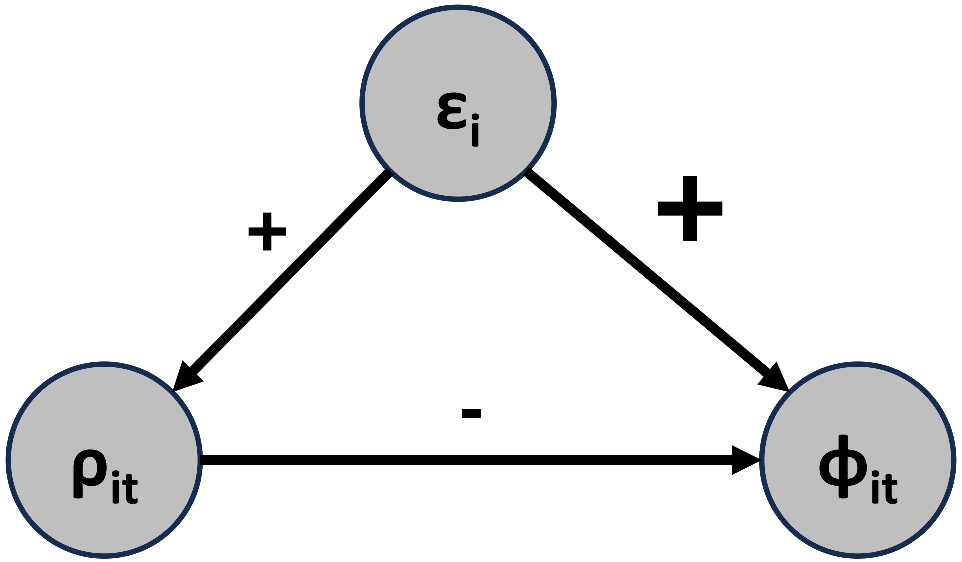




What is our observed effect of reproduction on survival?

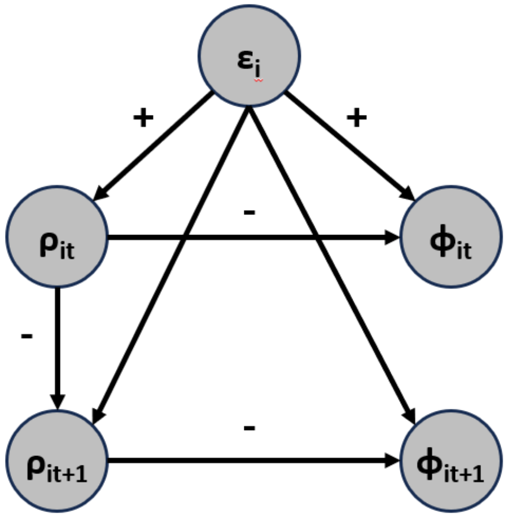


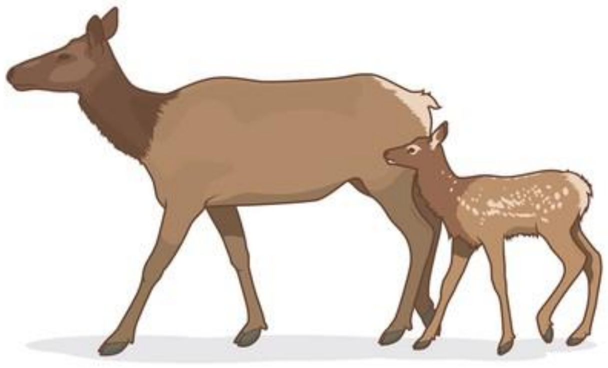




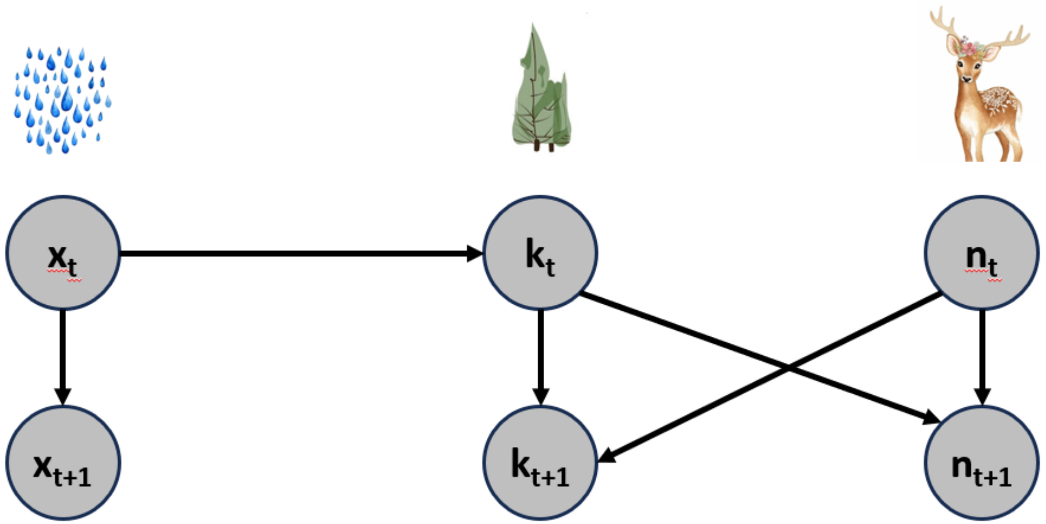
Hi-quality females have more fawns
They also survive at higher rates

Failing to account for cross-lags or dynamic processes increases error (i.e., false negatives and false positives)





Density-dependence example

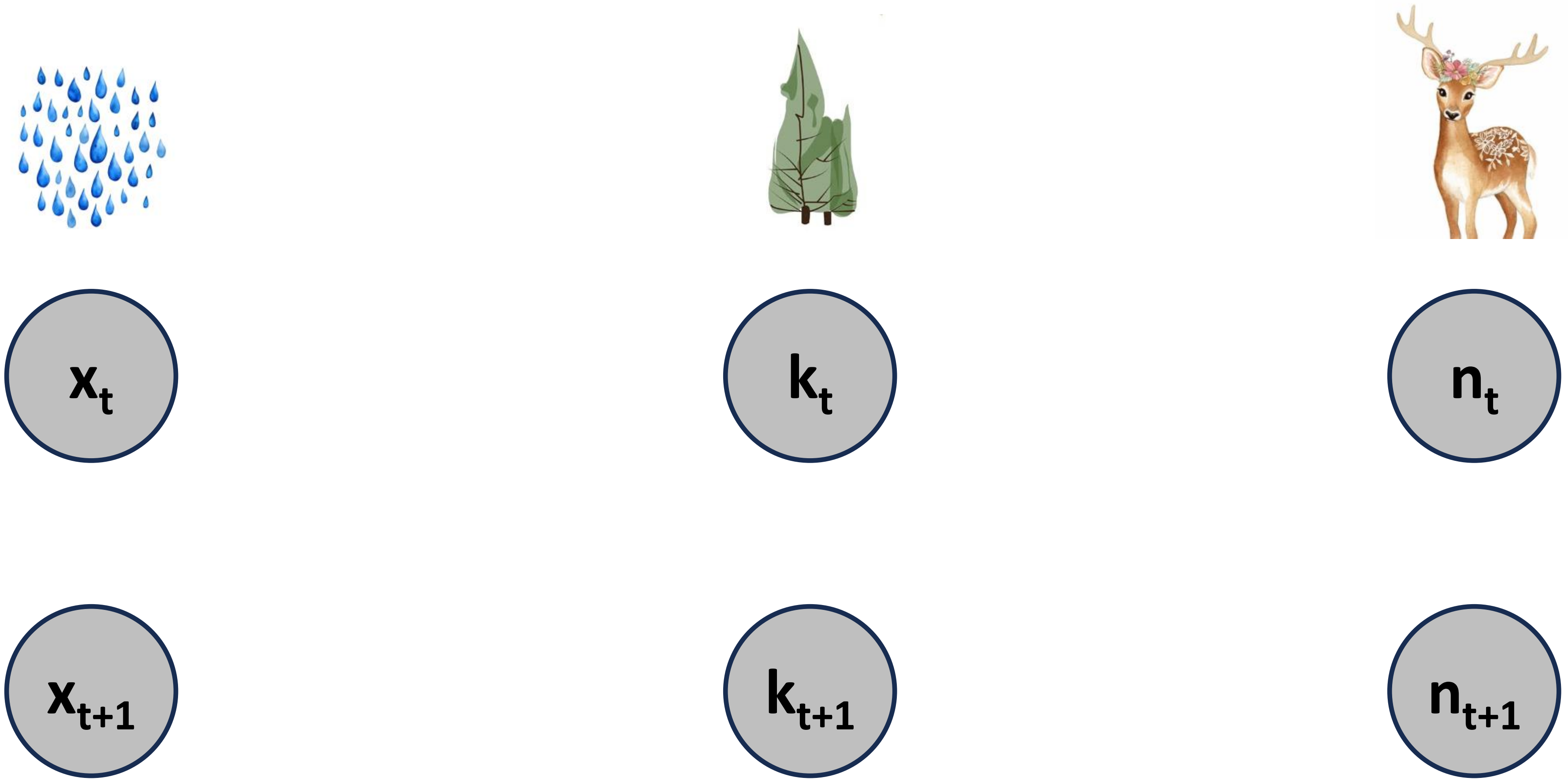


Leopold (1933); Ricker (1954)

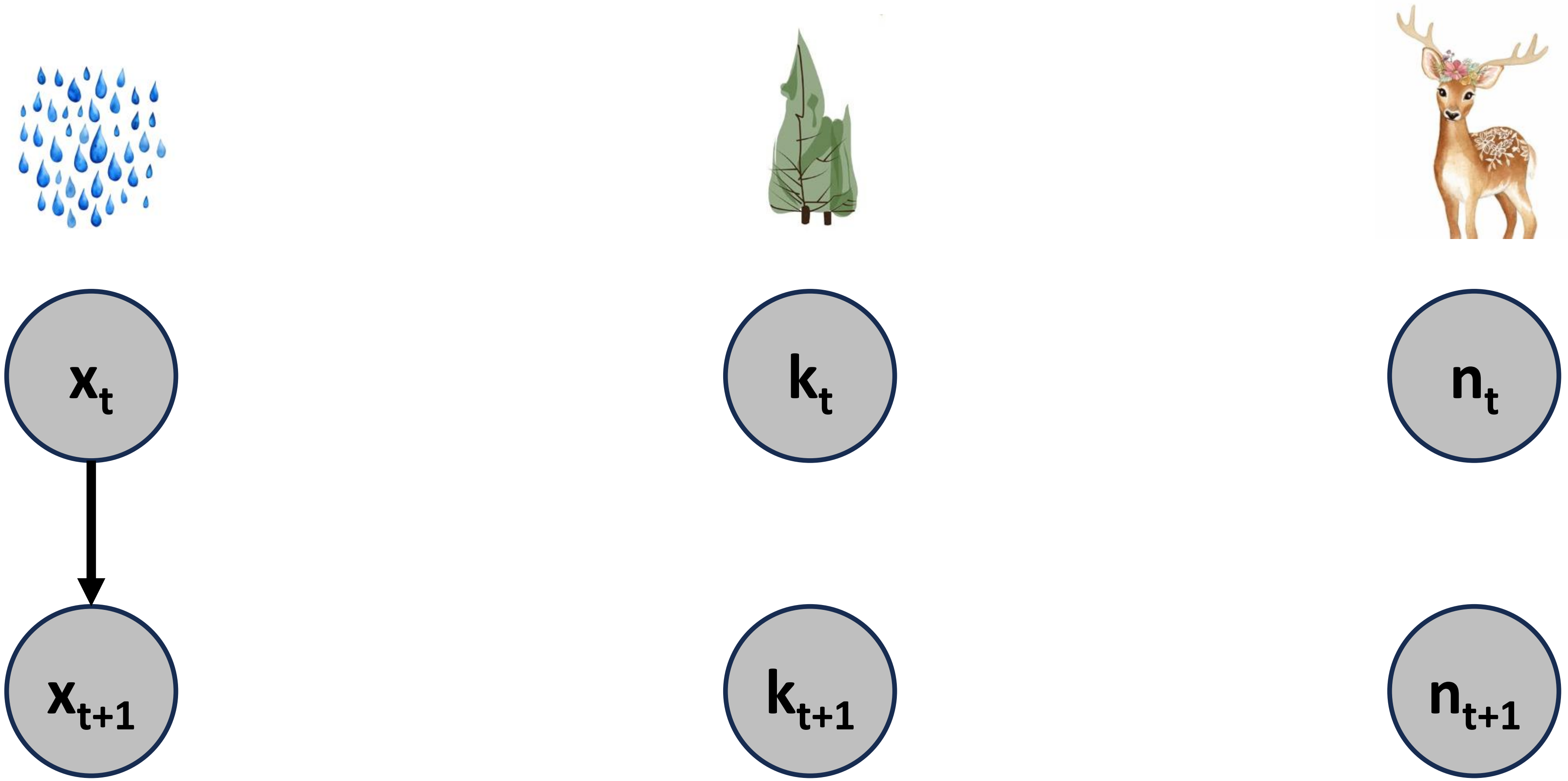
Environmental variation (x), vegetation (k), and an herbivore (n)

x_t k_t n_t

Environmental variation (x), vegetation (k), and an herbivore (n)

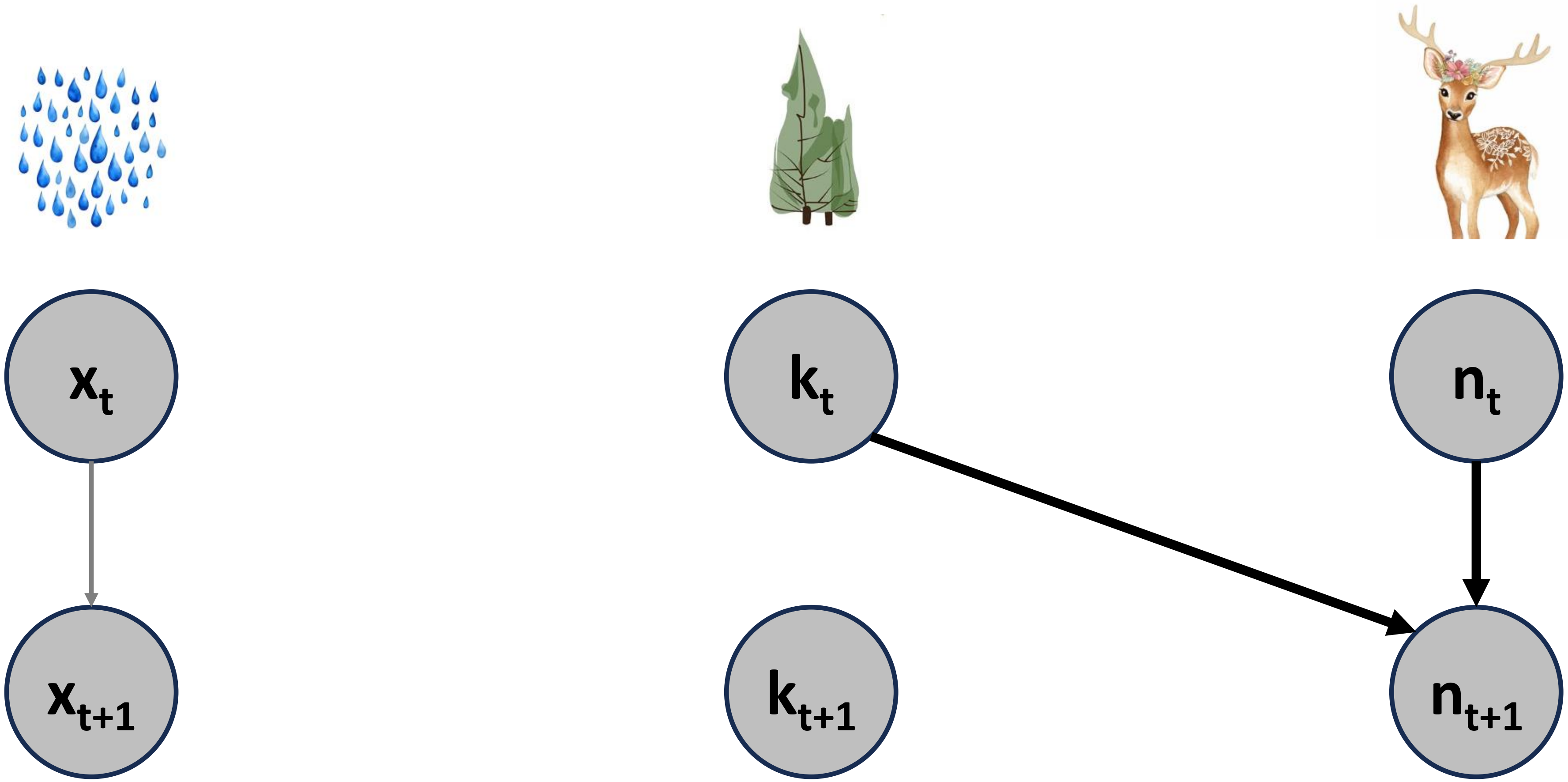


Environmental variation (x) is auto-regressive (AR1)



$$x_{t+1} \sim \mathrm{normal}(\rho \times x_t, \sigma^2)$$

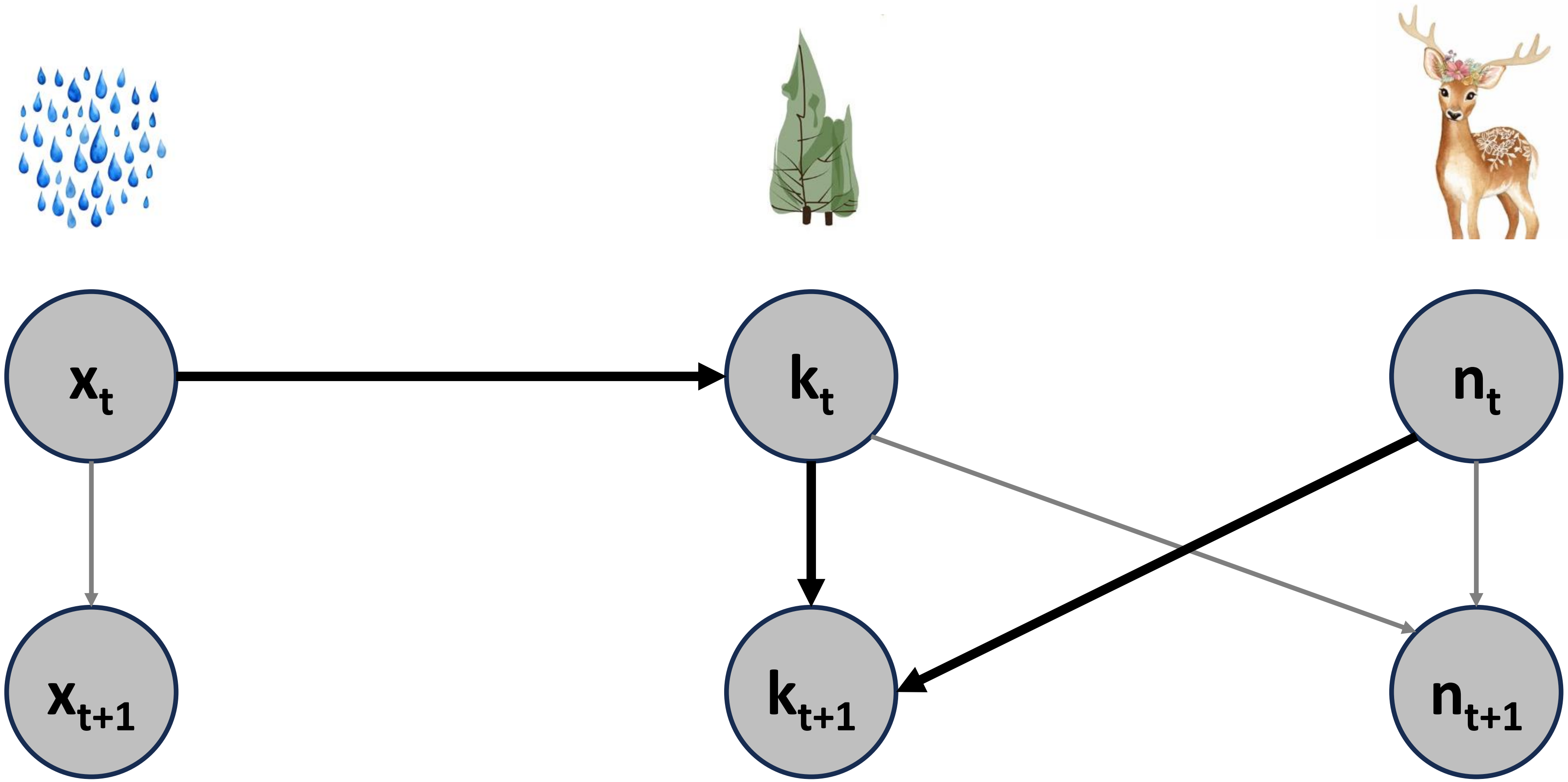
Herbivore (n) population growth is density-dependent



$$n_{t+1} \sim \text{Poisson}\left(n_t \times e^{r\left(1 - \frac{n_t}{k_t}\right)}\right)$$

Ricker (1954)

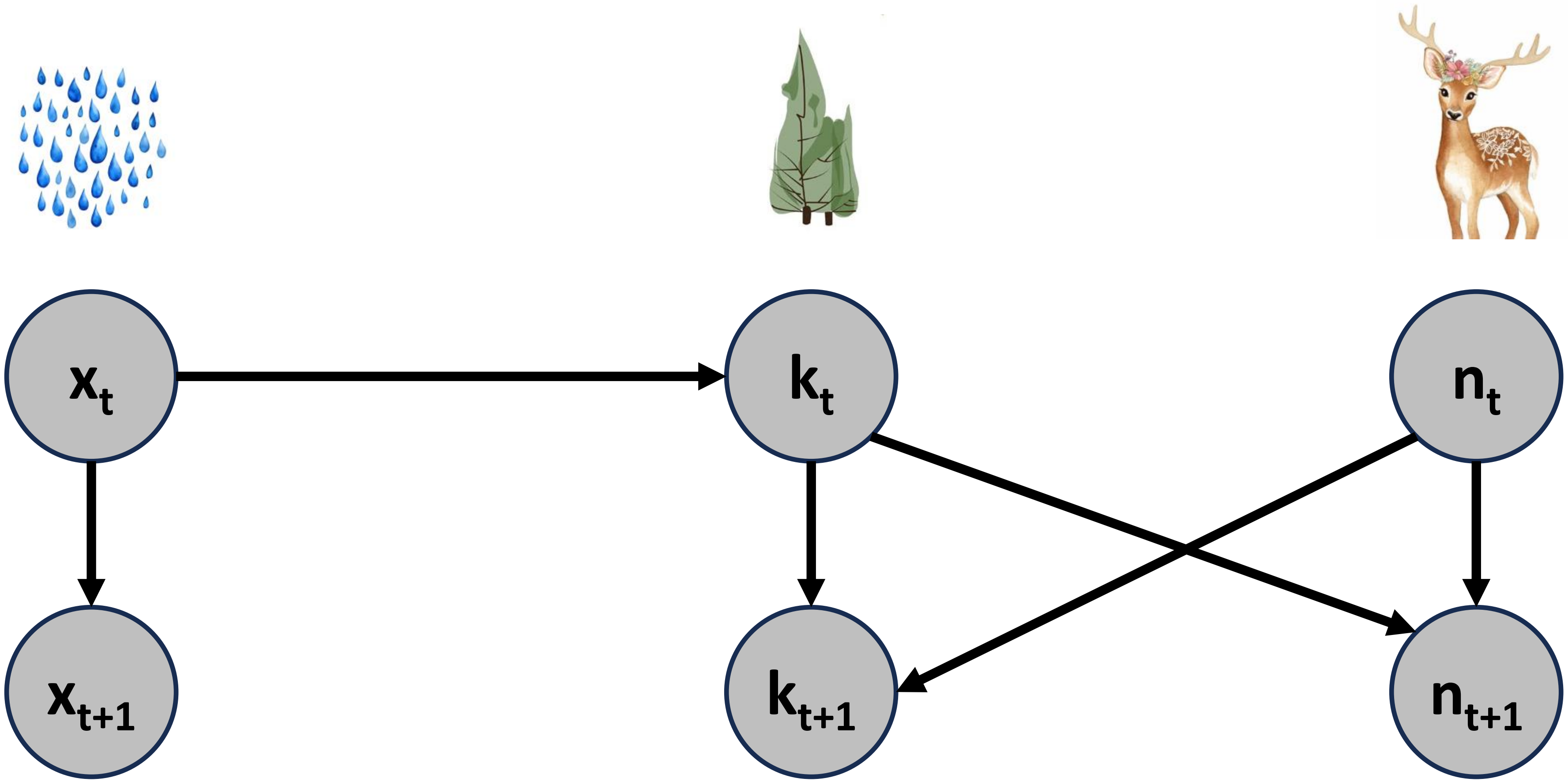
Carrying capacity changes due to x and ungulate density (n/k)



$$k_{t+1} \sim \mathrm{Poisson}\left(k_t \times e^{\delta_1\left(1-\frac{n_t}{k_t}\right)+\delta_2 x_t}\right)$$

Leopold (1933)

This is complicated, but not really (?)

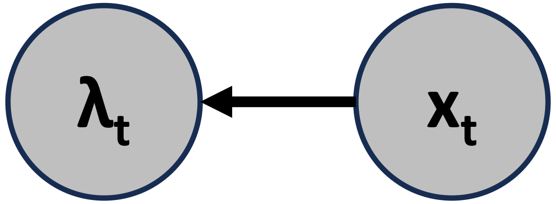


Leopold (1933); Ricker (1954)

Let’s simulate some data and run a naïve model

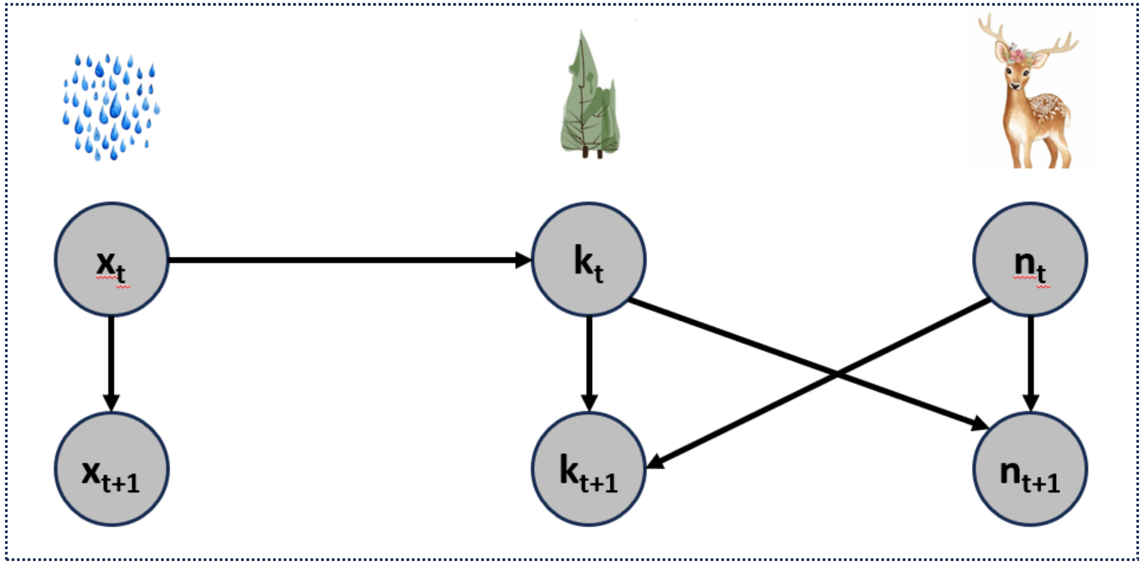
Analysis

$$\lambda_t = \frac{n_{t+1}}{n_t}$$



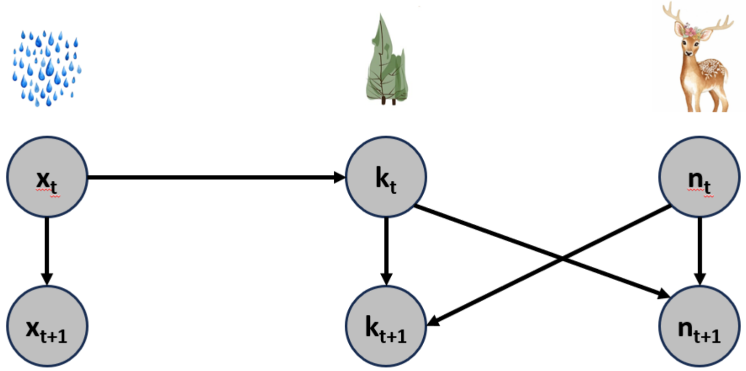
$$\lambda_t \sim \mathrm{normal}(\boldsymbol{\beta X}, \sigma^2)$$

Simulation

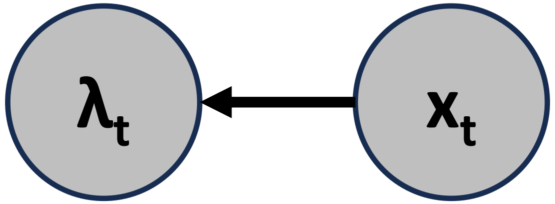


What does λ_t ~ x_t look like across 1k simulations?

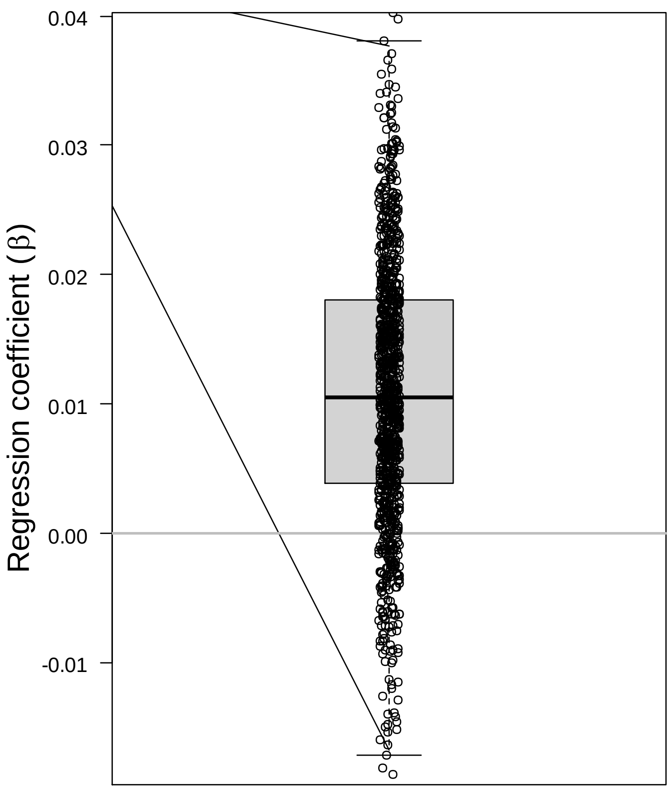
Results are not encouraging

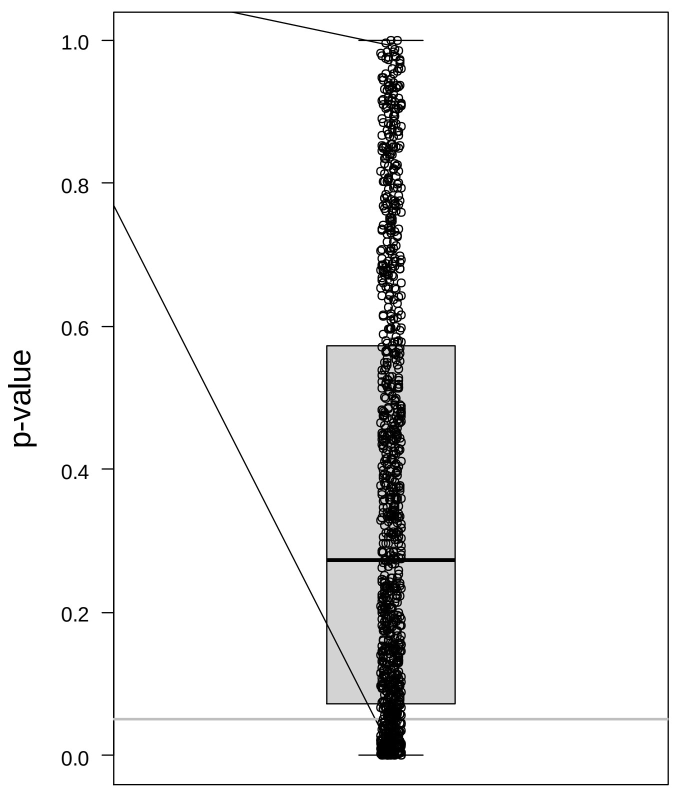


$$\lambda_t = \frac{n_{t+1}}{n_t}$$



$$\lambda_t \sim \mathrm{normal}(\boldsymbol{\beta X}, \sigma^2)$$

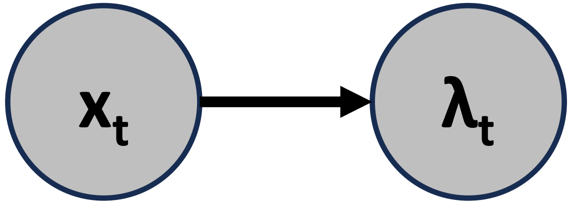


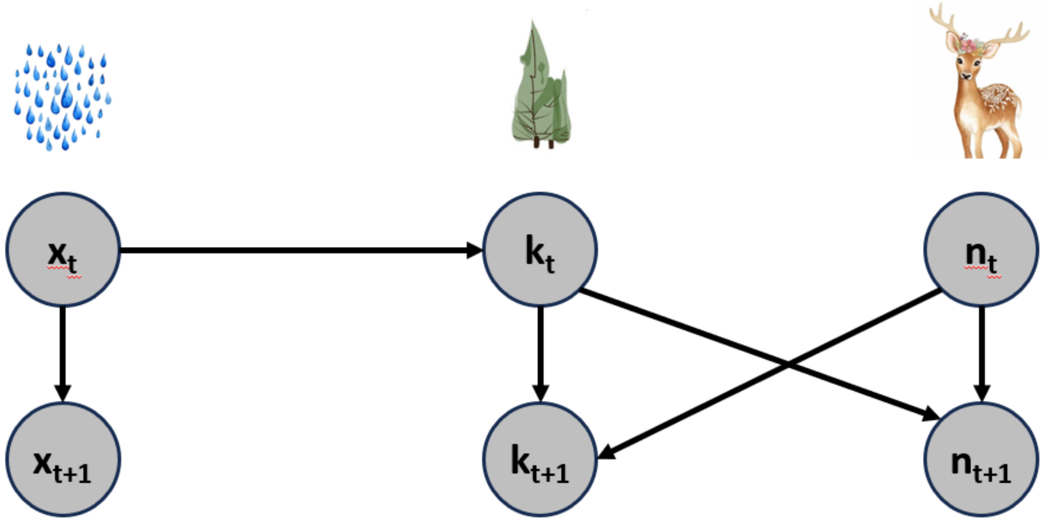


85% of betas are positive, 80% are 'not statistically significant'

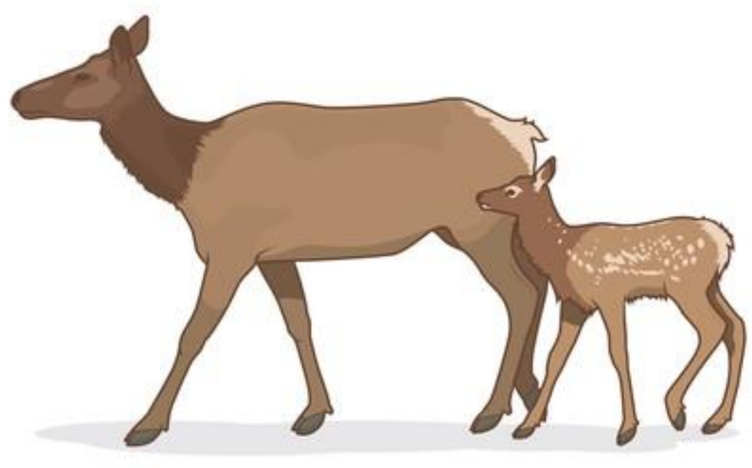
Failing to account for cross-lags or dynamic processes increases type II error (i.e., false negatives)

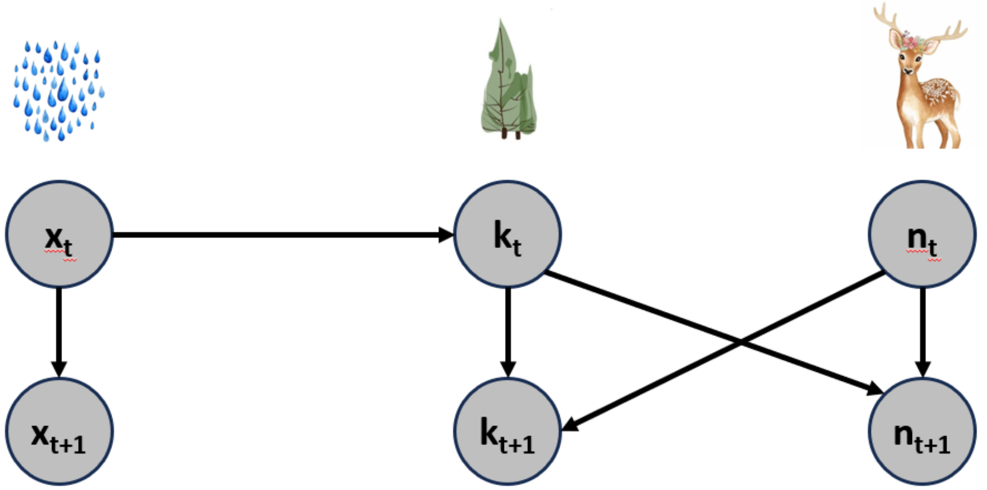
$$\lambda_t = \frac{n_{t+1}}{n_t}$$



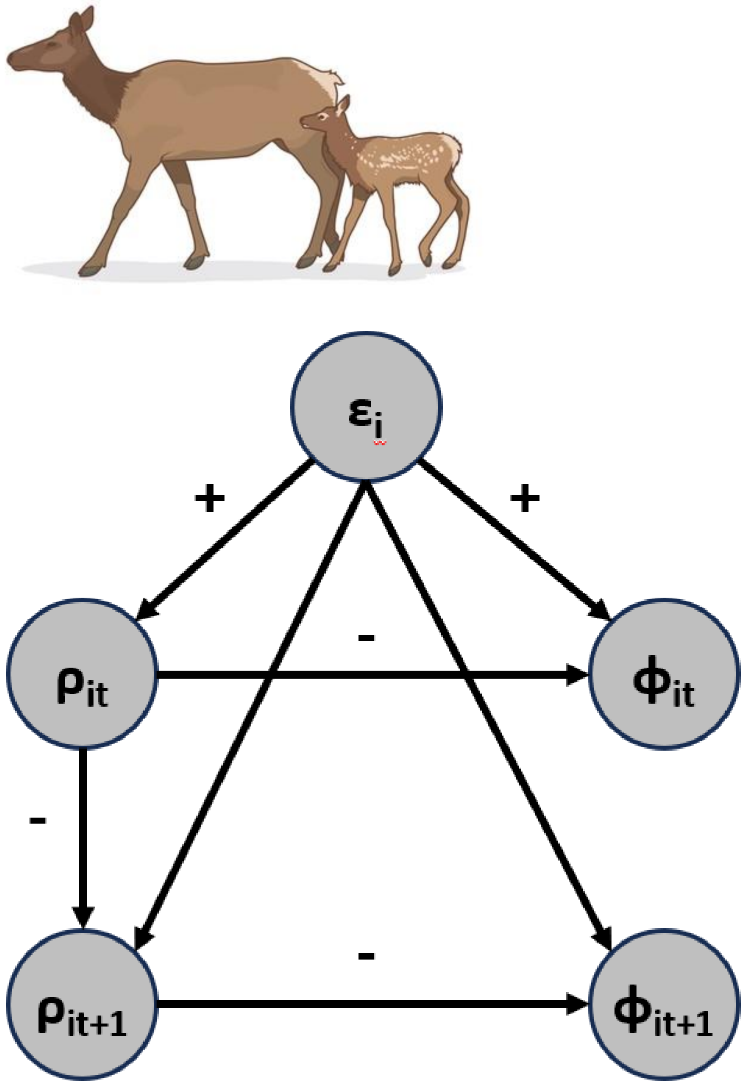


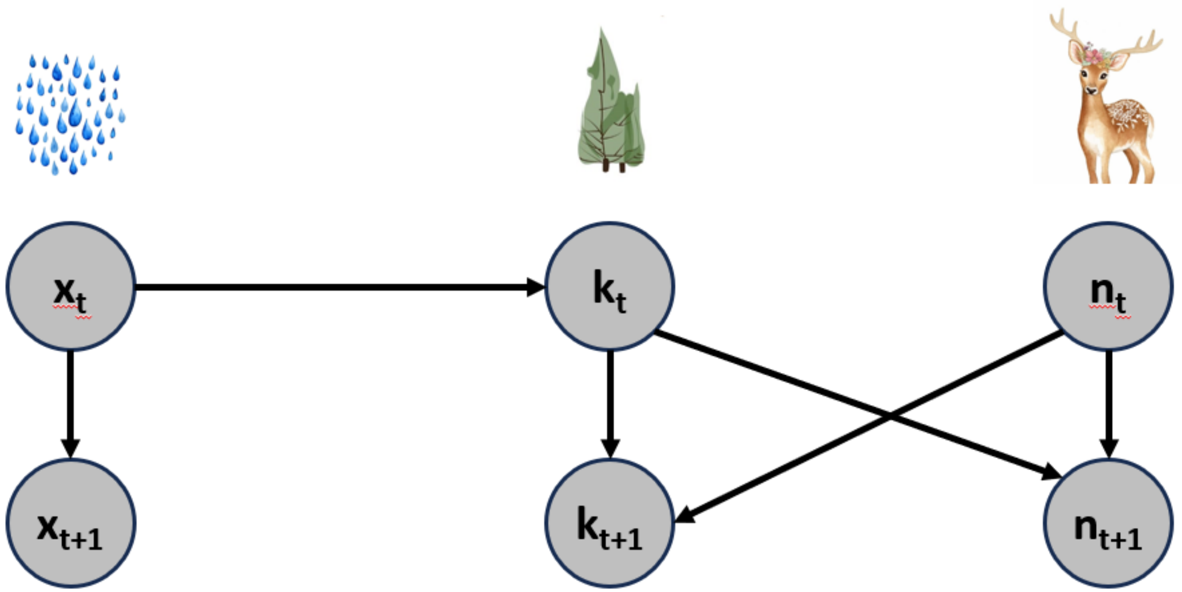
Failing to account for cross-lags or dynamic processes increases type I and type II error



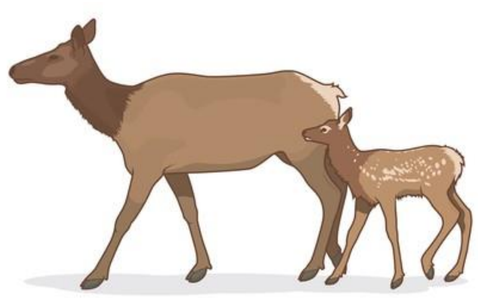


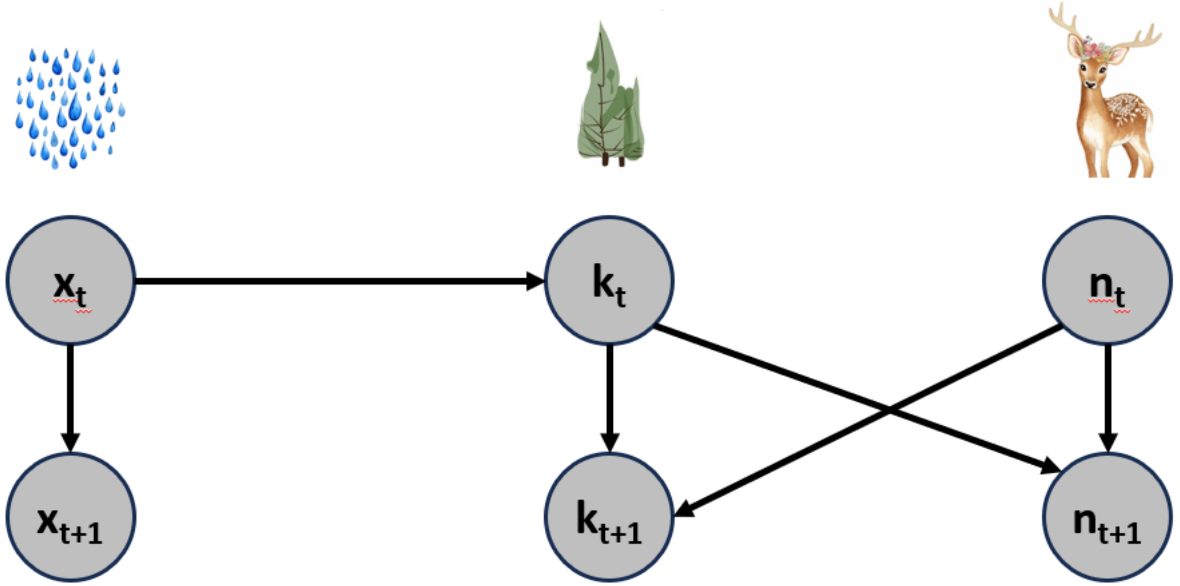
These are ‘simple’ models! [or at least simple ideas]





JAGS code is provided for both analyses on GitHub





SEM_workshop/R_scripts/Lecture6_scripts/Lecture6a_life_history_trade_off.R
SEM_workshop/R_scripts/Lecture6_scripts/Lecture6b_dynamic_SEM_herbivore_carrying_capacity.R

Bayesian inference and flexibility moving forward

There is a Bayesian SEM package with the exact same syntax as ‘lavaan’…

It’s called ‘blavaan’

Bayesian inference and flexibility moving forward

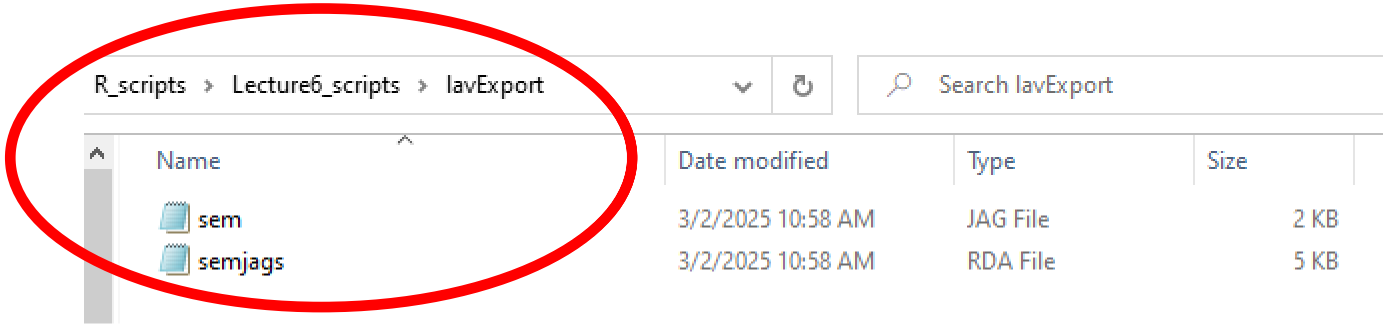
Instead of using ‘sem()’ it uses ‘bsem()’

You can literally change two letters and run the same analysis in JAGS or Stan

This package will also output functioning JAGS or Stan code for you

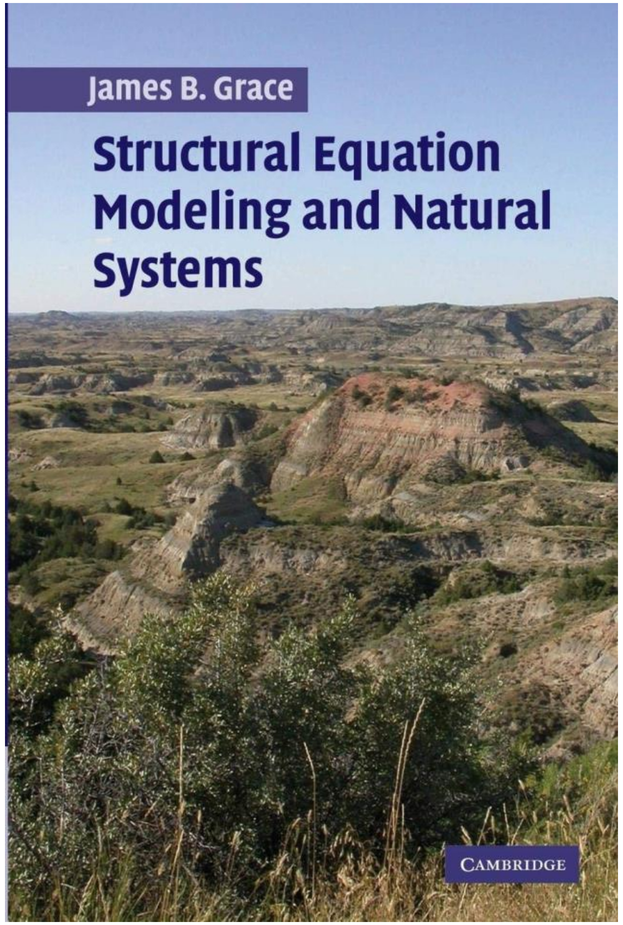
*(the Stan code will be quite complicated)

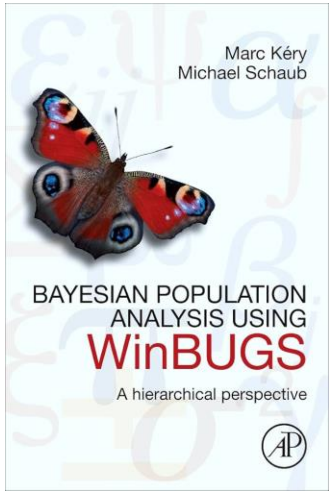
```
d <- data.frame(c = canopy, s = subcan, y = warblers)
sem1 <- bsem('m =~ c + s
            y ~ m
            c ~ 1
            s ~ 1',
            data = d,
            target = 'jags',
            mcmcfile = T)
summary(sem1)
# ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
# look in your working directory
# there will be a perfectly functioning JAGS model file
# that was used to generate the parameter estimates in a lavExport folder
# you may have to change some parameter names & priors, but that's it!
# ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

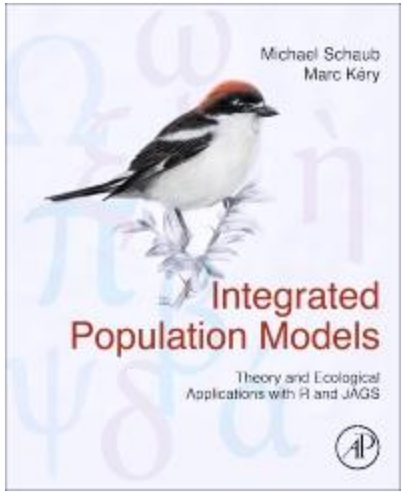


https://github.com/thomasriecke/SEM_workshop/R_scripts/Lecture6_scripts/Lecture6c_lavaan_v_blavaan.R

Imagine you are interested in a SEM underlying an IPM…

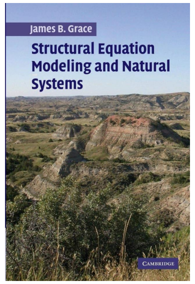


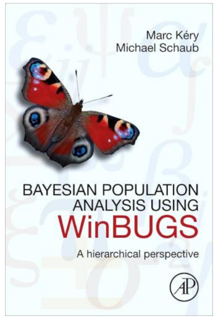


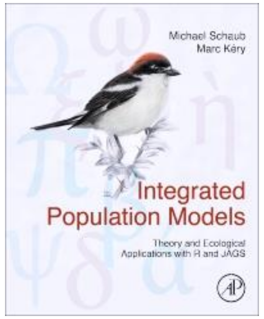


Or an occupancy model, or a complex RSF or SSF, etc.

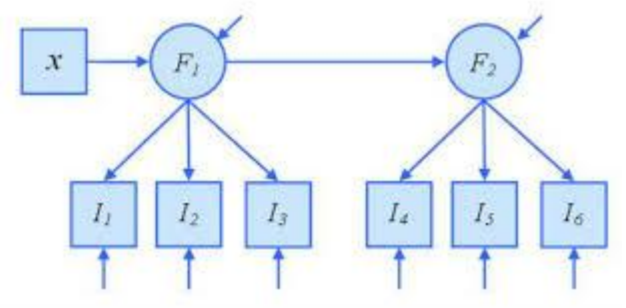
Imagine you are interested in a SEM underlying an IPM



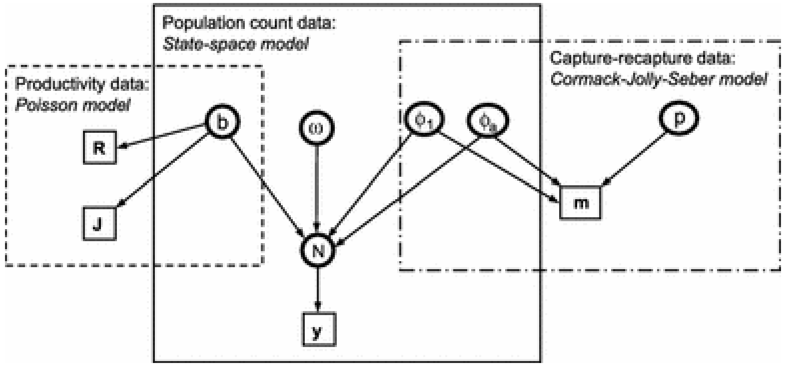




An ecological system model

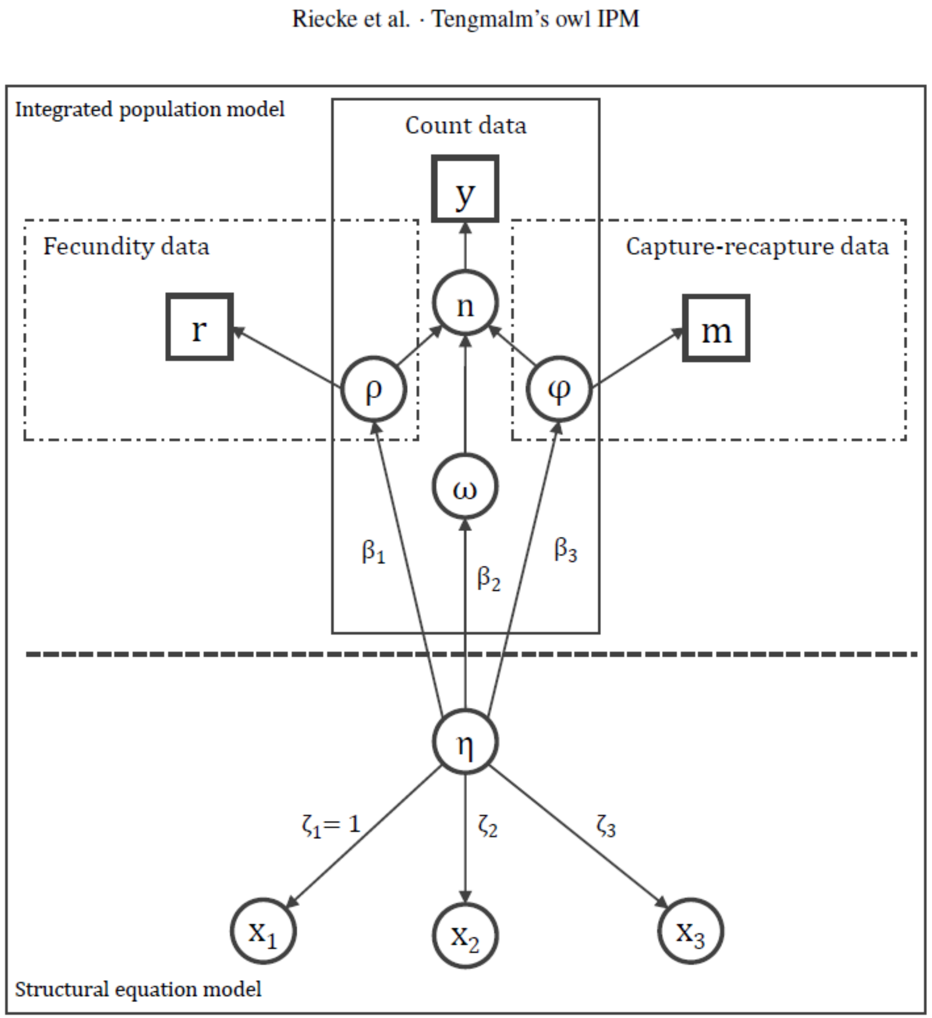


An integrated population model



There is no R package for this (there shouldn't be either)

Imagine you are interested in a SEM underlying an IPM



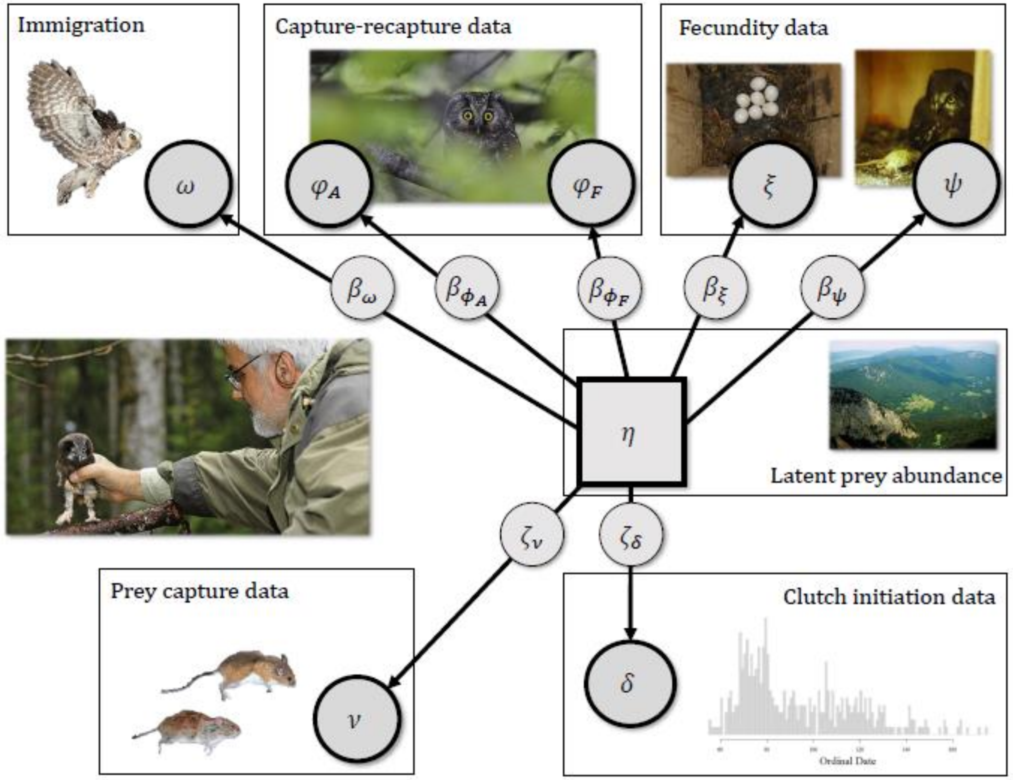
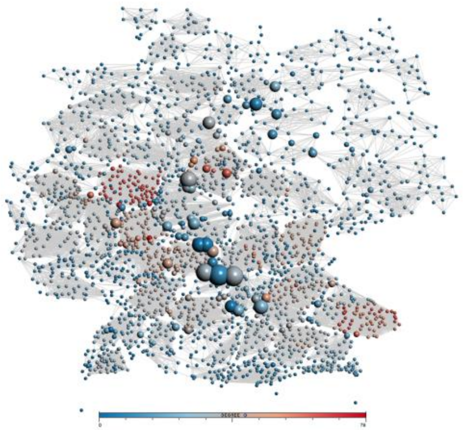


Figure 2. A conceptual figure demonstrating the modelled relationships between the mean number of *Apodemus* mouse and vole (Arvicolinae) remains discovered in nest boxes following breeding (ν), mean laying date (δ), latent breeding conditions (η; i.e., rodent abundance), and the demographic parameters clutch size (ξ), the probability that each egg fledges (ψ), adult survival (ϕ_A), fledgling survival to adulthood (ϕ_F), and the expected number of immigrants (ω) for Tengmalm's owls breeding in the Jura Mountains in northwestern Switzerland and eastern France (1990-2020).

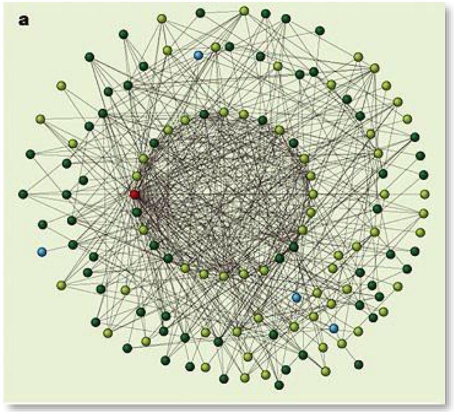
Conclusion

Ecological systems are unbelievably complex and beautiful!



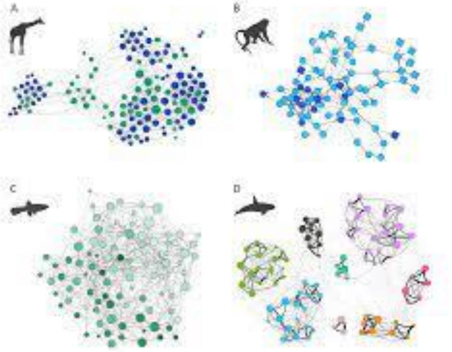
Climate network

Abiotic systems



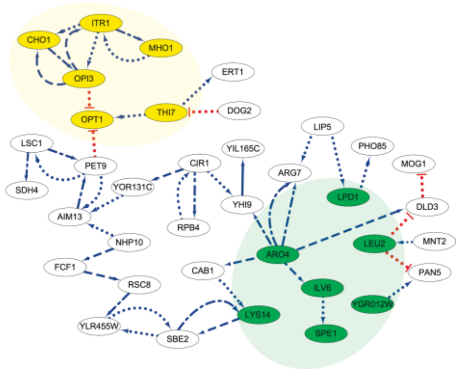
Food Network

Within communities



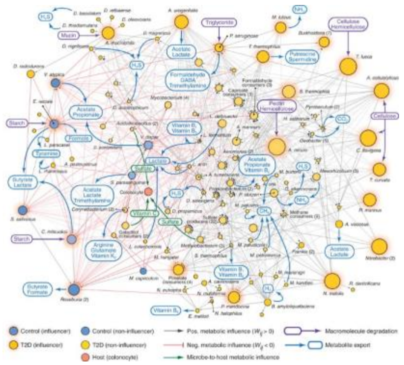
Social Network

Within populations



Gene Network

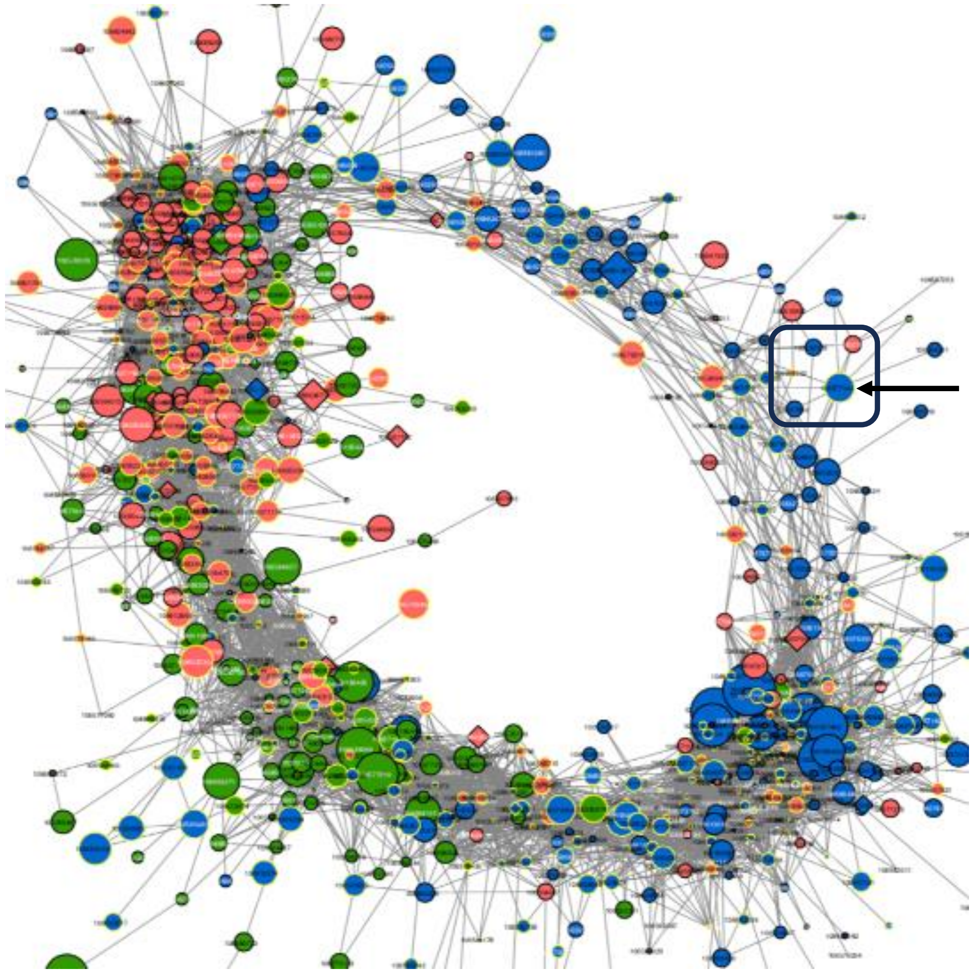
Within individuals



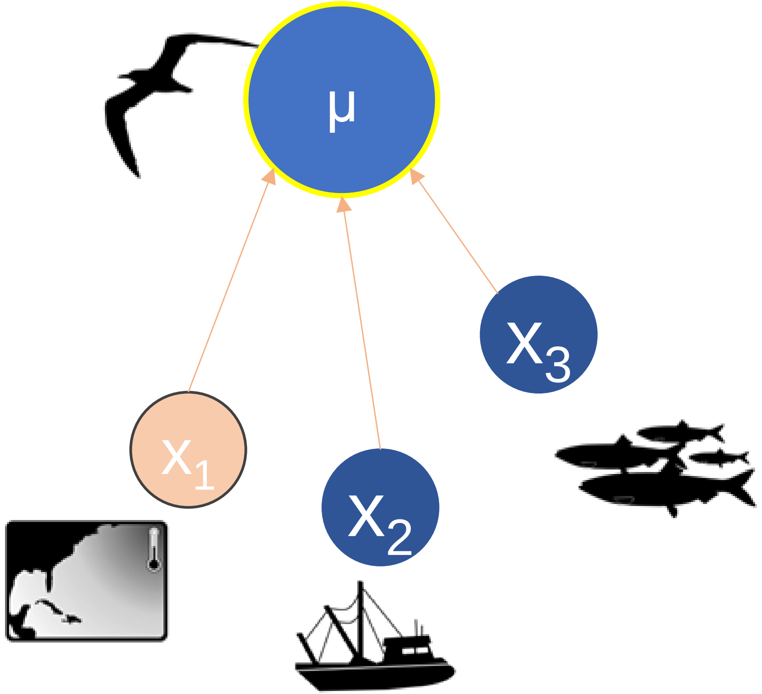
Microbial Network

Within individuals

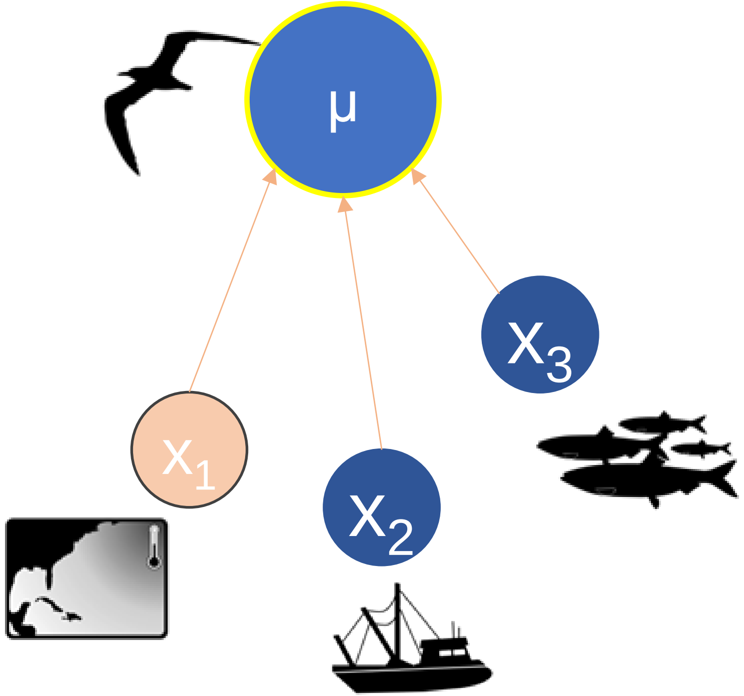
<u>GLMs are not bad</u>, SEMs don't 'replace' them!

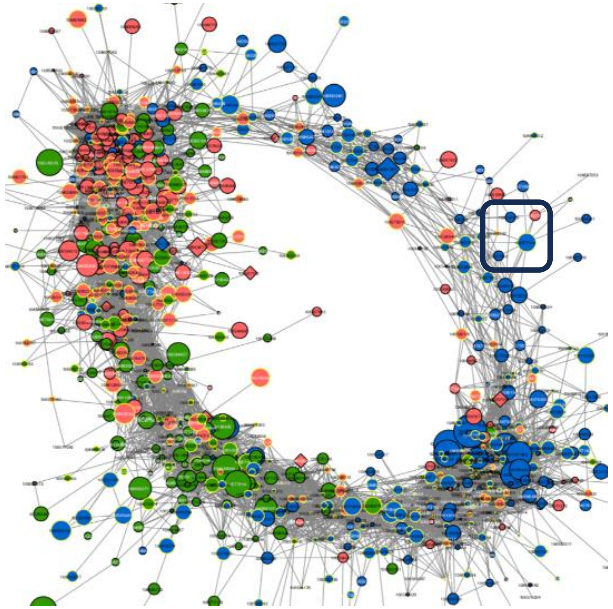


Response



SEMs are just more than one GLM





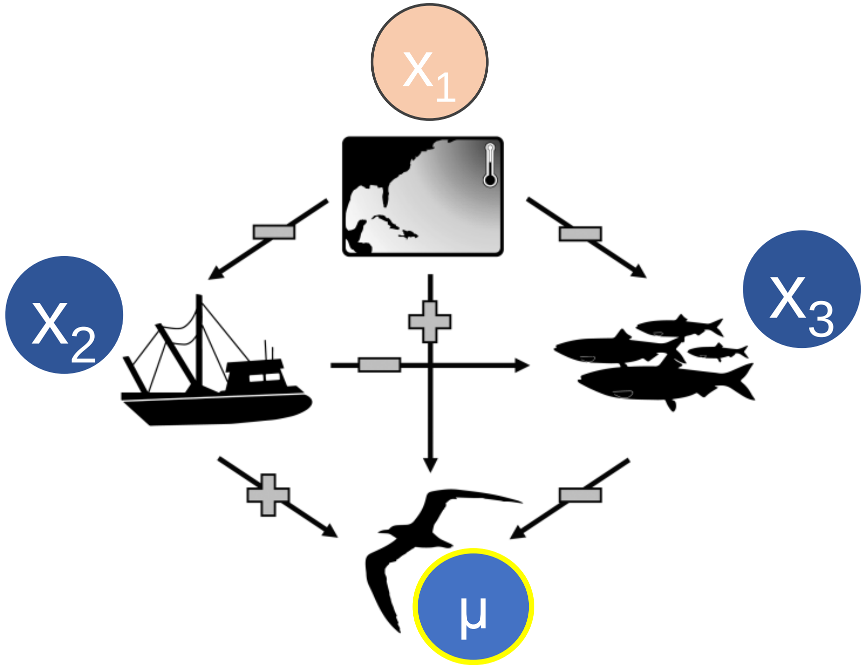
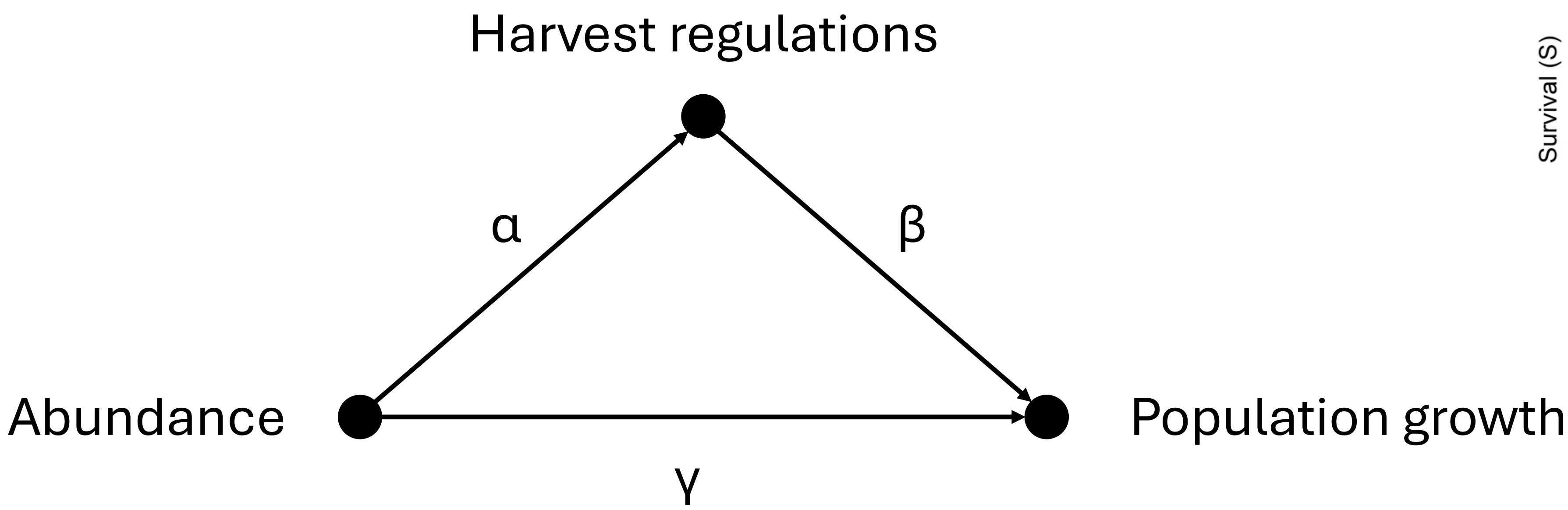
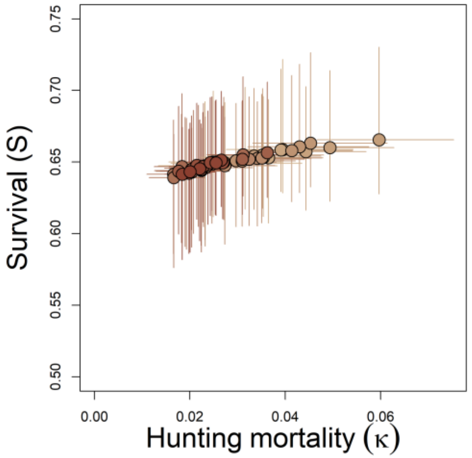


FIGURE 1 Simplified path diagram describing the hypothesized directionality (plus: Positive, bar: Negative association) regarding how environmental variables (i.e., sea-surface temperatures in the North Atlantic, fishery pressure, and fish production) influenced one another, as well as the indirect and direct pathways in which these sources of environmental variability influenced Royal tern mortality.

Gibson, Riecke, et al. **(2023)** *Global Change Biology*

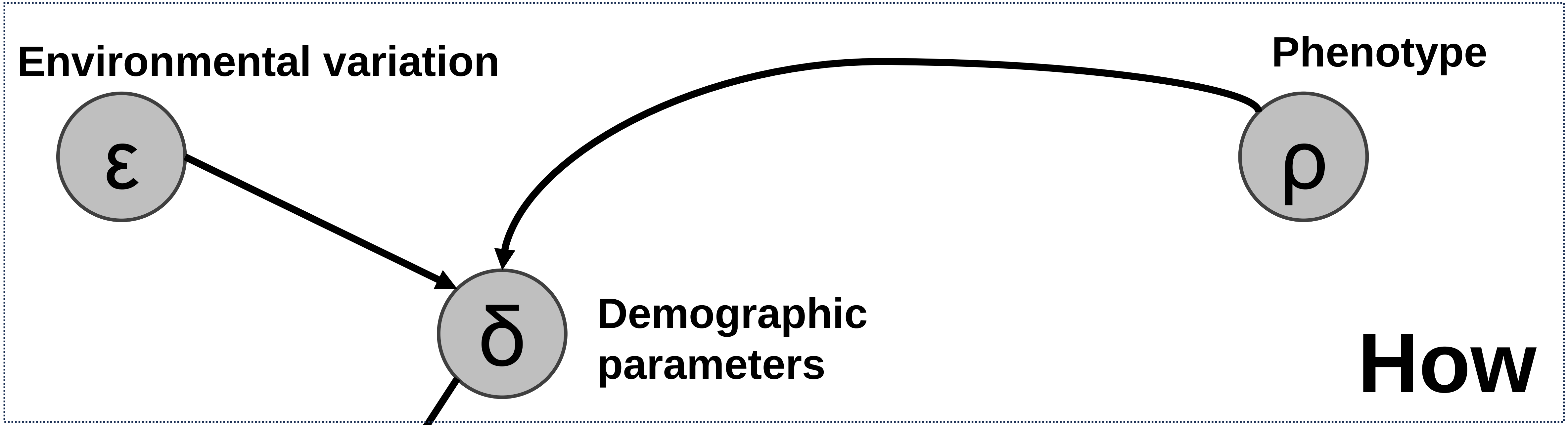
SEMs allow us to think simply about complex processes

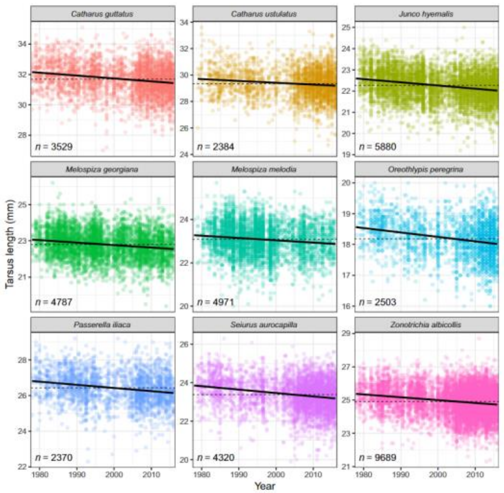




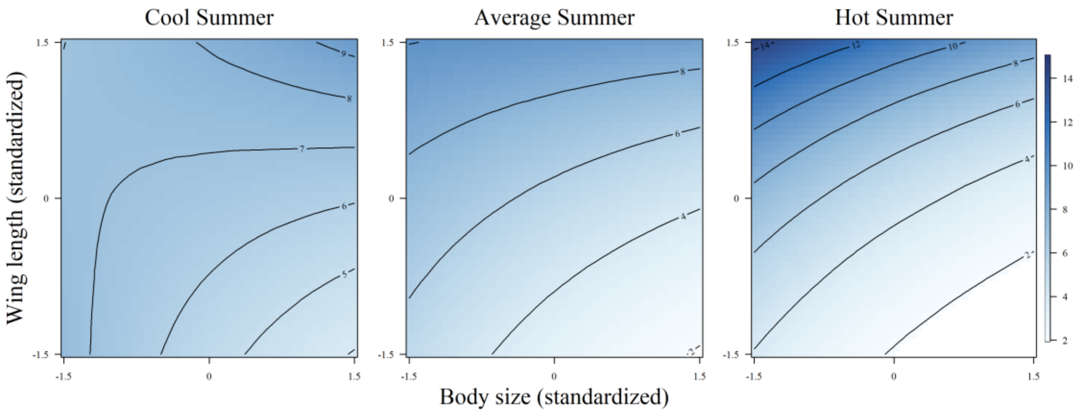
α: harvest management strategies
β: effects of harvest
γ: density-dependence

SEMs facilitate ‘inter-disciplinary’ models!

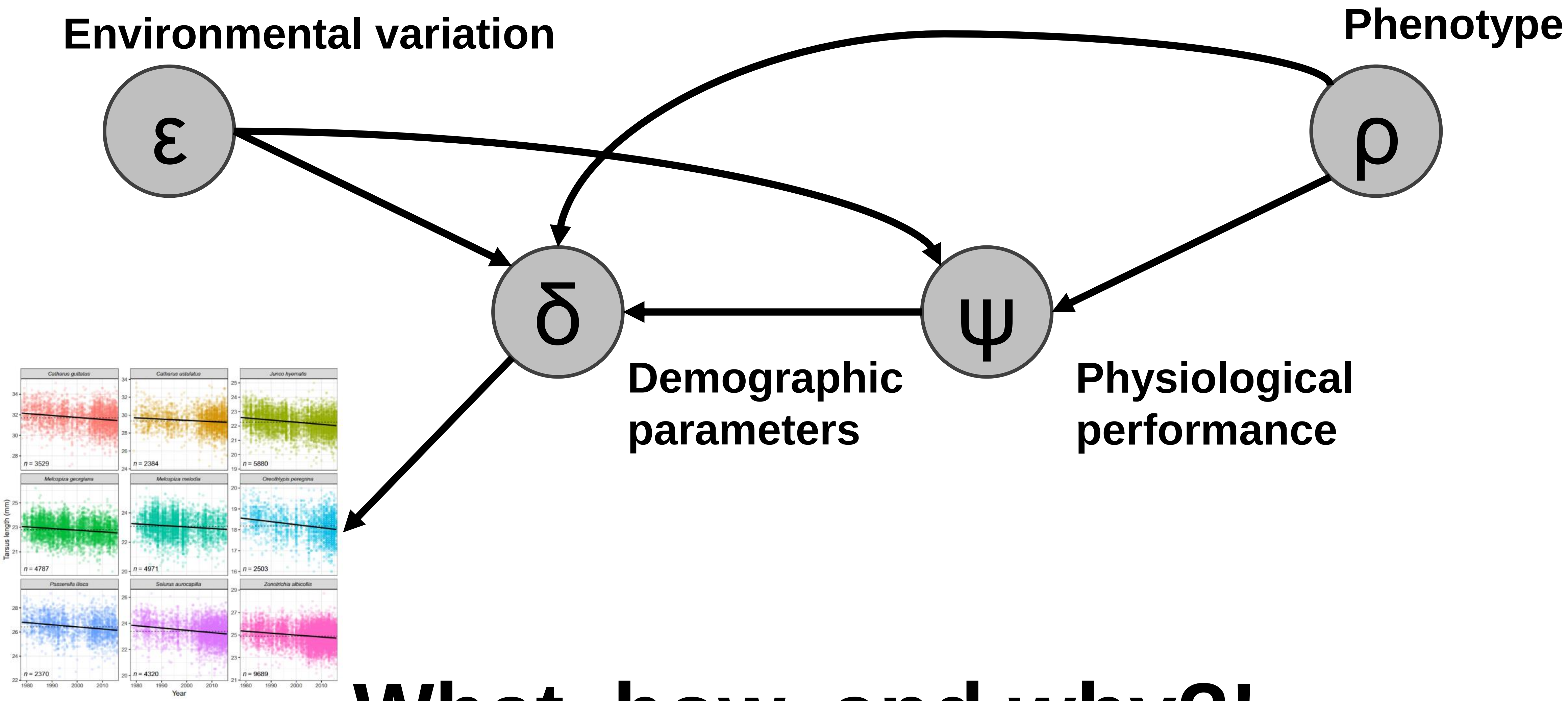




What

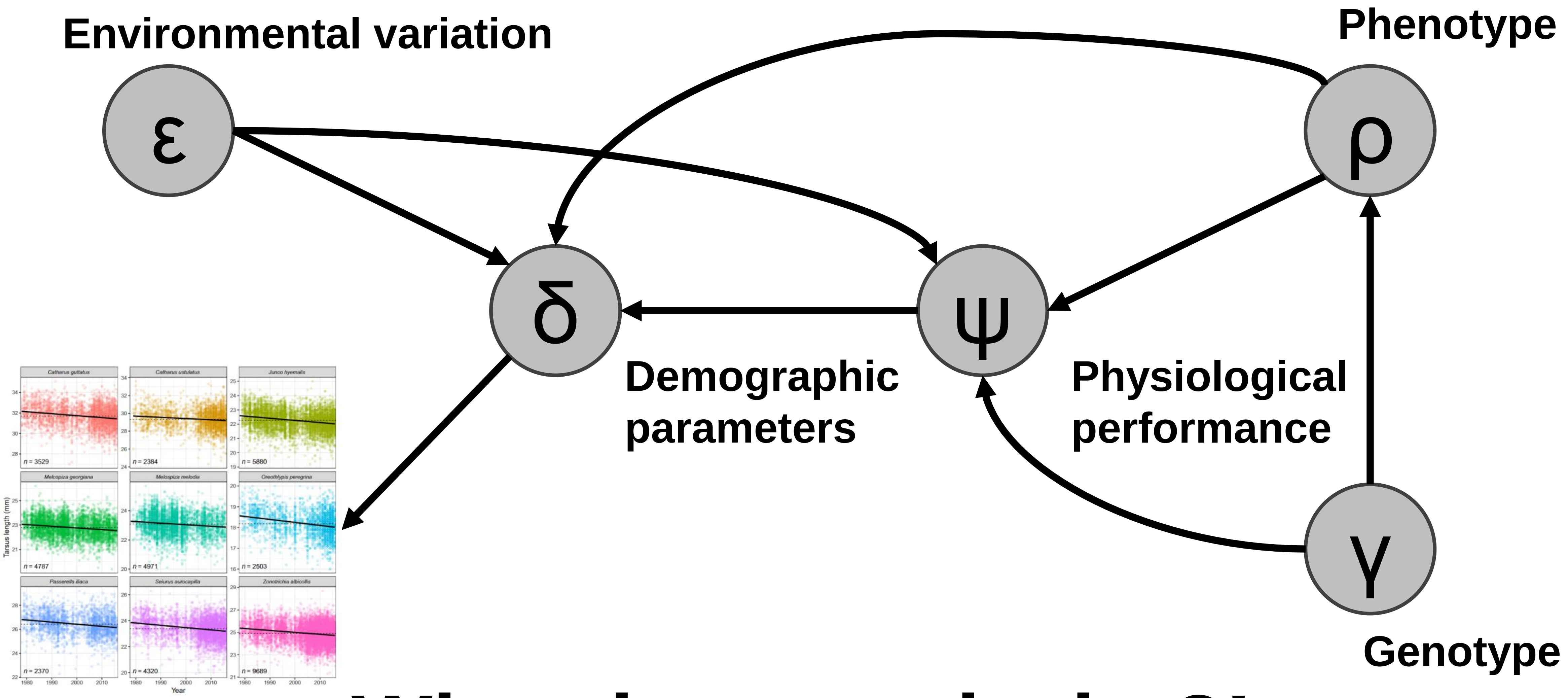


SEMs facilitate 'inter-disciplinary' models!



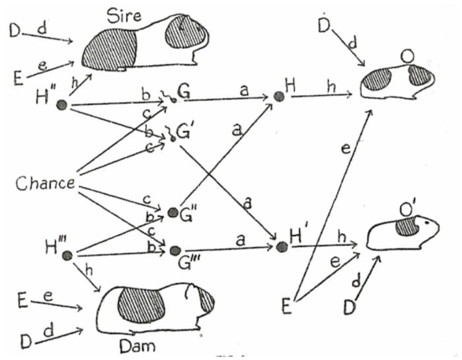
What, how, and why?!

SEMs facilitate ‘inter-disciplinary’ models!



What, how, and why?!

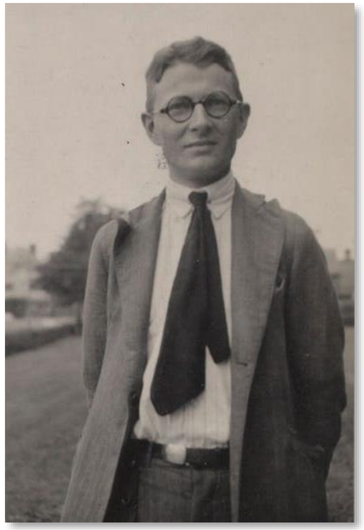
These aren’t new concepts



THE METHOD OF PATH COEFFICIENTS

By

SEWALL WRIGHT
Department of Zoology, The University of Chicago.



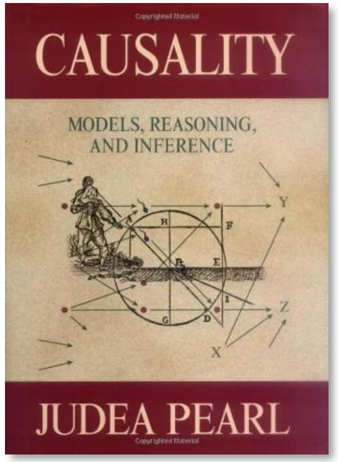
ON THE INADEQUACY OF THE PARTIAL AND MULTIPLE CORRELATION TECHNIQUE

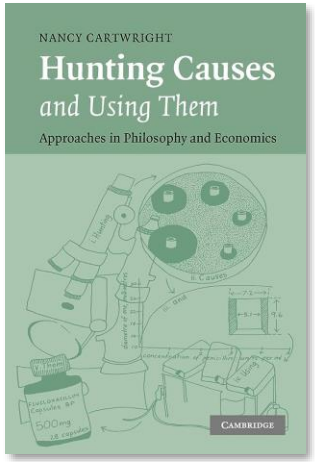
BARBARA STODDARD BURKS

Stanford University

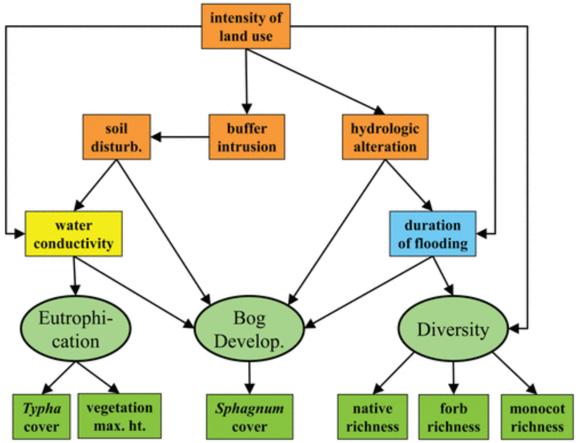
PART I. IN THE STUDY OF CAUSATION

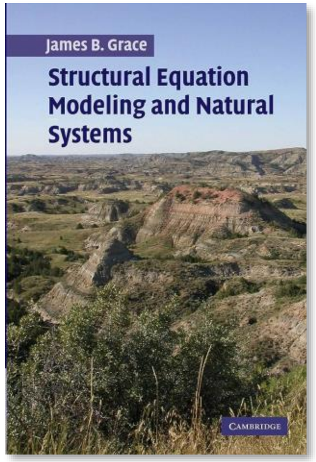
Logical considerations lead to the conclusion that the techniques of partial and multiple correlation are fraught with dangers that seriously restrict their applicability. In fact their attempted use in (*a*) isolating the causes which operate upon observed effects, and (*b*) defining the extent to which two measures involve common factors unique to themselves, often result in intepretations that are misleading and even untrue excepting in a few special types of situation. Only issues arising in the first field (*i.e.*, causation) will be discussed at this time. Consideration of the second field will be left for a subsequent paper (Part II).





These aren’t new concepts





Ecology, 93(2), 2012, pp. 248–255
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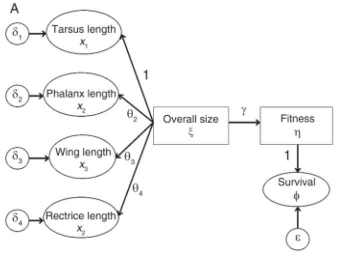
Testing hypotheses in evolutionary ecology with imperfect detection: capture–recapture structural equation modeling

Sarah Cubaynes,[1,2,4] Claire Doutrelant,[1] Arnaud Grégoire,[1] Philippe Perret,[1] Bruno Faivre,[3] and Olivier Gimenez[1]

[1]*Centre d'Ecologie Evolutive et Fonctionnelle UMR 5175, 1919 Route de Mende, 34293 Montpellier, Cedex 5, France*
[2]*Institut de Mathématiques et Modélisation de Montpellier, UNR 5149, Place Eugène Bataillon, 34095 Montpellier, Cedex 5, France*
[3]*Biogéoscience, Université de Bourgogne UMR 5561, 6 Boulevard Gabriel, 21000 Dijon, France*

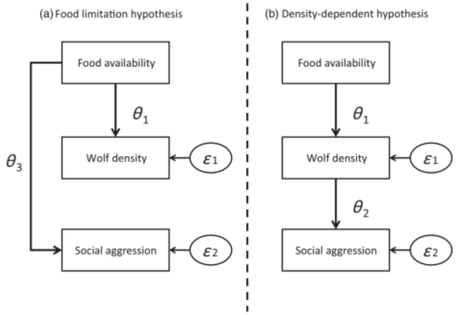


Journal of Animal Ecology
Journal of Animal Ecology 2014, **83**, 1344–1356 doi: 10.1111/1365-2656.12238

Density-dependent intraspecific aggression regulates survival in northern Yellowstone wolves (*Canis lupus*)

Sarah Cubaynes[1]*, Daniel R. MacNulty[2], Daniel R. Stahler[3], Kira A. Quimby[3], Douglas W. Smith[3] and Tim Coulson[1]

[1]*Department of Zoology, University of Oxford, South Parks Road, Oxford, OX1 3PS, UK;* [2]*Department of Wildland Resources, Utah State University, Logan, UT 84322, USA; and* [3]*Yellowstone Wolf Project, Yellowstone Center for Resources, Yellowstone National Park, Mammoth, WY 82190, USA*



Cubaynes et al. **(2012)** *Ecology*; Cubaynes et al. **(2014)** *Journal of Animal Ecology*

SEMs feel overwhelming?!

- SEMs are just more than one GLM
- SEMs allow us to model in the same way that we think…
- Dig into the code, and use `blavaan` to help ‘check’ yourself
- Feel free to reach out with questions (or goofy bug fixes!)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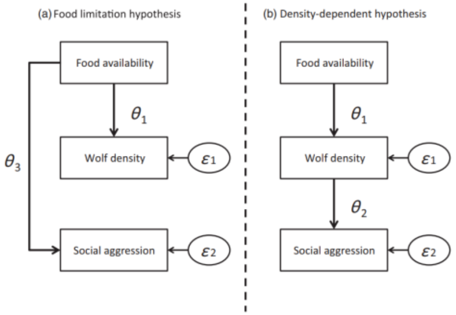

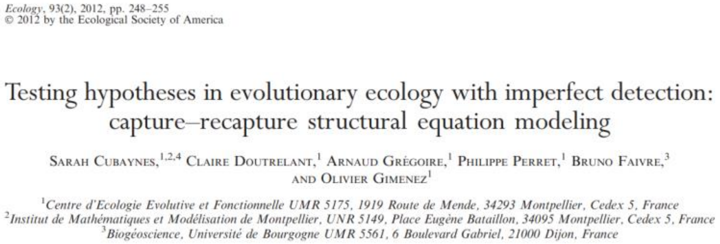
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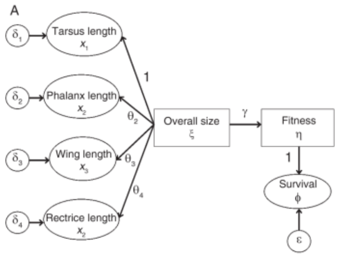


Facilitators!

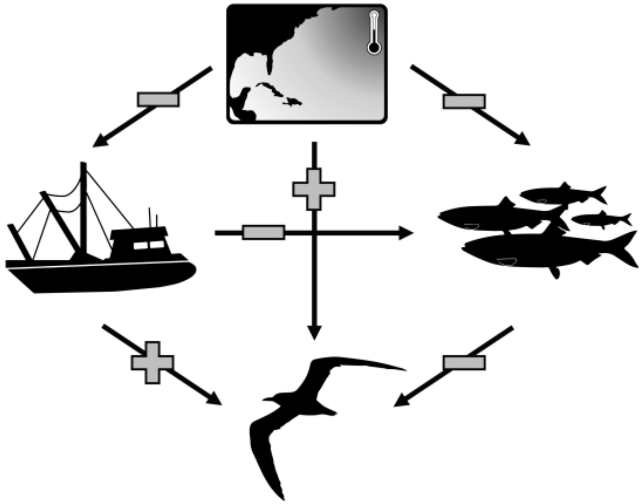
Colton Padilla

Kaitlyn Vega

Sunny Domschot

Liv Lundin

Questions?



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