Lecture 6

Dynamics of small populations

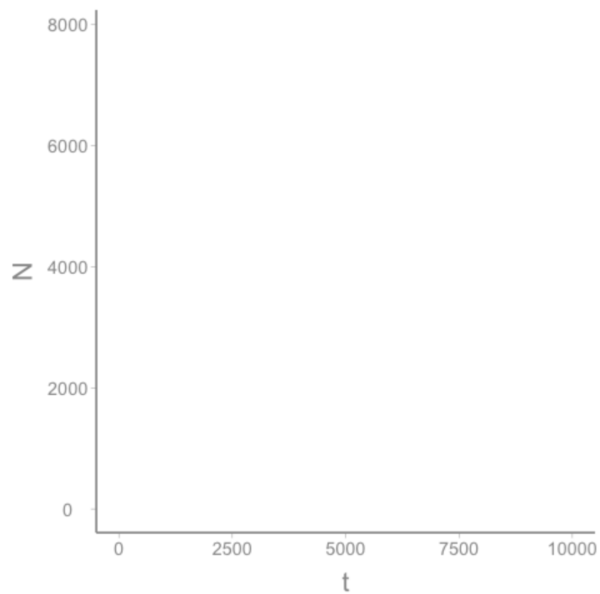
WILD3810 (Spring 2020)

Readings

> Mills 224-243

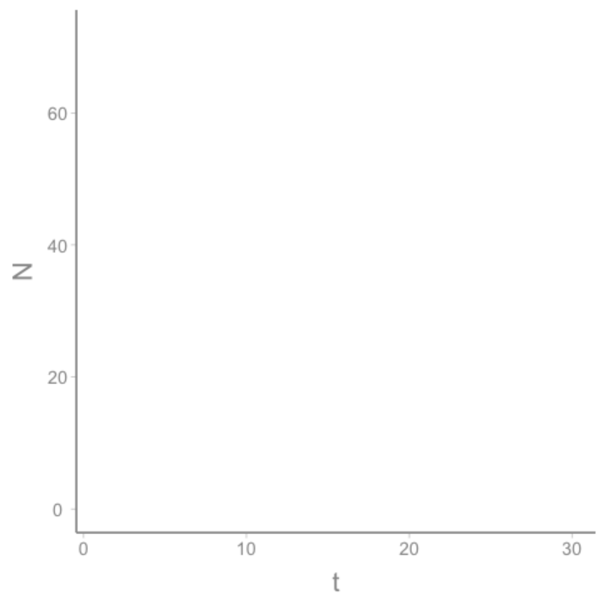
Stochasticity and extinction risk

Over a long enough time scales, the fate of any population that is subject to stochasticity is *extinction*



Stochasticity and extinction risk

Stochasticity, particularly demographic stochasticity, is most consequential at small population sizes



Genetic stochasticity

In addition to demographic and environmental stochasticity, **genetic stochasticity** also increases extinction risk for small populations

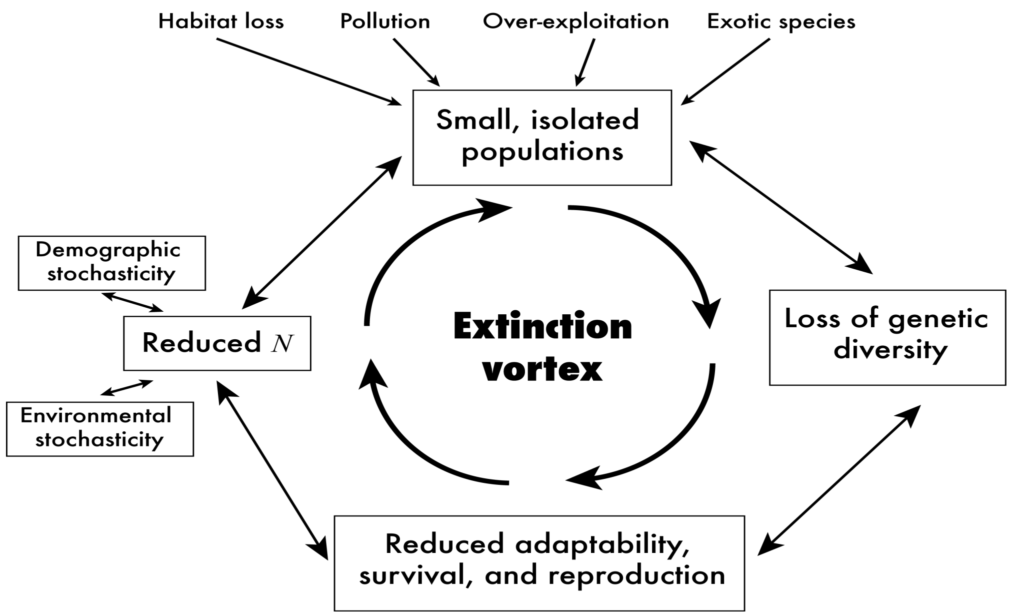
Genetic drift leads to random accumulation and expression of harmful alleles, which can reduce demographic rates [1]

Inbreeding depression can also lead to expression of harmful alleles

Extinction vortex

Extinction vortex

As populations decrease in size, they reach a point where **environmental stochasticity**, **demographic stochasticity**, and **genetic stochasticity** interact to drive populations towards extinction



Extinction vortex

The danger with the extinction vortex is that focusing on a single factor (e.g., deterministic cause of decline) is not enough

Once a population is small, removing the cause of decline will not remove the stochastic threats

All threats have to be managed and considered together

What is a "small" population?

Detecting when species have entered the extinction vortex is difficult

But risk of exinction is related to population size

- small populations are at higher risk than large ones

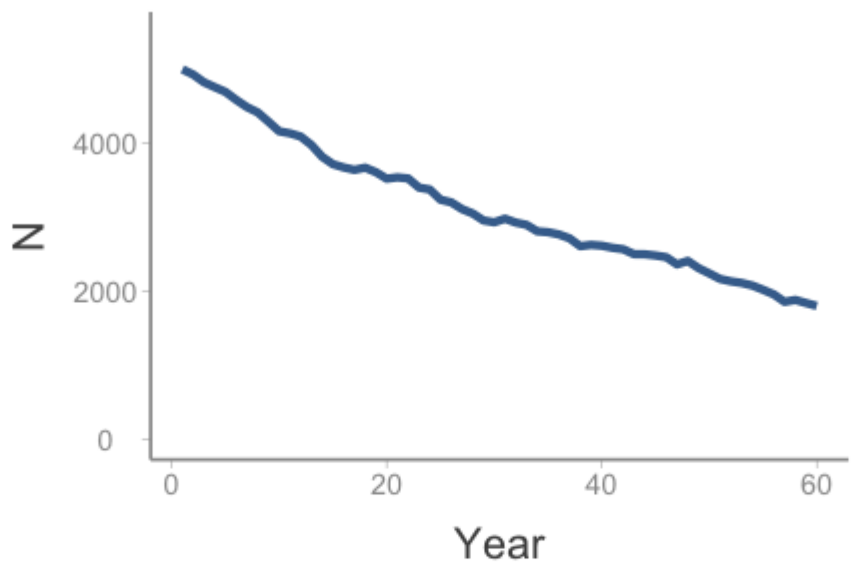
What defines a "small" population?

What is a "small" population?

This is a difficult question because "small" is a relative term

"Small" compared to what?

- Historical population size?



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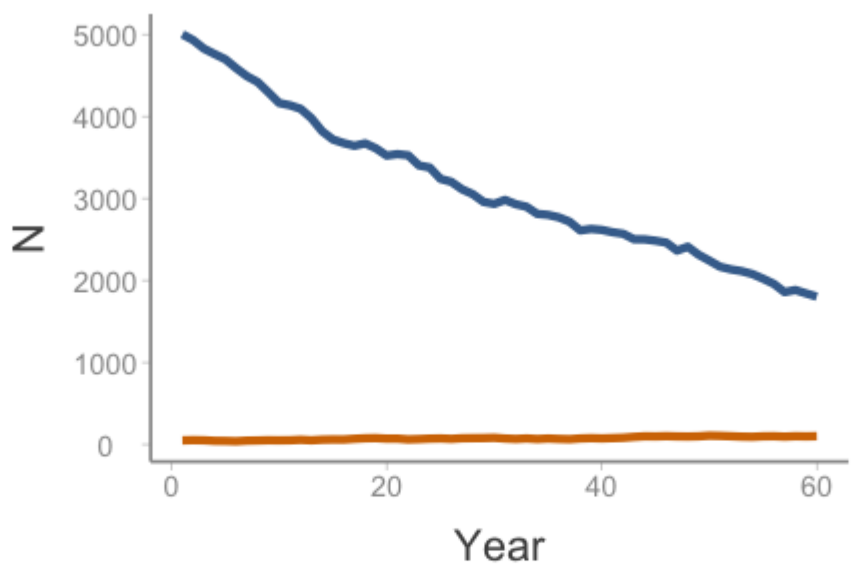
"Small" compared to what?

- Historical population size?
- Other species?

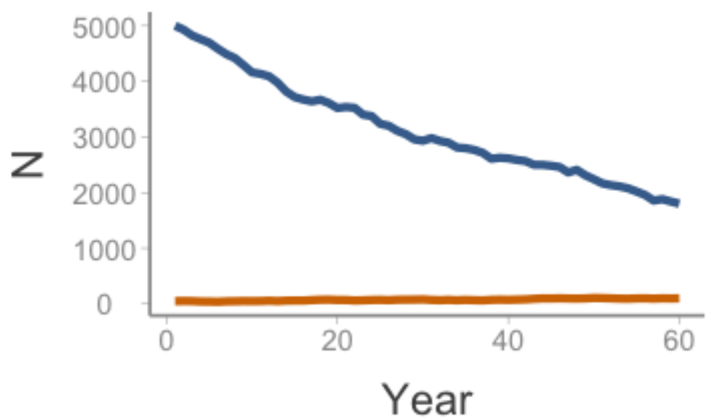


What is a "small" population?

This is a difficult question because "small" is a relative term

"Small" compared to what?

- Historical population size?
- Other species?
- Management standards?



What is a "small" population?

There is a long history of trying to define the minimum abundance that avoids extinction (*minimum viable population*):

1) 50-500 rules (Soule 1980; Frankel & Soule 1981):

> Effective population size (N_e) of 50 needed to avoid negative consequences of inbreeding depression; $N_e = 500$ needed for maintenence of genetic diversity to allow adapation [1]

Focused on captive breeding not wild populations

$N_e = 500$ probably too small for wild populations subject to stochasticity

What is a "small" population?

There is a long history of trying to define the minimum abundance that avoids extinction (*minimum viable population*):

1) 50-500 rules (Soule 1980; Frankel & Soule 1981)

2) 1400-4000 (Brook et al. 2006; Traill et al. 2007):

> 1400-4000 individuals found to promote low risk of extinction over moderate timescales (20-100 years)

Improvement over 50-500 rule because focuses is on "risk of extinction" rather than on abundance itself

Good rule-of-thumb but not a magic number

Problems with MVP approach

1) We probably don't want to aim for the *minimum* population size

2) There is not really a single minimum number of individuals (uncertainty!)

3) Populations provide ecological functions that may not be met at low population sizes

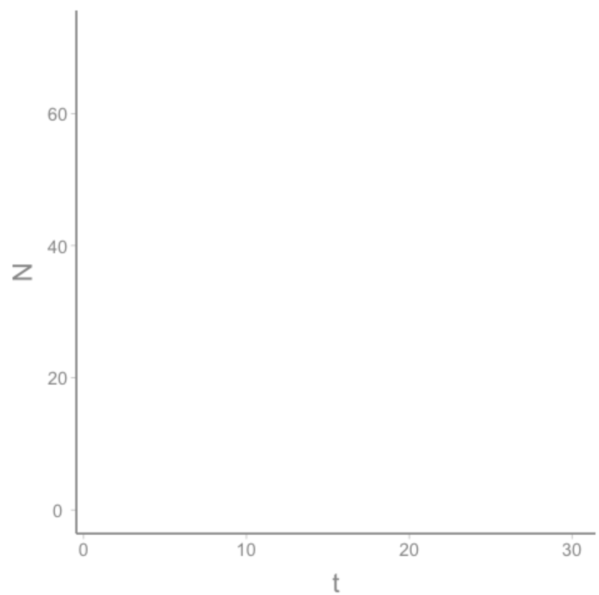
Many factors influence risk of extinction so maintenance of a population should consider multiple risk factors

Predictors of exinction risk

Predictors of exinction risk

1) Abundance

- smaller populations are at higher risk of extinction than larger ones

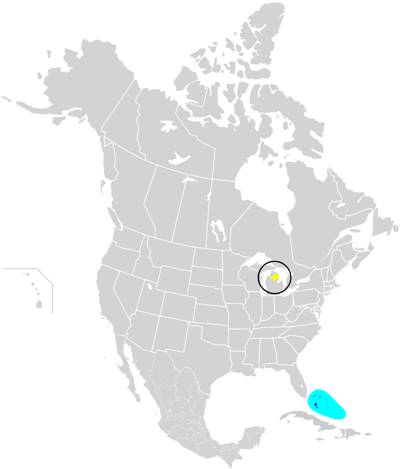


Predictors of exinction risk

1) Abundance

2) Range size

- Species restricted to small area/highly specialized are often at a higher risk of extinction than widespread species



Predictors of exinction risk

1) Abundance

2) Range size

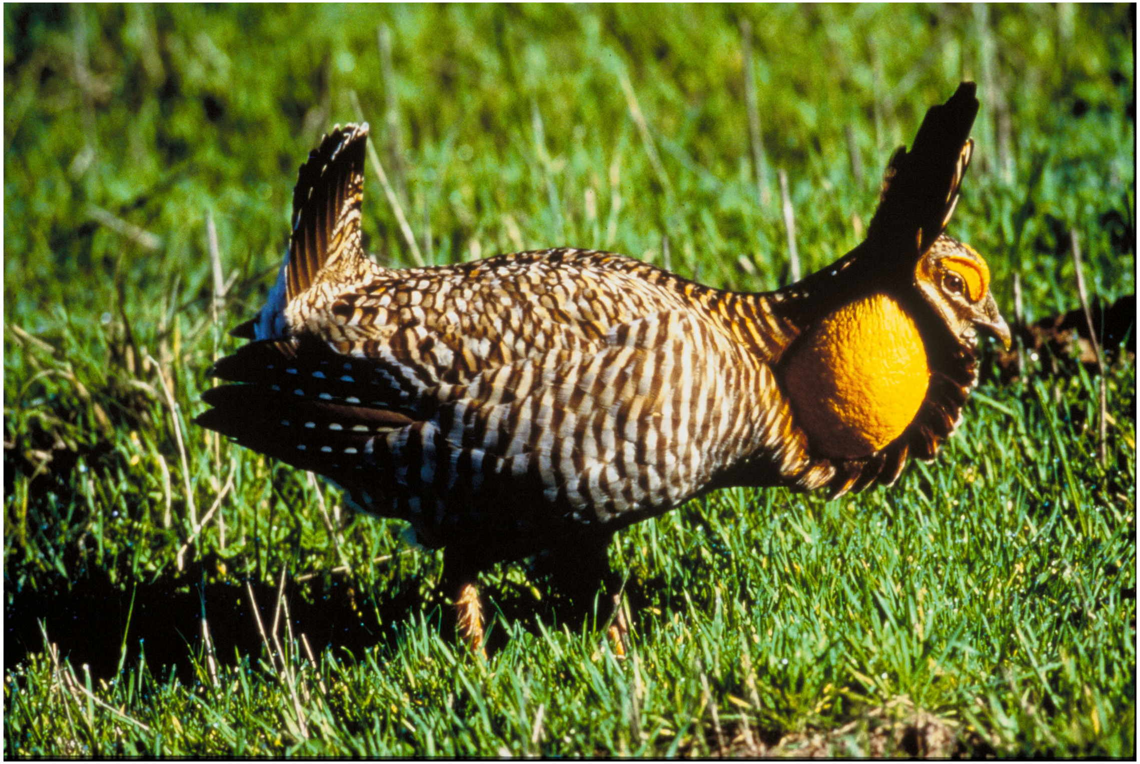
- Species restricted to small area/highly specialized are often at a higher risk of extinction than widespread species

  a) small range and specialization are generally correlated with population size
  b) the restricted habitats used by these species are at higher risk of catastrophic loss

Predictors of exinction risk

1) Abundance

2) Range size



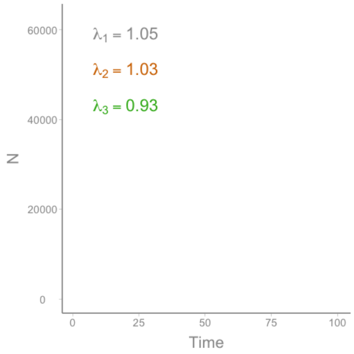
Predictors of exinction risk

1) Abundance

2) Range size

3) Population growth rate

- Species with low and/or highly variable growth rates are at higher risk of extinction than species with stable and/or high growth rates



Predictors of exinction risk

1) Abundance

2) Range size

3) Population growth rate

4) Body size

- Population growth rate and abundance tend to decrease with increasing body size so large-bodied species are generally at higher risk than small bodied species

Predictors of exinction risk

1) Abundance

2) Range size

3) Population growth rate

4) Body size

5) Movement

- Species that are able to colonize new habitats are generally at lower risk of extinction because:

  a) Better able to colonize suitable habitat; and
  b) Increased gene flow limits drift/inbreeding depression

Population viability analysis

Population viability analysis

The above criteria have proven useful for predicting which species are vulnerable to extinction

Due to the complex and interacting factors that determine extinction risk, these criteria are often too simple to accurately assess true risk of extinction

When data are available, a more useful tool for predicting extinction risk is *population viability analysis* (PVA)

Population viability analysis

PVA is a tool (or more accurately a set of methods) that:

> use data and models to estimate the likelihoods of a population crossing thresholds of viability within various time spans, and to give insights into factors that constitute the biggest threats [1]

Population viability analysis

PVA is a tool (or more accurately a set of methods) that:

> use data and models to estimate the likelihoods of a population crossing thresholds of viability within various time spans, and to give insights into factors that constitute the biggest threats [1]

Unlike minimum viable populations, PVA provides a means of determining "population viability" without the need to set a threshold abundance

Components of a PVA

Components of a PVA

1) Viability

- The first step of a PVA is defining what we mean by viable
- This is an abundance level that we want to maintain our population at or above
- In the most simple case, a viable means not extinct $(N > 0)$

Rather than $(N > 0)$ we may also want keep abundance above some level where, e.g.

- Allee effects might kick in
- ecological functions are detrimented
- monitoring becomes unreliable

Components of a PVA

1) Viability

Thus, PVA is usually based on *quasi-extinction* thresholds that are > 0

Below these thresholds, some management action [1] might be triggered to prevent absolute extinction

Components of a PVA

1) Viability

2) Time frame

- As we learned earlier, over long enough time periods, every population will go extinct
- Critical to determine the specific time frame *relevant to our management objectives*

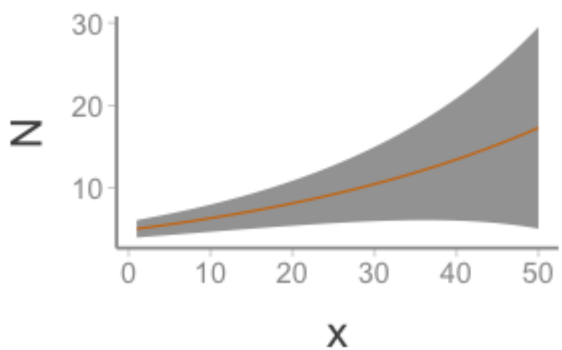
Components of a PVA

1) Viability

2) Time frame

One of the central issues with any type of prediction is that predictions are less certain the farther in the future we try to predict

- The longer the time frame, the more ways there are for stochastic sources of variation to accumulate



Components of a PVA

1) Viability

2) Time frame

Most PVAs incorporate both short-term and long-term objectives

- Long-term objectives are generally based solely on biology - maintaining populations above the quasi-extinction threshold for several decades
- Short-term goals are more focused on political, legal, and social realities - what *can* we do now to maintain or increase population viability?

Components of a PVA

1) Viability

2) Time frame

By monitoring the population and re-running the PVA with new data, managers can assess whether short-term actions are helping (or hurting) meet long-term objectives.

Components of a PVA

1) Viability

2) Time frame

3) Likelihood of risk

- The reason we need PVA is that we cannot say with certainty what will happen in the future due to stochasticity [1]
- PVAs are based on estimating probabilities of meeting viability objectives over our defined time frames
- These probabilities capture the inherent *uncertainty* in our predictions

Components of a PVA

1) Viability

2) Time frame

3) Likelihood of risk

- The likelihood of risk can be expressed in different ways

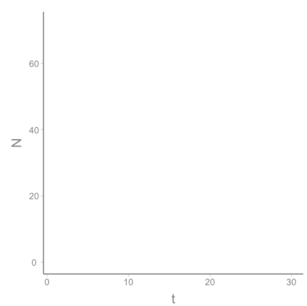
Components of a PVA

1) Viability

2) Time frame

3) Likelihood of risk

- Overall quasi-extinction probability



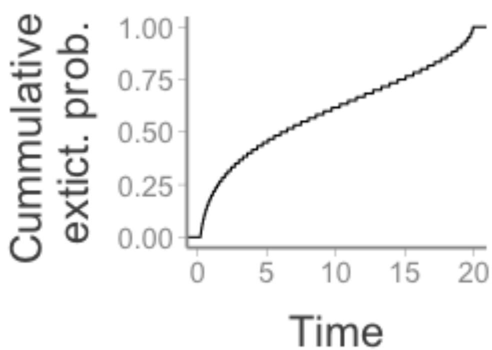
Components of a PVA

1) Viability

2) Time frame

3) Likelihood of risk

- Cumulative probability of declining below the quasi-extinction threshold



Components of a PVA

1) Viability

2) Time frame

3) Likelihood of risk

In all cases, it's important to remember that these are *probabililities* - we don't know exactly how things will turn out

PVA can be used to estimate these probabilities but they cannot be used to tell us what level of risk we are willing to accept. That is a value judgement.

Types of PVA

Types of PVA

Once we have established our quasi-extinction thresholds, time frames, and likelihoods of risk, we can build the PVA

As mentioned above, PVA actually refers to a variety of modeling techniques

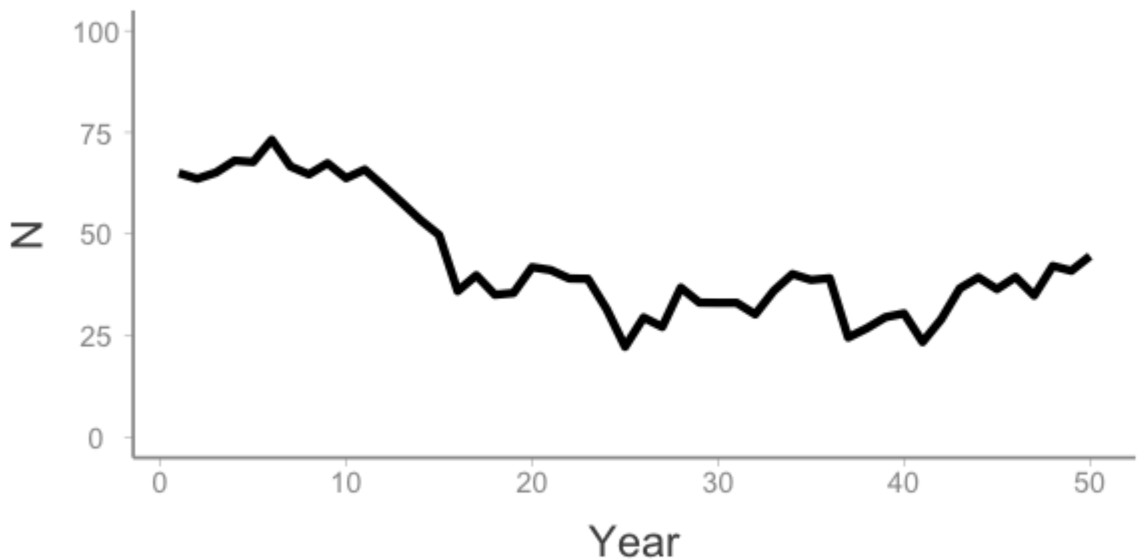
The type of PVA we choose usually depends on the available data

Types of PVA

Time-series

The most straightforward type of PVA is based on a time series of abundance data

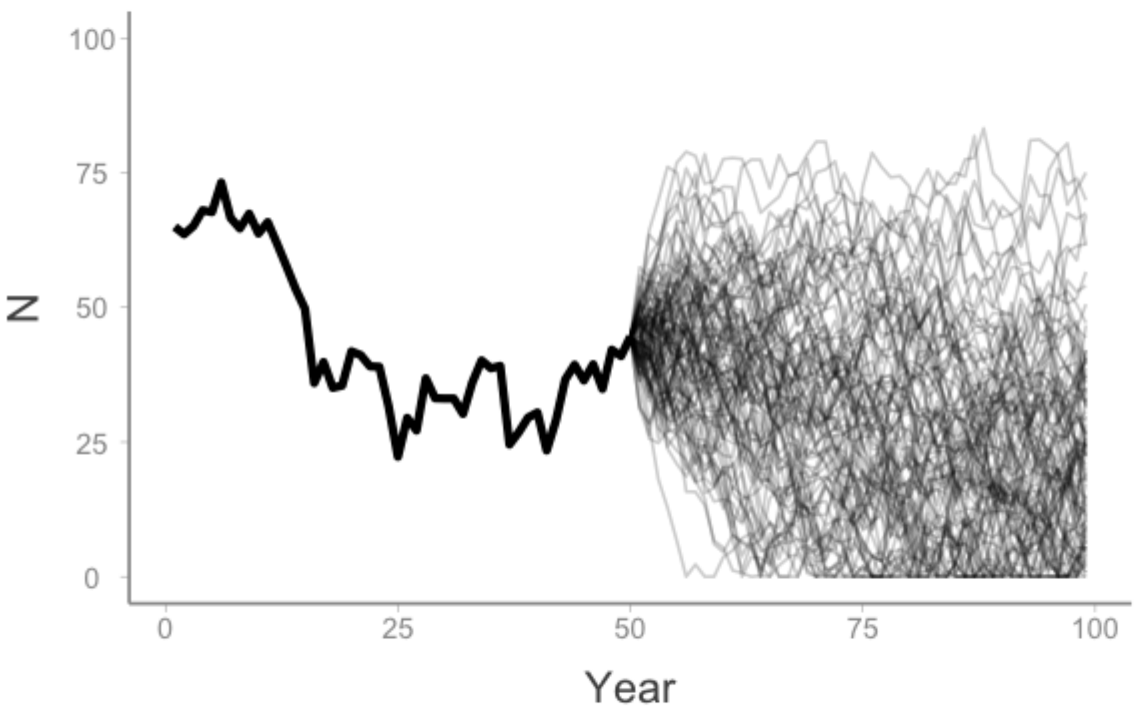
- use data to estimate r and σ^2



Types of PVA

Time-series

Use r and σ^2 to **simulate** future dynamics



Types of PVA

Time-series

Summarize simulated populations to predict future dynamics:

- 39% probability of extinction
- 58% probability of $N < 10$
- 75% probability of $N < 20$

Types of PVA

Time-series

More complex time-series PVAs can account for:

- Density-dependence
- Changes in r over time
- Effects of management actions

Types of PVA

Demographically-explicit

Rather than model r, model b and d directly

- Incorporate variance, density-dependence, and covariation in vital rates
- Mechanistic management predictions
- Possible to include effects of genetic processes (e.g., inbreeding depression) on vital rates

Types of PVA

Demographically-explicit

Rather than model r, model b and d directly

But

- require lots of data
- challenging to construct

Types of PVA

Spatial

In addition to b and d, viability influenced by movement:

- immigration and emigration

Spatially-explicit PVAs model *how many* individuals and *where* they are

- allow locally-extinct patches to become re-colonized
- allow gene flow to add genetic variation

Considerations for using PVA

1) Data quality

- Time frame
- Sampling error

Considerations for using PVA

1) Data quality

2) Uncertainty

- Do we need accurate predictions of extinction risk? Or is relative risk be enough?
- Account for uncertainty using simulations

Considerations for using PVA

1) Data quality

2) Uncertainty

3) Other sources of information

- Expert opinion
- Rules-of-thumb