Wildtierkundekurs Modul II

Theory 1: Introduction

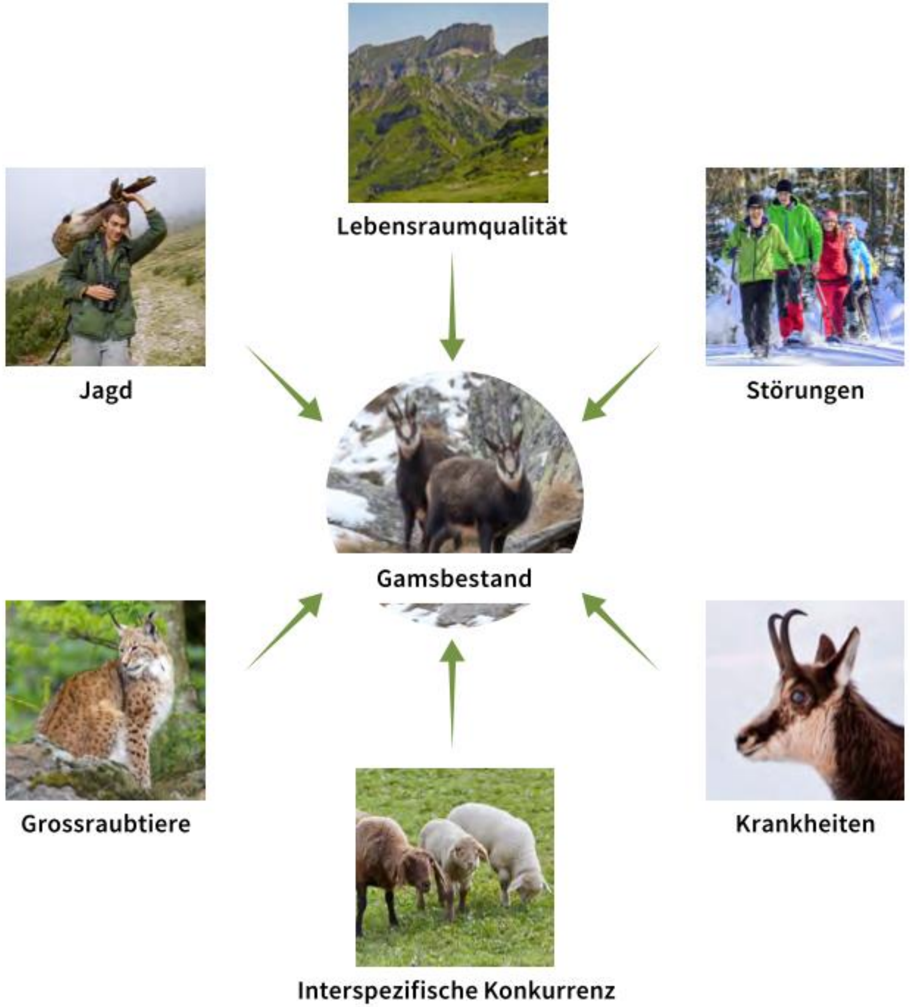


Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Urgent questions for wildlife managers and conservationists

What are the major mortality causes of chamois?

How will the return of large predators affect harvesting quotas in the future?



https://www.jagdschweiz.ch/projekte/gamsmanagement/

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Urgent questions for wildlife managers and conservationists

How will climate affect the distribution of European and mountain hare in the future?

© Adobe Stock

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

Urgent questions for wildlife managers and conservationists

Is the Wildcat population in Switzerland increasing?

How does hybridisation with domestic cats play into this?

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

Urgent questions for wildlife managers and conservationists

What is the impact of mowing deaths on roe deer population growth rate?

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Estimation of unknown parameters

To answer above questions, we need to **estimate population parameters**.

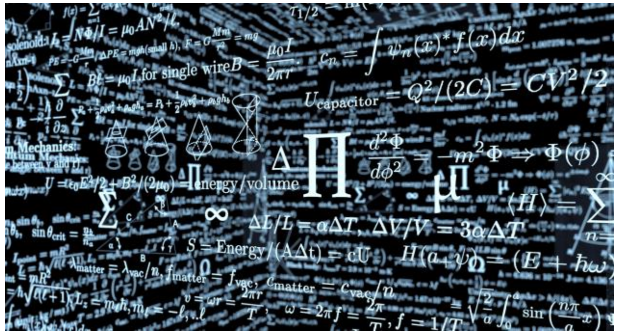
Answers to ecological questions are rarely obvious. We need some **statistical techniques**/tools to find out.

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Computers can do the work, why bother understanding?

Some calculations are easy but some involve heavy math and require sofisticated **computer software** to **do the work for us**.

However: Even if we don’t need to know the glory details for every method **we’ll need to know the principles** behind – what are the underlying assumptions and what can go wrong.



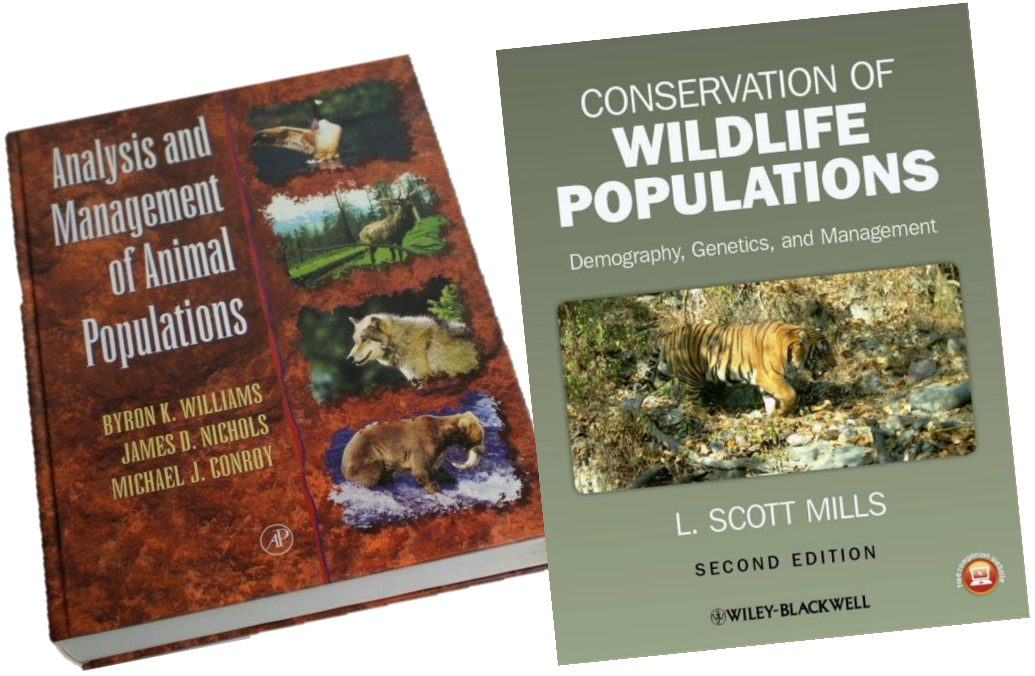
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

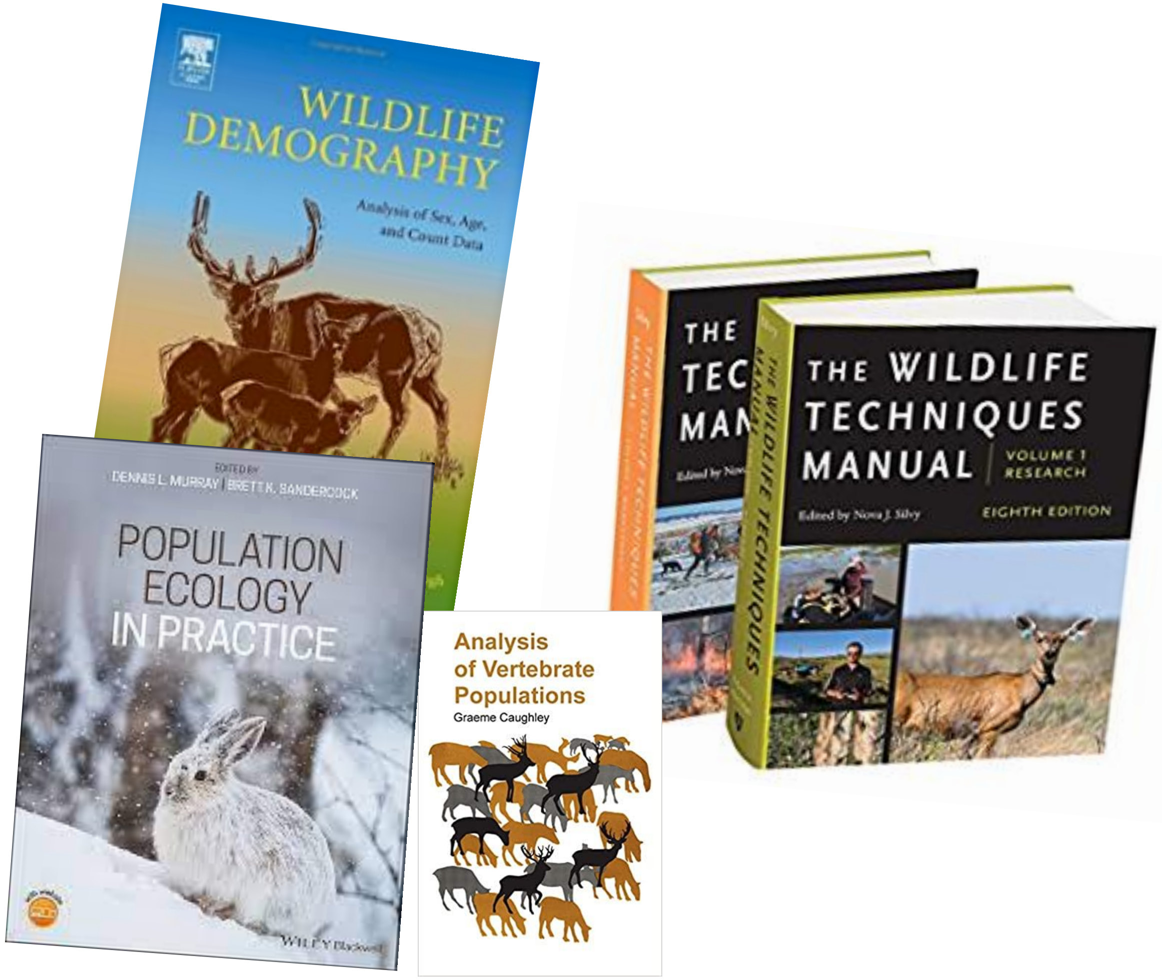
What we do in this course…

In today's lectures we'll give you a brief overview of quantitative methods in wildlife management and conservation

At the end of the day you should have an idea where to go and dig deeper for your specific project/study.

Recommended literature





Todays lectures 08:00 – 11:45

Morning

Theory part I: Introduction to ecological data collection and analysis (ca. 60min)

Theory part II: Estimating animal abundance for unmarked populations (ca. 45min)

Tutorial: Estimating animal abundance (ca. 30min)

Theory part II: Estimating animal abundance using capture methods (ca. 45min)

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Todays lectures 13:00 – 16:45

Afternoon

Theory part III: Estimating survival and reproduction (ca. 60min)

Theory part IV: Animal movement (ca. 45min)

Theory part V: Conservation genetics (ca. 30min)

Tutorial: plan an ecological study (group taks; 45min)

Why do ecologists collect data?

"Reliable knowledge is nothing less than the outcome of the quest to judge truth" Mills 2006

[...] "without comparison to a factual referent, an idea of the mind is only an opinion" Charles Romesburg 1981

Science wants to move from opinion to knowledge.

To acquire knowledge, we need the facts – i.e. collect data and test them against our ideas.

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Increasing scientific knowledge

Fundamental steps in planing an ecological study:

- Identify a relevant ecological question
- Come up with hypotheses
- Deduce predictions
- Go to the field and collect the data to test predictions

→ Recursive process

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Approach the truth by sampling

True parameter values or true effects are difficult to ascertain.

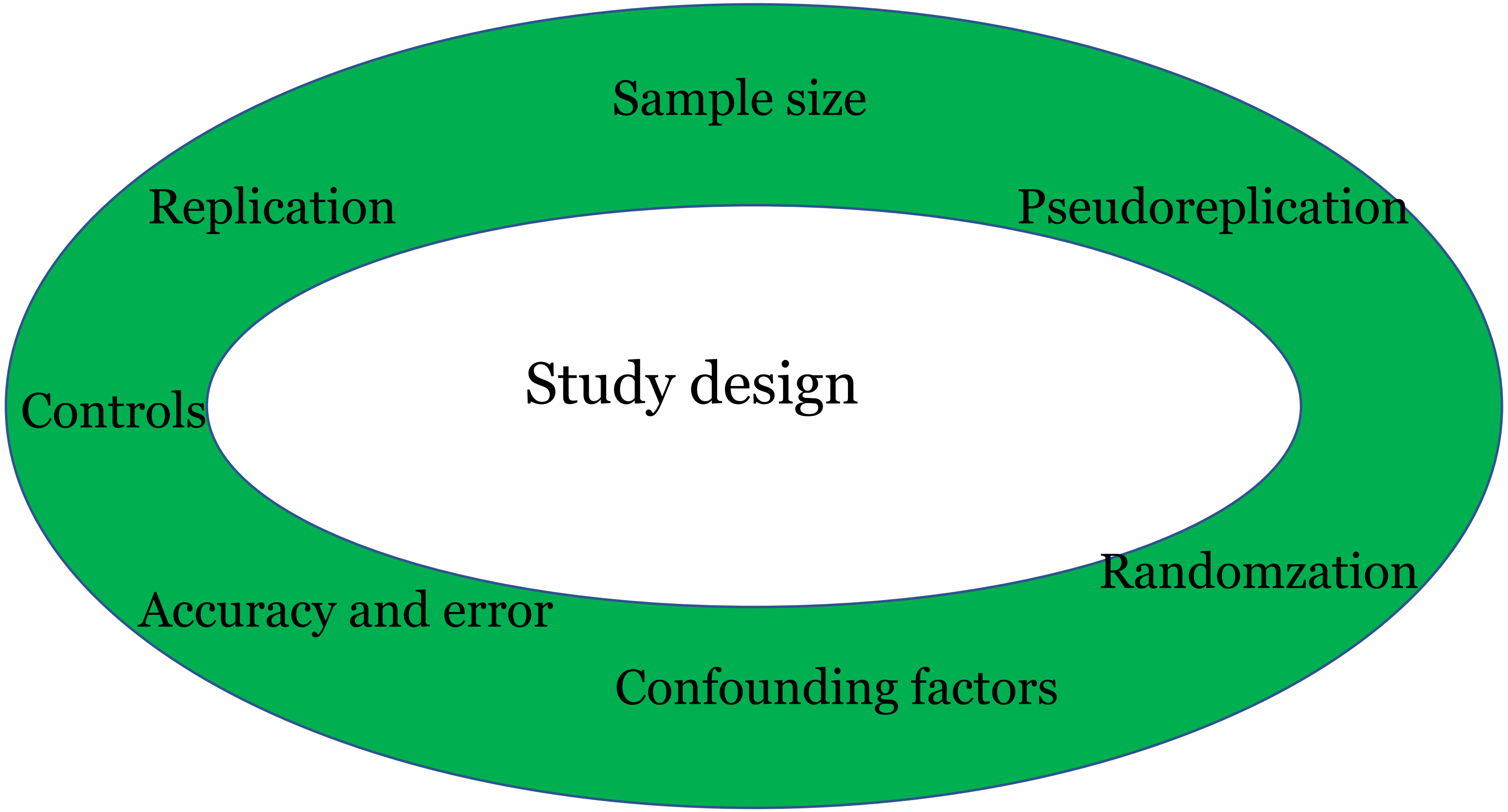
By sampling we **estimate** the parameters or treatment effects.

The real world is messy! No two individuals are alike, external factors affect a response, sampling is always subject to error, etc…

In general: the messier the data the more sophisticated the stats.
→ important to carefully design your study!

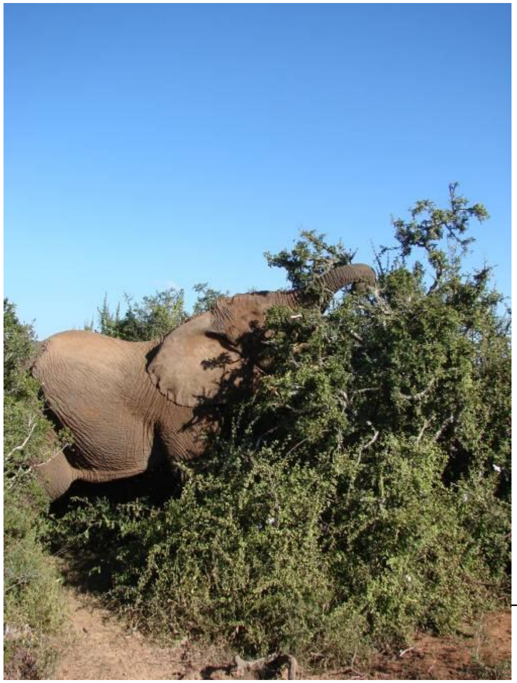
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

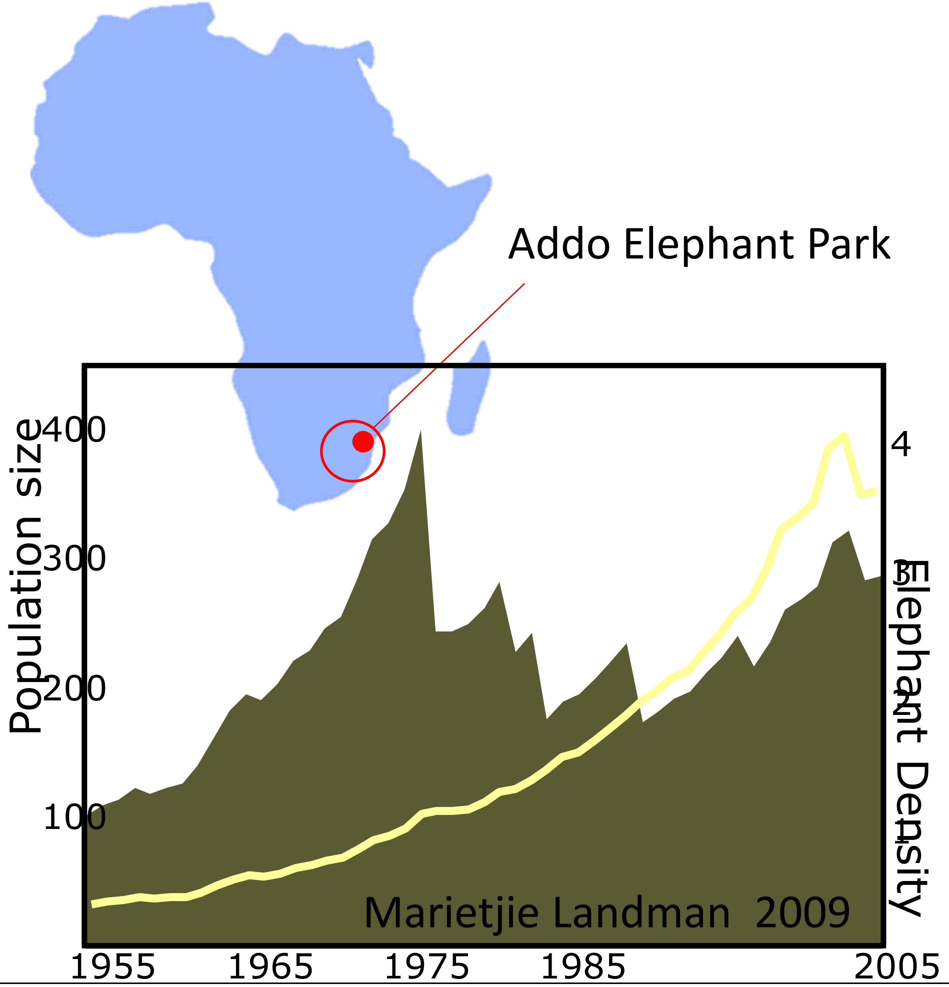
Key concepts of designing ecological studies



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Africa and its elephant problem





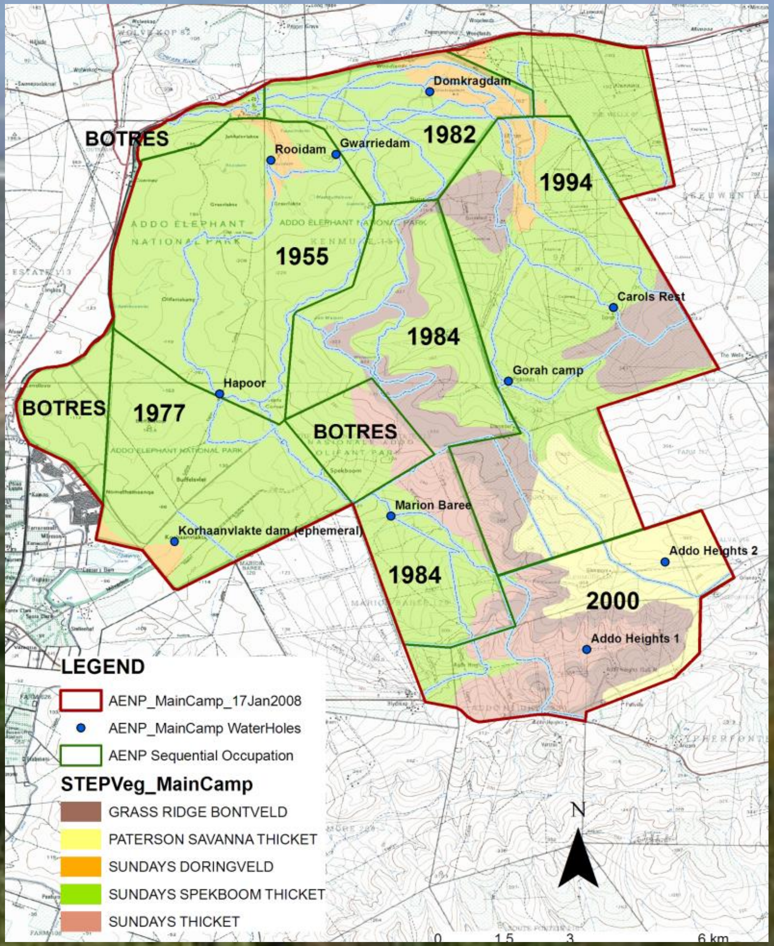
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

- Reduction in vegetation density and plant heights due to elephant impact have long been recognized)

- It was proposed that the vegetation is adapted to top-down feeding by elephants

- Yet an exponential decrease in vegetation height as a function of duration of elephant occupation has been recorded

- Tame elephants were found to choose forage from the bottom-upwards in a feeding trail → trunk as a grazing adaptation



- Are wild elephants top down feeders?
- Do feeding heights change over time?

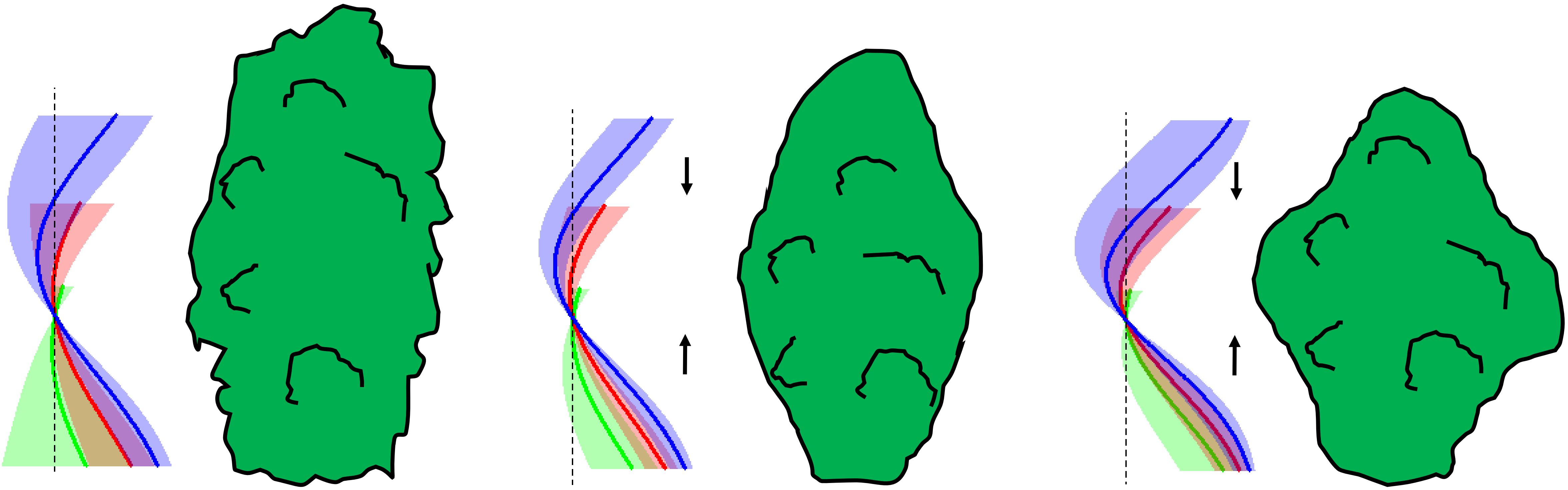
Feeding heights of elephants in Addo

What are the feeding heights of elephants?

I measured 2000 feeding events of 170 elephants in Addo Elephant park South Africa.

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Feeding heights of elephants in Addo



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

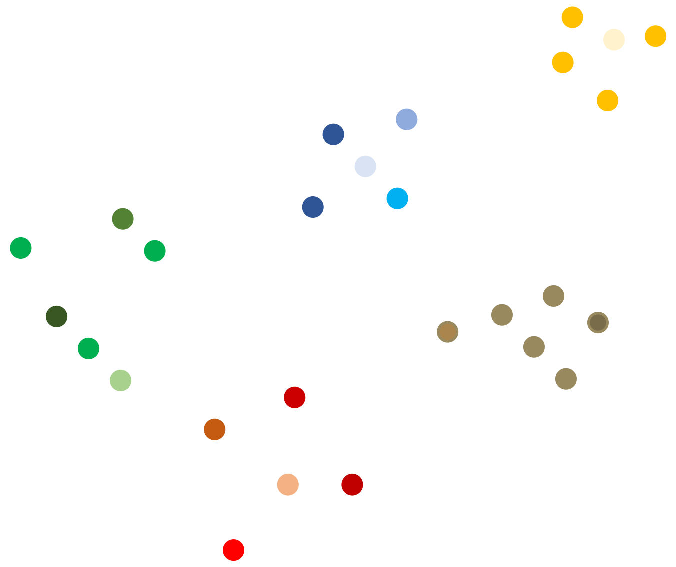
Replication

Populations are not homogeneous - individuals vary in their characteristics

Almost never will you sample the entire population

Replication ensures reliable sampling

The more variation the more replicates are required



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Sample size

What is the required number of independent sampling units?

Depends on variation of the parameter and the precision pursued.

In ecology almost always: the more the better!

But collecting data is expensive.

→ If you want to know when to stop, do a **power analysis**!

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Sample size and pseudoreplication

Beware of pseudoreplication

Your sample size is the number of replicates!

Each data point must be independent – dependent data points are just subsamples

What is a independent data point may depend on the study question

Hurlbert 1984

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Pseudoreplication

What are the feeding heights of elephants?

I measured 2000 feeding events of 170 elephants in Addo Elephant park South Africa.

What is the sample size ?

What's the sample size if the question is, what are the feeding heights of all elephants in Africa?

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

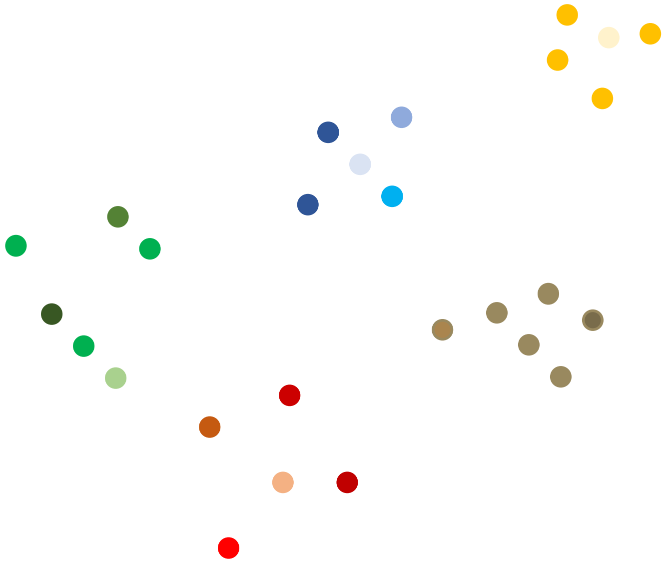
Randomization

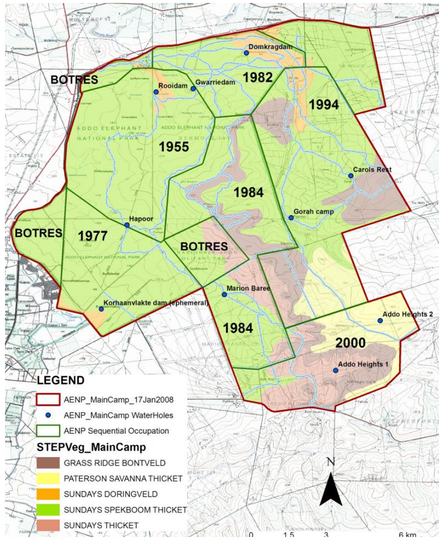
Each sampling unit of a population should have equal chance of getting selected.

Randomization and stratification

Each sampling unit of a population should have equal chance of getting selected.

Stratified sampling → if known heterogeneity within population





Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

Randomization

Randomization refers to the specific question under consideration.

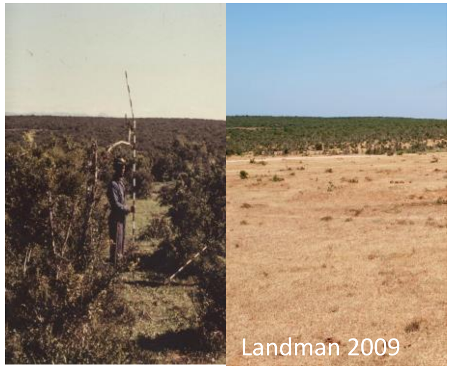
Example: fawns found in meadows may not be a random sample for the question of bed site selection of roe deer does, but it may be if you’re interested in roe deer litter size

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Controls

In experimental treatments a control group only differs from the treatment group in that it lacks the treatment

A way of ascerting true controls is by randomization



Randomization helps controlling for confounding factors

→ What could be a good control area for vegetation state in elephant study?

Example of control experiment

Predator removal study wants to find out if removal of red foxes influences survival of hare leverets

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Example of control experiment and randomization

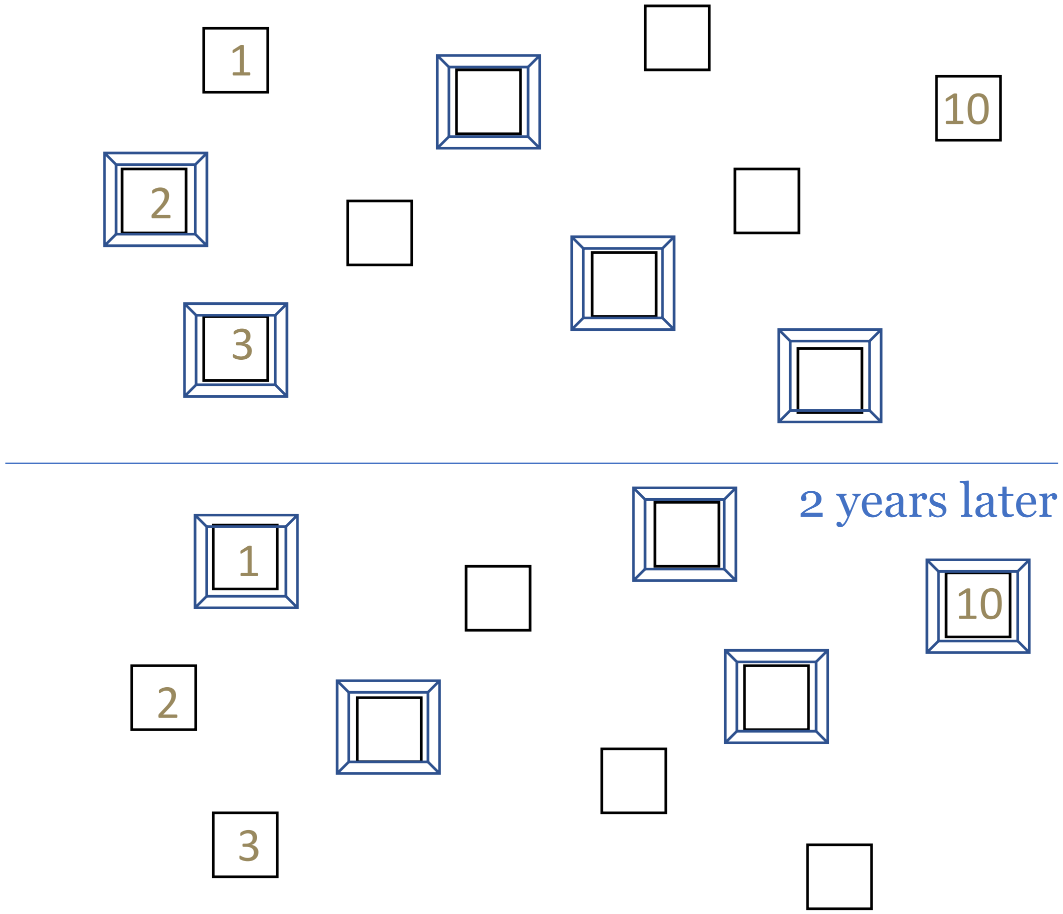
Choose 10 identical plots

Randomly assign 5 plots as controls and 5 as treatment

Remove red foxes in the treatment plots

Alternate control plots and treatment plots after 2 years

Each plot and 2-year period is a replicate → 10 replications per treatment/control



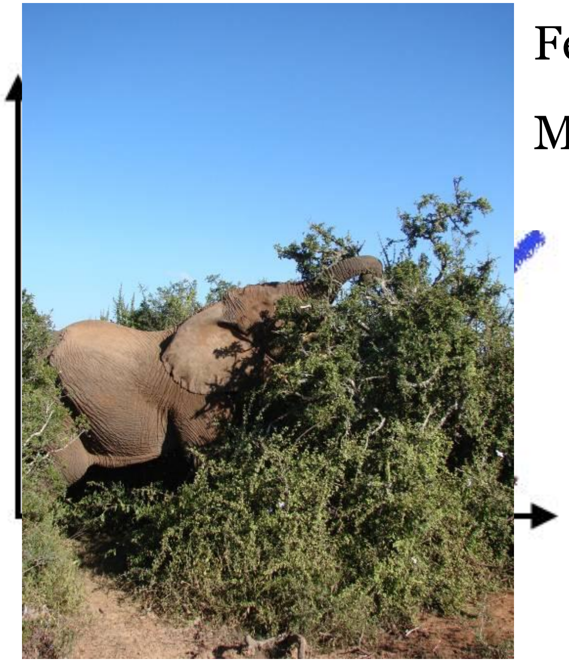
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Confounding factors and Simpson's paradox

Failing to control for relevant confounding factors can lead to completely opposite conclusions → feeding heights of elephants as a function of age

Simpson's paradox

In this example, body size and sex are confounding factors



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

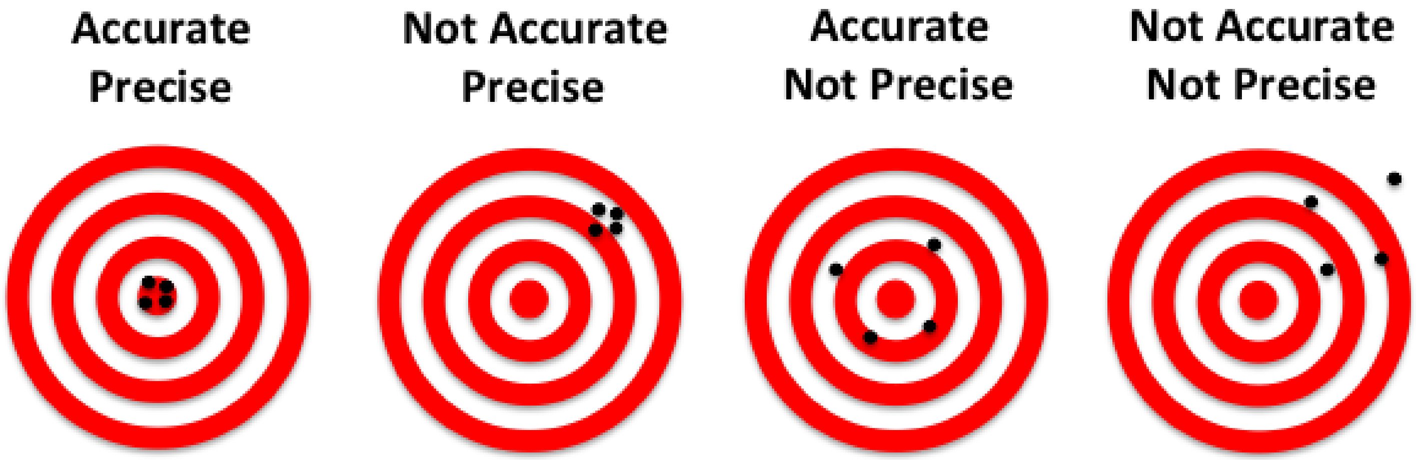
Accuracy and error

“Accuracy and error are two sides of the same coin.” Mills 2006

Accuracy: **closeness to a true value**

Bias: systematic deviation of estimate from true parameter

Precision: **closeness of repeated measurements to the same value**
Precision is quantified by variance

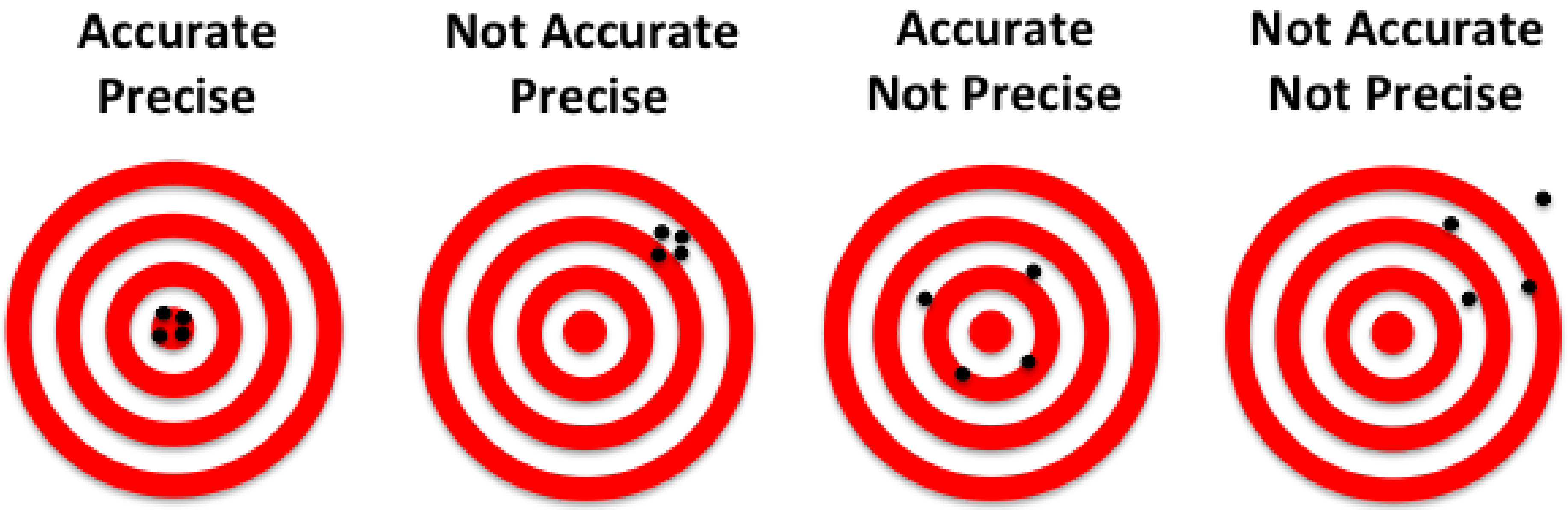


Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Accuracy and error

Know your bias and correct for it!

A good estimate is unbiased and precise!



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Sources of sampling variation

Process variance (genuine biological variation)

- Temporal (e.g. weather, seasons, etc.)
- Spatial (varying environments, conditions)
- Demographic (individuals differ)

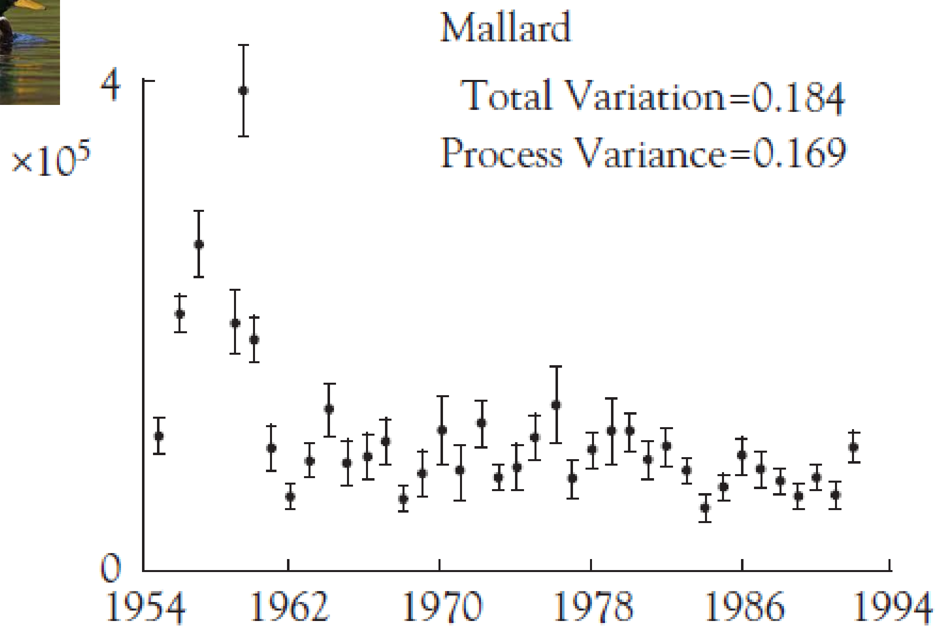
Knowing process variance is important for management and conservation decisions

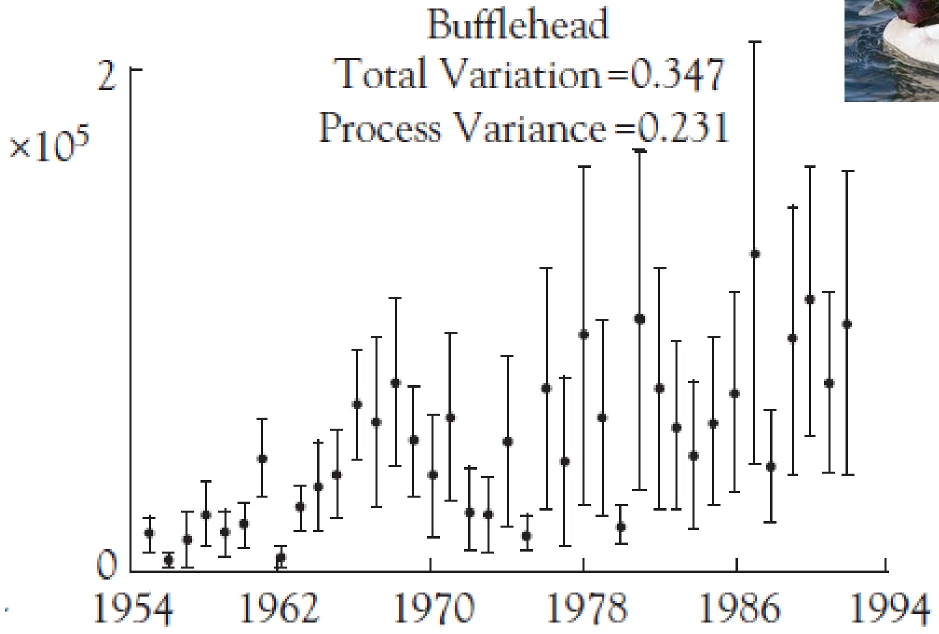
Sample variance (incomplete information)

- Subsampling effects (individuals differ)

Process variance = Total variance – sample variance

Consequences of sampling and process variance





Mills 2006; Conservation of Wildlife Populations, Chap. 5, p. 100

Measuring variation of a sample

Sample variance indicates the spread of your measurements correcting for finite sampling. The general formula is:

Mean sum of squares

$$s^2 = \frac{\Sigma (y_i - \bar{y})^2}{n-1}$$

Degrees of freedom

y_i = i[th] data point in the sample
$\bar{y}$ = sample mean
n = number of data points in the sample

Depending on statistical methods calculating variance can get very nasty!

$$\widehat{\mathrm{Var}}(\hat{S}_H) = \hat{S}_H^2 \left[\left(\frac{(\hat{R}_3+1)}{(\hat{R}_1+1)(\hat{R}_3-\hat{R}_1)} \right)^2 \cdot \widehat{\mathrm{Var}}(\hat{R}_1) + \left(\frac{(\hat{R}_3+1)}{(\hat{R}_2+1)(\hat{R}_3-\hat{R}_2)} \right)^2 \cdot \widehat{\mathrm{Var}}(\hat{R}_2) + \left(\frac{(\hat{R}_3+1)}{(\hat{R}_3+\hat{R}_1)(\hat{R}_3-\hat{R}_2)} \right)^2 \cdot \widehat{\mathrm{Var}}(\hat{R}_3) \right].$$

...but it's always the same underlying principle.

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Measuring variation of a sample

- **Standard deviation** $s = \sqrt{s^2}$

Measure for dispersion of observations around the sample mean $\bar{y}$

Units are more intuitive, e.g. animals per km²

$\mu \pm 1.96$ SD contains 95% of the population observations (μ ~Norm)

- **Standard error** $SE = \frac{\sqrt{s^2}}{\sqrt{n}}$

How much would our estimator of population mean vary under repeated sampling?

Our confidence that estimated mean of sample is close to true population mean

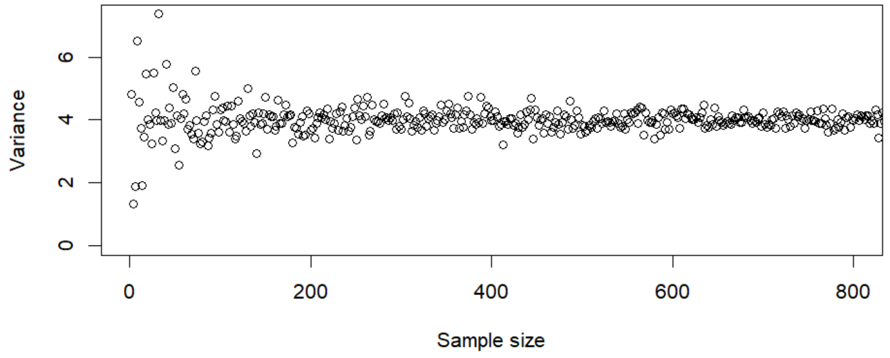
- X% **Confidence interval** $CI = \bar{y} \pm t_{(1-0.x|n-1)} * SE$

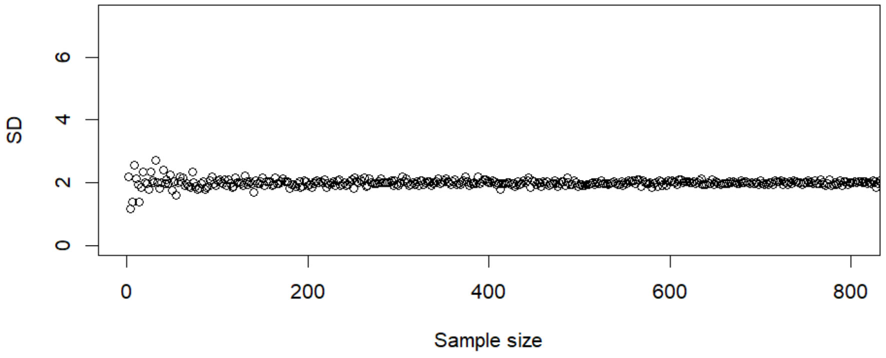
If study would be repeated 100 times, the calculated 95%-CIs would contain the true population mean in 95 times – probabilistic statement about the interval.

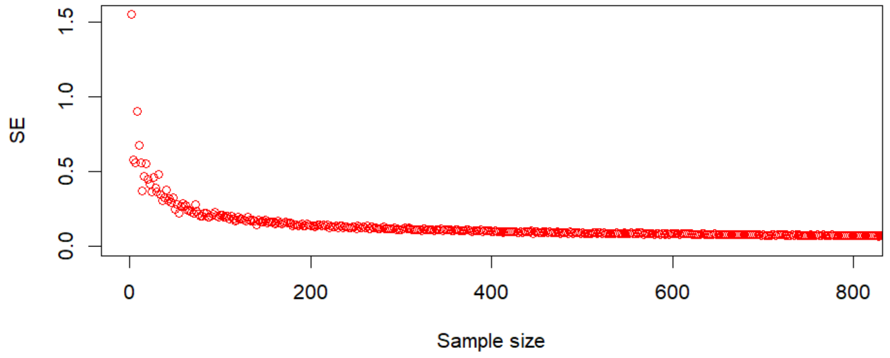
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

What happens with VAR, SD and SE as we increase sample size?

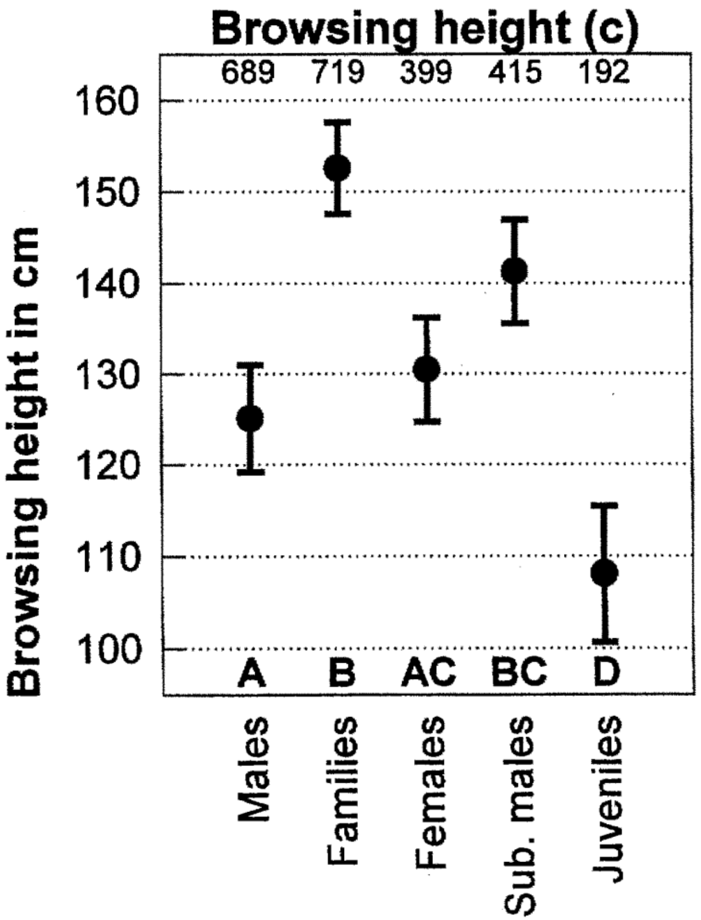






Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Measuring variation



Measuring variation

Increasing n will reduce SE, but not the variance or SD.
(It reduces the «variance of the variance»...)

Always be aware of what measure you indicate.

CI non-overlapping: difference is ALWAYS statistically significant
CI overlapping: difference may or may not be statistically significant
SE non-overlapping: difference may or may not be statistically significant
SE overlapping: difference is NEVER statistically significant
SD tells you NOTHING about statistical significance (it does not account for sample size)

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

What is a significant difference?

Threshold of 0.05 is arbitrary

Interpretation of statistical p-values:

- $p > 0.1$ little or no evidence against the null hypothesis
- $0.1 > p > 0.05$ weak evidence
- $0.05 > p > 0.01$ Evidence
- $0.01 > p > 0.001$ Strong Evidence
- $p < 0.001$ Very strong evidence

Muff et al. TREE 2022 - Rewriting results sections in the language of evidence

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

What is a significant difference?

Statistical significance ≠ biological relevance

e.g. you measure a 2.5% difference in feeding height between male and female elephants

This difference may be biologically relevant, but still be statistically insignificant because of insufficient sample size.

Vice-versa anything will become statistically significant when only sample size is large enough – two parameters of different populations will never be identical

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Type of errors

In hypothesis testing we talk about 2 kinds of error

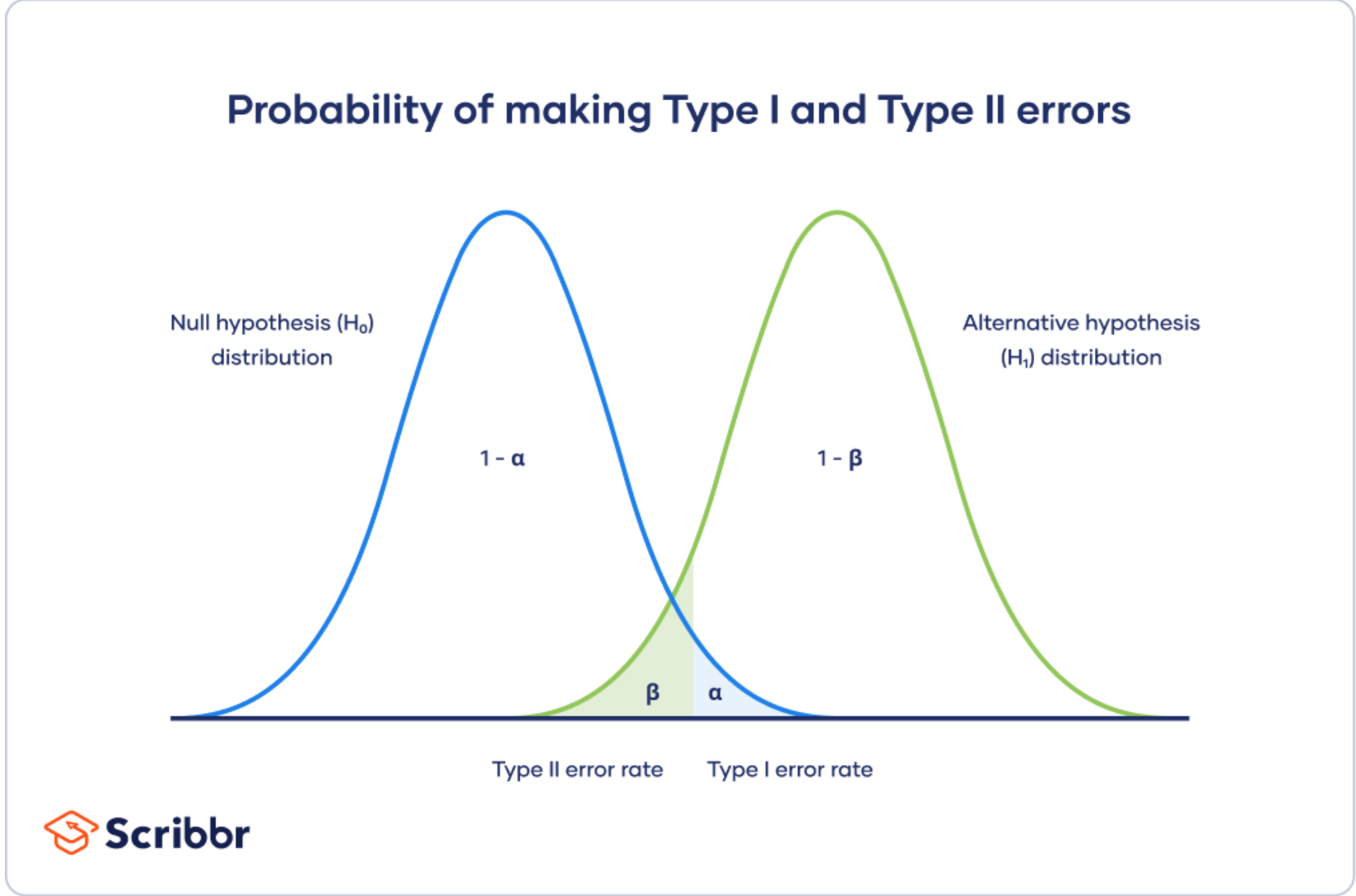
- Type I error (α) – false positive
- Type II error (β) – false negative

Most common level of type I error $\alpha = 5\%$

However, often the type II error is neglected

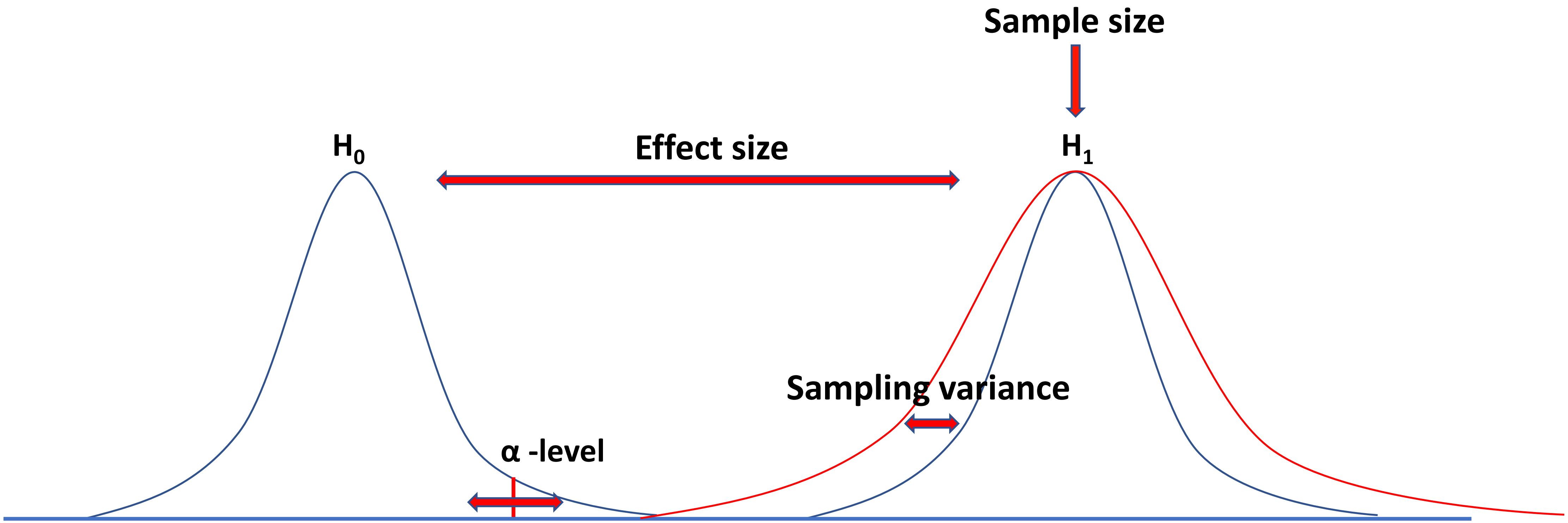
→ **1- β is called the power** - risk of missing true differences

Alpha and beta are reversely related



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Determinants of power



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Power analysis

How do these parameters relate to power?

$$\text{Power} \propto \frac{ES\ \alpha\ \sqrt{n}}{\sigma}$$

The exact relationship depends on the specific statistical test – hence the proportionality sign

Sample size is the only parameter which is under the control of the researcher
→ we can calculate the required sample size for a specific level of power

β can be 5% or 10% but certainly should never be larger than 20%

Wildtier Schweiz

Power analysis

Before we can estimate the required sample size we need to have a rough idea about the **expected effect size** and **sampling variance**

→ pilot study or published results

→ Sensitivity analysis - different scenarios

→ Biological relevance

Power analysis

Example comparing two means:

The sample size is determined by calculating the target test value which is based on the z-value (standard normal distribution)

The target test value (z) is called the **power index (PI)**

→ **Specific for a given α & β level**

$$PI = \frac{d\mu}{\sigma\sqrt{2/n}} \rightarrow n = 2(PI\,\frac{\sigma}{d\mu})^2$$

Power analysis example

Do feeding heights of male and female elephants differ?

What's the required sample size for a risk of 5% to commit a type II error (given α also 5%) → PI-value =3.6

We collected feeding heights of 25 male and female elephants (50 total) in a pilot study and the two means were 82cm and 71cm – so the difference in the two means was 11cm. The SD was 45.

The required sample size then is: $n = 2(\text{PI}\,\frac{\sigma}{d\mu})^2 = 2 \times (3.6 \times \frac{45}{11})^2 = 433.8 \approx 434\ \textit{elephants per group}$!

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch