Meta-analysis in biological and environmental sciences

yDiv/HIGRADE course 23-26 October 2017

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iDiv is a research centre of the

DFG Deutsche Forschungsgemeinschaft

Day 1	**Introduction to meta-analysis** • What is a meta-analysis? • Examples of meta-analyses • Why performing a meta-analysis? • Procedure of meta-analysis in a nutshell **Searching the literature** **Effect sizes and moderators** **Data extraction/Coding**
Day 2	**Meta-analytic models** • Fixed effects model • Random effects model • Mixed effects/hierarchical model **Quantifying and explaining heterogeneity**
Day 3	**Assumptions, biases and confounding effects** • Variance homogeneity and normality of residuals • Publication bias • Sensitivity analysis **Interpretation and presentation of results** • Format for meta-analysis report • PRISMA flow diagram • Forest plots
Day 4	**Methodological issues, advances, and common mistakes** • Non-independence among effect sizes • Non-independence of moderators • Missing data **Criticism of meta-analysis**

Organisation

Location iDiv Leipzig, Deutscher Platz 5a, room Symbiosis

Course Dates 23-26 October 2017

Daily Schedule 09:00 am - 5:00 pm

9-10.30	Lecture I
10.30-11.00	Coffee Break
11-12.30	Lecture II + Exercises
12.30-1.30	Lunch Break
1.30-3.00	Lecture III + Exercises
3.00-3.30	Coffee Break
3.30-5.00	Exercises

INTRODUCTION

Who are you?

Where are you from? Where are you working?

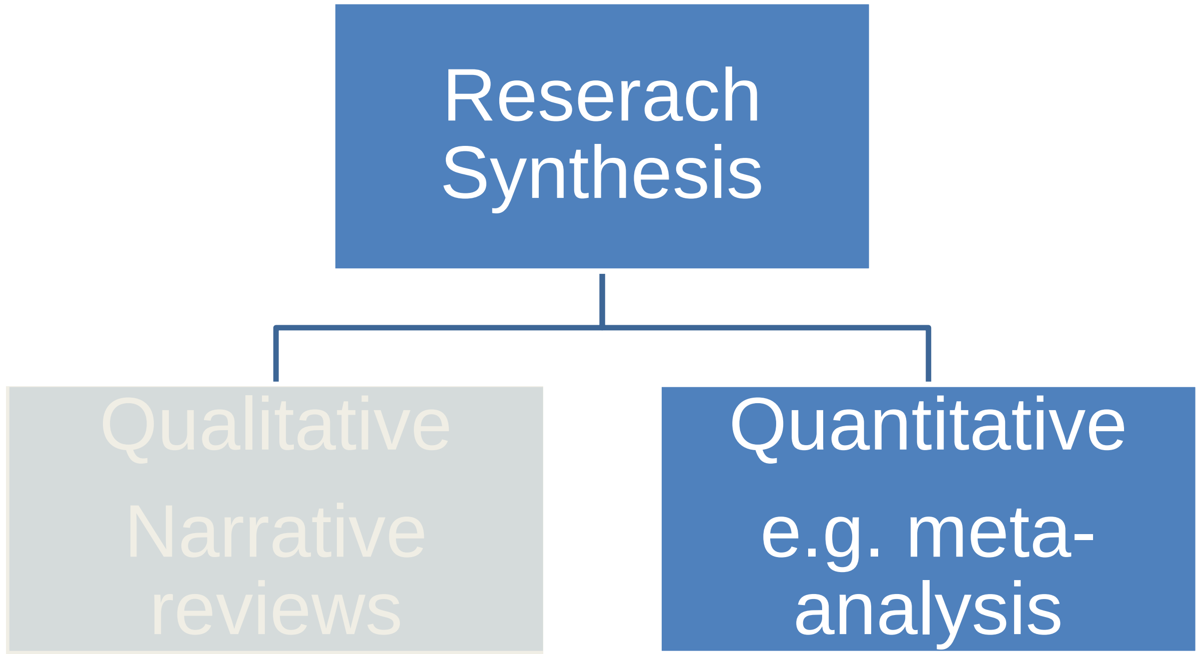
Past or recent experiences with meta-analysis or plans for the future?

Do you have expectations for the course?

Meta-analysis in biological and environmental sciences

Introduction

What is meta-analysis and why is it important?

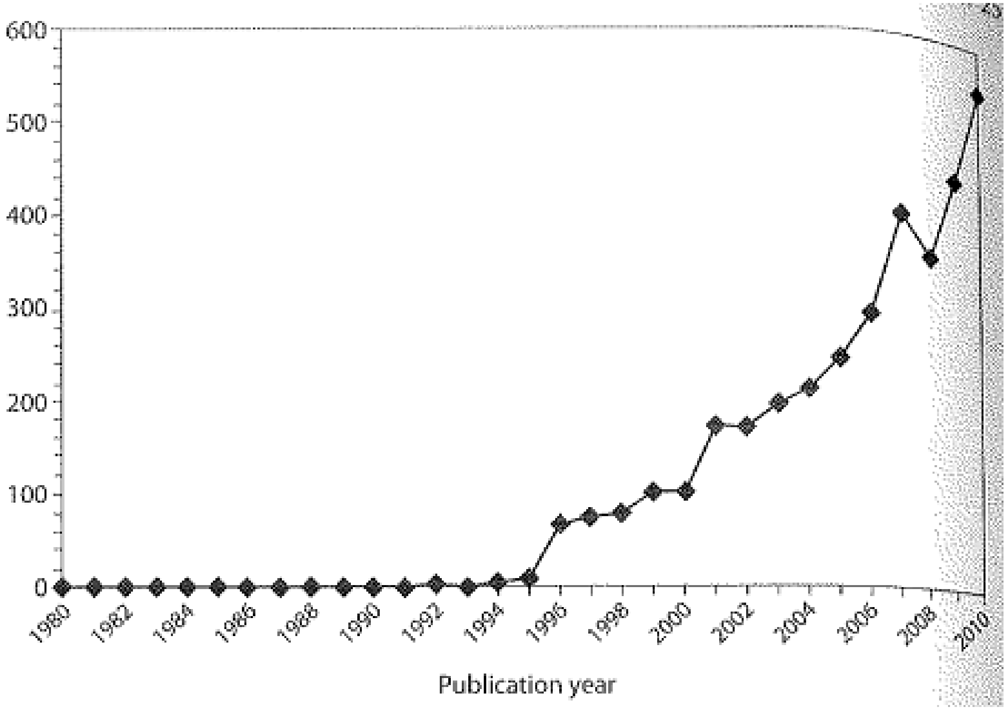


- A set of statistical methods to quantitatively combine results of independent data sets addressing the same research question
- Powerful, informative and objective
- Creating generalizations or resolving conflicts

Short history of meta-analysis

- Originally developed in the social sciences and medicine in the late 1970s
- First introduced into ecology in the early 1990s

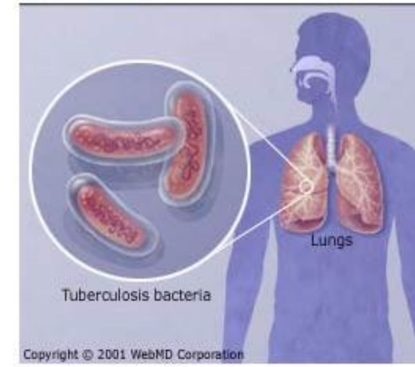
Number of ecological and evolutionary studies indexed in the Web of Knowledge with „meta-analysis“ or „meta analysis“ in title, abstract or keyword between 1980 and 2010*

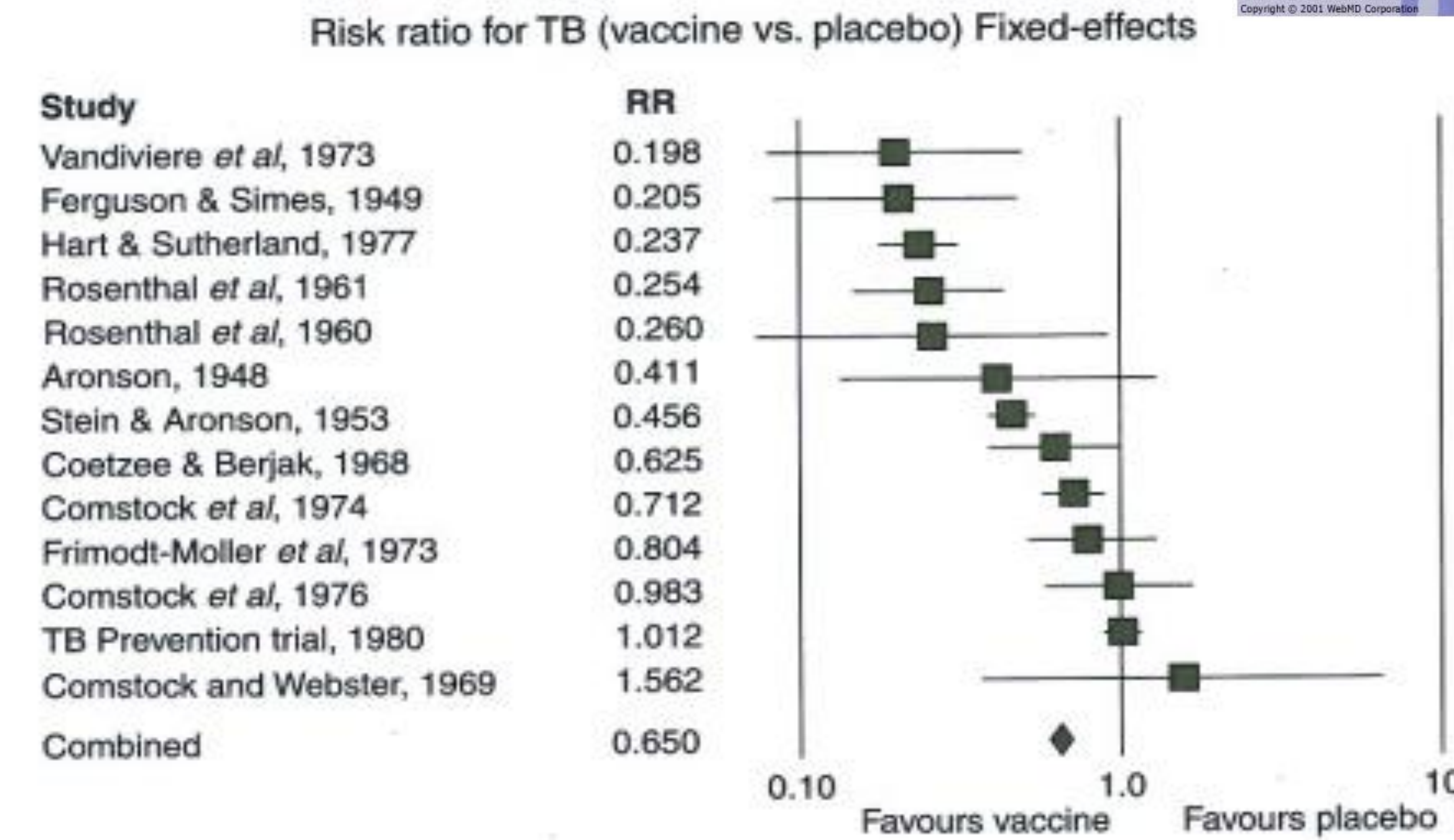


Koricheva et al. (2013), Fig. 25.1.C

Example Medicine

Quantify the efficacy of BCG vaccine against tuberculosis (TB)

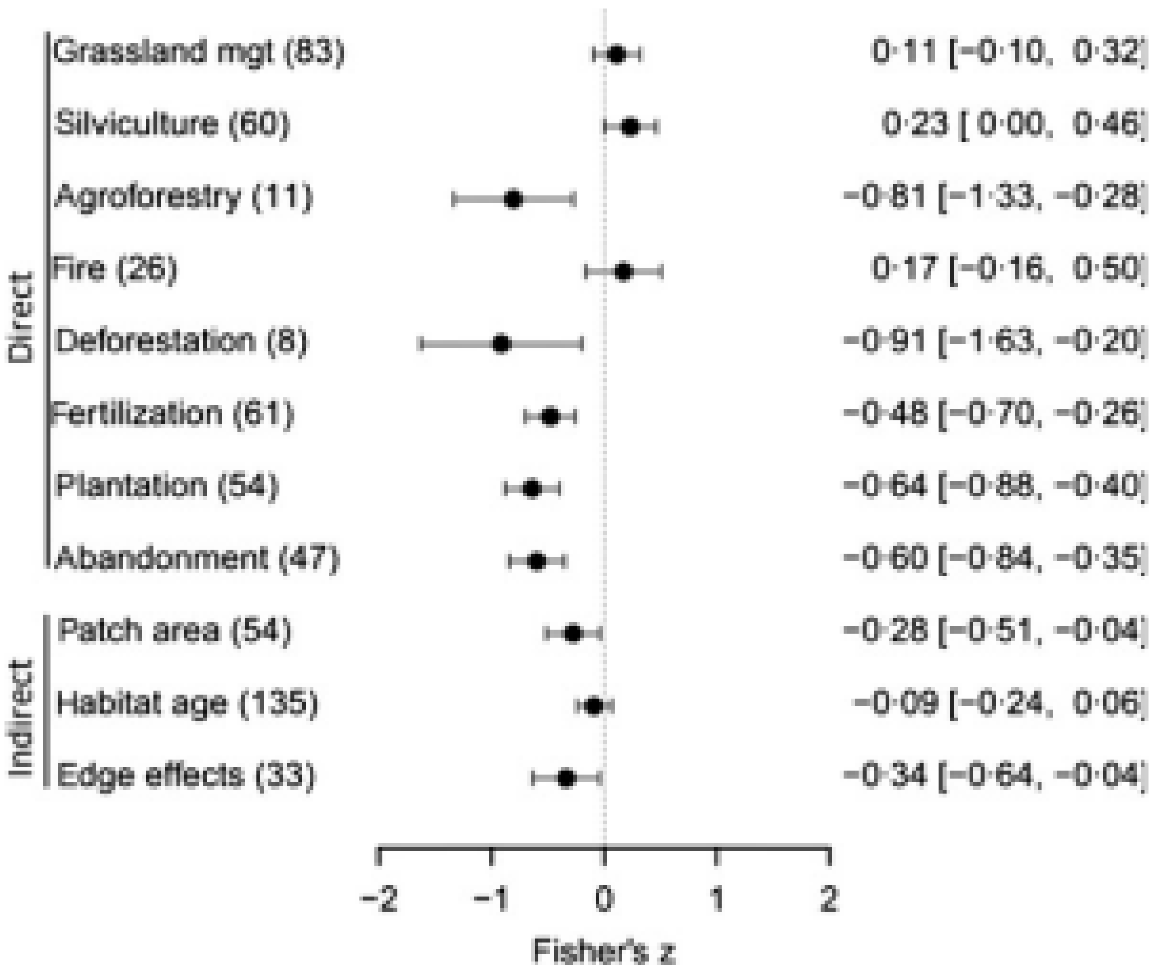




Borenstein (2009) *Introduction to Meta-Analysis*.
Colditz et al. (1994). Efficacy of BCG vaccine in the prevention of tuberculosis: meta-analysis of the published literature. *Jama*.

Example Ecology 1

Gerstner et al. (2014) Effects of land use on plant diversity - A global meta-analysis. *Journal of Applied Ecology*



Direction and magnitude of the effect of land use on plant species richness

What makes a meta-analysis special?

- Aims to find generalized answers for a commonly addressed research question
- Data is not gathered in the field but from the literature or other sources
- Broadens the spectrum of co-variables (many fields with slightly different conditions)
- Accounting for unequal precision among studies by weighting each study's outcome

Why performing a meta-analysis?

- Combine apples and oranges to produce a fruit salad

- Summarize existing evidence on a research question
- Combining results across sites that differ in their covariates
- Identify gaps in the literature where more research is needed
- Helps to design new studies
- Put new studies in context by describing the body of evidence

Questions that could be addressed in a meta-analysis

- What is the combined magnitude of the effect under study?
- Is the overall effect significantly different from zero?
- Do any characteristics of the studies influence the magnitude of the observed effect

Applications of meta-analysis in ecology

- Generating new hypotheses and testing hypotheses which are difficult to test within single study (cross-ecosystem comparisons, latitudinal patterns, cross-taxa comparisons)
- Assessing impact of major environmental drivers (climate change, invasive species, biodiversity loss)
- Assessing effectiveness of conservation and management strategies

  => evidence-based conservation and management
- Combining results of multi-site experiments or long-term experiments (within-study meta-analysis)
- Identifying knowledge gaps

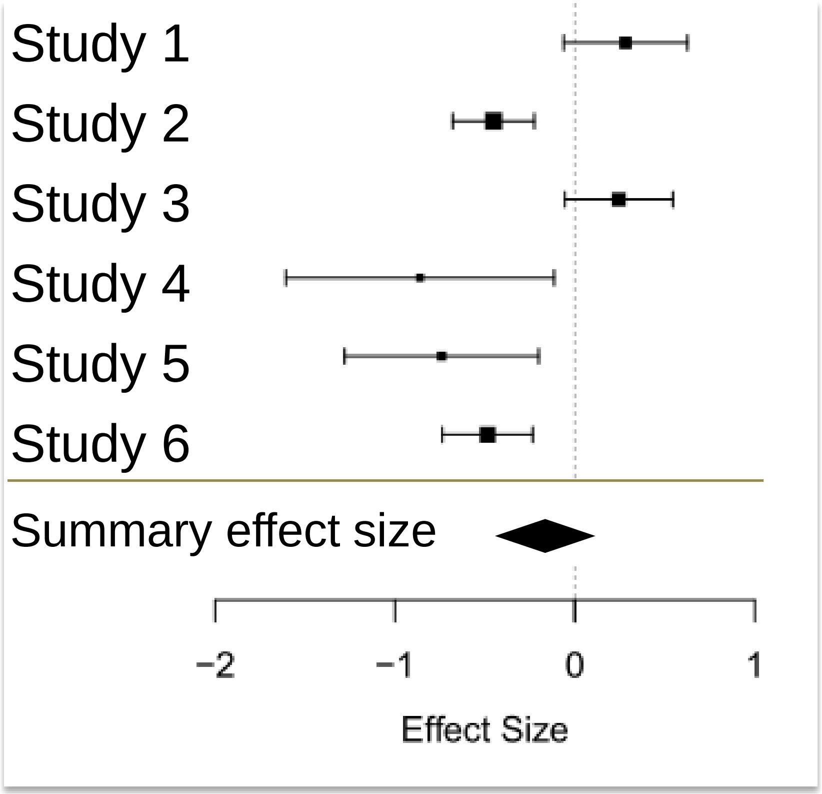
When is meta-analysis most useful?

- There is a moderate to large amount of empirical work available
- The results are variable across studies
- The expected magnitude of the effect is relatively weak
- The sample sizes of individual studies are limited for some reason

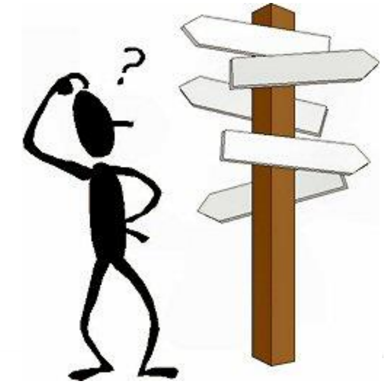
Meta-Analysis vs Meta-Study

Meta-Study … Systematic review and statistical synthesis across sets of case studies

Meta-Analysis … A set of statistical methods for combining outcomes (effect sizes) across different data sets addressing the same research question to examine patterns of response across these data sets and sources of hetero-geneity in outcomes (Koricheva & Gurevitch 2013)

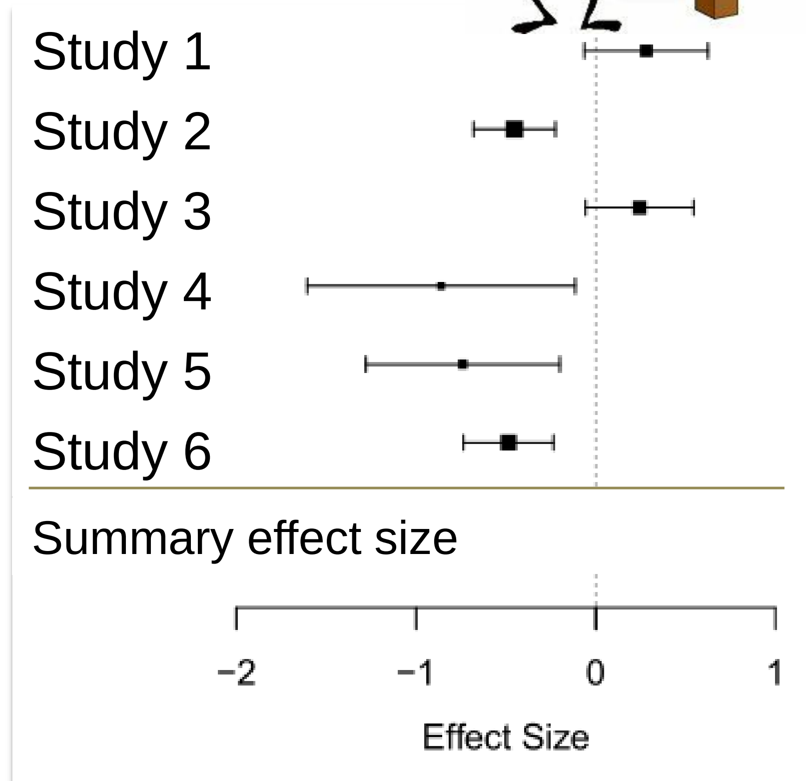


Meta-Analysis of primary data vs Meta-Analysis of summary statistics



Meta-Analysis of summary statistics

- Transform observed effects into standardized effect sizes
- Variances of effect sizes can be estimated within case studies
- Effect sizes are used as response variable in the meta-analytic model and are often weighted using their inverse variance



Meta-Analysis of primary data

- Primary data or derived measures can be directly used as responses and linked using a group id
- Less prone to biases and has more power to detect the effect of a covariate

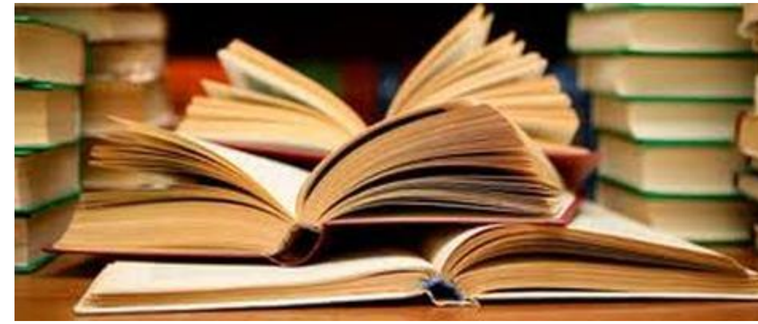
Procedure of meta-analysis in a nutshell

1. Formulating a research question
2. Searching a representative set of relevant studies (reproducible and objective)
3. Transforming the outcome of each study into a standardized measure of the direction and magnitude of an effect of interest in each study
4. Combine effect sizes across studies in a meta-analytical model
5. Analyse heterogeneity within and between studies

Meta-analysis in biological and environmental sciences

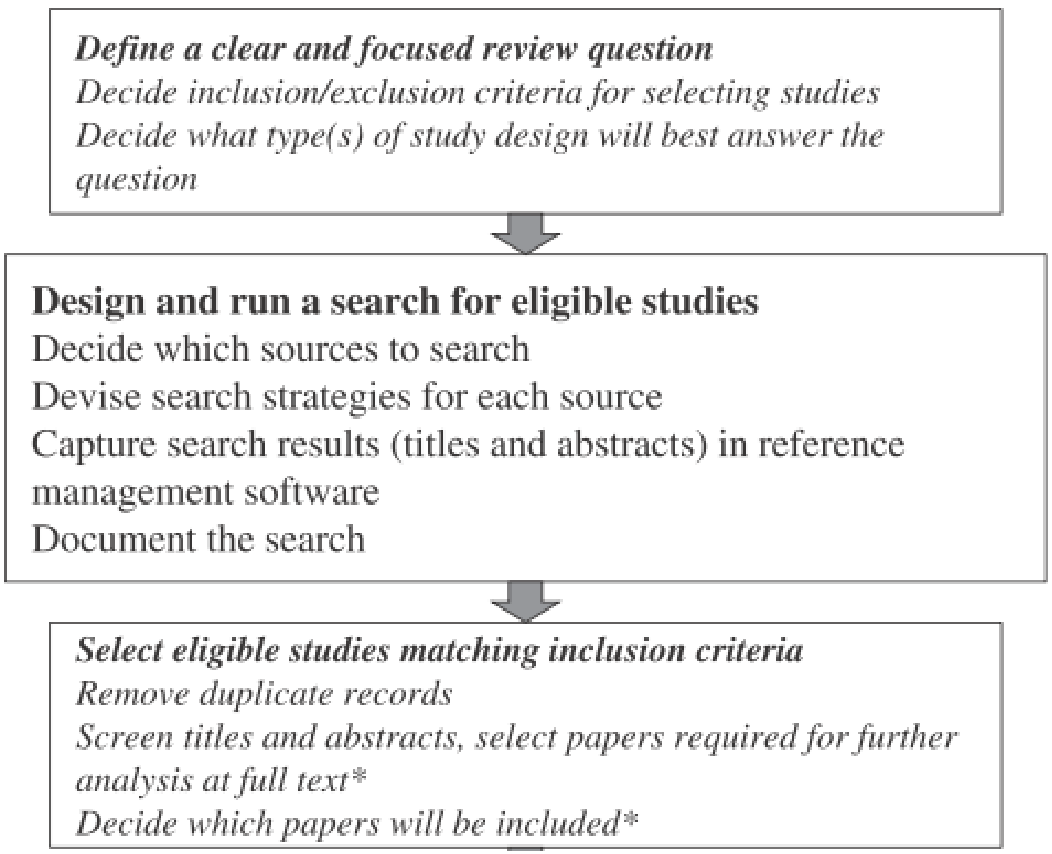
Searching the Literature

Literature Search

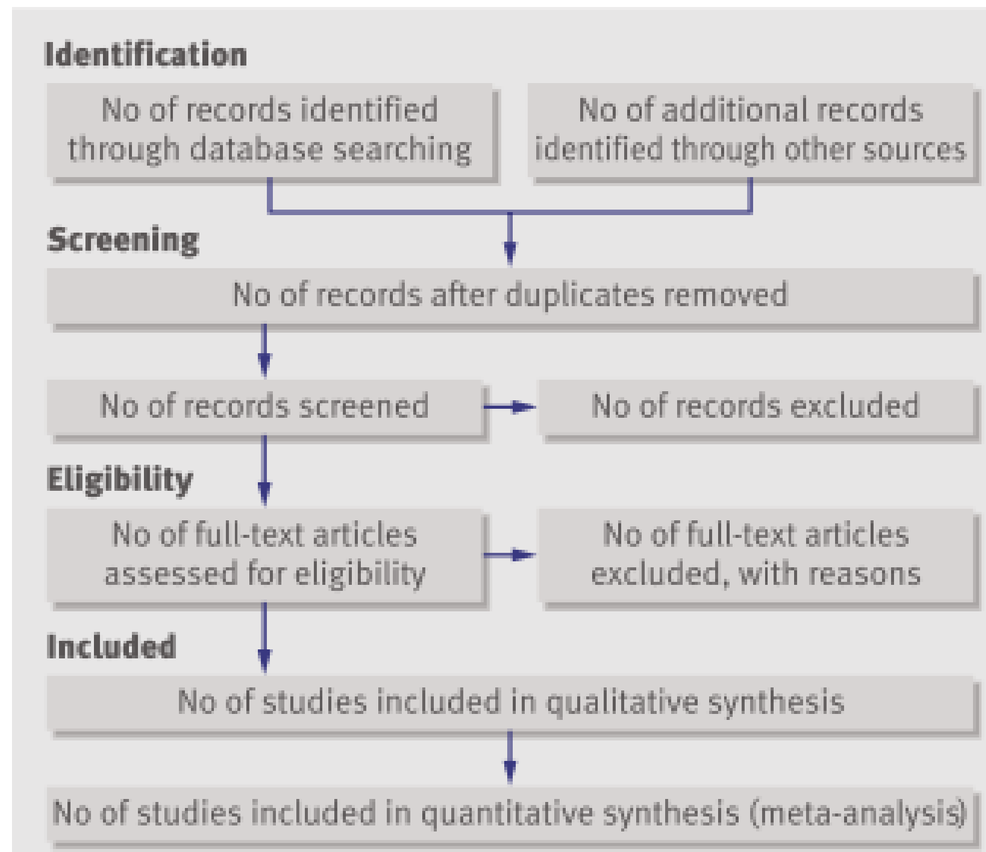


Systematic reviews

- Use an a-priori protocol, which describes the search methodology, i.e. detailed search strategy and inclusion criteria
- Review process becomes rigorous, transparent and repeatable



Bayliss & Beyer 2014 ResSynthMeth



Liberati et al. 2009 BMJ

What is wrong with non-systematic narrative reviews?

- No strict criteria for selection of studies for review or for judging study quality
  - high degree of subjectivity
  - low repeatability

- Low efficiency in handling a large number of studies

- Limited ability to deal with variation in study outcomes
  - the results of studies are often found to be “inconsistent”, “inconclusive” or “conflicting”
  - little help in conflict resolution and decision making

Search Strategy - Sources

- Previous reviews on the topic
- Lists of references in retrieved studies
- Reference databases and search engines
  - Keyword searches
  - Cited references searches
- Hand search of selected journals
- Informal channels

Search Strategy - Useful reference databases and search engines

- Web of Science
- Google Scholar
- JSTOR
- AGRICOLA
- Scopus (search engine for science-specific Web pages)
- Scirus (abstract and citation database)
- Conference Proceedings Citation Index
- Dissertation Abstracts online

Search Strategy – Search operators and wildcards

- Search operators AND, OR, NOT, NEAR, and SAME may be used to combine terms in order to broaden or narrow retrieval.

Operator	Purpose	Example
AND	find records containing all terms separated by the operator	**Beverage AND bottle** finds records containing both terms. **Beverage AND bottle AND beer** finds records containing all three terms.
OR	find records containing any of the terms separated by the operator	**Beverage OR bottle** finds records containing either beverage or bottle (or both).
NOT	exclude records containing certain words from your search	**Beverage NOT bottle** finds records containing beverage but excludes records containing bottle.

- A wildcard is a symbol used to replace or represent one or more characters
  - asterisk (*), which represents one or more characters

    e.g. "comp*" matches anything beginning with "comp" which means "comp", "complete", and "computer" are all matched
  - question mark (?), which represents a single character

    e.g. "c?mp" matches "camp" and "comp“

    "c??p" would match both of the above examples as well as "coop“.

Question formulation: PICO method

P=population

I=intervention

C=comparator

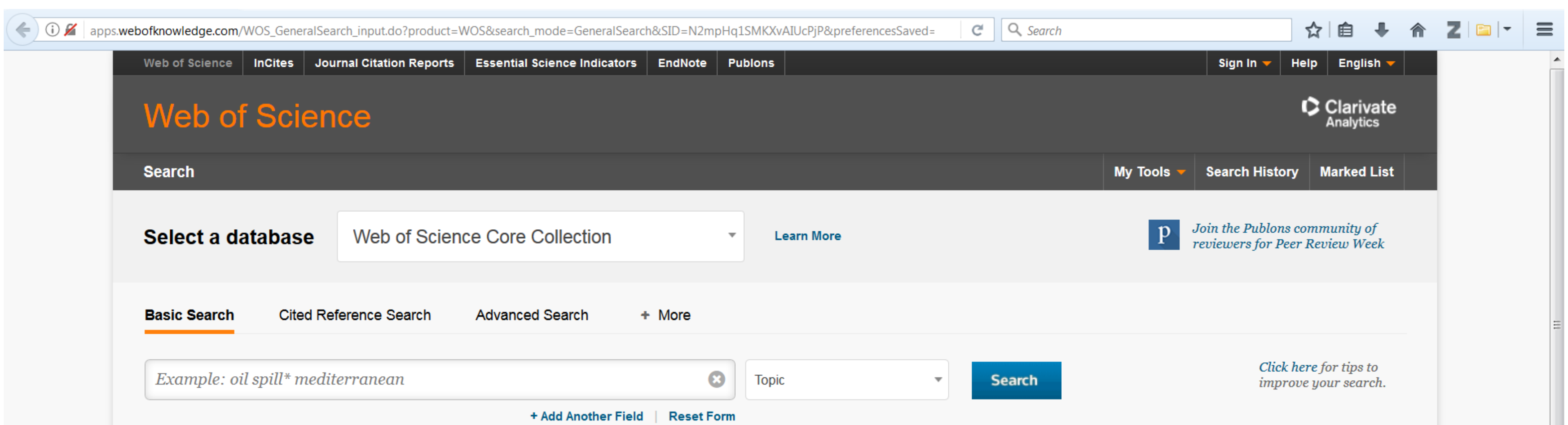
O=outcome

„What is the effect of grazing *(intervention)* compared to no grazing *(comparator)* on plant *(population)* species richness *(outcome)*?“

EXERCISE 1.1

How to perform keyword searches in Web of Science using search operators and wild cards?

1. List keywords relevant for your research question
2. Use wildcard symbols (?, *) to capture alternative spellings or multiple derivations of words of interest
3. Use search operators (AND, OR, NOT) to combine keywords and restrict your search to the most relevant hits
4. Compare the number of hits using different wildcards and search operators



EXERCISE 1.1

How to perform keyword searches in Web of Science using search operators and wild cards?

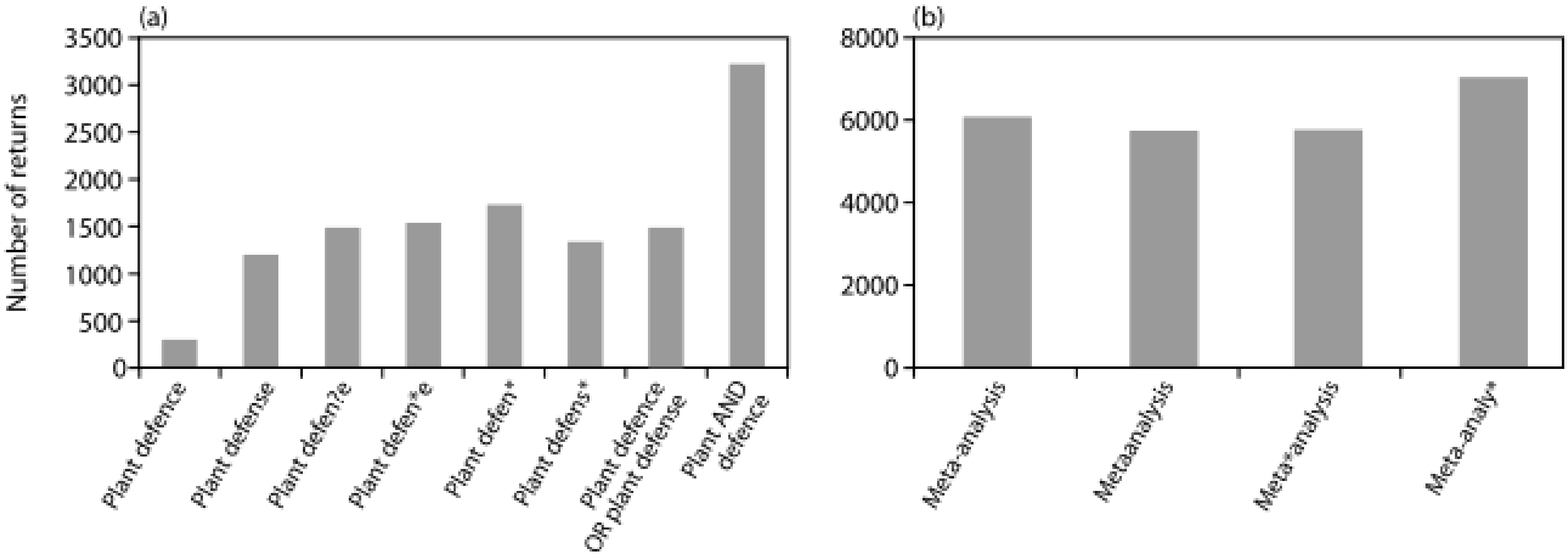


Figure 4.1. Examples of the effect of keyword choice on number of returns from an online scientific database.

Koricheva et al. (2013)

Inclusion Criteria

- Should be formulated a priori, but might need to be modified after initial search
- Should be closely linked to the research question, e.g.:
  - Population: Plants
  - Intervention: grazing
  - Comparator: no grazing
  - Outcome: species richness
- The aim is to make study selection unbiased and repeatable

How to deal with a very large number of studies?

- Growing body of literature
- Literature search resulted in 10000 potentially relevant studies is not unlikely
- Include/exclude studies based on content, method, and provided data
- Title and abstract screening can be facilitated by software tools

  e.g. `abstrackr` is a free, open-source tool for facilitating the citation screening process. Upload your abstracts, invite reviewers, and get to screening! Machine learning technologies are applied to semi-automate the screening process and prioritize the screening of those articles most likely relevant to the review at hand.

  https://www.brown.edu/academics/public-health/research/evidence-synthesis-in-health/research-initiatives/software-0

Conducting a meta-analysis

1. Choose appropriate effect size and moderators
2. Design the database
3. Extract the data / Code the studies
4. Choose appropriate model and software (e.g. R, MetaWin, openMEE)
5. Check assumptions and biases
   Calculate mean effect sizes and confidence intervals
   Test for heterogeneity and influence of moderators
6. Interpret and present results

Meta-analysis in biological and environmental sciences

Effect sizes and Moderators

What is an effect size?

- Effect size expresses the magnitude of an effect of interest
  - e.g.: effect of elevated CO_2 on photosynthesis or strength of the relationship between two life history traits
- Effect sizes are the common currency which allows combination of results from different studies into a single, standardized and comparable metric of outcome

Types of primary data and effect sizes

- Comparison of two groups (e.g. control and experimental) in terms of continuous response variables

  => effect sizes based on means

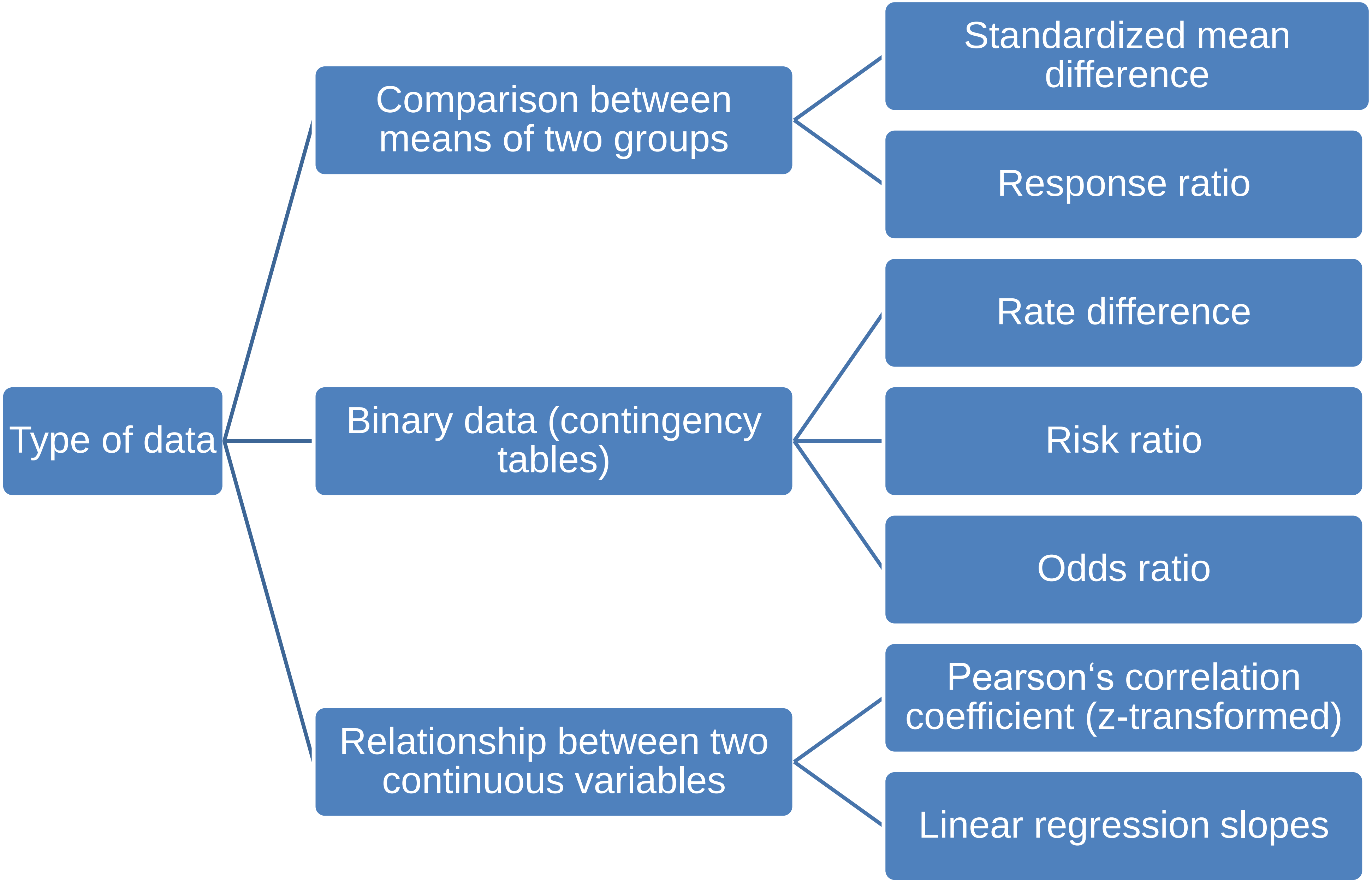
- Comparison of two groups in terms of categorical response variable (2 x 2 contingency table)

  => effect sizes based on binary data

- Relationship between two continuous variables

  => effect sizes based on correlations

Choosing effect size measure



Effect sizes based on means

Standardized mean differences Hedges' d

$$d = \frac{\overline{X}_T - \overline{X}_c}{s} J \qquad var(d) = \frac{n_{\mathrm{C}} + n_{\mathrm{T}}}{n_{\mathrm{C}} n_{\mathrm{T}}} + \frac{d^2}{2(n_{\mathrm{C}} + n_{\mathrm{T}})}$$

$\overline{X}_T$	mean of the experimental group
$\overline{X}_c$	mean of the control group
s	pooled standard deviation
J	correction term that removes small-sample-size bias
$n_{\mathrm{C}}, n_{\mathrm{T}}$	sample size of the control/treatment group

$$s = \sqrt{\frac{(n_C - 1)\sigma_c^2 + (n_T - 1)\sigma_T^2}{n_C + n_T - 2}}$$

$$J = 1 - \frac{3}{4(n_{\mathrm{C}} + n_{\mathrm{T}} - 2) - 1}$$

Effect sizes based on means

Standardized mean differences Hedges' d

Advantages

- Works well for small sample sizes (n=5-10)

Problems

- Interpretation of the magnitude of the effect
- Difference in d may reflect either differences in the magnitude of the effect or in variance among studies
- Some data needed for calculation of d (most commonly SD or sample sizes) are often missing

Interpretation of magnitude of d

- Cohen’s benchmarks:
  $|d| = 0.2$ – small effects
  $|d| = 0.5$ – moderate effects
  $|d| = 0.8$ – large effects
- Comparison with mean effects reported in other meta-analyses on similar topics

Effect sizes based on means

Standardized mean differences Hedges' d

Example

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2008) **17**, 585–599

META-ANALYSIS

Do arthropod assemblages display globally consistent responses to intensified agricultural land use and management?

S. J. Attwood[1]*, M. Maron[1], A. P. N. House[2] and C. Zammit[3]

Arthropod responses to intensified agricultural land use and management

A positive *d* value indicated greater abundance or richness for less intensive land use, and a negative value greater abundance or richness for more intensive land use.

Effect sizes based on means

Response ratio R

$$\ln R = \ln \frac{\overline{X}_T}{\overline{X}_c} \qquad var(\ln \mathrm{R}) = \frac{s_{\mathrm{T}}{}^2}{n_{\mathrm{T}} \overline{X}_T{}^2} + \frac{s_{\mathrm{C}}{}^2}{n_{\mathrm{C}} \overline{X}_C{}^2}$$

$\overline{X}_T$ mean of the treatment group
$\overline{X}_c$ mean of the control group
s_{C}, s_{T} standard deviation of the control/treatment group
n_{C}, n_{T} sample size of the control/treatment group

Effect sizes based on means

Response ratio R

Advantages of response ratio

- Easily interpretable: $R = \exp(\ln R)$
- Easily convertable into percent change: $\%\ change = R \cdot 100 - 100$
- Effect sizes are not affected by different variance in control and experimental groups
- SD/SE are not needed for calculation of the effect size (but needed to calculate variance)

Limitations

- Can only be used if means are less or greater than zero
- Both means have the same sign

Effect sizes based on means

Response ratio R

Example

Botany
American Journal of Botany 98(3): 539–548. 2011.

A SYNTHESIS OF PLANT INVASION EFFECTS ON BIODIVERSITY ACROSS SPATIAL SCALES[1]

KRISTIN I. POWELL[2], JONATHAN M. CHASE, AND TIFFANY M. KNIGHT

Department of Biology, Washington University in Saint Louis, 1 Brookings Drive, Campus Box 1137, Saint Louis, Missouri 63130 USA

Effects of invasion in species richness

$$\ln R = \ln\left(\frac{\text{species richness in uninvaded plots}}{\text{species richness in invaded plots}}\right)$$

ln R > 0: Invasive species reduce local species richness

Effect sizes based on binary data

	Treatment	Control	Total
Response	A	B	A+B
No response	C	D	C+D
Total	$\mathbf{N_T = A + C}$	$\mathbf{N_C = B + D}$	A+B+C+D

- Seldomly used in ecology
- Useful when comparing the odds of species survival under different conditions
- Possible effect size metrics:

Rate difference	$\mathrm{RD} = \frac{A}{N_T} - \frac{B}{N_C}$	$\mathrm{Var}_{RD} = \frac{\frac{A}{N_T}\left(1-\frac{A}{N_T}\right)}{N_T} + \frac{\frac{B}{N_C}\left(1-\frac{B}{N_C}\right)}{N_C}$
Risk ratio	$\mathrm{RR} = \frac{A}{N_T} \Big/ \frac{B}{N_C}$	$\mathrm{Var}_{RR} = \frac{\left(1-\frac{A}{N_T}\right)}{A} + \frac{\left(1-\frac{B}{N_C}\right)}{B}$
Odds ratio	$\mathrm{OR} = \frac{A}{C} \Big/ \frac{B}{D}$	

Effect sizes based on binary data

Example:

Journal of Ecology 2005
93, 748–757

Is the change of plant–plant interactions with abiotic stress predictable? A meta-analysis of field results in arid environments

FERNANDO T. MAESTRE*, FERNANDO VALLADARES† and JAMES F. REYNOLDS*‡

**Department of Biology, Duke University, Phytotron Building, Science Drive, Box 90340, Durham, NC 27708–0339, USA, †Centro de Ciencias Medioambientales, CSIC, Serrano 115, E-28006 Madrid, Spain, ‡Division of Environmental Science and Policy, Nicholas School of the Environment, Duke University, Durham, NC 27708–0339, USA*

An odds ratio metric was calculated as the ratio of the odds of survival in the presence of neighbours (neighbour treatment) to the odds of survival in their absence (control)

Effect sizes based on two continuous variables

Pearson's r

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

n	number of samples
x_i, y_i	data points

- when the magnitude of r approaches +/-1, the distribution of r becomes skewed away from normal
- Solution: Fisher's z-transformation

$$z = \frac{1}{2}\ln\frac{1+r}{1-r}, \qquad \mathrm{var(z)} = \frac{1}{\mathrm{n}-3}$$

- back-transformation:

$$r = \frac{e^{2z}-1}{e^{2z}+1}$$

Effect sizes based on correlations

Pearson’s r

- Varies from –1 to +1
- Cohen’s ”rules-of-thumb”:

  | r | = 0.10 – small

  | r | = 0.25 – medium

  | r | = 0.40 - large
- Coefficient of determination (r^2)
- Could be obtained from various test statistics

Statistic	Conversion equation	Degrees of freedom
Z (standard normal deviate)	$r = \frac{Z}{\sqrt{N}}$	n/a
t	$r = \sqrt{\frac{t^2}{t^2 + df}}$	d.f. = $N_1 + N_2 - 2$
$F_{[1,df]}$	$r = \sqrt{\frac{F}{F + df}}$	Numerator = 1 d.f. Denominator = $N - 1$ df
$\chi^2_{(1)}$	$r = \sqrt{\frac{\chi^2_{(1)}}{N}}$	1

Effect sizes based on two continuous variables

Pearson’s r

Example:

Ecology Letters, (2014) doi: 10.1111/ele.12277

REVIEW AND SYNTHESIS

Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales

Anke Stein,[1]* Katharina Gerstner[2] and Holger Kreft[1]*

Abstract
Environmental heterogeneity is regarded as one of the most important factors governing species richness gradients. An increase in available niche space, provision of refuges and opportunities for

z-transformed correlation between environmental heterogeneity and species richness

Effect sizes based on two continuous variables

Slopes from linear regressions

- Slopes from simple linear regression can be used as effect sizes providing that:
  - The slope in every study is measured in the same units
  - Measure of variance of the estimate of the slope is available (or can be estimated from other statistics, see Rosenberg et al. 2013 In: Handbook of Meta-Analysis in Ecology and Evolution)

Effect sizes based on two continuous variables

Slopes from linear regressions

Example:

Ecology, 82(9), 2001, pp. 2381–2396

WHAT IS THE OBSERVED RELATIONSHIP BETWEEN SPECIES RICHNESS AND PRODUCTIVITY?

GARY G. MITTELBACH,[1,2] CHRISTOPHER F. STEINER,[1,2] SAMUEL M. SCHEINER,[4]
KATHERINE L. GROSS,[1,3] HEATHER L. REYNOLDS,[1,5] ROBERT B. WAIDE,[6] MICHAEL R. WILLIG,[4,7]
STANLEY I. DODSON,[8] AND LAURA GOUGH[9]

standardized quadratic regression coefficients of species richness–productivity relationships

Using non-standard metrics of effect size

- Requirements for the effect size metrics:
  - The measure of effect is comparable across studies
  - Effect size metrics should not depend on aspects of study design which may vary from study to study (e.g. sample size)
  - Estimate of effect size should be computable from the summary information provided in a primary study (i.e. no re-analysis of raw data should be necessary)
  - Effect size metric should be easily interpretable in terms of its biological/practical significance
  - Sampling distribution of the metric should be known to allow calculation of variances and confidence intervals
- If effect of interest has known distribution, variances are relatively easy to derive:
  - Mean and variance are equal for Poisson and binomial distribution (rate of occurrence, proportions)
  - For metrics with normal distribution (e.g. population mean), sample size can be used as a proxy for variance if we can assume that sampling variances are equal

Choose appropriate model and software
Software

Stand-alone meta-analysis software

- MetaWin 2.0
- OpenMEE[1]

R

- R-package metafor
- R-package lme4
- R-package mcmcglmm

[1] http://www.cebm.brown.edu/open_mee

The R-package `metafor`

- *escalc* does the calculation of effect sizes
  - provide the necessary data components (i.e. sample size, mean, variances, correlation, etc.).
  - Indicate the effect size you want with `measure`.
  - For data in "long" format, i.e. multiple rows per study, corresponding to different treatment groups, it is possible to specify the variables for the effect size calculation using a formula
- *rma* is the main modeling function of metafor.
- *rma* stands for random effects meta-analysis
- *rma* is also a wrapper for *escalc*, and will compute effect sizes before modeling (if you like).

The R-package `metafor`

- *rma* returns an object of the class `rma`.
  - This object behaves like a list.
  - You can use the function `names` to see available elements.
- Frequently Used Elements

Name	Description
b	Summary effect
ci.lb, ci.ub	lower and upper bound of the 95% confidence interval
vb	variance-covariance of summary effects
fit.stats	model fit statistics log-likelihood, deviance, AIC, BIC, and AICc values
QE, QEp	test statistic for the test of (residual) heterogeneity and corresponding p-value
QM, QMp	test statistic for the heterogeneity explained by the model (called omnibus test of coefficients) and corresponding p-value
I2	value of I^2
yi, vi	Vectors of study effect sizes and corresponding variances

The R-package `metafor`

- Functions to extract informations from a `rma` object

Name	Description
coef	Summary effect
confint	confidence interval
summary	summary table of meta-analytic model

- Specifying the Model
  - The function can be used to fit fixed- and random/mixed-effects models

method	Description
FE	Fixed-effects model
DL	Random-effects model using DerSimonian-Laird estimator (Methods-of-Moments)
ML	Random-effects model using Maximum-Likelhood estimator
REML	Random-effects model using Restricted maximum-likelihood estimator

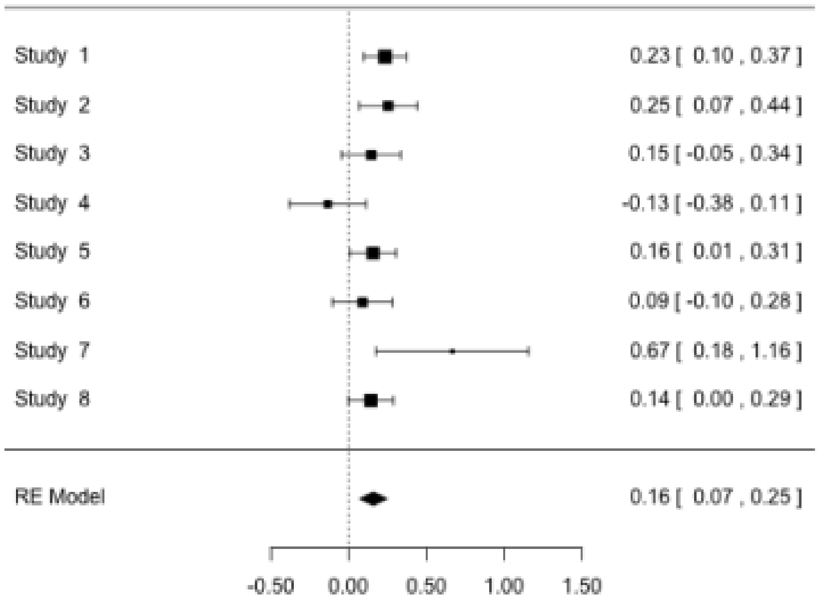
  - as well as meta-regression models including moderators using the mods=~mods1 + mods2

Visualizing effect sizes

The Forest Plot

“Seeing the forest through the trees... “

- Plots effect sizes and their precisions
- The most common way to report the results of a meta-analysis
- Can help identify patterns across effects
- Can help spot large variation in effects or possible outliers
- `forest` is the function to plot forest plots of rma-objects
- Custimizing forest plots
  - order: Sort by "obs", "fit", "prec", etc.
  - slab: Change study labels
  - ilab: Add study information
  - transf: Apply function to effects
  - refline: Location to plot vertical ‘reference’ line
  - psize: Symbol sizes



EXAMPLE 1.1

https://dylancraven.github.io/MetaAnalysis_Course/

https://dylancraven.github.io/MetaAnalysis_Course/pages/Day1.html

1. Calculating effect sizes.
2. Visualizing effect sizes using forest plots.

EXERCISE 1.2

1. Data

   Stewart, G.B. A database on windfarm impacts on birds.

2. Calculate effect sizes and their variances.
3. Visualize effect sizes using forest plots.

Meta-analysis in biological and environmental sciences

Data Extraction

Retrieval of data from primary studies

- Choosing a metric of effect size
- Obtaining effect sizes or data needed for their calculation from text, tables or graphs
  - enlarging graphs
  - digitizing graphs (e.g. ImageJ or WebPlot Digitizer)

Data Extraction

- Develop a protocol on how to code the information from studies in the database
- Ensure the database contains all the information you need and is set out logically so that it is easy to complete and difficult to enter data in the wrong place
- Keep a bibliographic library of studies and explain why some were excluded
- Practice coding, discuss within a group, make notes on decisions
- Watch the basic structure of papers: Where are the most important pieces of information are, e.g. last paragraph of the introduction, methods, and results

Database design

Flat database

Study and data ID		Potential moderators			Data for calculation of the effect measure		Data source
Study	Species	Taxon	Habitat	Status	r	N	Source
Adler et al. 1986	Peromyscus leucopus	mammal	interior	resident	0.33	21	Table 1
Ambuel & Temple 1983	Pheuticus ludovicanus	bird	edge	migrant	0.44	26	Figure 3B
Bach 1984	Acalymma vittatum	Insect	interior	resident	-0.04	21	t test p. 355
Bach 1984	Acalymma innubom	insect	interior	resident	0.66	18	t test p. 356

Database design

Relational database

Ref No	Author	Year	Plant species	Insect species	Treat-ment	Para-meter	Effect size d
1	Smith	1985	Betula pendula	Epirrita autumnata	shading	pupal weight	0.56
2	Young & Wan	1990	Pinus sylvestris	Diprion pini	drought	RGR	0.25
3	Jones et al.	1976	Populus nigra	Aphis fabae	ozone	survival	-0.86
4	Larson	2001	Quercus robur	Lymantria dispar	acid rain	survival	0.35

Plant species	Plant type	Growth rate	Leaf longevity
Betula pendula	Angiosperm	Fast	Decid
Pinus sylvestris	Gymnosperm	Slow	Evergr
Populus nigra	Angiosperm	Fast	Decid

Insect species	Feeding guild	Speciali zation	Order
Epirrita autumnata	chewing	Poly	Lepidoptera
Diprion pini	chewing	Mono	Hymenoptera
Aphis fabae	sucking	Poly	Hemiptera