

Environment Impact Assessment

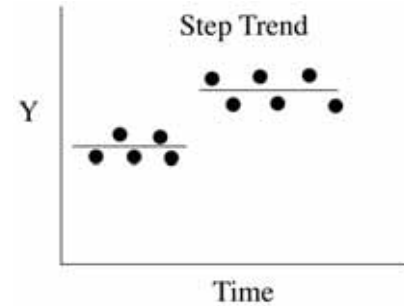
Environmental Impact Assessments are required for any large project. This talk will review the most important aspects of the design and analysis of impact studies from a statistical perspective.

Carl James Schwarz
Department of Statistics and Actuarial Science
Simon Fraser University

cschwarz@stat.sfu.ca

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Before-After Designs (not recommended!)

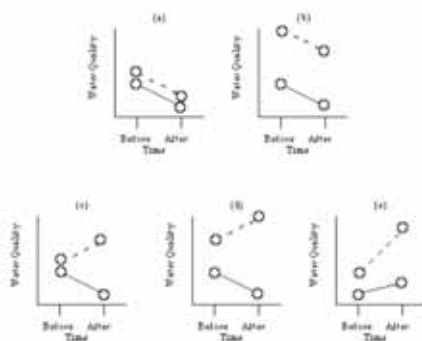


- Temporal Effects unrelated to environmental impact (e.g. protocol effects)

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Basic BACI

- Before/After; Control/Impact

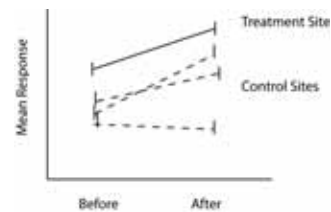


- Control sites(s) account for temporal change !
- Evidence of impact = non-parallelism = test for interactions between Time (B/A) and Treatment (C/I) factors.
- Estimate the degree of non-parallelism because “there are always impacts”; is it biologically relevant?

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BACI – multiple controls

“... The control site was poorly chosen ...”

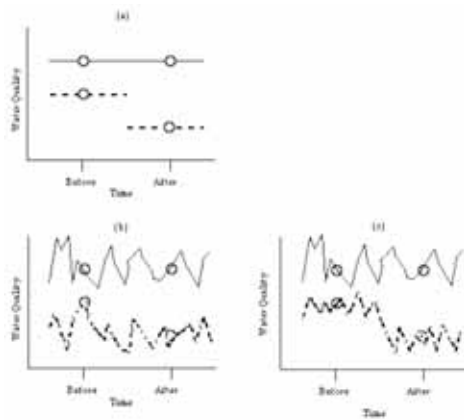


- Also possible to have multiple impact sites in some cases.
- Unbalance/missing values can be used and provide information.
- Evidence of impact = non-parallelism = test for interactions between Time (B/A) and Treatment (C/I) factors.
- Estimate the degree of non-parallelism because “there are always impacts”; is it biologically relevant?

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BACI – multiple times before/after

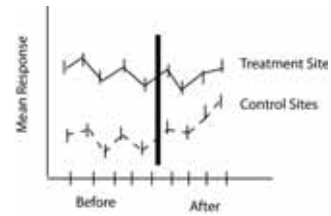
“... the observed difference was an artefact of the two years chosen relative to natural year-to-year variation ...”



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BACI – multiple times before/after

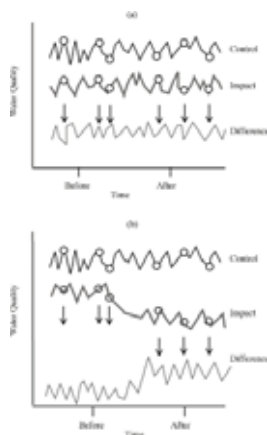
- Multiple measurements before/after impact



- Multiple control sites also desirable.
- Evidence of impact = non-parallelism = test for interactions between Time (B/A) and Treatment (C/I) factors.
- Estimate the degree of non-parallelism because “there are always impacts”; is it biologically relevant?

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BACI – multiple times before/after – PAIR!

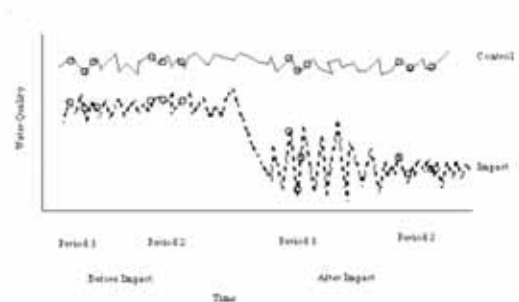


- Pairing (in time) leads to “cancellation” of common temporal effects and increased power.
- Missing data and unpaired times can still be used

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BACI – think beyond the mean

- Is the mean or variance that is changing?

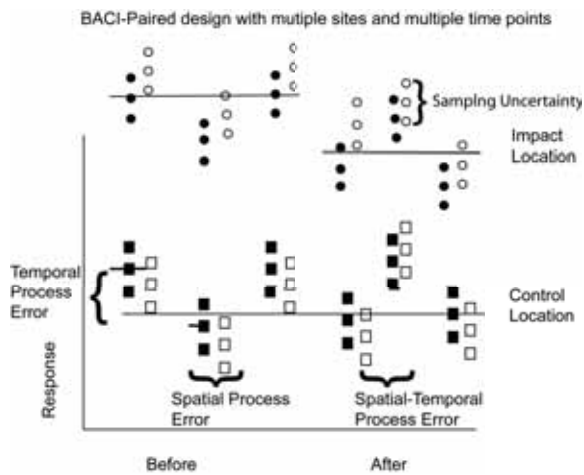


- Take measurements at different scales (e.g. monthly/yearly)

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BACI – power/sample size

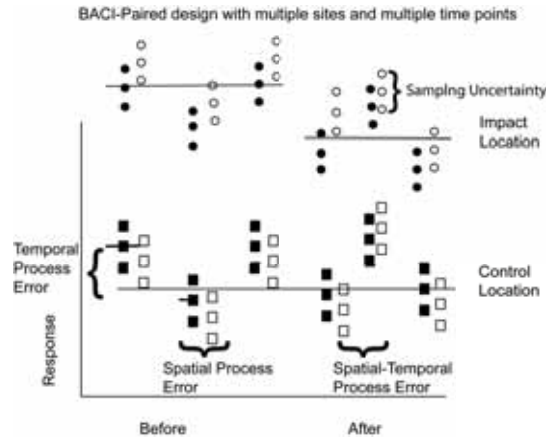
- Beware of spatial and temporal process error



- Temporal process error = year effects
- Spatial process error = site specific effects
- Spatial-temporal process error = inconsistent year/site effects
- Sampling error = measurement error

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BACI – power/sample size



- Pairing in time “eliminates” temporal process error
- Permanent sites “eliminate” spatial process error (but not always easy to do this).
- NO EASY WAY TO “eliminate” spatial-temporal process error except via pairing/permanent sites and this basically limits power of design
- Sampling error can be reduced, but often “small” relative to other effects. DON'T OVER SAMPLE!

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BACI – power/sample size

- Use methods as outlined in Stroup (1999).
 - estimate variance components (3 process errors + sampling error) [Need at least 2 years of baseline data to estimate temporal, spatial-temporal process error.]
 - what is biologically important effect (HARD)!
 - use LinearMixedModels with “fake” data
 - * F-statistic leads to power of test
- Simple to change sampling effort at the 3 levels
 - generally # years more important than # samples

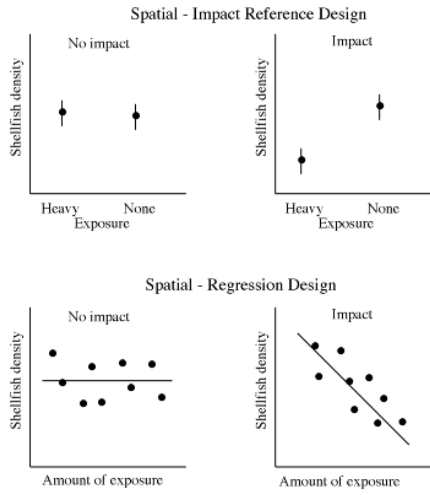
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Designs for Accidental Impacts

- In some cases, you need to assess impact without any prior information (e.g. oil spill).
- Weins and Parker (1995)
- Think about
 - spatial aspects (not all of site equally impacted)
 - * equal natural factors at all sites
 - * sampling interval short relative to scale of temporal variation
 - temporal aspects (changes in time differ if exposed or control)
 - * natural factors in equilibrium
 - * protocol effects negligible

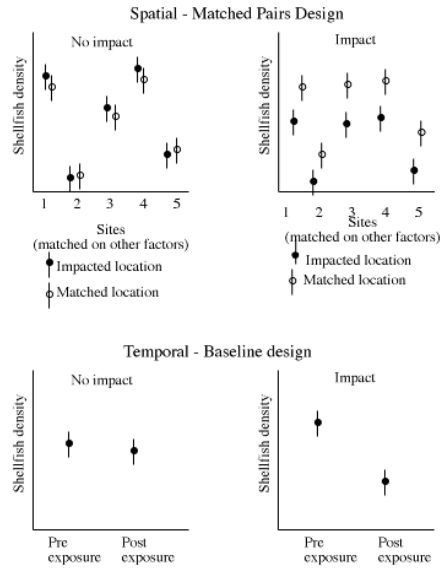
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Designs for Accidental Impacts



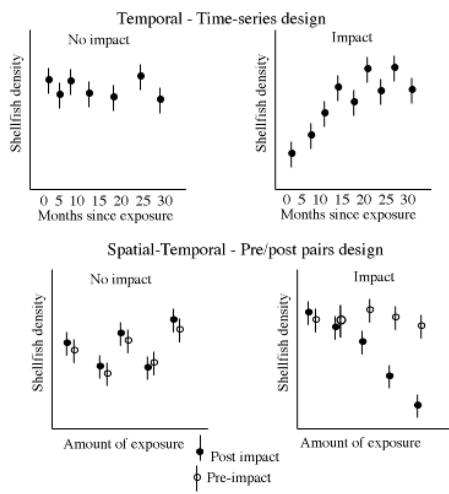
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Designs for Accidental Impacts



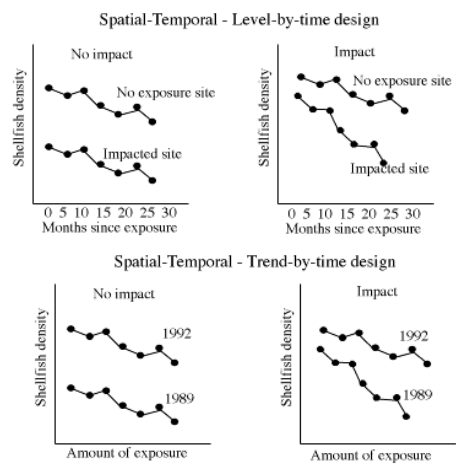
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Designs for Accidental Impacts



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Designs for Accidental Impacts



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Designs for Accidental Impacts – Ranking

- Defensibility (1=least, 4=most)
 - temporal baseline 1
 - spatial impact-reference 2
 - spatial regression 2
 - spatial matched pairs 2
 - temporal time series 2
 - spatial-temporal pre-post pairs 3
 - spatial-temporal level-by-time 4
 - spatial-temporal trend-by-time 4
- Refer to Weins and Parker (1995) paper for more comparisons by sampling methods, usefulness of covariates.

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Analysis and Reporting

- Friends don't let friends use Excel for statistics!



- Problems with Excel
 - largest collection of poor graphs in the world
 - many algorithms poorly coded, not stable, treat missing values incorrectly
 - documentation poor
 - not “reproducible” (no audit trail)
- Tiers of software
 - SAS/SPSS;
 - JMP/Systat/StatSoft/Stata;
 - R/Splus
- See references at end for more details esp. U. Reading site on Excel and Statistics

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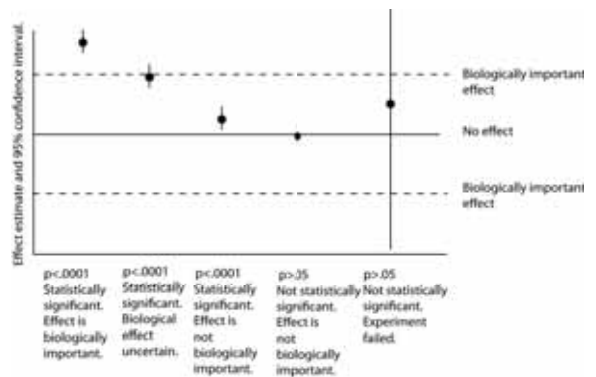
Analysis and Reporting

- Match analysis to design!
 - default design in most computer packages = single factor CRD ≠ BACI designs!
 - most BACI designs are variants of split plot/strip plots
- Consequences of bad match between design and analysis:
 - reported se TOO SMALL
 - reported p-values TOO SMALL
 - too many false positives
- Think reproducible analysis and reporting
 - put data/code into e-appendix

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Analysis and Reporting

- Statistical significance ≠ biological importance.
- Failure to detect effect ≠ no effect.



- Always report effect size and measure of precision
- Always put into context – what is biologically important (HARD!)
- p-values often not needed.

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Analysis and Reporting

“A non-parametric [insert your favorite procedure] was used because of outliers and small sample sizes”

- Non-parametric \neq no assumptions.
- Non-parametric = different assumptions.
- Non-parametric used for small sample sizes/bad designs
 - Relative efficiency of most non-parametric tests is about same as parametric procedures, i.e. won't do better in small sample sizes
- How will you get estimates of effect size after non-parametric procedure?
 - some procedures do exist, but only in simple situations.
- No amount of statistical wizardry will compensate for poorly collected or inadequate amount of data.

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Analysis and Reporting

“ Bootstrapping was used because of outliers and small sample sizes”

- Bootstrapping is a non-parametric procedure and so all of the previous slide still apply
- DANGER – naïve application of bootstrap can lead to inconsistent results
 - * Stratified/blocked designs/split-plot design with small blocks or strata, i.e. most BACI designs!
 - * Refer to Manly (2007).
- No amount of statistical wizardry will compensate for poorly collected or inadequate amount of data.

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Summary - I

- NO to Before/After designs with NO controls.
- BACI designs
 - replicate control sites
 - multiple measurements before/after - PAIRED
 - permanent monitoring sites
 - spatial-temporal process error = limiting factor for power of BACI. Pair/block/permanent sites as much as possible!
 - # years is generally more important than # sites or #samples.
 - contact me for demo power analyses.
- Accidental impact assessment. Use
 - spatial-temporal level-by-time (or)
 - spatial-temporal trend-by-time

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Summary - II

- Analysis and reporting
 - Use extreme CAUTION with Excel!
 - Audit trail on analysis
 - Match analysis to design (!)
 - * Put code/data into e-appendix
 - Statistical significance \neq biological importance.
 - Failure to detect effect \neq no effect.
 - Always report effect size and measure of precision.
 - Not necessary to report p -values.
 - What is biologically important? (HARD)
- IMHO non-parametric and bootstrapping overused. These WILL NOT correct for small sample size, poor study design. These “sweep” outliers under table rather than being upfront in their treatment.

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References:

Conover, W. J. (1999). Practical non-parametric statistics. Wiley.

Excel and Statistics:

<http://www.cs.uiowa.edu/~jcryer/JSMTalk2001.pdf>

<http://www.practicalstats.com/xlstats/excelstats.html>

<http://www.rdg.ac.uk/sse/software/excel/home.html> <= hints on using Excel properly

Manly, B. F. J. (2007). Randomization, Bootstrap, and Monte Carlo methods in Biology. 3rd Edition. Chapman and Hall.

Wiens, J.A., Parker, K. R. (1995). Analyzing the Effects of Accidental Environmental Impacts: Approaches and Assumptions. Ecological Applications 5, 1069-1083.

<http://dx.doi.org/10.2307/2269355>

Samples of BACI design and analysis available at:

<http://www.stat.sfu.ca/~cschwarz/CourseNotes>

Stroup, W. W. (1999). Mixed model procedures to assess power, precision, and sample size in the design of experiments. Pages 15-24 in Proc. Biopharmaceutical Section. Am. Stat. Assoc., Baltimore, MD.

<http://www.stat.sfu.ca/~cschwarz/Stat-650/Notes/MyPrograms/Power/stroup-1999-power.pdf>