

Experimental design and analysis

BACI environmental sampling designs

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Basic BACI designs

- Impact monitoring
- Single Impact & Control areas
- Some sub-samples?
- Sampled through time
 - Before & After periods
 - Times within each period

BACI test

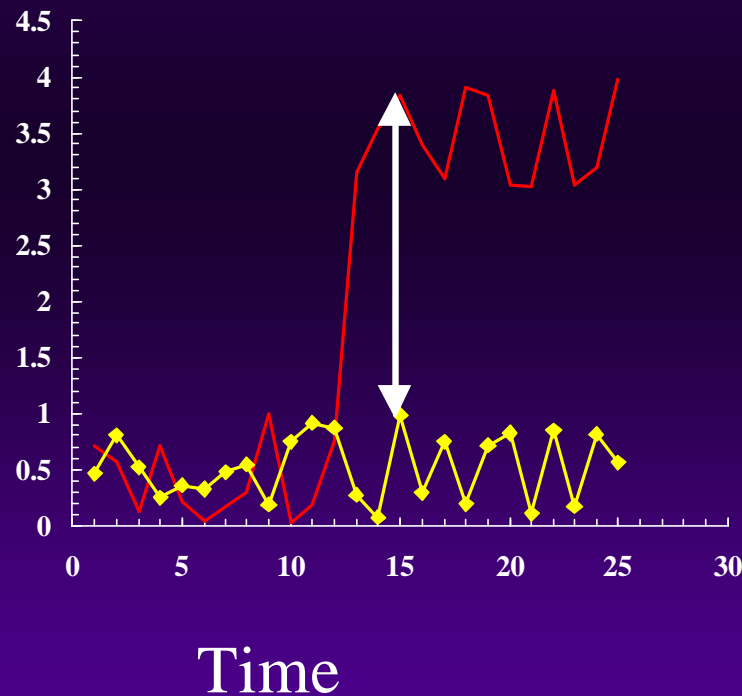
- Did the Impact area change, *relative* to the Control area, after the particular human activity occurred?
- Complex analysis or *t-test*

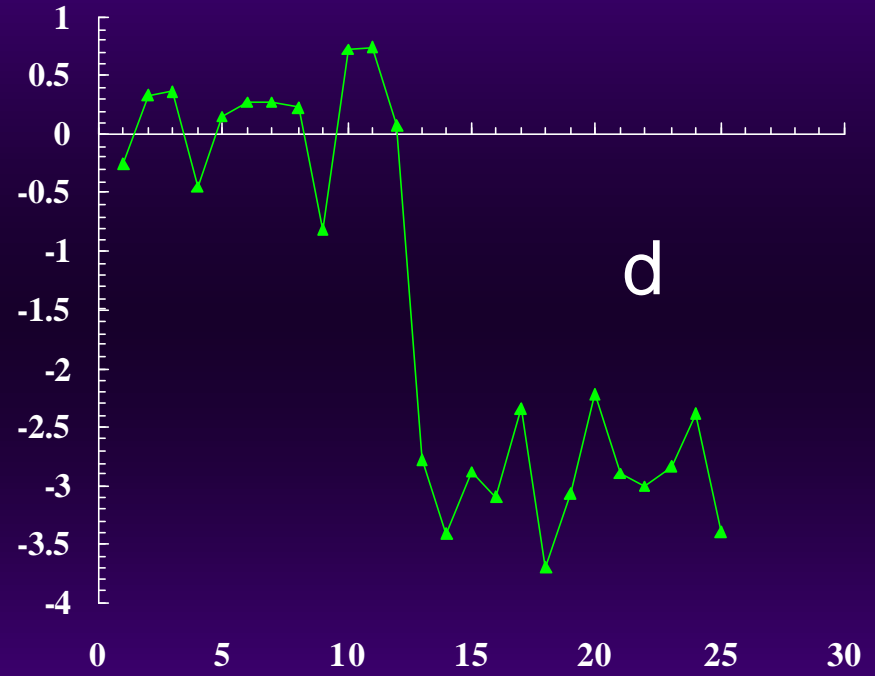
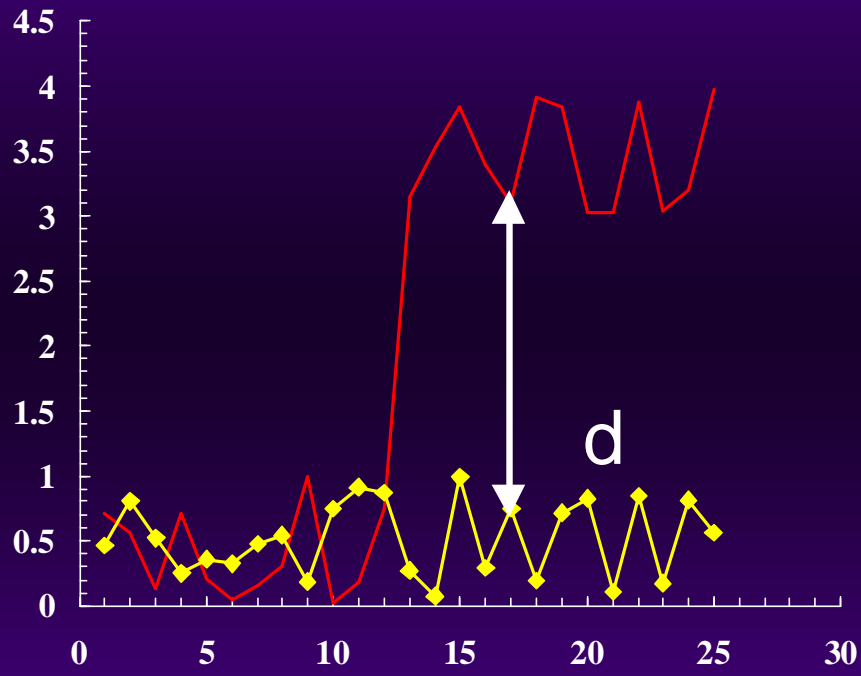
Procedure

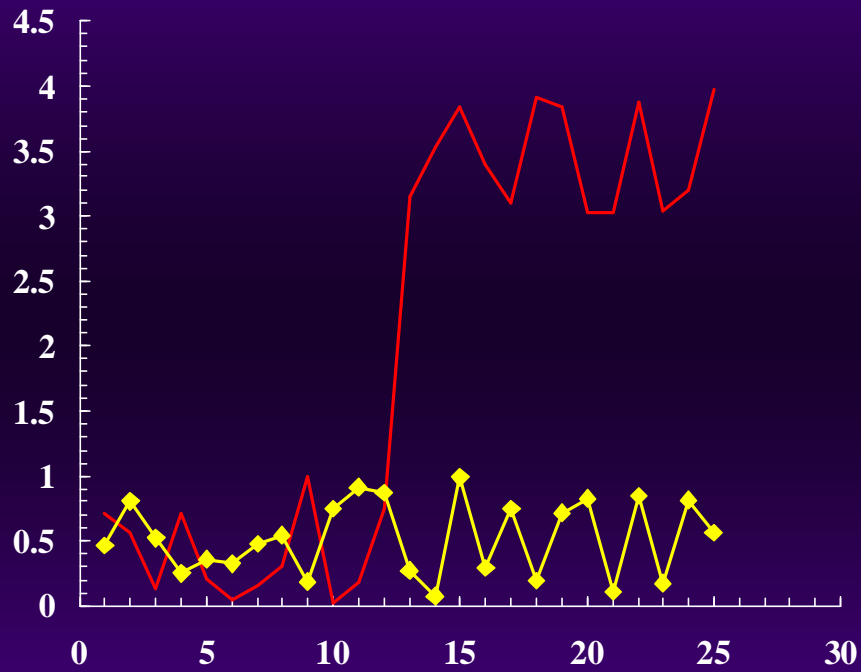
Plot values for each location through time

Calculate $d_i = C_i - I_i$ for each time i

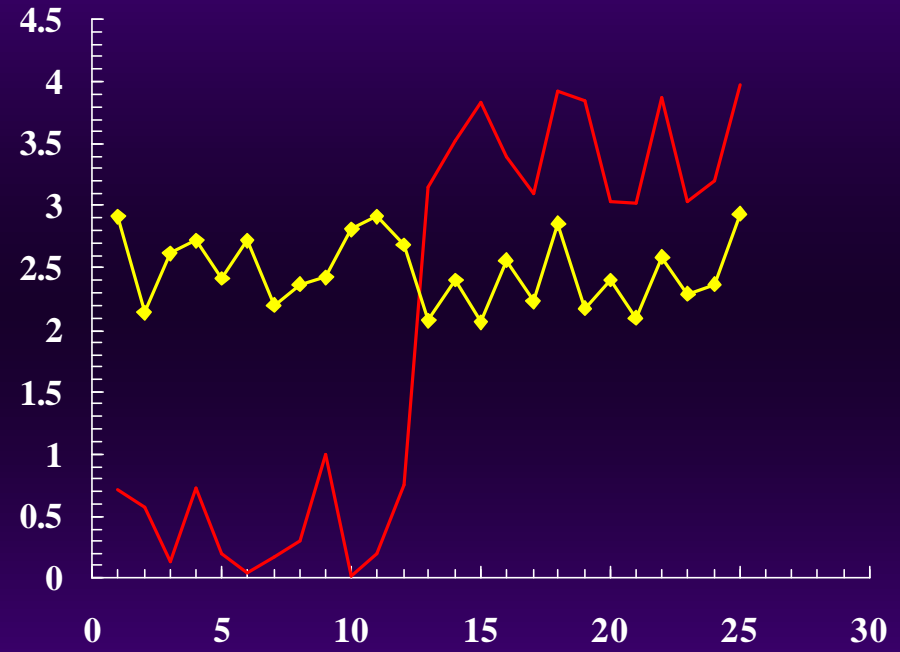
Compare d values between groups (Before & After) - ANOVA or t -test.





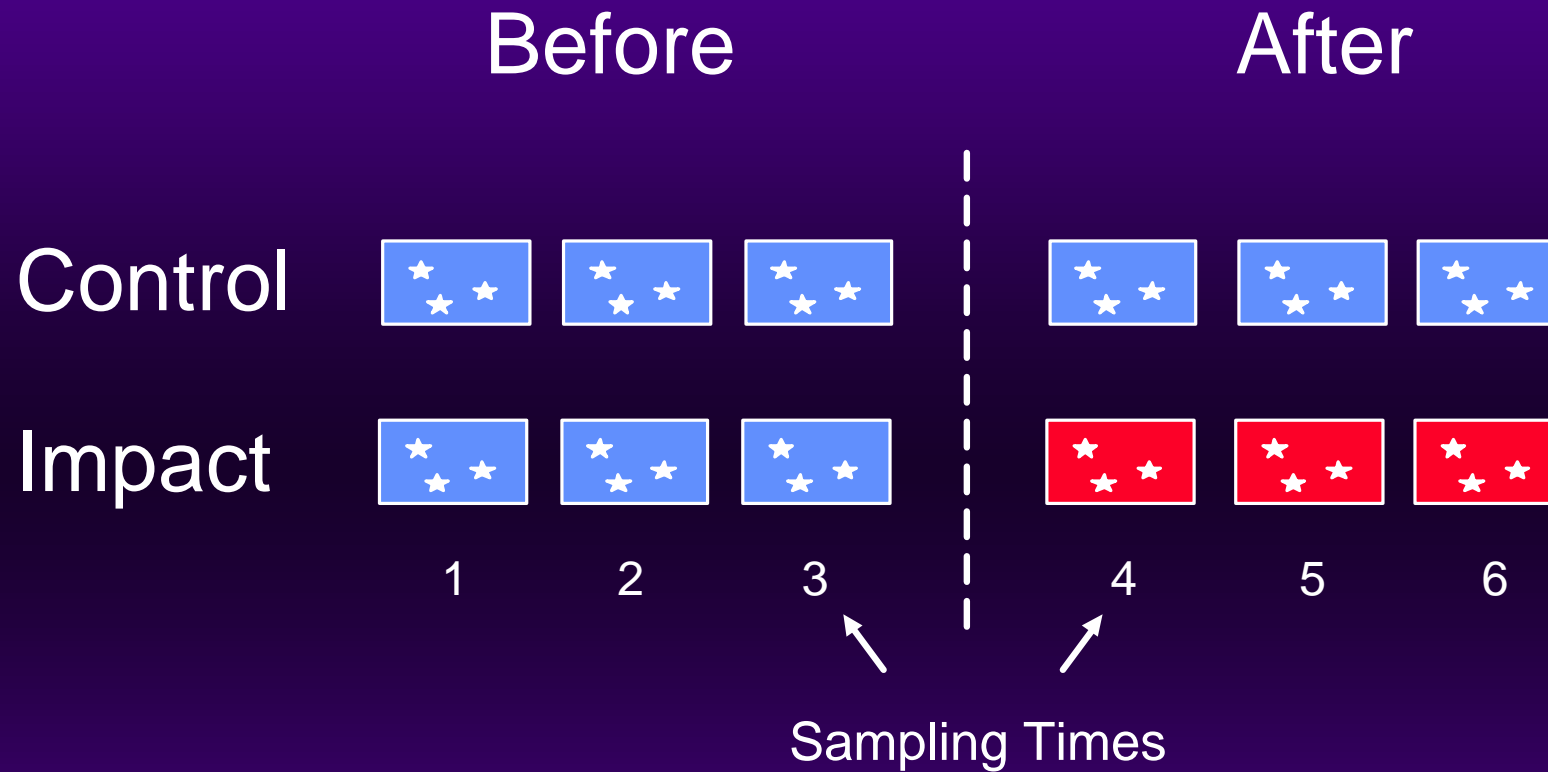


Time



Time

BACI as a partly-nested design

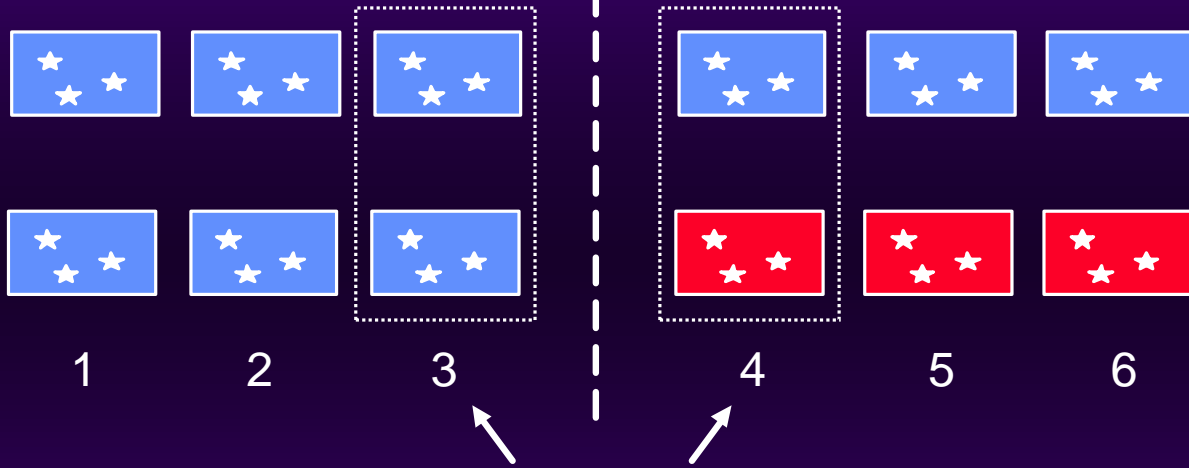


Before

After

Control

Impact



“Plots”

The linear model

- Times (T) nested within Before & After (BA)
- Crossed with Control-Impact (CI)
- Time random, but BA and CI are fixed

Linear model

$$y_{ijpm} = m + C_i + B_p + T(B)_{jp} + CB_{ip} + CT(B)_{ijp} (+ e_{ijpm})$$

m Grand mean

C_i Control or Impact

B_p Before or After

$T(B)_{jp}$ Time j within Before or After period p ;

CB_{ip} Before-After x Control-Impact interaction

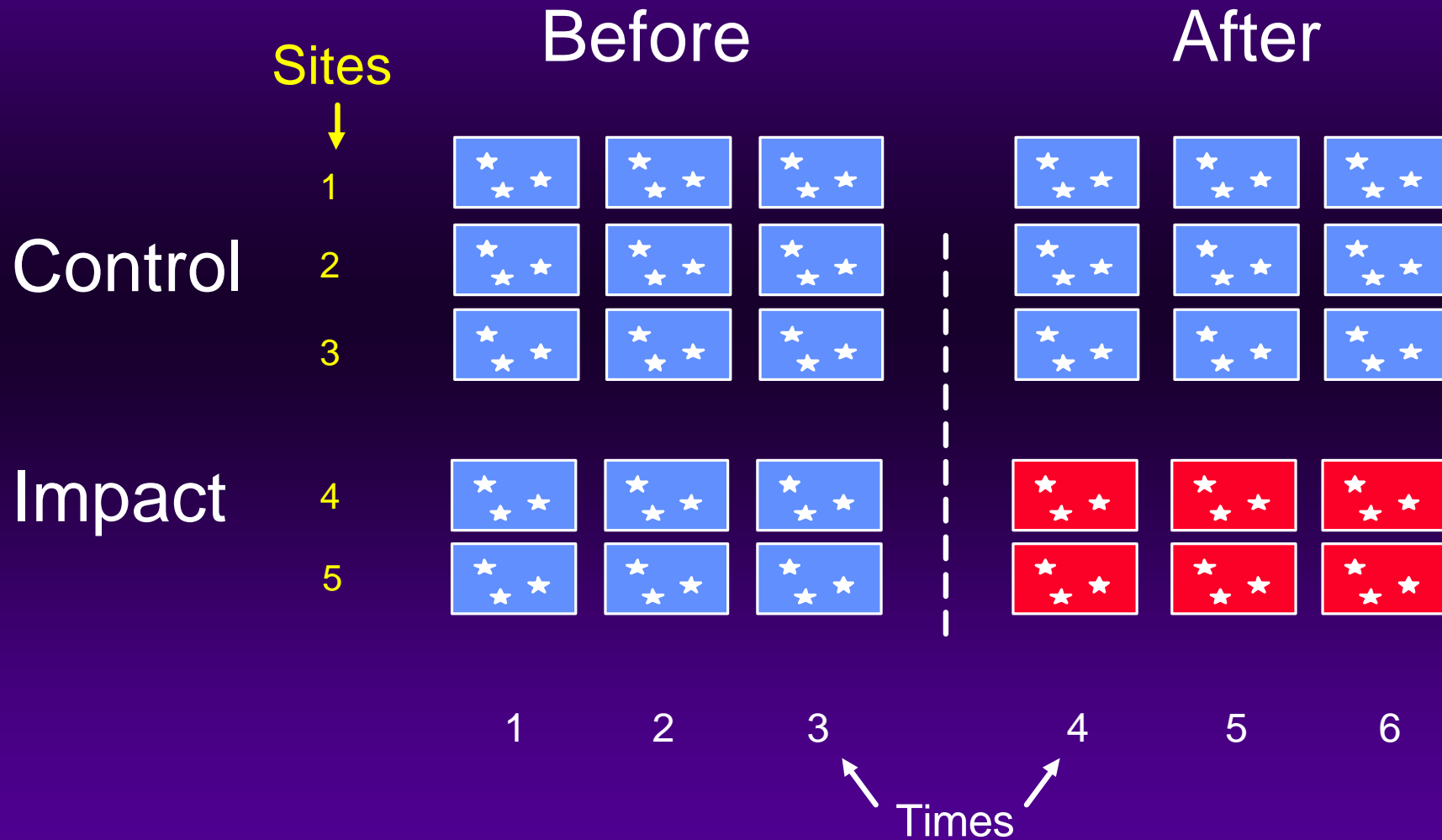
$CT(B)_{ijp}$ interaction between C-I and

e_{ijpm} the residual variation

BACI

- No replication in most cases
 - no Times x CI interaction
 - sub-samples at each site may allow this interaction to be tested, but it is of little interest
- Power depends on number of times

MBACI designs



MBACI

- Now four factors:
 - Before-After - fixed
 - Times within Before & After - fixed??
 - CI - fixed
 - Sites within Control & Impact - random
- $DV = \mathbf{m} + BA + T(BA) + CI + S(CI) + BA * CI + CI * T(BA) + BA * S(CI)$

Linear model

$$y_{inmpj} = m + C_i + l(C)_{in} + B_p + T(B)_{pj} + CB_{ip} + CT(B)_{ipj} + l(C)B_{inp} + l(C)T(B)_{inpj} (+ e_{inmpj})$$

m	grand mean
C_i	Control or Impact
$l(C)_{in}$	location within Control or impact
B_p	Before or After the activity starts
$T(B)_{pj}$	Time within Before or After
CB_{ip}	Control-Impact x Before or After interaction
$CT(B)_{ipj}$	interaction between C-I and times
$l(C)B_{inp}$	interaction between locations and B-A
$l(C)T(B)_{inpj}$	location by time interaction
e_{inmpj}	the residual variation

MBACI

- Test $BA * CI$ using $BA * l(CI)$ as denominator
- Power depends on # of sites
- Because test is made with BA x locations, critical assumptions are about how the BA changes occur at the “replicate” sites

MBACI example -

Keough & Quinn (2000), *Ecol. Appl.*

- Effect of marine protected areas in the absence of strict enforcement
- Areas open to recreational harvesting for >75 y, and areas closed for 75 y, opened in 1992
- DV is mean size of a common limpet
- Factor A: Harvesting
 - units of replication are individual reefs
- Factor B (reefs) nested within factor A

ANOVA table

Source of Variation	Num Df	Den Df	<i>MS</i>	<i>F</i>	<i>P</i>
Harvesting	1	6	319.92	13.64	0.010
Before-After	1	6	52.01	15.84	0.007
H x B-A	1	6	37.87	11.54	0.015
Sites(Harvesting)	6	Res	23.45	1.86	0.119
Years(B-A)	6	Res	45.40	3.61	0.008
Sites x B-A	6	Res	3.28	0.26	0.951
Year x Harvesting	6	Res	7.78	0.62	0.714
Residual MS	31		12.59		



Key test is H x B-A, which is tested using Sites x B-A. This effect is significant

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