Lecture 8

Quasi Experiments- First Focus on Dealing with Lack of Randomization

- Ignore the Problem
- Matched Pairs Designs
- ANCOVA Adjustment
- Before-After-Control-Impact Designs

Difficulties with traditional experimental designs

- No reasonable control areas often
  (Expense, Practicality, Uniqueness)

- Lack of randomization
  (Practicality)
- Lack of replication
  (Expense, Practicality)

Quasi-Experimental Design Alternatives Development

Control-Treatment Designs (With Replication)

•We will focus mainly on designs where there is no possibility of randomization but replication is possible first because that has a rich set of possibilities with formal statistical analyses available.

•If there is no replication possible then the procedures are adhoc and case specific and generally not very satisfactory without other kinds of data to strengthen the inference.

•For simplicity of exposition we will consider two treatments.

Quasi-Experimental Design Alternatives Development

Control-Treatment Designs (With Replication)

Randomisation is possible (ideal)

When there is no randomisation possible then:

- Do Nothing
- Use of Matched Pairs Designs
- Use of Analysis of Covariance
- Use of Before and After Treatment Measurements.

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Possible.

Standard Design analysed

- with two sample t tests
- or paired t tests
- or various ANOVA's depending on design if more than two treatments

Two Sample T Test

Comparison of Two Treatment Means (A, B) when we have normal distributions with equal variances-Students t test with (n_1+n_2-2) df. Completely Random Design

$$H_0 \quad \mu_A = \mu_B$$

$$H_1 \quad \mu_A \neq \mu_B$$

$$T = \frac{(\bar{x}_A - \bar{x}_B)}{\sqrt{\frac{2s^2}{n}}}$$

Calculate p values etc.

Paired T Test

Paired Plots Two Treats A and B

Equivalent to a Randomised Complete Block Design

Paired T Test (Assumes Normality)

$$\mathrm{D_i} = (\mathrm{X_{Ai}} - \mathrm{X_{Bi}}) \qquad i = 1,\ldots,n$$

$$\mathrm{H_0} \quad \mu_D = \mu_A - \mu_B = 0$$

$$\mathrm{H_1} \quad \mu_D = \mu_A - \mu_B \neq 0$$

$$T = \frac{\overline{D}}{\sqrt{\frac{s_D{}^2}{n}}} \quad \mathrm{df} = (\mathrm{n} - 1)$$

Calculate p values etc

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Problems

Looks like Standard Design analyzed with a t test or ANOVAs but differences between control and treatment (s) are confounded with inherent site differences.

The only thing you can do is try and justify that there are no inherent site differences or at least that they are unimportant.

Turkey Study Revisited

- Lets revisit the turkey study in modified form
- Two Treatments- Control Regions No Hunt, Hunted Region 8 Week Hunt
- Both Treatments replicated but not randomized.
- The problem we have is possible confounding- now discussed at length.

CONFOUNDING

- Confounding is when it is impossible to separate two variables with the data and design at hand
- Here Regional differences due to other reasons are confounded with hunting regime differences. We cannot be sure what causes any differences we see.
- This confounding is because of lack of randomization of the hunting regime treatments.
- This is an excellent (negative) example of the strength of using randomization

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Solutions

- Use a Matched Pairs Design
- Analysis of Covariance
- Add Before Measurements

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Matched Pairs Approach

Match pairs of control and "treated" replicates as closely as possible so that the difference between the two can be attributed to the treatment effect.

Problem is that there might be some factor you have ignored.Not as good as randomization.

Matched Pairs Example

- Exxon Valdez Oil Spill : Coastal Habitat Injury Assessment Study (McDonald et. al (1995) reported in Manly (2001 p 125). I modified the way presented.
- They used 5 pairs of control (A) and oil impacted sites (B) and measured the biomass of mussels.
- Not much info on how they did the matching. One has oil influenced Sites and then tries to find a control or unoiled site with similar characteristics.

Paired T Test

Paired Plots Two Treats A and B

Equivalent to a Randomised Complete Block Design

Paired T Test (Assumes Normality)

$$\mathrm{D_i} = (\mathrm{X_{Ai}} - \mathrm{X_{Bi}}) \qquad i = 1, \ldots, n$$

$$\mathrm{H_0} \quad \mu_D = \mu_A - \mu_B = 0$$

$$\mathrm{H_1} \quad \mu_D = \mu_A - \mu_B \neq 0$$

$$T = \frac{\overline{D}}{\sqrt{\dfrac{s_D{}^2}{n}}} \quad \mathrm{df} = (\mathrm{n} - 1)$$

Calculate p values etc

Here df=4

Hypothetical Matched Design Example

- Effects of a Wild Fire on a Plant Community
- Find 5 control regions of not burned habitat (A) and 5 burned Regions (B) and measured the biomass of mussels.
- Usually would be paired but you could do it unpaired as well. Try and make them comparable in other important variables

Two Sample T Test

Comparison of Two Treatment Means (A, B) when we have normal distributions with equal variances-Students t test with (n_1+n_2-2) df. Completely Random Design

$$H_0 \quad \mu_A = \mu_B$$

$$H_1 \quad \mu_A \neq \mu_B$$

$$T = \frac{(\bar{x}_A - \bar{x}_B)}{\sqrt{\frac{2s^2}{n}}}$$

Calculate p values etc.

Here df $= 8$.

ANOVA Table:

- Two treatments with 5 reps of each
- Completely Random Design

Source	df
Treats	1
Residual	8
Total	9

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Solutions

Use a Matched Pairs Design

Analysis of Covariance

Add Before Measurements

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Analysis of Covariance

Based on a critical covariate adjust the treatment means to the same level of the covariate.

Very Similar idea to matched pairs design.

Problem is that there might be some other covariate you have ignored.Not as good as randomization.

Note-We also recommended ANCOVA earlier for true experiments

Analysis of Covariance:Review

Useful for comparison of treatments when there is an important auxiliary continuous variable. Very useful to adjust treatment means when randomization not possible

Here illustrate linear additive model with a several treatments with a Covariate (x)

$$y_{ij} = \mu + \tau_i + \beta(X_{ij} - \bar{X}) + \varepsilon_{ij}$$

- A key point is to note that β does not change with treatment.

Analysis of Covariance: Diagram

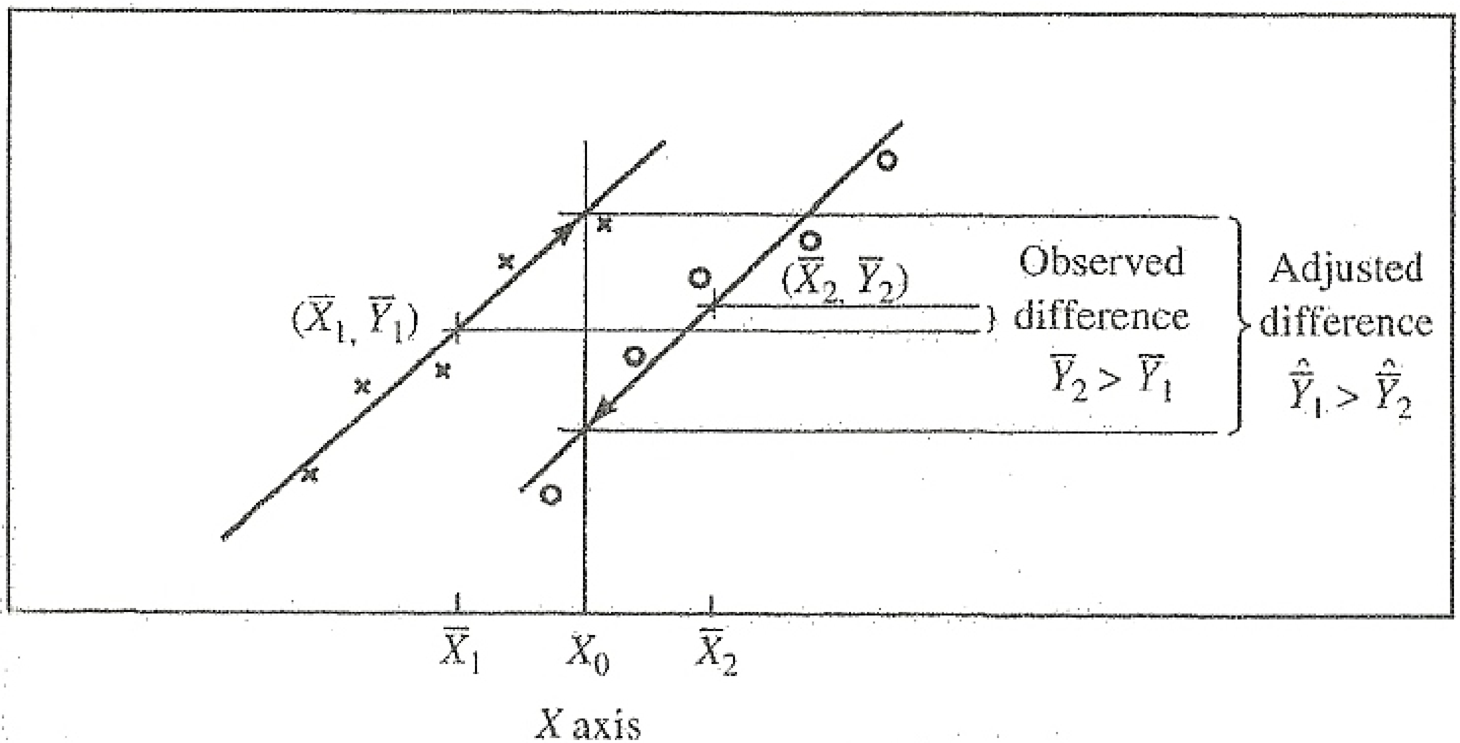


FIGURE 17.1
Error control and adjustment of treatment means by covariance.

All reps adjusted to a common Value of covariate X_{0},

ANCOVA: Again Some Crucial Points

- **For ecologists an extremely valuable technique and especially if treatments are not randomized (ie if not a true expt.**
- However, even in true experiments its very valuable.
- Adjusts treatments to a common value of the covariate x.
- Crucial to check if the slope is invariant to the treatment. If so a very powerful technique and best applied this way.
- If slope changes more complex regression procedures needed because then the treatment effect varies with x as well.

ANCOVA Example 1

- Wind Turbine design effects on bird fatalities (response variable). Replicate sites with two types of turbines but sites cannot be randomised.
- From Anderson et al. (1999) as reported in Morrison et al. (2001 p. 45).
- Very important covariate is bird use at each site. That can vary a lot.

ANCOVA Table:

- Two treatments with 5 reps of each
- Completely Random Design

Source	df
Treats	1
Covariate	1
Residual	7
Total	9

ANOVA Table: For Comparison

- Two treatments with 5 reps of each
- Completely Random Design

Source	df
Treats	1
Residual	8 (note the extra df here)
Total	9

ANCOVA Example 2

- Body size (response variable Snout Vent Length) differences in a snake species (Crotalus lepidous) in two populations at two elevations in Big Bend National Park.
- Covariate is age of snake.
- In this study the snake is the unit used so we don’t have true replication of the populations. Therefore some issues with what the results mean.
- Beaupre (1995) as reported in Scheiner and Grurevitch Ch 7 p 118.

CONTROL-TREATMENT DESIGNS WITH REPLICATION

Randomisation Not Possible.

Solutions

- Use a Matched Pairs Design
- Analysis of Covariance
- Add Before Measurements and Use BACI Approach

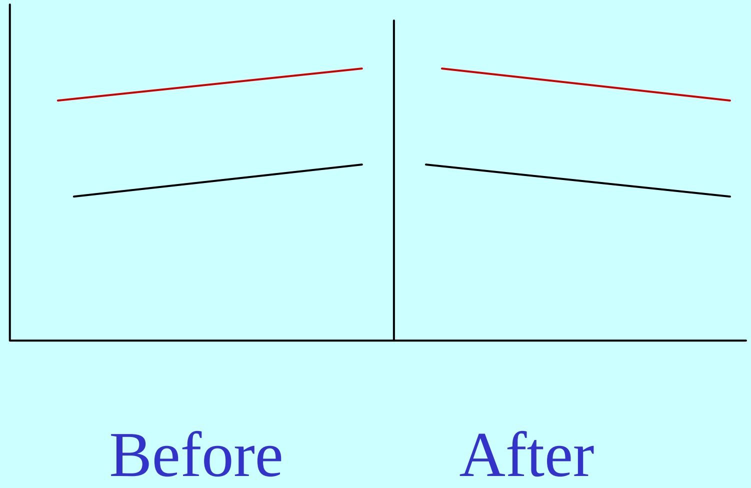
CONTROL-TREATMENT DESIGNS WITH REPLICATION:BACI

- Addition of measurements before the treatment or control is applied to the replicate experimental units.
- Assuming the controls and treatment plots have the same trajectories aside from an impact effect. Then can adjust out the inherent site differences between treated and controls.
- There is no need to assume that the control and impacted sites are equal the way we did for the matched design.
- Related to the ANCOVA approach. Again we adjust out effects of inherent site differences but way better than ANCOVA in my opinion.
- Still not as good as randomization. Model based but a really good approach in my opinion.

Before- After- Control-Impact Designs

Conceptual Figure-No Impact , True Mean Pattern

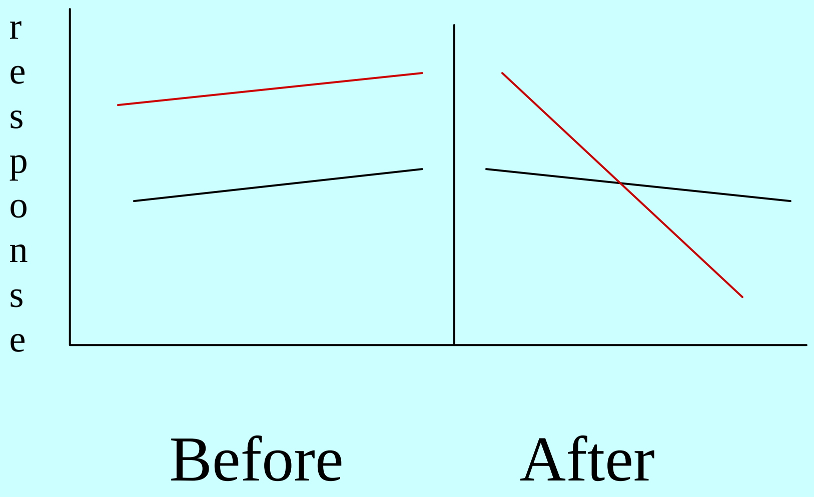
Red- Impact Mean trend
Black-Control Mean trend



Notice the impacted sites are always higher due to inherent differences. No impact effect

Before- After- Control-Impact Designs

Conceptual Figure on True Mean Pattern- Negative Impact Seen

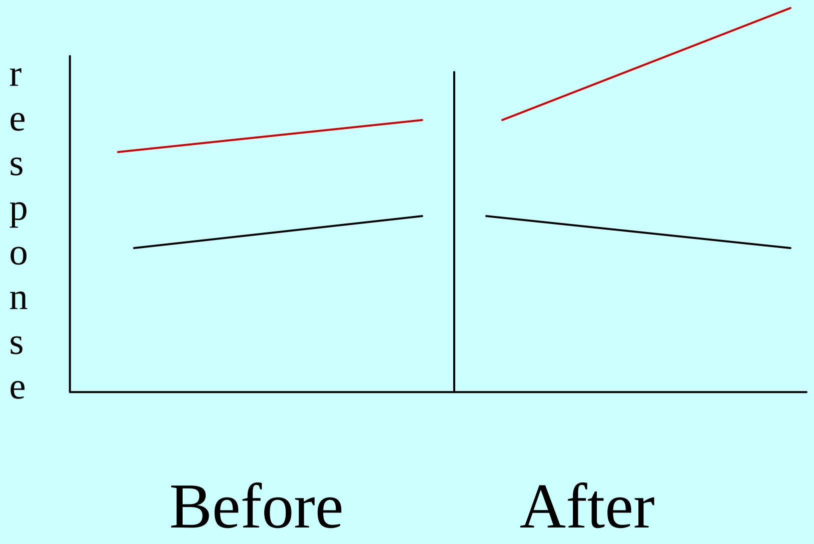


Red- Impact Mean trend

Black-Control Mean trend

Before- After- Control-Impact Designs

Conceptual Figure on True Mean Pattern- Positive Impact Seen

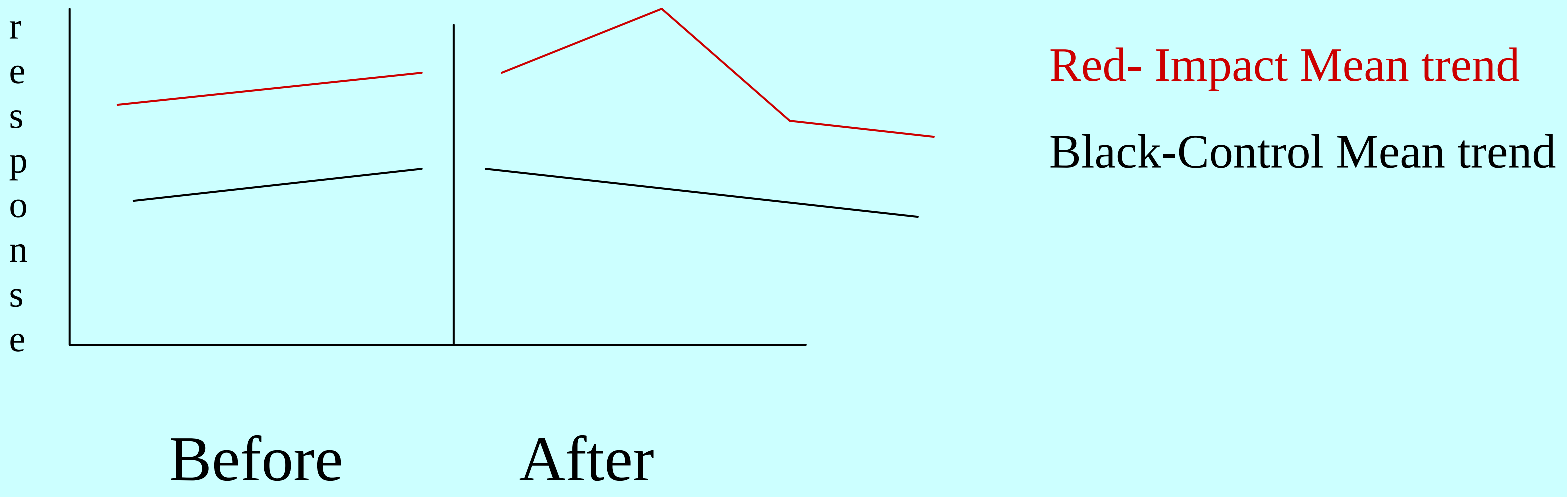


Red- Impact Mean trend

Black-Control Mean trend

Before- After- Control-Impact Designs

Conceptual Figure on True Mean Pattern- Positive then Negative Impact Seen and then Parallel again. Many other patterns over time are possible.



Before- After- Control-Impact Designs: Key Assumption Repeated

The control and treatment plots have the same trajectories aside from an effect due to the impact or treatment

This means we then can adjust out the inherent site differences between treated and controls.

This also means we do not have to assume that the control and treated plots are equal except for the treatments effect

Two Examples without Replication

- I emphasize these are not statistically ideal but I want to illustrate the general ideas first.
- Later will look at examples with replication which are even better!
- When I do that I will talk about the analysis metrics as I did for the other earlier designs in today’s lecture.

BACI DESIGN EXAMPLE: HUBBARD BROOK RECOVERY OF A FORESTED SYSTEM AFTER DEFORESTATION

- Likens et al. (1970) Ecological Monograph, Likens et al. (1978) Science Volume 199 p 492-496.
- Classic Hubbard Brook, New Hampshire Study on Deforestation.
- A beautiful example of a BACI Design and I highly recommend you read it.

BACI DESIGN EXAMPLE: HUBBARD BROOK RECOVERY OF A FORESTED SYSTEM AFTER DEFORESTATION

- One Control (Reference) Watershed
- One Clearcut Watershed
- No replication but the responses are so large that the results are convincing
- Measured responses over Time (Before and After 1965-68). Many variables measured like stream flow, evapotranspiration and net export of Ca,K, and Nitrate
- Classic pattern of large increases in many variables on clearcut compared to control site which then returned to baseline levels after some years.

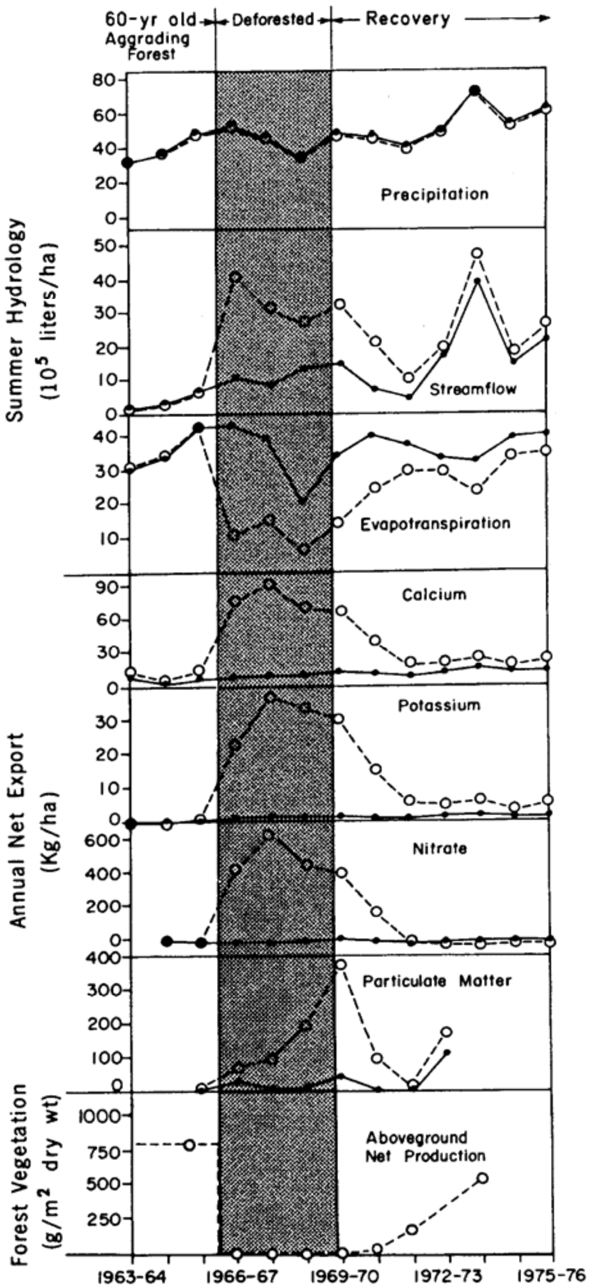


Fig. 1. Effects of deforestation on hydrology, biogeochemistry, and aboveground net production in an experimentally deforested northern hardwood forest ecosystem (○---○, W-2) are compared with a forested reference ecosystem (●—●, W-6). A 60-year-old forest (W-2) was experimentally devegetated during the autumn of 1965, maintained bare of vegetation for three growing seasons, and then allowed to revegetate during the growing season of 1969. Major hydrologic effects were observed during the summer growing season, June through September; dormant season effects were relatively minor. Evapotranspiration during the growing season is calculated as the difference between precipitation and stream flow and does not include changes in storage of soil moisture.

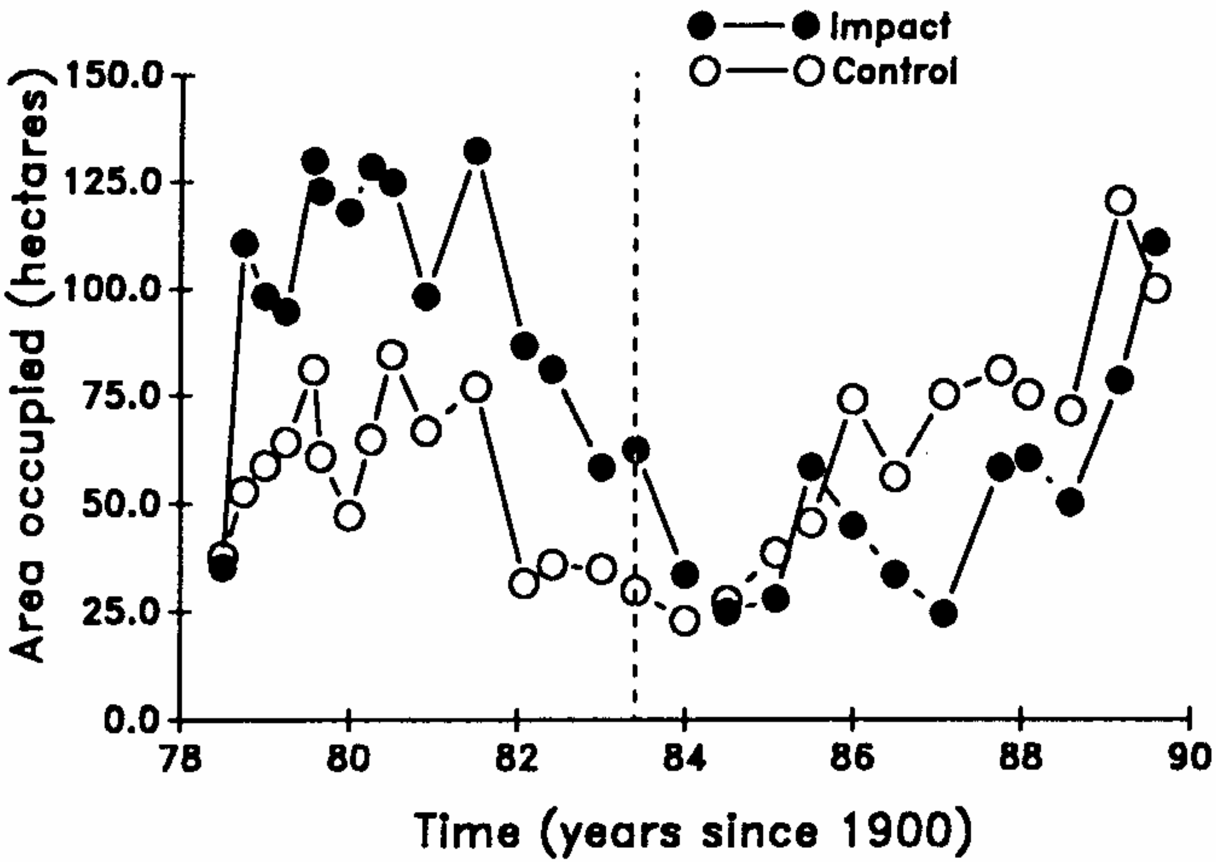
BACI Designs: Another Simple Example

- Bence et al (1996).Ch 8 in Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats.Eds Schmidt and Osenberg. Academic Press.
- Nuclear Power Plant Example on Giant Kelp Forests in S California. One Control Site and One Impacted Site over Time (Before and After 1983 when nuclear plant went online).

BACI Designs: Nuclear Power Plant Example

- One Control Site and One Impacted Site over Time (Before and After 1983 when nuclear plant went online).
- Control-San Mateo Kelp Forest
- Impact- San Onofre Kelp Forest-Reduced light levels on the Ocean Floor from the cooling system
- Measure-Area Occupied by the Kelp Forest

Note- In this case again without true replication but still useful to illustrate the concepts



Notice the shift in black pts after 1983

Figure 8.1. Data on areas occupied by densities of giant kelp plants exceeding approximately 0.04 m^{-2}, as determined by side-scan SONAR for the Impact (San Onofre kelp forest) and Control (San Mateo kelp forest) sites over time. Data were collected by Ecosystem Management Associates for 300 survey areas at each site (see Murdoch et al. 1989). Dashed vertical line separates Before and After periods.