2 Collecting Data (Cont'd)

MTH 3240 Environmental Statistics

Spring 2020

Notes

Objectives

Objectives:

- Distinguish between replication and pseudoreplication.
- Distinguish between snapshot and trajectory studies.
- Distinguish between observational studies and experiments.
- Explain how confounding variables preclude establishing cause-and-effect using observational studies.
- List the three principles of experimental design.
- State why impact assessment studies are seldom experiments.
- Know how to carry out before-after, control-impact, and BACI impact assessment studies.

Notes

Designing Studies

- In these slides we'll look at some issues related to designing environmental field studies.

Notes

Replication Versus Pseudoreplication

- ***Replication*** refers to measuring a variable on **several** individuals (e.g. several soil or water specimens, quadrats, time points, etc.) instead of on just one.

  Each additional **replicate** increases the **sample size** by **one**.

Notes

- Measurements made on specimens gathered **too close together** *spatially* or *temporally* will be **redundant**.

  Such (redundant) measurements are called ***pseudo-replicates***.

  In effect, each **pseudoreplicate** is a **duplicate** of a measurement already made, and therefore *doesn't* increase the sample size.

  Pseudoreplication should be **avoided** whenever possible by separating measurements sufficiently in space or time.

Notes

Snapshot Versus Trajectory Studies

- A question that sometimes arises is whether **replication** should be done in **space** or in **time**.
- A ***snapshot study*** is one in which **replication** is done in **space**, i.e. a variable is measured at **several spatial locations** (all at roughly the **same time**).
- A ***trajectory study*** is one in which **replication** is done in **time**, i.e. the variable is measured at **several time points** (all at the **same location**).

Notes

- If the goal of the study is to make generalizations over a **spatial region**, a **snapshot** study is appropriate.
- If the study goal is to make generalizations over a **period of time**, a **trajectory** study is appropriate.
- The two types of studies (**snapshot** and **trajectory**) can be **combined** in a single study – i.e. replication can be done over **space** *and* **time**.

Notes

Observational Studies Versus Experiments

- We're often interested in the **relationship** between two variables.

  One is designated the ***explanatory variable*** and the other the ***response variable***.

Notes

Example

Studies have shown that there's a relationship between **ozone levels** near large cities and **mortality rates** in those cities – mortality rates, especially among the elderly, tend to be higher when ozone levels are high.

In these studies:

- **Ozone level** is the **explanatory variable**.
- **Mortality rate** is the **response**.

Notes

Example

A study was carried out to determine if exposure to **copper pollution** has any effect on the **reproductive capabilities** of earthworms.

Earthworms were assigned randomly to soils containing different concentrations of **copper**, and their **cocoon productions** measured.

In this study:

- **Copper** concentration is the **explanatory variable**.
- **Cocoon production** is the **response**.

Notes

Observational Studies vs Experiments

- Studies to investigate the *relationship* between two variables are of two types: **observational studies** and **experiments**.

  They differ in terms of:

  1. How the data are collected.
  2. The conclusions that can be drawn.

Notes

- In ***observational studies***, the explanatory and response variables are merely *observed* (measured) on individuals, and *no treatments are imposed* on them.
- In ***experiments***, *treatments are imposed* on individuals in a deliberate attempt to induce a response.

Notes

- **Observational studies**, by themselves, **can't establish cause-and-effect** relationships because of the possible presence of **confounding variables**.

Example (Cont'd)

The studies that have shown that **mortality rates** among the elderly are higher when **ozone levels** are high are **observational studies**.

But the chemical formation of ozone in the atmosphere requires both heat and sunlight, so **heightened ozone levels** are associated with **hotter temperatures**.

Notes

It's known that **mortality rates** among the elderly tend to be **high** on **hot days** due to **heat exposure**.

So it might be the **heat**, *not the ozone*, that's causing the deaths.

Here, the effect of **temperature** on mortality is said to be **confounded** with the effect (if any) of **ozone**, i.e. **temperature** is a **confounding variable**.

Notes

- In general, a ***confounding variable*** is one whose **effect** on the **response** *can't be distinguished* from the **effect** (if any) of the **explanatory variable**.

  Confounding variables are often "lurking" in the background (that is, not measured in the study).

Notes

- **Establishing cause-and-effect** requires performing a well-designed **experiment**.
- In experiments, the **explanatory variable** is sometimes called the ***factor***.

  The different **levels** of the factor are called ***treatments***.

Notes

Example

In the earthworm *experiment*, the **factor** is **copper concentration** and the **treatments** are the **different concentrations** used in the study.

Notes

- The ***three principles of experimental design*** are:
  1. **Randomization** - Randomly assign experimental units to treatment and control groups so that the groups will be (roughly) the same before the treatments are applied.
  2. **Control** - Compare at least two groups in the experiment, even if one of them is a control group that receives no treatment, and hold potentially confounding variables constant across the groups.
  3. **Replication** - Include more than one individual in each group so that the results of the experiment will be reliable.

Notes

Impact Assessment Studies

- ***Impact assessment studies*** are used to determine if disturbances such as oil spills or construction projects had any effect on the environment.

  They're also used to assess the impacts of changes in management practices (e.g. forest or wildlife management).

- We'll use the term ***impact event*** to refer to the disturbance (or management practice change) and call any site *potentially* impacted an ***impact site***.

  A ***control site*** will be a site *known* to be *unaffected* by the impact event.

Notes

- **Impact events** can be either of two types, **pulse** and **press**.
- ***Pulse*** events are relatively short-term anthropogenic or natural disturbances.

  They're often unforeseen accidents or natural disasters.

  Examples: Oil spills, chemical spills, nuclear plant ”meltdowns”, forest fires, and floods.

- Impacts of **pulse** events are sudden, large changes in environmental variables, followed by a return over time to their pre-event levels.

Notes

- ***Press*** events are long-term, sustained disturbances, such as a permanent alterations of the environment.

  They're often foreseeable anthropogenic perturbations.

  Examples: Sustained discharge of toxic chemicals or sewage, construction of a permanent structure such as a highway or dam, and sustained overharvesting of a plant or animal species.
- Impacts of **press** events are large, lasting changes in environmental variables.

Notes

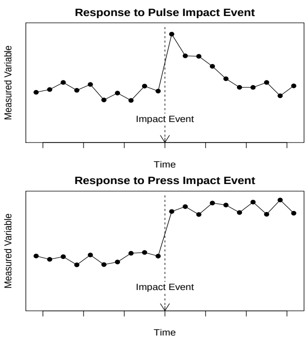

Figure: The response of a variable to a pulse impact event (top) and a press event (bottom).

Notes

- Most **impact assessment studies** are one of three types:
  - **Before-after** studies.
  - **Control-impact** studies.
  - **Before-after-control-impact** (or ***BACI***) studies.
- Impact assessment studies are **observational studies**, *not experiments*, because sites *aren't randomly assigned* to impact and control conditions.

  Thus establishing cause-and-effect is a challenge.

Notes

- In ***before-after*** studies, an environmental variable is measured **before** and **after** the impact event, but **only** at the **impact site**.

  They're used when no suitable control site is available.

  They require advance knowledge that the event is going to occur.

  So, for example, they can be used to asses the impact of a new construction project, but not an unforeseen event like an oil spill or flood.

Notes

- A drawback is that the **effect** (if any) of the **impact event** is **confounded** with the **effects** of **other variables** that are **changing naturally over time**, such as weather conditions, human population encroachment, etc.

Notes

- In ***control-impact*** studies, the environmental variable is measured **after** the impact event at the **impact site** *and* at a nearby, unaffected **control site**.

  They don't require advance knowledge of the impact event.

  So they're used to assess the impacts of unforeseen events like oil spills and floods.

  The **control site** should be chosen to be as **similar** as possible **to the impact site** (so that potentially confounding variables are constant across the two sites).

Notes

- A drawback is that as hard as we might try to choose the control site to be similar to the impact site, there will always be differences, and the **effect** (if any) of the **impact event** will be **confounded** with the **effects** of **variables that differ** across the two sites (e.g. soil conditions, proximity to industries, etc.).

Notes

- In ***before-after-control-impact*** (or ***BACI***) studies, the environmental variable is measured both **before and after** the impact event at both the **impact site and a control site**.

  They require advance knowledge of the impact event (*and* they require a suitable control site), so they can't be used to asses the impacts of unforeseen events like oil spills or floods.

  The **control site** should be chosen to be as **similar** as possible **to the impact site**.

Notes

- In BACI studies, there are **two ways** to decide if the **impact event** had an **effect**:
  - The first is to compare the **change** in the measured variable at the **impact site**, from before the event to after, to the **change** at the **control site**.
  - The second way is to compare the **difference** in the measured variable between the two sites **before** the event to the **difference after**.

Notes

- Well designed **BACI** studies are **preferred** over both before-after and control-impact designs because:
  - They **control** for variables that are changing naturally over time (like weather conditions, human population encroachment, etc.).
  - They also **control** for variables that differ across the sites (like soil conditions, proximity to industries, etc.).

Notes

- **BACI** studies can be **snapshot** studies, **trajectory** studies, or a **combination** of the two, as seen on the next slide.

Notes

Trajectory Type BACI Study

		Before			After		
		T1	T2	T3	T4	T5	T6
Control	S1	X	X	X	X	X	X
Impact	S2	X	X	X	X	X	X

Snapshot Type BACI Study

		Before	After
		T1	T2
	S1	X	X
Control	S2	X	X
	S3	X	X
	S4	X	X
Impact	S5	X	X
	S6	X	X

Combination Trajectory/Snapshot BACI Study

		Before			After		
		T1	T2	T3	T4	T5	T6
	S1	X	X	X	X	X	X
Control	S2	X	X	X	X	X	X
	S3	X	X	X	X	X	X
	S4	X	X	X	X	X	X
Impact	S5	X	X	X	X	X	X
	S6	X	X	X	X	X	X

Above, an X is a measurement of the environmental variable, S1, S2, . . . are spatial locations, and T1, T2, . . . are time points.

Notes