Introduction to Research Methods & Experimental Design

Module 6

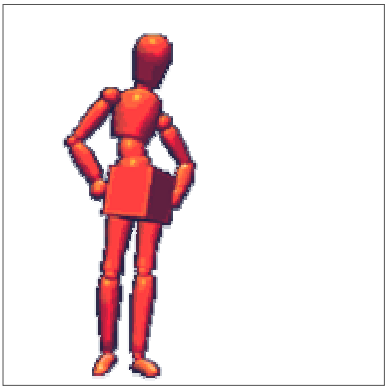
WATER ON THE WEB

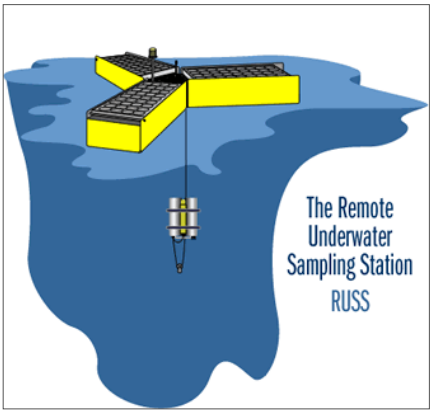
Objectives

Students will be able to:

- list the steps involved in the research process.
- identify societal goals and purposes for research.
- develop research objectives from goals.
- use established criteria to assess research hypotheses.
- categorize research variables
- create operational definitions
- define samples and explain sampling methods.
- determine the difference between reliability and validity.
- evaluate the importance of replication and randomization.
- explain experimental, causal-comparative, correlational, and descriptive research methods.
- identify Green's ten principles of research design.

Conducting research





Research process

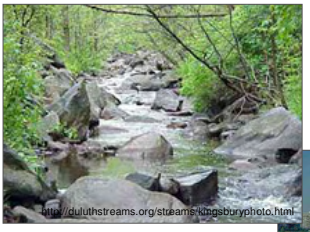
1. Society's goals and purposes
2. Problems identified
3. Objectives identified & refined
4. Question(s) isolated
5. Hypothesis or Research Question developed
6. Research & sampling design
7. Data collection
8. Data managed & analyzed
9. Results interpreted
10. Presentation of results

Society's goals and purposes

- **Research begins with a goal and a purpose**
  - Public and agency interests in water resources are grounded in their values and missions. Based on their perspectives, the public and agencies identify problems.
  - The problems lead to more specific questions that form the starting point for research.

Society's goals and purposes

- **What types of goals and uses might people have for their lakes, rivers, streams, and reservoirs?**



Society's goals and purposes

- **Society's goals generally address:**
  - Water quantity
  - Water quality
  - Impacts of water use
  - Water resource protection or remediation
  - Improved understanding of the resource
  - Responding to a resource crisis

Society's goals and purposes

- **Water quality**
  - Aquatic Life & Wildlife Support
  - Fish/Shellfish Consumption
  - Drinking Water Supply
  - Recreation
  - Agriculture

From goals to objectives

Social Goal

↓

Problem

↓

Objective

Protect the water quality in the stream.

↓

What is the current water quality of the stream?

↓

Sample water quality indicators in stream.

From goals to objectives

Improve lake water quality

↓

Algae blooms in lake affect swimming and result in bad smells

↓

Find how phosphorous is entering the lake

From goal, to problem, to objective, to question, to a hypothesis

- **Goal: Society wants to reduce eutrophication in Halsted's Bay, in Minnetonka, MN.**
  - Problem: It's not known if the nutrients causing eutrophication come from the sediments or non-point sources.
- **Objective: Determine the probable source of the nutrients causing eutrophication.**
  - Question: Are sediment nutrients affecting eutrophication?
- **Refined Q: Are sediment nutrients re-suspended in the Bay?**
  - Final Hypothesis: Sediments in Halsted's Bay are not re-suspended after major wind events.

Hypothesis

- **Declarative statements**
- **Testable**
- **Are resolved mathematically**
- **Address independent and dependent variable(s)**

Hypothesis: Which statements are declarative?

- Turbidity decreases fish reproduction.
- Does increased phosphorous in the water lead to algae blooms?
- How does water temperature affect development of invertebrates?
- Find the impacts of erosion on a stream.
- Study the spread of aquatic invasive species.
- Feedlot runoff does not affect the oxygen levels in Whatchagot River.
- How do two-cycle outboards affect the water quality of Lake Whereisit?
- Identify the source of pollution affecting the river.
- How is mercury entering our northern lakes?

Hypothesis: Which are testable?

- Aquatic invasive species can be spread by recreational boats.
- Macrophytes are beneficial.
- Development causes erosion.
- Fertilizers cause water pollution.
- Eliminating the introduction of oil and gasoline into stormwater drains will improve lake water quality according to the US EPA Clean Water Act.

http://geo.arc.nasa.gov/sge/casa/california.html

Hypothesis

- **Example Hypothesis:**
  - Sediments in Halsted's Bay are not re-suspended after major wind events.

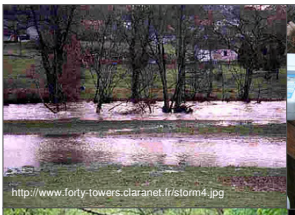
http://lakeaccess.org/lakedata/images/halsteds/halsteds1.jpg

Variables

- **Variable:**
  - Any thing or event that can change (have more than one value) while still having the same identity.
- **What stream variables might affect the number and type of fish caught in this electro-shocking effort?**

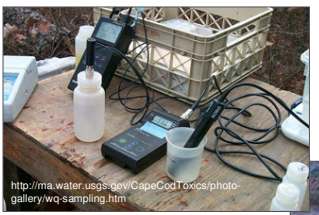
Variables

- **Variables can be:**
  - Discrete
  - Continuous
  - Nominal
  - Ordinal



Variables

- **Categorize these variables:**
  - Water depth
  - Sex of an organism
  - Dissolved oxygen
  - Turbidity
  - Stream flow
  - Dates for spawning
  - Water color
  - Growth rates
  - pH
  - Electrical conductivity
  - Dominance
  - Where something occurs (spatial variable)
  - When something occurs (temporal variable)



Variables: Independent and dependent

- **What is the independent/dependent variable?**
  - Increases in turbidity result in decreased dissolved oxygen
  - Increasing algae populations result in increased dissolved oxygen.
  - Stream flow rates correlate to electrical conductivity.
  - Water temperature affects the start of spawning for trout.
  - The presence of PCB's affects the reproductive success of sturgeon.

Operational definitions

- **Specifically defining a variable as a type of data in a way that permits another researcher to measure the same variable.**

Operational definitions

- **Create operational definitions for these phrases**
  - “large” lake
  - “narrow” river
  - “young” fish
  - “rocky” bottom
  - “fast-moving” stream
  - “clean” water
  - “early” spawning
  - “cold” water

Review

- **Improve these hypotheses:**
  - Carp populations affect water quality.
  - Shoreline vegetation is important for fish in a stream.
  - Development should not occur on stream banks with high slopes.
  - New reservoirs have more macro-invertebrates.
  - Decreasing nutrient inputs into a lake improves water quality.

Review process of hypothesis development

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Review process of hypothesis development

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Research and sampling design

- **Who collects what, when, where, and how?**

Research and sampling design

- **Basic concepts and principles**
  - Variable
  - Operational definition
  - Sample
  - Variability
  - Replication
  - Independence

- **Basic concepts and principles**
  - Sample size
  - Uncertainty
  - Randomization
  - Control
  - Reliability
  - Validity

Research and sampling design

- **Sample:**
  - A representative portion of the population.
  - The size of the sample is referred to as “n”.
  - The entire population is referred to as “N”.

Research and sampling design

- **Types of sampling**
  - Convenience or accidental sampling
  - Random sampling
  - Stratified random sampling
  - Cluster sampling
  - Systematic sampling

Sample types

- **Which type of sampling might you use…**
  - If you were looking for population information about a species like walleye?
  - If you wanted to show the impacts of a pollutant on benthic macro-invertebrates in a stream?
  - If you wanted to determine the impacts of road salt on electrical conductivity in streams?
  - If you wanted to determine water clarity in a lake?

Variability

- **Sources**
  - Individual differences (sampling error)
  - Measurement error

Validity

- **Do the methods and tools truly measure what they are intended to measure?**
  - Internal
  - External
  - Statistical

Reliability

- **Do the methods and tools/instruments produce consistent results across multiple observations?**

Research horror stories

- Determining life history of a benthic amphipod

http://www.cee.vt.edu/program_areas/environmental/teach/smprimer/dredges/dredges.html

Research horror stories

- Studying animals that live between sand grains on a beach

http://www.coolweblog.com/par/white%20sand%20beach.jp

Treatment

- **Refers to the variable that is manipulated and/or being investigated as the predictor/causative variable: the independent variable.**

Treatment

- **What's the treatment?**
  - Temperature is being investigated for its effects on fish growth rates.
  - Water clarity is being studied to see if it will improve if phosphorous inputs to the lake are reduced.
  - Different levels of photosynthetic activity are being studied to see their effects on DO.

Research horror stories

Replication

- **Replicate samples:**
  - Multiple samples or observations are desirable and increase confidence in research conclusions and predictions.
- **Affects reliability**
- **Consider time, space, scale, and samples in designing replications.**

Replication

- **Direct replication**
- **Systematic replication**

Randomization

- **Sampling**
  - Spatial
  - Temporal
- **Treatment**
  - Spatial
  - Temporal

Layout in research design

- Sample size
- Randomization
- Replication

Research horror stories

Research and sampling design basics

- Control variables
- Collect replicate sample data
- Collect sample data randomly
- Collect enough sample data for analysis
- Conduct preliminary sampling to test the research/sampling design
- Test and consider limitations of sampling methods and techniques

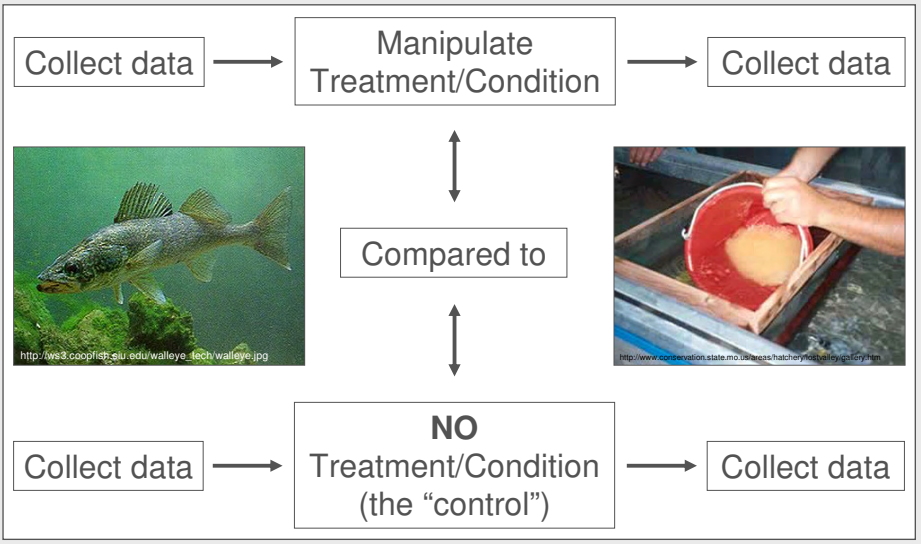
Categories of scientific research

- Experimental
- Causal-comparative
- Correlational
- Descriptive

Experimental research

- **Identifies cause-effect relationships**
- **Involves the manipulation of independent variables in the process of testing a hypothesis**
  - Attempts to constrain other variables
  - Results in statistical probability statement
  - Most laboratory research is experimental
  - Some field research is experimental

Experimental research design



Experimental research

- **Limitations**
  - May leave out important variables from consideration
  - May be “artificial”
  - Often restricted in small scales of time, space, and limited range of treatment conditions
  - May be ethically inappropriate

Causal-comparative research

- **Draws from two groups that are different on a critical variable (the independent variable)**
- **Subjects are not randomly assigned (instead they belong to categorical groups)**
- **Uses dependent and independent variables, but independent is varied by selecting the situation, not deliberately varied**

Causal-comparative research

Collect data → Treatment/Condition → Collect data

Compared to

Collect data → No/different Treatment/Condition (the "control") → Collect data

Causal-comparative research

- **Limitations**
  - Non-treatment variables cannot all be kept equal
  - Often temporal and/or spatial scales are used in layout design

Correlational research

- Finds relationships among variables
- Does not define cause-effect
- Does not attempt to determine effects of independent variable

Correlational research

Treatment/Condition → Collect data

and

No Treatment/Condition → Collect data

or

Range of Treatment/Condition → Collect data

Correlational or simple experimental research

- **Example:**
  - Collect electrical conductivity data in streams before and after rainfalls.

Collect data → Treatment/Condition → Collect data

Descriptive/naturalistic research

- **Describes a situation**
- **Does not manipulate variables**
- **Does not attempt to define cause-effect relationship**

Descriptive research

- **Example:**
  - Collect walleye egg hatching data below pulp mill outfall.

Treatment/Condition → Collect data

Applied water resources research

- **Inventory/census**
- **Surveillance**
- **Monitoring**

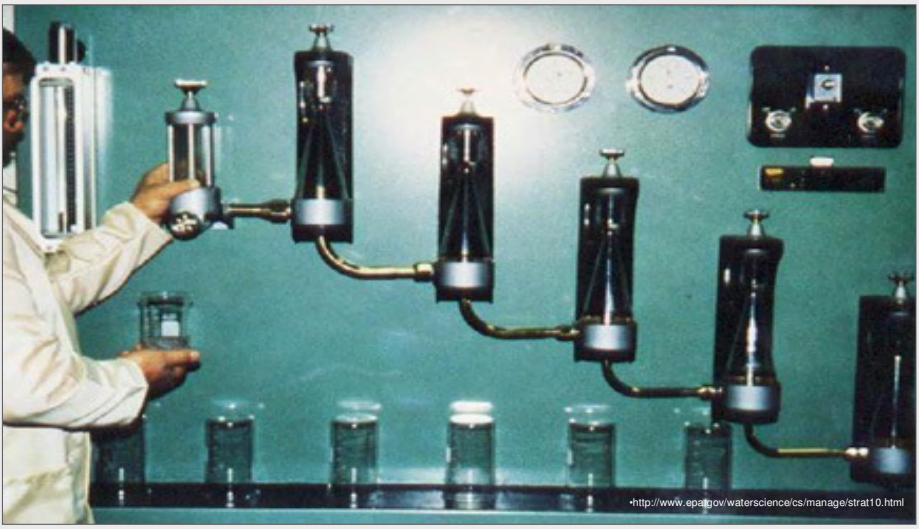
Monitoring

- Compliance
- Hypothesis testing
- Trend
- Retrospective (effects-oriented)
- Predictive (stressor-oriented)
- Anticipatory

Compliance monitoring

•http://photogallery.nrcs.usda.gov/JPG/AK/NRCSAK97012.JPG

Hypothesis testing monitoring

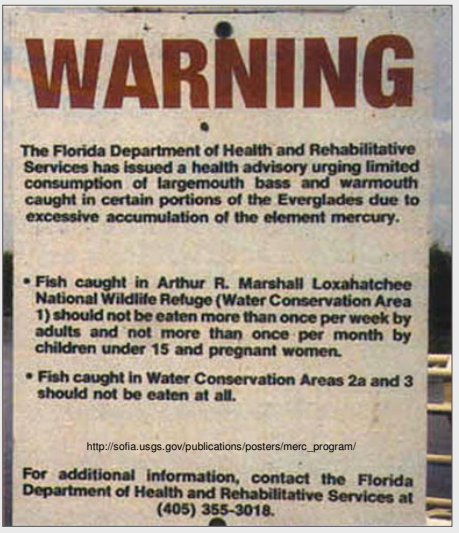


Trend monitoring

Retrospective (effects) oriented monitoring

http://www.seagrant.umn.edu/pubs/vgl/medium/213.jpg

Predictive (stressor-oriented) monitoring



http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/peril_toxins.html

Anticipatory monitoring

http://www.nwhc.usgs.gov/research/amph_dc/frogxray.html


http://www.usgs.gov/amphibians.html

Recommendations for field studies:

- Conduct long-term studies whenever possible
- Conduct experiments AND observations at several spatial scales
- Use tractable organisms and systems to establish processes
- Use natural replicates whenever possible
- Be conscious of repeatability
- Embrace, do not shun, natural variation!

Green's ten principles

1. Be able to state your research question concisely.
2. Take replicate samples.
3. Use an equal number of randomly allocated replicate samples for each combination of controlled variables.
4. Use a control.
5. Carry out some preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options.
6. Verify that your sampling device or method is appropriate.
7. If you are sampling a large area, define appropriate sub-areas and use proportional sampling.
8. Use replicate samples to get the precision desired.
9. Test your data for error variation.
10. Stick with the results of your statistical analysis.

Module review

- Goal
- Objective
- Problem
- Hypothesis
- Inventory
- Retrospective monitoring
- Predictive monitoring
- Anticipatory monitoring
- Applied research
- Basic research
- Control
- Variable (types?)
- Descriptive research
- Correlational research
- Experimental research
- Replication
- Reliability
- Validity
- Randomization

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