

# Science and the Scientific Method

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NRC 601

*Research Concepts in Natural Resources*

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University of Massachusetts Amherst

Fall 2009

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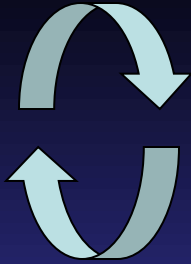
USGS Massachusetts Cooperative Fish and Wildlife Research Unit

*"Supposing is good, but finding out is better."*

-- Mark Twain

## *What is Science?*

- Latin *scientia* or *sciêns* for "to know"
- *Not* an activity, collection of facts, or advanced technology
- *It Is . . .*
  - a process, beyond the "scientific method"
  - a philosophy, for thinking about the world
  - an objective search for "truth"
  - (*given that "ultimate" truth is an elusive and unreasonable goal*)



## *What is the Scientific Method?*

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- the Scientific Method is *not* Science

*the philosophy, process, & practice of Science is much more*

- it is a *TOOL* for ...

forming and framing questions

collecting information to answer those questions

revising old and developing new questions

*This Feedback Loop is a key characteristic  
of the Scientific Method*

## *Four basic methods of Knowing*

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- (1) *Tenacity* - holding tight to traditional beliefs.
- (2) *Authority* - expert opinion.
- (3) *A Priori Method* - consequences based on a set of assumptions.
- (4) *Science* - a circular process of information, based on  
theory >>> testing >>> feedback

Science is the only method that is *self-correcting*; there are built in checks along the way.

# *Early Developments*

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- One of the early papers on the scientific method - 1890

Chamberlin, T. C. 1965. The method of multiple working hypotheses. *Science* 148:754-759.

- Formalized by Popper: hypotheses are tested & rejected

Popper, K. R. 1959. *The logic of scientific discovery*.

\_\_\_\_\_. 1963. *Conjectures and refutations: the growth of scientific knowledge*.

- Further emphasis: testing of multiple, alternate hypotheses

Platt, J. R. 1964. Strong inference. *Science* 146:347-353.

## *Science in Natural Resources*

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Natural resource conservation and management were built on natural history observations and conclusions from associations.

e.g.,

*Fish stocks decline given certain levels of sustained exploitation.*

*Ungulate reproductive rates are affected by severity of winter weather.*

*Tree growth is influenced by stand stocking levels.*

Thus we have a long tradition of management based on laws of association rather than on experimental tests of specific hypotheses.

# *Approaches to Research*

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## (1) Descriptive Studies

- search for a pattern, and then infer a mechanism
- biggest problem is that a mechanism must be invoked to explain the pattern . . .

*however,*

- several different mechanisms may produce the same pattern

## *Approaches to Research . . .*

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### (2) Comparative Studies

- follow directly from descriptive studies
- observational data are used to describe patterns
- patterns compared in order to infer differences

*however,*

- have the same problems of more general descriptive studies

## *Approaches to Research . . .*

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### (3) Models

- "all models are wrong, but some are useful"
- can provide insights and help us think about how a system may work

*however,*

- modeling exercises alone do not help us to infer the underlying cause or causes

# *Approaches to Research . . .*

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## (4) Experiments

- requires the researcher, in advance, to specify:
  - a. a question
  - b. a means of answering that question

thus,

- experiments tend to be better designed
- the goal is to hold all variables stable while manipulating a variable (or variables) of interest

# *Approaches to Research . . .*

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## Two classes of experiments

### 1. natural experiments

- the system provides the manipulation
- e.g., fire, windstorm, drought, annual differences

### 2. manipulative experiments

- involve treatments ( $t$ ) and controls ( $c$ )
- can be conducted in the lab or field
- e.g., dose-response experiments  
removal or additive experiments

## *Approaches to Research . . .*

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### Two classic early experiments in ecology:

Connell, J. H. 1961. The influence of interspecific competition and other factors on the distribution of the barnacle *Chthamalus stellatus*. *Ecology* 42:710-723.

Paine, R. T. 1963. Trophic relationships of eight sympatric predatory gastropods. *Ecology* 44:63-73.

## *What is the goal of Science?*

*To offer explanations about the natural world.*

- the scientific method is the most efficient technique for acquiring *reliable knowledge*.
- it enables us to determine the underlying mechanisms to observed patterns.
- we are thus able to go beyond mere description and ask *WHY* these patterns occur.

*There is nothing inherently wrong with descriptive, comparative, or modeling studies.*

*Well planned and executed descriptive studies often form the first step into new areas of inquiry and research.*

*However, the results from these studies are often equivocal, they do not address cause-and-effect, and they do not answer the question "Why?"*

# *How does the Scientific Method work?*

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## *Six steps*

- (1) Hypothesis development.
- (2) Experimental design.
- (3) Experimental execution.
- (4) Data analysis.
- (5) Interpretation of results ... *and* ...
- (6) *Feedback to Step 1* ...