1. Leopold and Carson each use very evocative and descriptive language like “silence” giving way to “pandemonium” of “trumpets, rattles, croaks, and cries” to describe a new day on the marsh. Describe a similar experience in nature.
2. Can you tell the difference between stilts, herons, geese, and coots? What does it take to know the natural world in this way?
3. Leopold describes the unfortunate paradox in wanting and needing to touch things to better understand them, with the reality that handling can often lead to destruction. Carson describes the unwanted side effects of well-intentioned actions. Discuss an experience you had that led you to understand this paradox.
4. Can you think of ways that people can appreciate and understand parts of the natural world without unintentionally destroying them?

CASE STUDY

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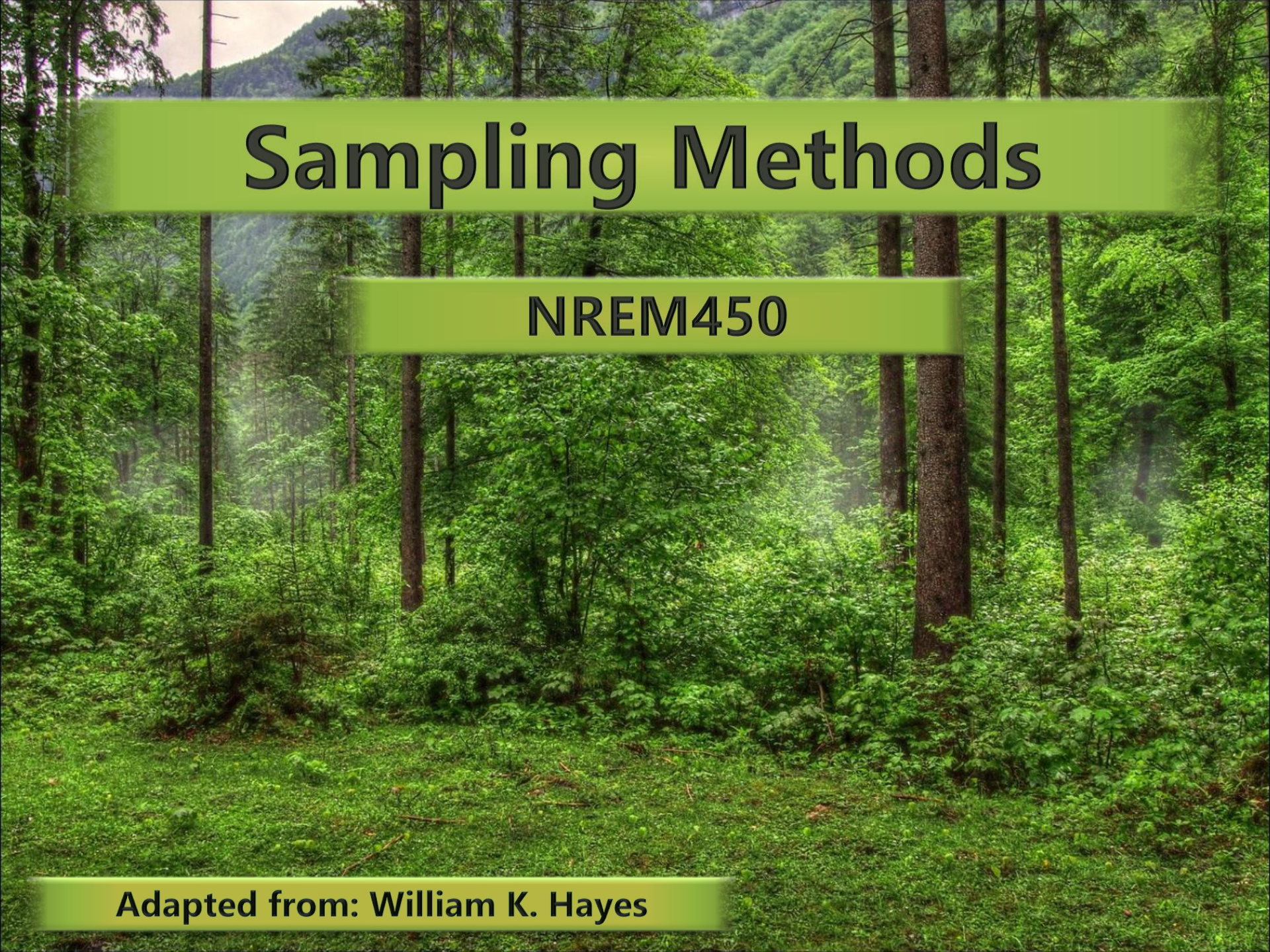

Sampling Methods
NREM450
Adapted from: William K. Hayes

General Considerations

WHY SAMPLE?
WHAT IS THE GOAL?

- To estimate population size
- To monitor population changes
- To ascertain why species have declined
- To examine population dynamics (growth rate and changes in abundance; rates of mortality, reproduction, etc.)

Know Your Organism

- It is ideal to study the literature and observe the organism(s) in the field prior to study

CENSUS VS. SURVEY

- What do we mean by a survey?

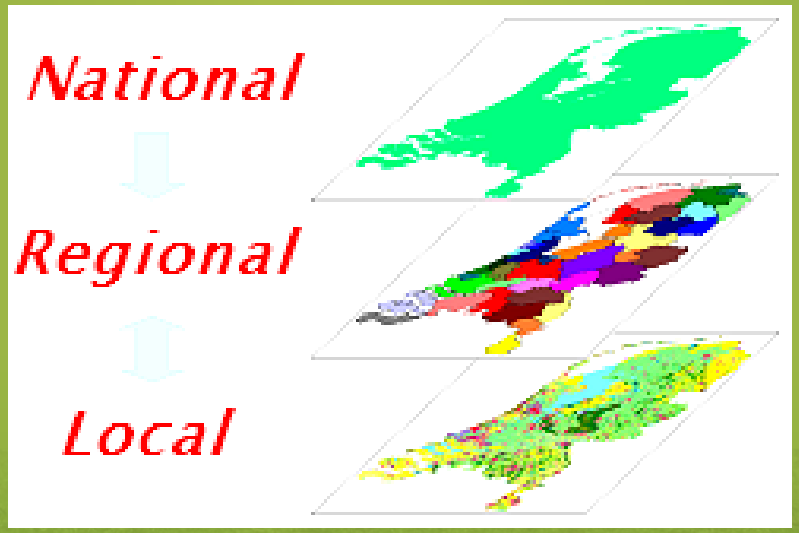
CENSUS VS. SURVEY

- Census
  - A full and complete count of the population
- Survey
  - A portion of the population is studied (most surveys represent only a sample of the population)
- Terms often used interchangeably

BASIC SAMPLING CONSIDERATIONS

BASIC SAMPLING CONSIDERATIONS

- Scale
  - What geographic scale do you wish to sample? The ideal sampling design depends on scale



BASIC SAMPLING CONSIDERATIONS

- Randomization
  - Essential to avoid error (bias) resulting from sampling in different habitats, at different times of the day, in different search patterns, etc.
  - Random number tables are often used to make sampling decisions

BASIC SAMPLING CONSIDERATIONS

- Replication and standardization
  - Multiple sampling efforts, standardized for consistency, will increase precision of population or density estimates and can minimize bias arising from individual samples
  - Sampling programs should be designed whenever possible to allow for statistical evaluation

BASIC SAMPLING CONSIDERATIONS

- Assumptions and independence
  - Every method has its own sets of assumptions; the investigator needs to be aware of these at the outset
  - Chief among these is the assumption that each observation and each sample is independent of others, as usually required by statistical models
- Use of multiple approaches
  - Several sampling methods may be used in conjunction to obtain more relevant and even more precise data and estimates

Reliability

KNOW THE RELIABILITY OF METHODS & DATA

- Know the reliability of the various methods and your data set
- Need to get a handle on three key aspects of your data:
  - Precision
  - Accuracy
  - Bias

KNOW THE RELIABILITY OF METHODS & DATA

- Precision
  - A measure of normal variation, i.e. how much the results deviate from the true value; precision increases with (and in proportion to the square root of the) sample size
  - Example – May use 95% Confidence Limits with CL1 and CL2 being lower and upper limits
  - Example – May use Percentage Relative Precision (PRP) for which N = population estimate and

$$PRP = 50 \times (CL2 - CL1) / N$$

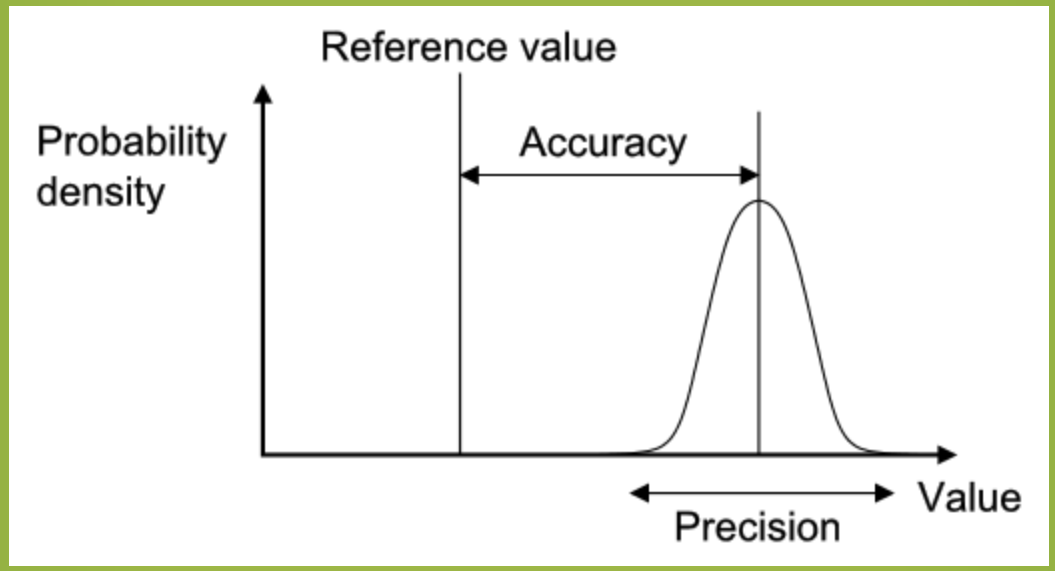
KNOW THE RELIABILITY OF METHODS & DATA

- Accuracy
  - A measure of how near the estimated (or sample) mean is to the true mean, and is often influenced by bias

KNOW THE RELIABILITY OF METHODS & DATA

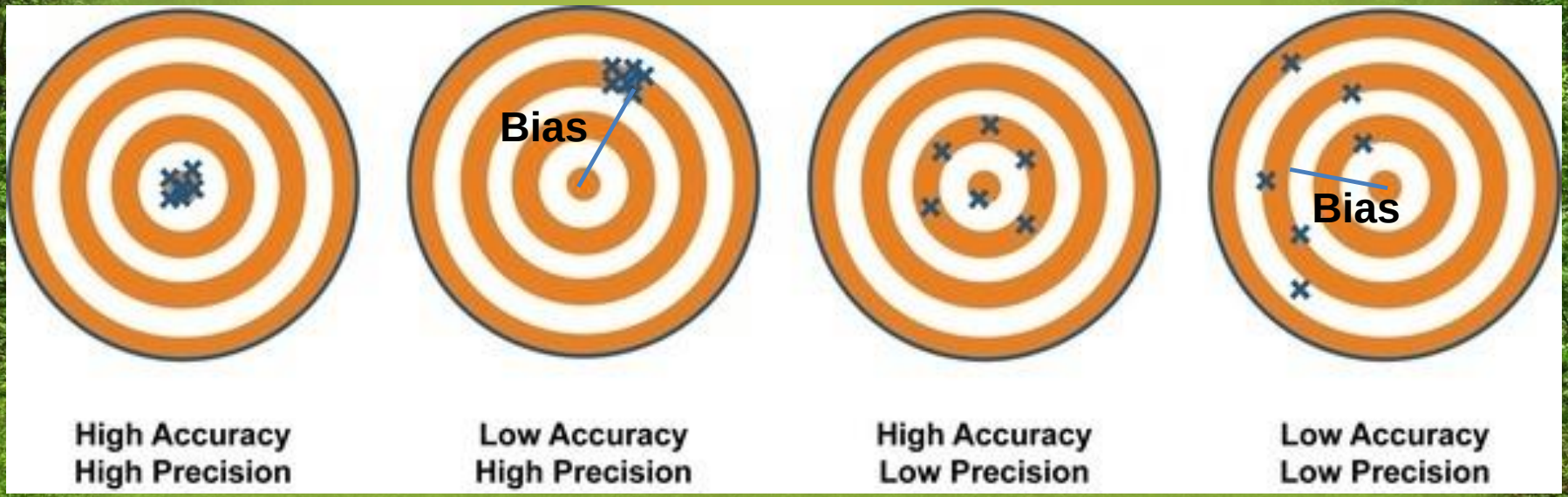
- Bias
  - Systematic measurement error in a certain direction (more or less than the true value) resulting from poor practical techniques. With systematic bias, multiple samples will not improve accuracy
  - There are many potential sources of bias and, while these cannot always be controlled, they should be identified and minimized

KNOW THE RELIABILITY OF METHODS & DATA



KNOW THE RELIABILITY OF METHODS & DATA

- Relationships among accuracy, precision, and bias



Observer	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6
Kainoa	3	6	1	15	3	7
Jodi	2	4	0	14	1	6
Peyton	3	6	3	14	5	6
Actual #	4	6	2	16	3	8

Three students collect survey data on number of nests per pond. Later that day, a DLNR biologist searches the ponds and finds the actual number of nests in each pond.

Which student has the highest precision? -Jodi

The highest accuracy? -Peyton

The lowest precision? -Peyton

The lowest accuracy? -Jodi

Explain.

KNOW THE RELIABILITY OF METHODS & DATA

- Sources of bias for detectability include variation in:
  - ~ Observer ability
  - ~ Effort and speed
  - ~ Species, gender, or size class
  - ~ Animal activity
  - ~ Time of day
  - ~ Detection methods
  - ~ Habitat variation
  - ~ Relative density
  - ~ Season
  - ~ Weather
  - ~ Increasing familiarity with habitat and/or individual animals

Other Considerations for Choice of Method

OTHER CONSIDERATIONS FOR CHOICE OF METHOD

- Price
  - Some methods are more expensive than others
- Manpower
  - Some methods are more labor-intensive than others
- Time
  - How much time is available and how much time is required by a given method?

OTHER CONSIDERATIONS FOR CHOICE OF METHOD

- Safety of Animals
  - Some methods are injurious or fatal to animals (or their habitats)
- Safety of Investigators
  - Some methods can be dangerous to implement
- Advantages / disadvantages
  - Relative to other techniques (will abbreviate as A/D)

OTHER CONSIDERATIONS FOR CHOICE OF METHOD

- Limitations (Biases)
  - For specific species, habitats, seasons, weather conditions
- Permits
  - Some permits are often required by local or government agencies for research on vertebrate animals, and many institutions require approval from committees that oversee animal research

Levels of Sampling (From Simplest to Most Invasive)

Levels of Sampling

- Detection and/or Observation
  - May be absolute (actual numbers) or relative (e.g., catch per unit effort)
- Capture
  - Passive methods – The animal enters a trap or detection device
  - Active Methods – The investigator actively finds and pursues the animal

Levels of Sampling

- Taking measurements
  - ~ Mass, body length, tail length, foot length, bill length, etc.)
- Marking
  - ~ For individual recognition
- Collecting biological samples
  - ~ Tissues, fluids, scales, hairs, feathers, feces, etc.

Collecting associated environmental data (as needed)

ASSOCIATED ENVIRONMENTAL DATA

- Basic Weather Data
  - May include temperature (at least minimum, maximum), precipitation, relative humidity, cloud cover, substrate moisture, barometric pressure, wind speed and direction, water levels, pH, etc.
  - Standard metric units are always ideal
- Geographic Characterization
  - May include country or island group, state or province, county (or district or other tertiary division), drainage system or other geographic data, specific locality, latitude and longitude (easily obtained by GPS), elevation

ASSOCIATED ENVIRONMENTAL DATA

- General Habitat Features
  - Useful to identify key features of various habitats to determine the distribution of different habitats in study area
  - Consider terrestrial habitats
    - ~ Kinds of vegetation, canopy cover, limb diameter at breast height, epiphyte load and type, nature of water-holding structures like tree holes, maintenance of habitat (natural, anthropogenic, fire), extent or regularity of seasonal flooding, description of climate, degree of disturbance, soil type, angle of slope, etc.

ASSOCIATED ENVIRONMENTAL DATA

- General Habitat Features
  - Consider aquatic habitats
    - ~ Habitat type (e.g., lake, pond, swamp, ditch, rain puddle), size (surface area), depth (minimum, maximum, average), relative duration of availability (e.g., permanent, vernal), nature of shoreline or emergent vegetation, current, substrate types, etc.

ASSOCIATED ENVIRONMENTAL DATA

- General Habitat Features
  - Consider marine habitats
    - ~ Habitat type (e.g., intertidal, subtidal, benthic, pelagic), depth, nature of substrate, habitat structure (e.g., rock size, kelp, flotsome), current, temperature, salinity, etc.

ASSOCIATED ENVIRONMENTAL DATA

- Microhabitat Features
  - Ideally, a number of elements should be recorded for each observation:
    - ~ Date and time of observation
    - ~ General location, vegetation type, elevation
    - ~ Horizontal position (e.g., distances from bodies of water, shade-casting vegetation, shore, etc.)
    - ~ Vertical position (subsurface, on soil surface, beneath shelter on surface, above ground height, in water, depth in water, etc.)

ASSOCIATED ENVIRONMENTAL DATA

- Microhabitat Features
  - Ideally, a number of elements should be recorded for each observation:
    - ~ Substrate (e.g., mineral soil, dead leaves, rock, log, vegetation)
    - ~ Special information (e.g., in sun or shade, in termite mound, under exfoliating rock, association with other species, etc.)

CONCLUSIONS

- Articulate your goal
- Know your target species
- Choose your methods wisely
- Understand the reliability and limitations of your data
- Don’t forget to collect associated environmental data

CASE STUDY

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