Model Based Statistics in Biology

Chapter 2.2 Types of Measurement Scale

ReCap (Ch 1, Ch 2.1)
Ch2 Quantities
2.1 Five part definition
2.2 Types of measurement scale
2.3 Data collection, recording, and error checking
2.4 Graphical and tabular display of data
Critique of graphs and tables (Lab 5)
2.5 Ratio Scale Units
Base
Standard Multiples
Commonly used units in biology
2.6 Dimensions

on chalk board

Not here last time?
Course Outline
Questionnaire results

Discussion of Cards Lab:
Anybody come up with "wrong" rule that works?
In 1997 mutually exclusive pairs introduced ("test" cards), before going to multiple working hypotheses ("crucial" cards).
Ask for discussion of this, comparison of "test" and "crucial."
In 1998 crucial cards only.

ReCap Chapter 1

The Role of Statistics in Science

Statistics have come to play a central role in the biological, psychological, and health sciences.

Model Based Statistics in Biology

Simplification required to deal with uncertainty and with biological complexity

△ Verbal, graphical, and formal model (equations)

Models are used to make: useful calculations (species extinction)
decisions (experiments. yes/no)

Role of statistics: Development of models (exploratory analysis)
Formal evaluation of models (confirmatory analysis)

Quantitative reasoning about biological phenomena.

Not a course in math. Not a course in rote learning of list of tests.
It is a course in how to think with measured quantities.
It will integrate models with statistics.

ReCap Chapter 2.1

Models express ideas about the relation of quantities.
Quantities defined in 5 parts.

Wrap-up

Measurements are made on many scales.
The most common are nominal, ordinal, interval, log ratio, and ratio scales.

Quizzes are weekly because one component of learning is active engagement with ma
Quizzes are second half of a lecture, one day a week.
Collaboration is encouraged in labs, in exercises, in note taking.
For example, use e-mail to exchange data sets.
Collaboration is not encouraged on quizzes and exams.
These are individual efforts.
Set-up of the room a problem (sitting adjacent)
So: Two versions of exams
Quiz today: Not collaborative. Open book. (just like exams)

I hand out the quiz as quickly as possible, 10-20 minutes before end of class.
To speed it up, someone from class helps me.

Types of Measurement Scale (Schneider 2009 *Quantitative Ecology* Chapter 3.5)

In 1946 the psychologist S.S. Stevens (*Science* 103:677) distinguished 4 types of measurement scale.

Nominal. Outcome of measurement is "yes" or "no" also coded as 0 or 1

Ordinal. Outcome is ranking: 1st, 2nd, 3rd, etc.
No information about magnitude of difference from one rank to next.

Interval. Number of units known, but zero point does not mean 'nothing'
Example of compass direction 0^o does not mean "no direction."
Direction is relative to this arbitrary point
Indices are often on an interval scale.
Index of relative abundance might be zero,
yet there were some animals present (undetected).
Other examples are dates (2 January, Julian day 180)
Latitude/longitude

Ratio. Both number of units and zero point are known.
Example of degrees Kelvin. Can say that there is no heat content at 0^o K
In contrast, 0^o C does not mean "no temperature." still heat, so it is interval.
Example of a count.
Can take ratios or doublings
Example of intrinsic rate of increase. A population with $r = 5\%$ year^{-1} has twice the intrinsic rate of increase as a population with $r = 2.5\%$ year^{-1}
In contrast, can't take twice 20 January.

Types of Measurement Scale

In 1959 Stevens expanded the typology to include log-interval and absolute scales.

Log interval scale:

Numbers are assigned so that ratios between values reflect ratios in the attribute being measured

Examples: density (mass divided by volume), speed (distance/time)

Absolute scale;

No units assigned

Example: Counts

Notes.

Ratio compared to interval

Ratio scale time (your age) versus interval scale time (calendar date)

Ratio scale length (lake diameter) versus interval scale (lat/long).

Interval scale measurements can often be converted to ratio scale, by taking a difference.

For example, 45^{o} means NorthEast, it is interval scale.

A sailboat turns 45^{o} (from 0^{o} to 45^{o}, from 30^{o} to 75^{o} , etc)

The difference in direction is on a ratio scale.

Nominal, ordinal, and ratio scales are commonly encountered in both the natural and social sciences.

Ratio and interval measurements are sometimes grouped together as <u>cardinal</u>, leading to: Nominal, Ordinal, Cardinal.

Nominal, ordinal, interval, and ratio scales differ in the amount of information.

Many 'non-parametric' tests reduce interval or ratio scale to a less informative rank scale and so can give different results than using the interval or ratio scale data for analysis.

These four types of scales are useful in understanding differences among statistical procedures. Examples:

ANOVA based on nominal scale explanatory variable (classes).

Regression based on interval or ratio scale explanatory variable.

Logistic regression for nominal scale counts (yes/no to a %)

Poisson regression for ratio scale counts.

References

Stevens, S. S. (1946). On the theory of scales of measurement. *Science* 103: 677–680. This article was published in a widely distributed journal, to address the claim (made by some physicists) that presence/absence, or ranks, were not legitimate types of measurement.

Stevens, S.S. Measurement and Man 1958. *Science* 127:383-389

Stevens, S.S. 1959 Measurement, psychophysics and utility. In: Churchman CW and Ratoosh P (eds). *Measurement: Definitions and Theories*. Pp 18–63. New York: Wiley,

Critiques

Velleman, P.F. and Wilkinson, L. (1993) Nominal, Ordinal, Interval and Ratio Typology Are Misleading. *The American Statistician*, 47: 65-723

Moscati, I 2018. Stevens and the Operational Definition of Measurement in Psychology, 1935–1950. Chapter 8 Pages 139–146 In: *Measuring Utility: From the Marginal Revolution to Behavioral Economics*. Oxford Studies in the History of Economics (New York: Oxford University Press.

Review

Brunsdon, C. 2018. Quantitative methods III: Scales of measurement in quantitative human geography. *Progress in Human Geography* 42: 610–621