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List of Participants

Name	Department	Schedule conflicts?	Textbook
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Jamye Rouette	Health Management		
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Instructor/Professor:

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Practical Information

Welcome!!

Major news:

- to find latest course information. . . → web page for VHM 801: `people.upei.ca/hstryhn/vhm801`
- to "connect" yourself to the course (information, discussion. . .) → log into Moodle account for VHM 801 (`moodle.upei.ca`),
- to follow the course efficiently → *recommended* that you decide about textbook pretty soon.

Today's lecture: Introduction and Gentle Start

- lots of practical details about the course, incl. discussion of schedule,
- descriptive statistics for distributions, in two forms:
  - graphical displays, e.g. histograms and box plots,[1]
  - numerical summaries, e.g. mean and median,[2]
- software demonstrations, but software practice for you in the lab session (tomorrow).

[1] Textbook coverage: Stephens: Chapter 3; Baldi & Moore: Chapter 1.
[2] Textbooks: Stephens: Chapter 2; Baldi & Moore: Chapter 2.

Computing Resources

Calculators:

- the traditional learning tool for statistics, and may improve understanding of formulas and methods,
- in this course: handy during labs, essential for exams; a calculator with basic calculus[3] should suffice.

Computers and statistical packages

- today we cannot imagine statistics without computers,
  - easier — avoids tedious calculations, and widens the feasible range of models and analyses,
  - increases also the risk of errors . . . ,
- in this course we use primarily[4] Minitab (version 17) but support also Stata (v. 13/14); both software packages:[5]
  - are well-documented and updated packages, and are available at the network (AVC/UPEI license),
  - have good graphing facilities,
  - have both menus and commands,
- you choose between Minitab and Stata — a trade-off:
  - Minitab: is easier to use, has better help facilities,
  - Stata: is used in the epi-courses (VHM 811 & 812), and has much wider range of statistical methods.

[3] Including memory and logarithm etc., possibly also "1-variable statistics".
[4] Virtually all demonstrations in lectures and labs will be based on Minitab.
[5] The course supports also R software, primarily for existing R users.

Course Exam

The course exam is made up by:

- 4 home assignments (two for 10% and two for 15%),
  - tentative dates: 29/9, 17/10, 3/11 and 17/11 (deadlines one week later),
  - will you have "own data" by November?
    (to replace the last assignment by a small project)
- final exam (50%):
  - *tentative* date: Tuesday 13/12,
  - 3 hours, in-class, open book,
  - no computers (instead: computer listings),
- mid-term exam (*optional* $\sim 15\%$):
  - *tentative* date: 27/10, duration: 1 hour,
  - covers Sessions $1 - 8$,
  - same conditions as final exam $\Rightarrow$ training session.

As a general rule, students who follow the course seriously should pass the exam rather easily...

Course marks in previous years:

Year	2008	2009	2010	2011	2012	2013	2014	2015
Avg. mark (%)	82.7	80.4	81.6	76.6	80.7	81.8	80.3	80.3

What's New? (vs. earlier years)

Changes in course content and organization:

- new textbooks (2014):
  - Baldi & Moore (3rd ed.) replaces previous main text (Moore, McCabe & Craig),
  - optional use of simpler text (Stephens version 4.1),
- new software or software versions (2015):
  - Minitab version 17: minor improvements over previous versions only, incl. some added analyses,
  - Stata version 14: few major changes in commands used in course from earlier versions,
  - R support: selected exercise solution files,
- new topics (2006 onwards):
  - reporting of statistical analysis in papers,
  - Bayesian methods (hard to fit into course schedule),
- inclusion of online media material (2011 onwards),
- open consultation hours (2006): possible to convert one of these into lab review covering selected problems (depending on room availability and interest...),
- optional mid-term exam (2007),
- inclusion of summary notes in lecture handouts (2013),
- inclusion of summary (review) problems in lectures (2014).

What is Statistics? and Why Statistics?

Statistics:

- 2 branches of statistics:
  - "official statistics" — the collection and display of figures in statistical yearbooks etc.,
  - "inferential statistics" — the science of analysing and interpreting data, typically from experiments or databases.
- "With statistics one can prove everything" — not true,
  - cannot really prove anything,
  - can separate random variation from systematic effects (differences, associations ...),
  - can (strongly) indicate certain tendencies in data,
  - statistical significance does *not* imply causation ..., (nor biological significance...).

Why statistics (in particular, Biostats 801)?

- mandatory[6], unless you've had "statistics" before,
- useful (indispensable) for data analysis,
- helps to develop critical sense for data and the results of data analysis,
- basics/building block for more advanced methods.

[6] UPEI Calendar: "All [AVC] students are expected to complete VHM 801 [...] unless comparable training has been completed prior to entry into the program."

Data

Give an example of data (real or hypothetical) related to your project!

Organization of data:

- individuals (units of measurement/observation, experimental units, subjects) = the objects described by a set of data (people, animals, things),
- variables = characteristics (measurements, recordings) of the individuals,
- organized in computer programs in spreadsheet format with individuals as rows and variables as columns.

Types of variables:

- quantitative[7] (either continuous or discrete):
  - takes numerical values for which arithmetic operations such as adding and averaging make sense,
  - values often have units or are counts,
- categorical (also grouped/qualitative):
  - places individuals into one of several categories,
  - categories often have labels,
  - categories may be unordered (nominal) or ordinal,
  - a quantitative variable may be split into categories.

[7] S further distinguishes between interval and ratio measurements.

Data Example: Parasites

"Natural Trichostrongylid exposure of calves in Lithuania" (study in parasitology):

- 19 calves, first all put at a naturally infected pasture in late spring; after 8 weeks, 9 calves moved to "safe" pasture (hay production),
- consider here faecal nematode eggs counts[8] at 10 weeks,
- 2 possible data layouts: 10 and 9 rows in 2 separate columns for each group of calves, or 19 rows with all calves:

	egg counts	
calves	infect.	safe
1	52	8
2	30	34
3	70	46
4	36	0
5	100	38
6	70	26
7	50	8
8	54	10
9	20	44
10	30	

calves	pasture	egg counts
1	infect.	52
2	infect.	30
3	infect.	70
...	...	...
10	infect.	30
11	safe	8
12	safe	34
13	safe	46
...	...	...
19	safe	44

[8] scaled to: per $0.1g$ of faeces.

Statistical Concepts and Procedures

Distributions:

- tell us what values a variable takes, and how often,
- features: shape, center, spread, and deviations from overall shape,
- distributions of continuous and categorical variables are the same thing, but displayed in different ways,
  - categorical distributions as a list of values and how often each value occurs,
  - quantitative distributions often displayed in groups,
- 2 types of distributions:
  - data (observed or empirical distributions),
  - theoretical (that we use for modelling data).

Outline of statistical analysis (first part):

- Data description:
  - descriptive statistics: plots, tables, simple statistics,
  - purpose:
    - provide overview of the data,
    - detect errors / "different observations" (outliers[9])
    - focus attention on what's relevant,
    - aid subsequent modelling of the data.

[9] Outlier (informal def.): observation that does not belong with the other values.

Graphs of Categorical Variables

Another data example: Migration to/from PEI July 2014 – June 2015:[10]

Province	Immigrants to PEI Count	Immigrants to PEI Proportion	Emigrants from PEI Count	Emigrants from PEI Proportion
NL	196	8.9%	142	4.1%
NS	343	15.6%	615	17.9%
NB	322	14.6%	295	8.6%
QC	95	4.3%	107	3.1%
ON	738	33.5%	786	22.8%
MB	25	1.1%	29	0.8%
SK	24	1.1%	44	1.3%
AB	345	15.7%	1097	31.8%
BC	91	4.1%	286	8.3%
terr.	23	1.0%	44	1.3%
total	2202	100.0%	3445	100.0%

Bar graph:

- displays number in each group as a bar of corresponding height,
- generated in Minitab using the menu Graph–Bar chart (using "Values from a table", and province as a categorical variable).

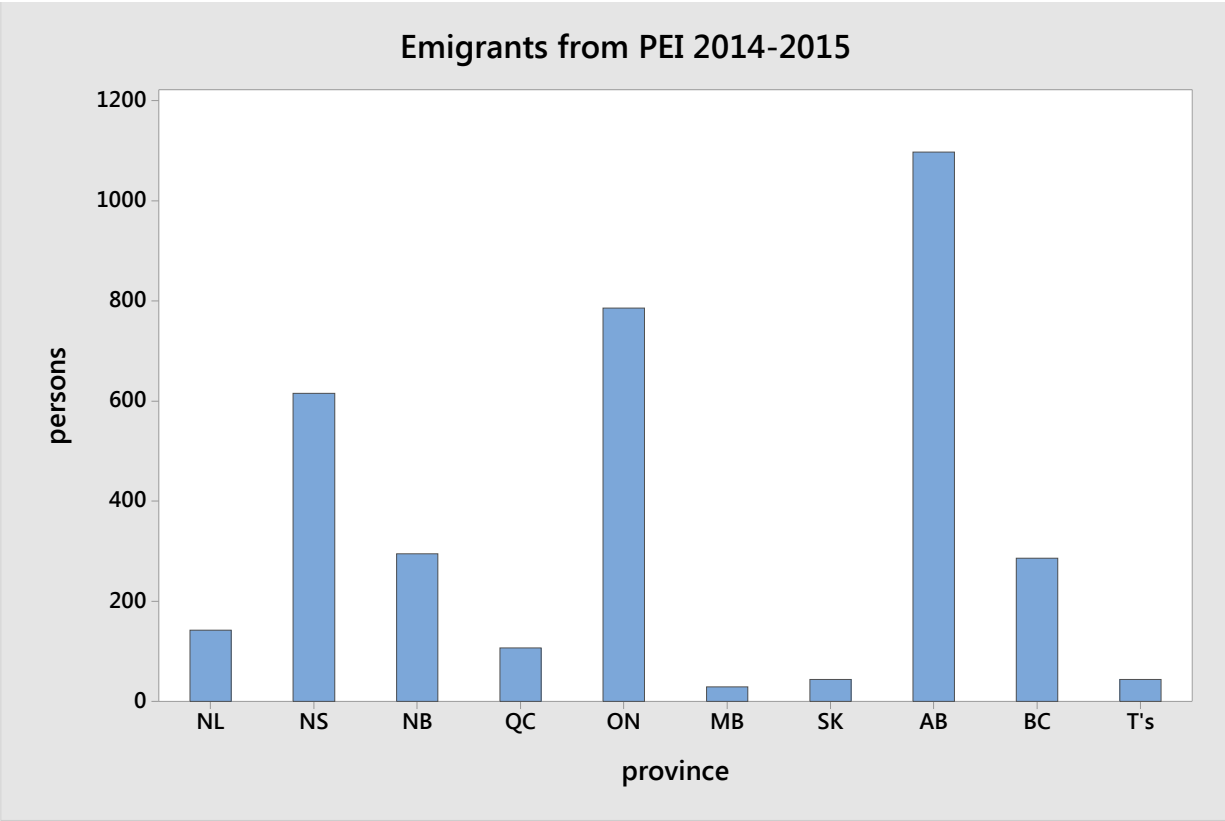
Pie chart:

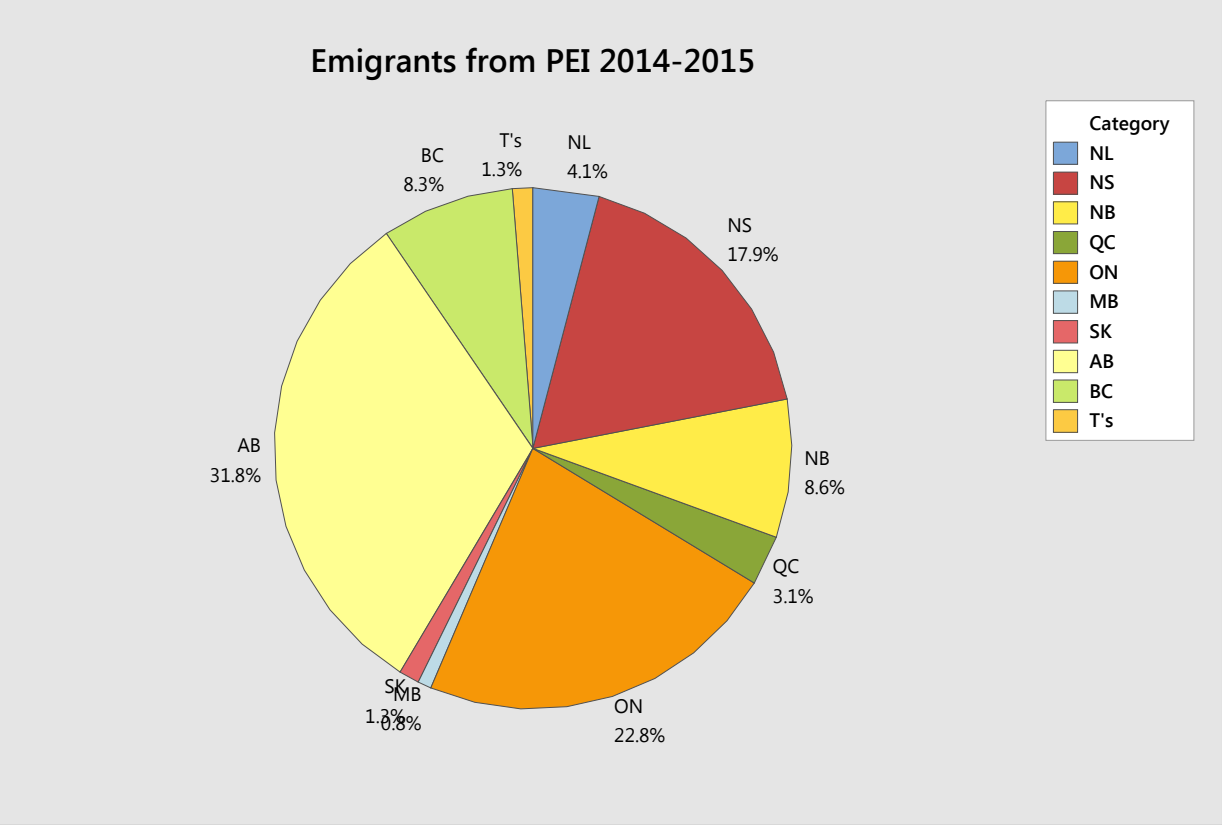
- displays the proportions (summing up to 100%) as corresponding parts of a pie,
- generated in Minitab using the menu Graph–Pie Chart (as above).

Note: pie charts are only for proportions; in bar graphs, the numbers need not to be seen relative to their total.

[10] https://www.princeedwardisland.ca/sites/default/files/publications/stats2015.pdf

Bar Graph and Pie Chart





Graphs of Quantitative Data: Stemplots

Stem plot (or, stem and leaf plot):

- more a (vertical) listing than a plot, displaying a distribution's pattern — shape, center, spread,
- requires first the separation of each data value into "leaf" and "stem" parts,
  - for two-digit numbers (e.g. 15), the "stem" is usually the first digit (1), and the "leaf" is usually the last digit (5),
  - for multi-digit numbers (e.g. 156), may truncate least important digits to retain two digits (i.e., 156 $\rightarrow$ 150),
  - may split stems further before separating into stems/leaves,
- method of display:
  - write stems in a vertical column sorted (increasingly) from top to bottom,
  - write leaves right of stems (and separated by vertical line), and sorted out from the stem,
- back-to-back stem plots for two groups using same stems.

Stem plot (done manually) for parasite data, safe group:

```
Safe group (0,8,8,10,26,34,38,44,46)

  0 | 088
  1 | 0
  2 | 6
  3 | 48
  4 | 46
```

Stemplots Produced by Software

Minitab plots (cannot be done side-by-side):

```
Infected                Safe
1    2    0             3    0   088
4    3    006           4    1   0
4    4                 (1)   2   6
(3)  5    024           4    3   48
3    6                 2    4   46
3    7    00
1    8
1    9
1    10   0
```

Stata plots (cannot be done side-by-side):

```
Infected                Safe
2** | 0                 0** | 088
3** | 006               1** | 0
4** |                   2** | 6
5** | 024               3** | 48
6** |                   4** | 46
7** | 00
8** |
9** |
10** | 0
```

Graphs of Quantitative Data: Histograms

Stem plots are good for small datasets, for larger datasets we often use histograms:

- divide the data range into classes of *equal* width,
- for each class, count the number of observations and draw corresponding bar/bin (no space between bars),
- may also plot the proportions (relative frequencies) by dividing with the total number of observations,
- procedures exist also for histograms of unequal width, where the bar area and not the height reflects the numbers (Exercise 1.22).

Demonstration by another data set: Weight in g of 162 crabs.

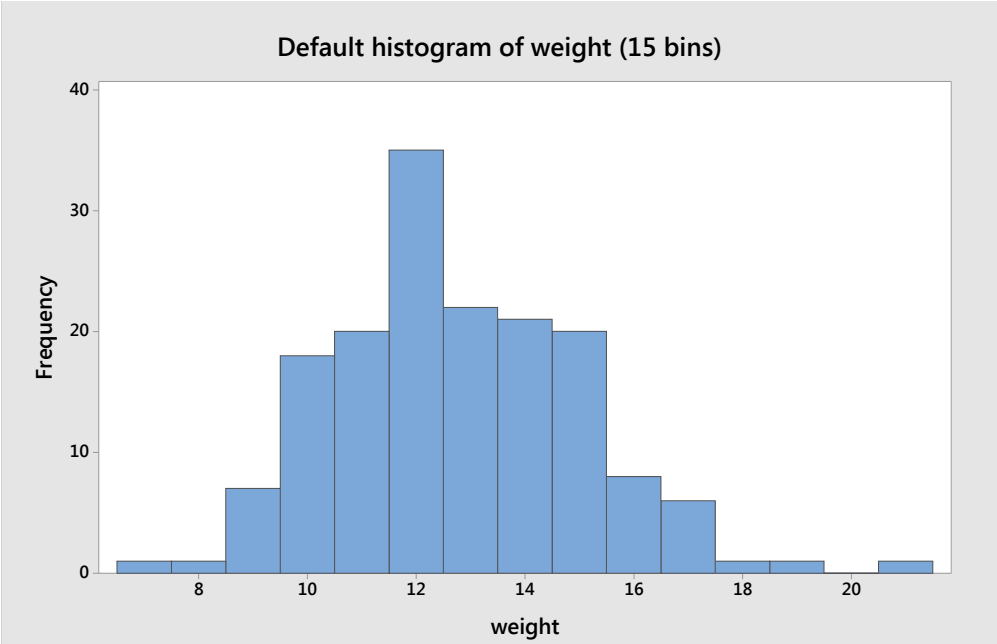
Histograms in practice:

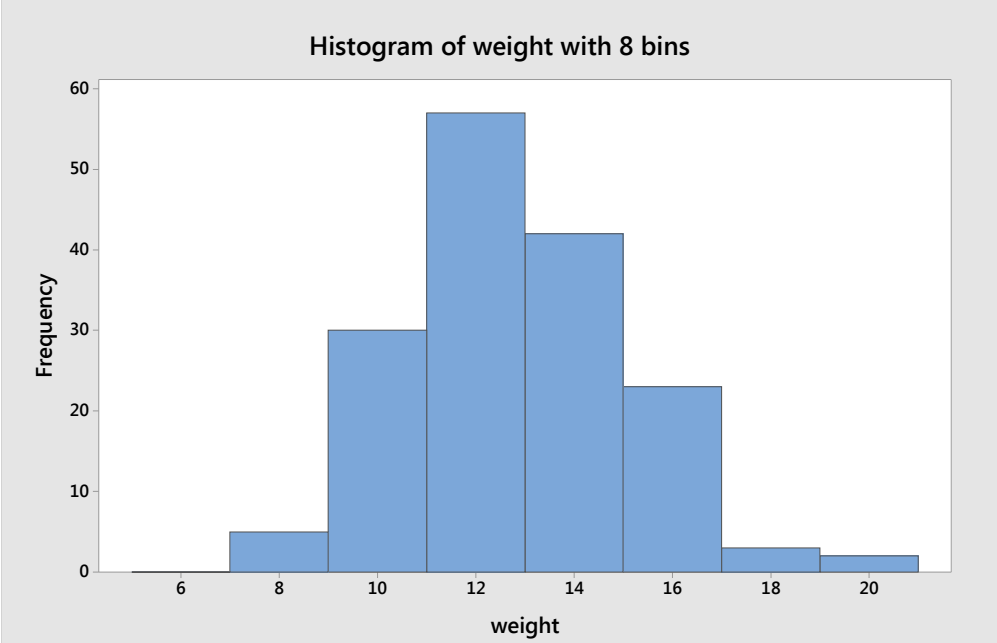
- generated by computer program, here Minitab using command Graph−Histogram,
- displays the distribution's shape, and shows additional features such as mode(s) and symmetry/skewness,
- the number and location of bars affect the shape of the histogram; rules of thumb exist.[11]

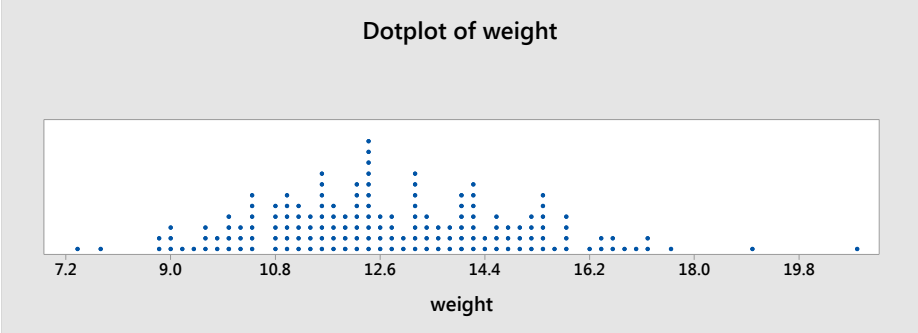
In a dotplot, data points are marked above a horizontal axis: most useful for small n.

[11] For n observations, the Stata default is $\sqrt{n}$ bars for $n \leq 900$, and $10 \times log_{10}(n)$ bars for $n > 900$, whereas the R default (Sturges' formula) is $(1 + log_2(n))$ bars.

Graphs for Crab Weight Data







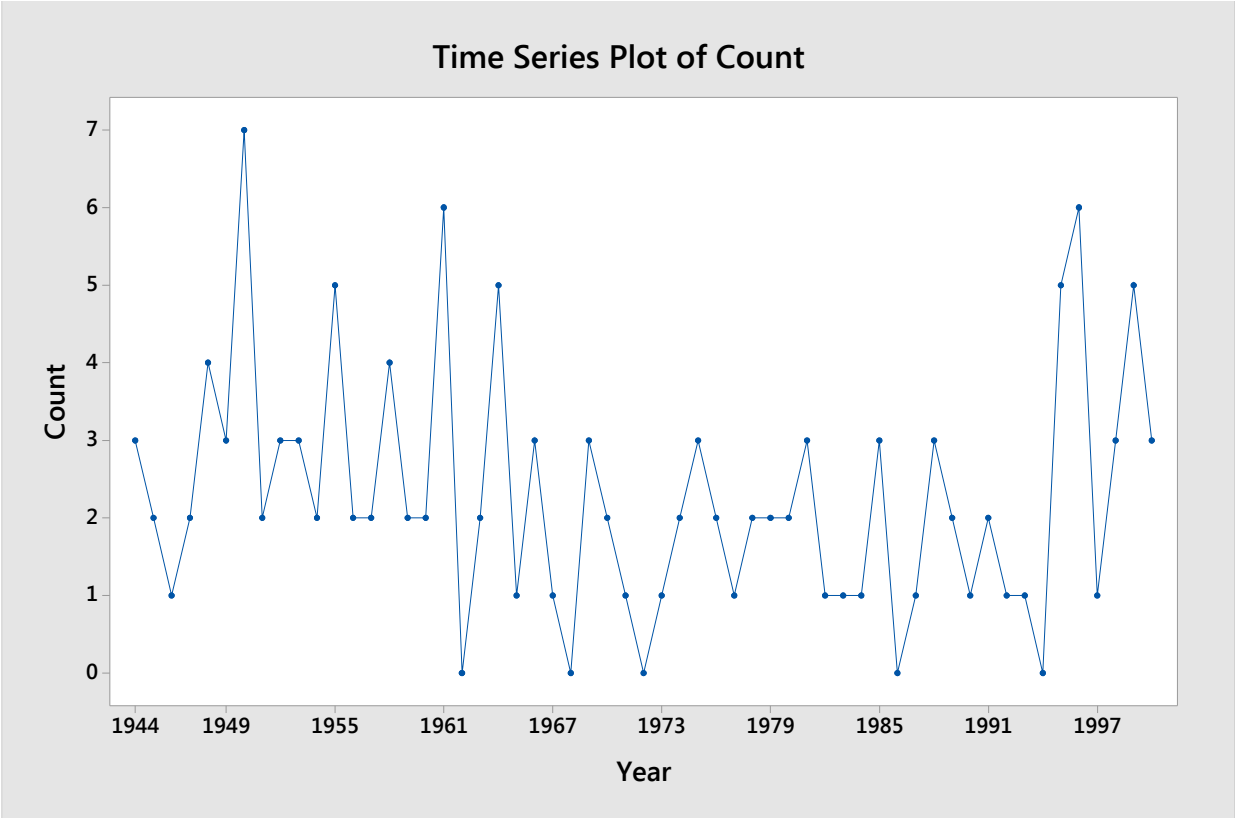
Time Plots

Time plots = plots against time (time as x-axis):
may be useful for descriptive purposes, e.g. to show,

- trend: persistent, long-term rise or fall,
- seasonal (periodic) variation: repeating patterns, not necessarily related to yearly seasons,
- data errors or unstable conditions developing over time,

Example: Hurricanes (Atlantic) in the United States (Exercise 1.23):

- plot generated using Minitab command Graph−Time Series Plot (with Year as "Stamp" variable).



Mean and Median

Mean (average) and median (middle value) are numeric quantities related to the center of a distribution, but different in definition and interpretation. We will first define them for an observed distribution (data).

Data: $x_1, \ldots, x_n$, a total of n obs. in arbitrary order.

Mean/average:

$$\bar{x} = \frac{x_1 + \ldots + x_n}{n} \quad \text{or} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i.$$

- most commonly used and perhaps most intuitive single value reported from a sample/dataset,
- can be appreciably affected by a few extreme obs.

Median:

- order the observations from smallest to largest,
- next step depends on whether n is odd or even:
  - odd: median = observation in the middle, that is, number $(n+1)/2$ from either end,
  - even: median = average of two middle observations, that is, numbers $n/2$ and $(n+2)/2$.

- has 50% of distribution to either side,
- is little affected by a few extreme observations
  $\Rightarrow$ resistant (or robust).

Statistics for parasite data:

Pasture	n	mean	s	min	Q_1	median	Q_3	max
infected	10	51.2	24.0	20	30	51	70	100
safe	9	23.8	17.6	0	8	26	41	46

Symmetry/skewness and measures of center:

- symmetric distribution: mean = median,
- right-skewed distribution: mean > median,
- left-skewed distribution: mean < median.

Percentiles:

- other divisions of a distribution than 50:50,
- pth percentile:
  - has p % below and $100-p$ % above,
  - determined as $(p/100) \times (n+1)$ largest obs.
    if value not number then either roundoff or interpolate between nearest obs. (software differences exist),
- special names: median M $(p = 50)$, first quartile Q_1 $(p=25)$, third quartile Q_3 $(p=75)$.

Simple Measures of Spread

Spread (width) of an observed distrib. we can measure by:

- range:
  - ∗ formula: max − min,
  - ∗ simple and easy to compute, but not resistant,
  - ∗ no theoretical counterpart in unbounded distributions (⇒ tends to increase with sample size),
- interquartile range (IQR):
  - ∗ formula: $Q_3 - Q_1$,
  - ∗ more difficult to calculate, but resistant,
- 5-number summary of a distribution:
  min, Q1, median, Q3, max,
  - ∗ gives a fair overview of the distribution's shape,
  - ∗ graphical representation = boxplot, available in Minitab using menu Graph−Boxplot.

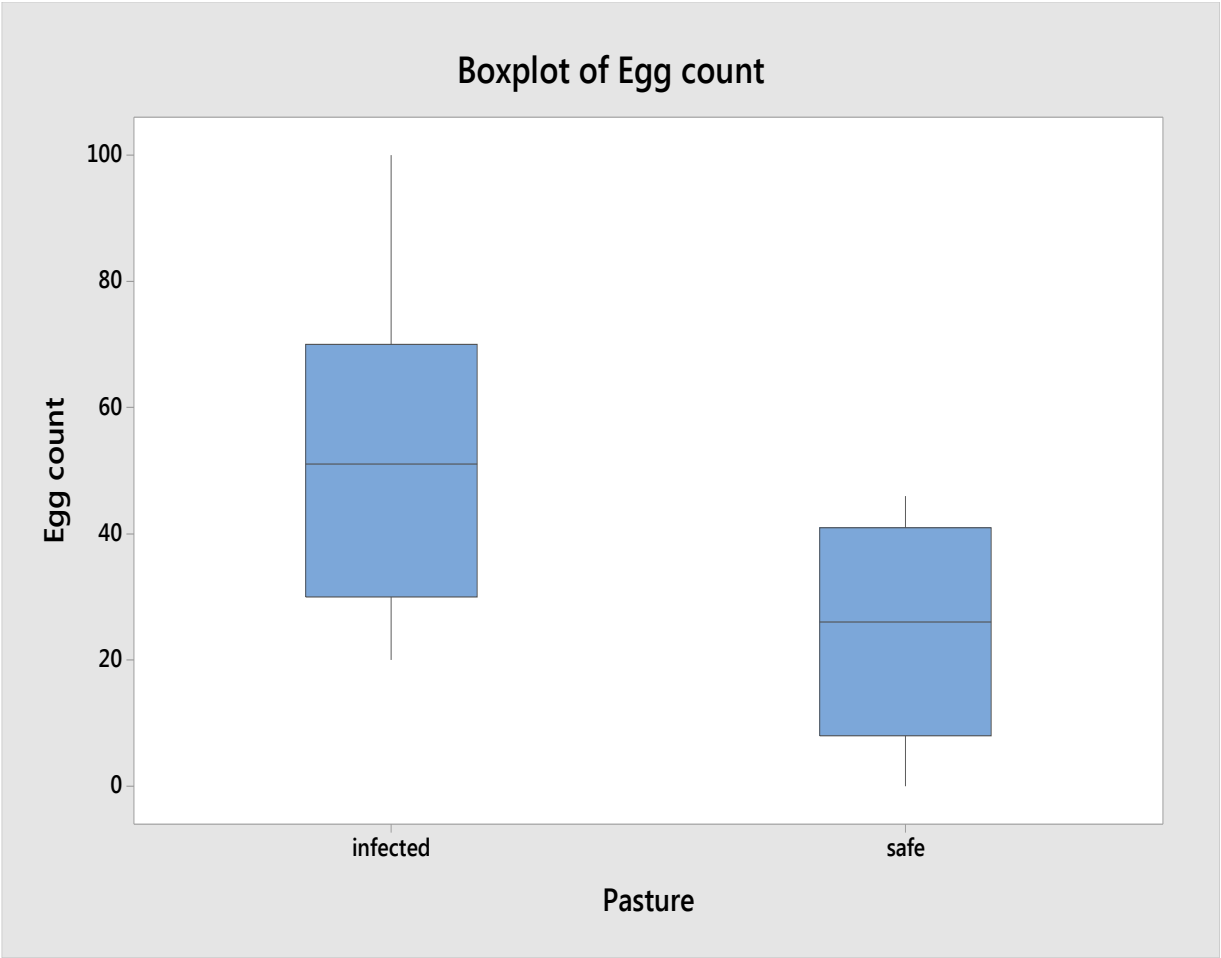
Interquartile criterion for suspected outliers:

- rule: "*suspected outlier*" if more than $1.5 \times$ IQR beyond Q_1 or Q_3 (⇒ observations worth looking at...),
- a rough guideline — often indicates too many outliers,
- based on symmetric distribution; in normal distrib.: 1.5 IQR beyond Q_3 (Q_1) $\sim$ 99.65% (0.35%) percentile.

Boxplot for Parasite Data

Also called box and whisker plot:

- the box is formed by Q_1 and Q_3,
- the box is divided by the median (in some software, the mean is also indicated),
- some software allows to adjust the width of the box (e.g. proportional to the square-root of the number of obs.),
- the whiskers extend at most 1.5 IQR beyond the box,
- observations beyond the whiskers $\sim$ asterisks.



Standard Deviation

Definition of variance s^2 and standard deviation s of an observed distribution $x_1, \ldots, x_n$:

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2, \quad \text{and} \quad s = \sqrt{s^2}.$$

— that is, we average the *squared deviations from* $\bar{x}$.

Properties of s and s^2:

- s most natural: same scale as observations themselves (s^2 on scale of squared observations)
- s^2 mathematically simplest (but less important to us),
- s measures spread about the mean,
- $s = 0$ means no dispersion (all observations equal), otherwise $s > 0$,
- s most commonly used measure of spread, and justifiably so (in my opinion), despite its pitfalls:
  - s certainly not resistant (more sensitive to extremes than $\bar{x}$),
  - as an overall measure, s does not take into account skewness in the distribution (with different spreads left and right of the center),
  - never take for granted that a distrib. with a certain mean and spread looks like a nice (normal) distrib.,
- coefficient of variation (cv) $= s/\bar{x}$ ("relative spread").

Summary Notes

Course content and organization:

* applied statistics course based on use of statistical software and with focus on critical thinking about data and results,
* course offers a wealth of options enabling each student to select the most effective learning tools,
* class participation is not required but strongly recommended (both lectures and labs),
* textbook reading is strongly recommended (and may be helpful as preparation for lectures and/or labs),
* marks are based on submitted home assignments and exams.

Descriptive analysis involves graphical and numerical representations of data,

* different techniques apply to quantitative and categorical data (and may need to be customized to actual data),
* two primary features of distributions for quantitative data are: location (center) and spread.

Key words and concepts:

- data structured by cases (individuals) and variables,
- distributions (of observed data),
- outlier (outlying observation),
- mean, median, percentiles,
- interquartile range, standard deviation, 5-number summary,
- resistant statistic.