Quality Assurance & Quality Control

References

- Primary Reference
  - Michener and Brunt (2000) Ecological Data: Design, Management and Processing. Blackwell Science.
    - Edwards (2000), “Data Quality Assurance”
    - Brunt (2000) Ch. 2, “Data Management Principles, Implementation, and Administration”
    - Michener (2000) Ch. 7: “Transforming Data into Information and Knowledge”

Outline:

- Define QA/QC
- QC procedures
  - Designing data sheets
  - Data entry using validation rules, filters, lookup tables
- QA procedures
  - Graphics and Statistics
  - Outlier detection
    - Samples
    - Simple linear regression

QA/QC

- “mechanisms [that] are designed to prevent the introduction of errors into a data set, a process known as data contamination”

Brunt 2000

Errors (2 types)

- Commission: Incorrect or inaccurate data in a dataset
  - Can be easy to find
  - Malfunctioning instrumentation
    - Sensor drift
    - Low batteries
    - Damage
    - Animal mischief
  - Data entry errors

- Omission
  - Difficult or impossible to find
  - Inadequate documentation of data values, sampling methods, anomalies in field, human errors

Quality Control

- "mechanisms that are applied in advance, with *a priori* knowledge to 'control' data quality during the data acquisition process"

Brunt 2000

Quality Assurance

- "mechanisms [that] can be applied after the data have been collected and entered in a computer to identify errors of omission and commission"
  - graphics
  - statistics

Brunt 2000

QA/QC Activities

- Defining and enforcing standards for formats, codes, measurement units and metadata.
- Checking for unusual or unreasonable patterns in data.
- Checking for comparability of values between data sets.

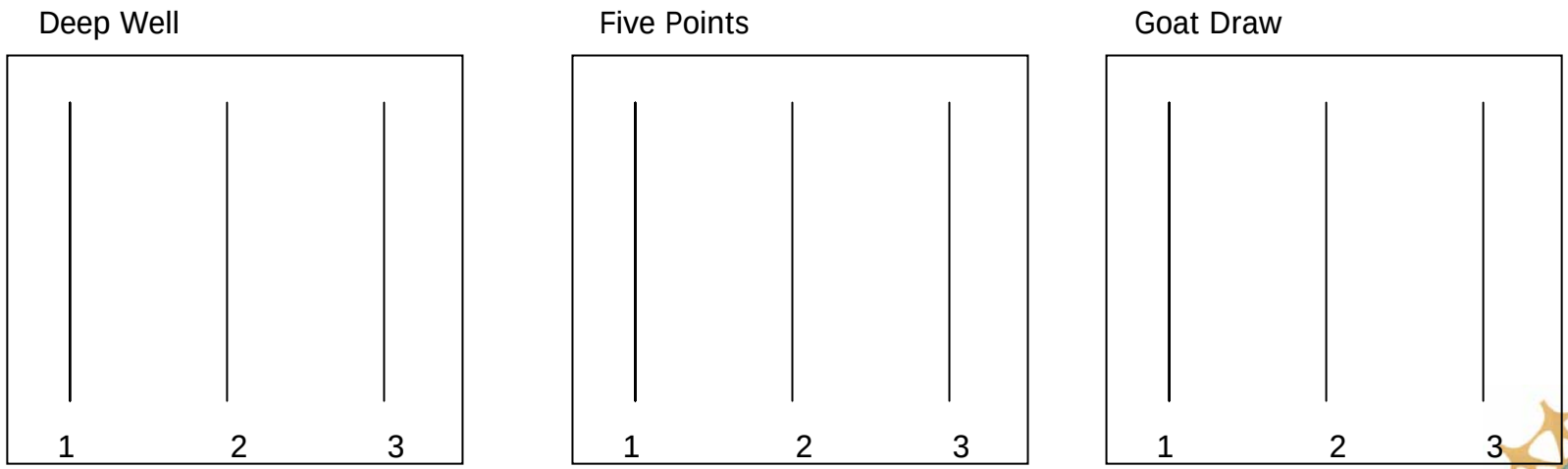
Brunt 2000

Outline:

- Define QA/QC
- QC procedures
  - Designing data sheets
  - Data entry using validation rules, filters, lookup tables
- QA procedures
  - Graphics and Statistics
  - Outlier detection
    - Samples
    - Simple linear regression

Flowering Plant Phenology – Data Collection Form Design

- Three sites, each with 3 transects
- On each transect, every species will have its phenological class recorded



Data Collection Form Development:

What's wrong with this data sheet?

Plant	Life Stage

PHENOLOGY DATA SHEET

Collectors:_____

Date:_____ **Time**:_____

Location: deep well, five points, goat draw

Transect: 1 2 3

Notes: _____

Plant	Life Stage								
ardi	P/G	V	B	FL	FR	M	S	D	NP
arpu	P/G	V	B	FL	FR	M	S	D	NP
atca	P/G	V	B	FL	FR	M	S	D	NP
bamu	P/G	V	B	FL	FR	M	S	D	NP
zigr	P/G	V	B	FL	FR	M	S	D	NP
	P/G	V	B	FL	FR	M	S	D	NP
	P/G	V	B	FL	FR	M	S	D	NP

P/G = perennating or germinating
V = vegetating
B = budding
FL = flowering
FR = fruiting

M = dispersing
S = senescing
D = dead
NP = not present

PHENOLOGY DATA ENTRY

Collectors Troy Maddux

Date: 16 May 1991 **Time:** 13:12

Location: Deep Well

Transect: 1

Notes: Cloudy day, 3 gopher burrows on transect

	P/G	V	B	FL	FR	M	S	D	NP
ardi	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
arpu	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
asbr	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
deob	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N

Outline:

- Define QA/QC
- QC procedures
  - Designing data sheets
  - Data entry using validation rules, filters and lookup tables
- QA procedures
  - Graphics and Statistics
  - Outlier detection
    - Samples
    - Simple linear regression

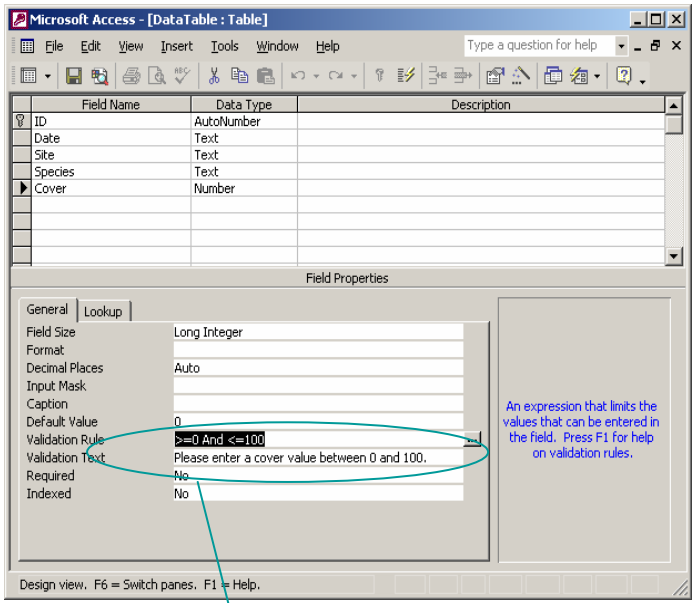
Validation Rules:

- Control the values that a user can enter into a field

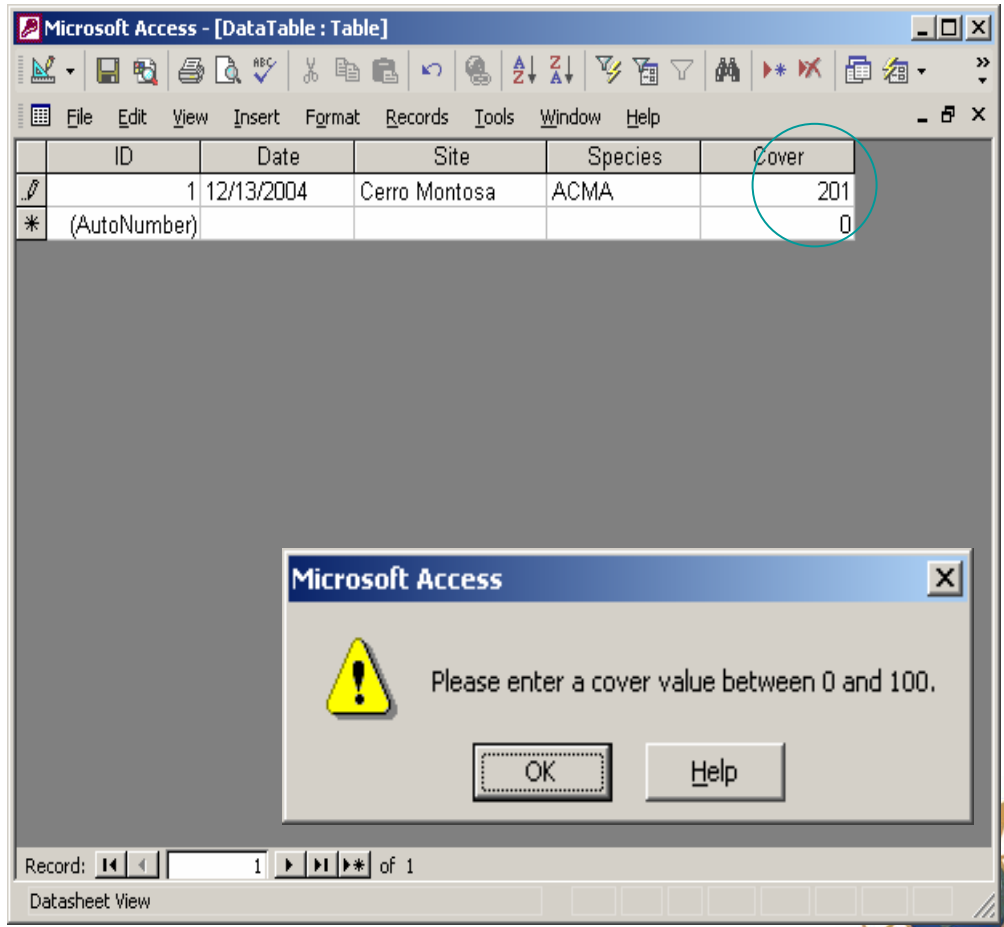
Validation Rule Examples:

- >= 10
- Between 0 and 100
- Between #1/1/70# and Date()

Validation rules in MS Access: Enter in Table Design View



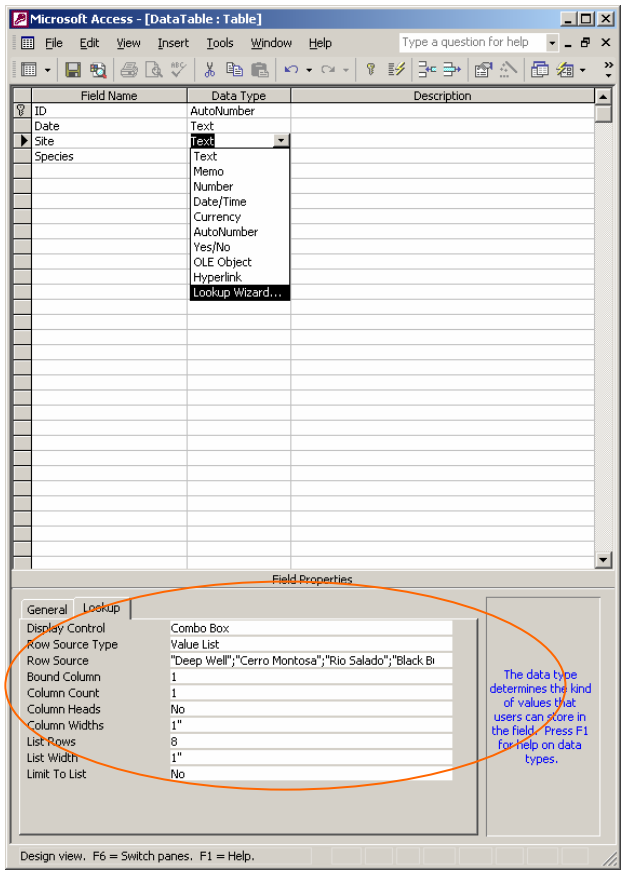
>=0 and <= 100

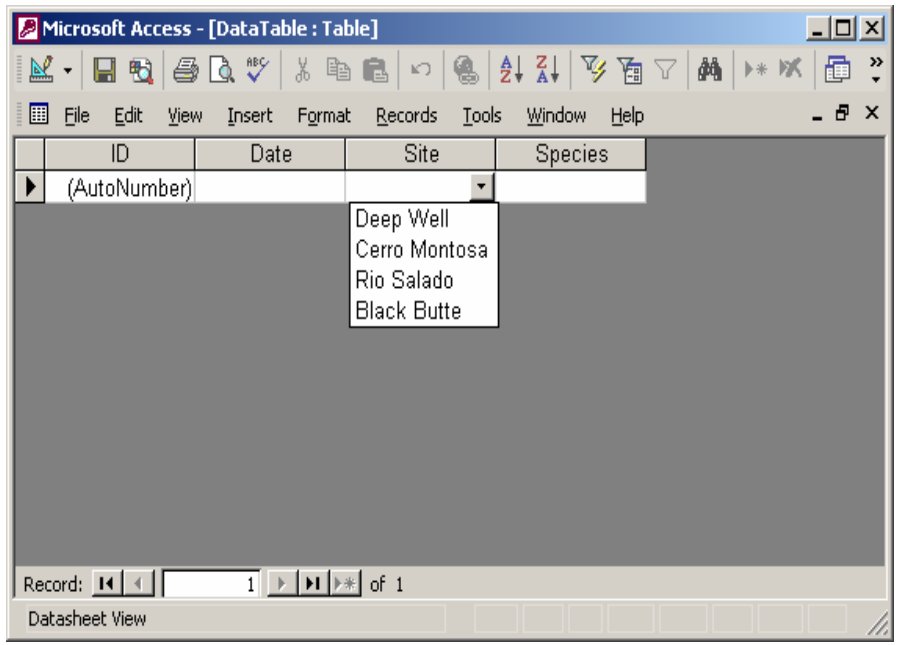


Look-up Fields

- Display a list of values from which entry can be selected

Look-up Tables in MS Access: Enter in Table Design View

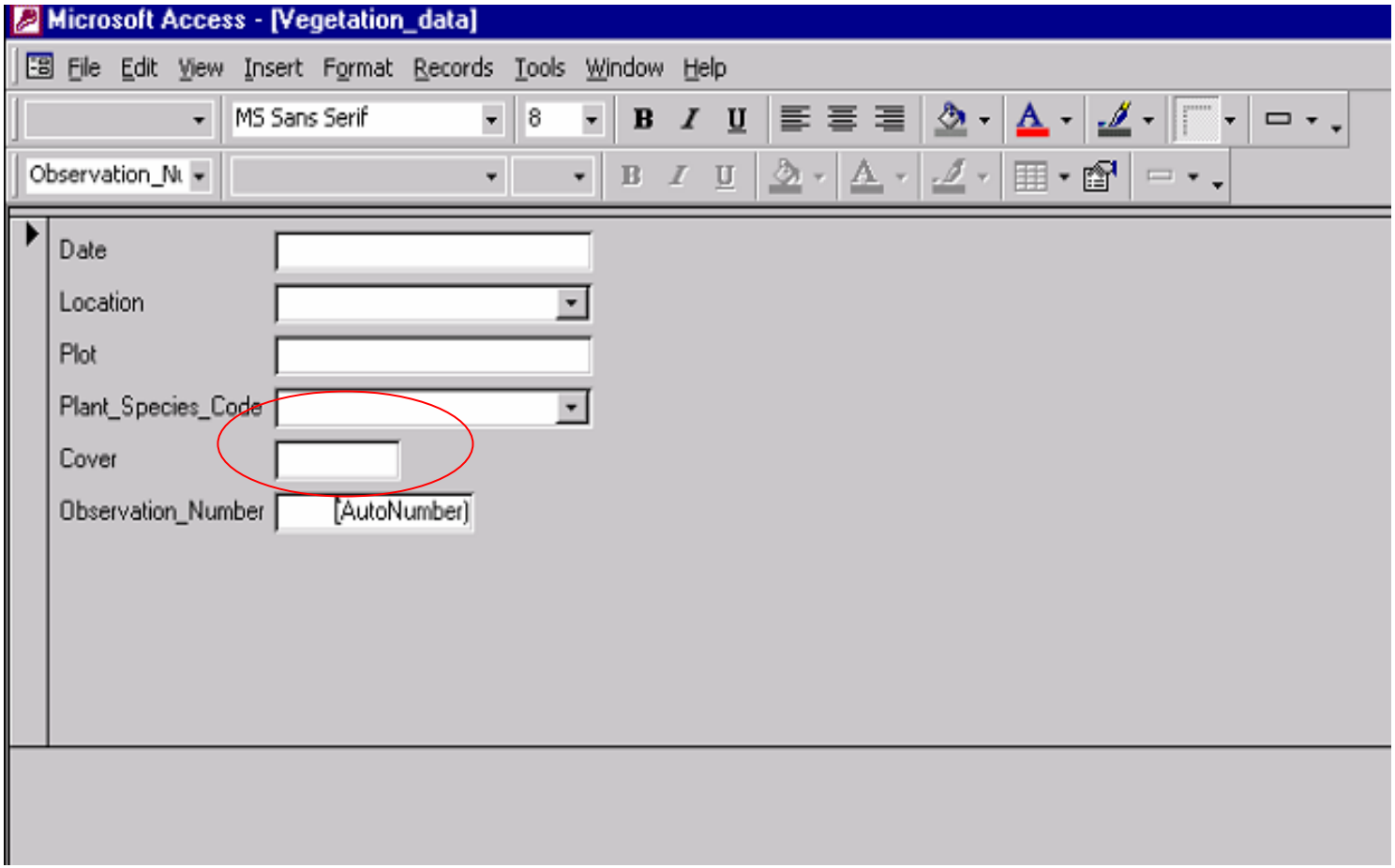


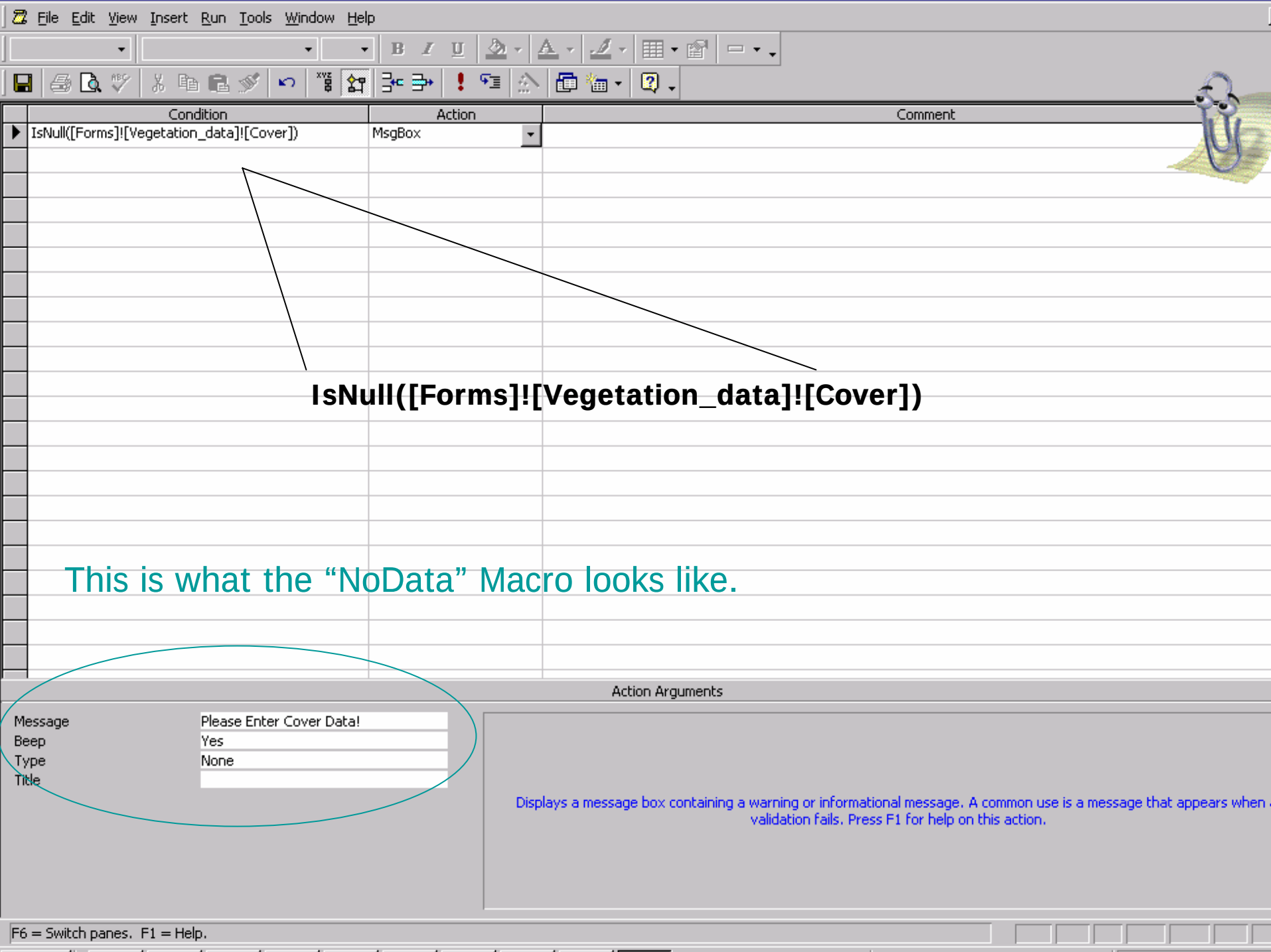


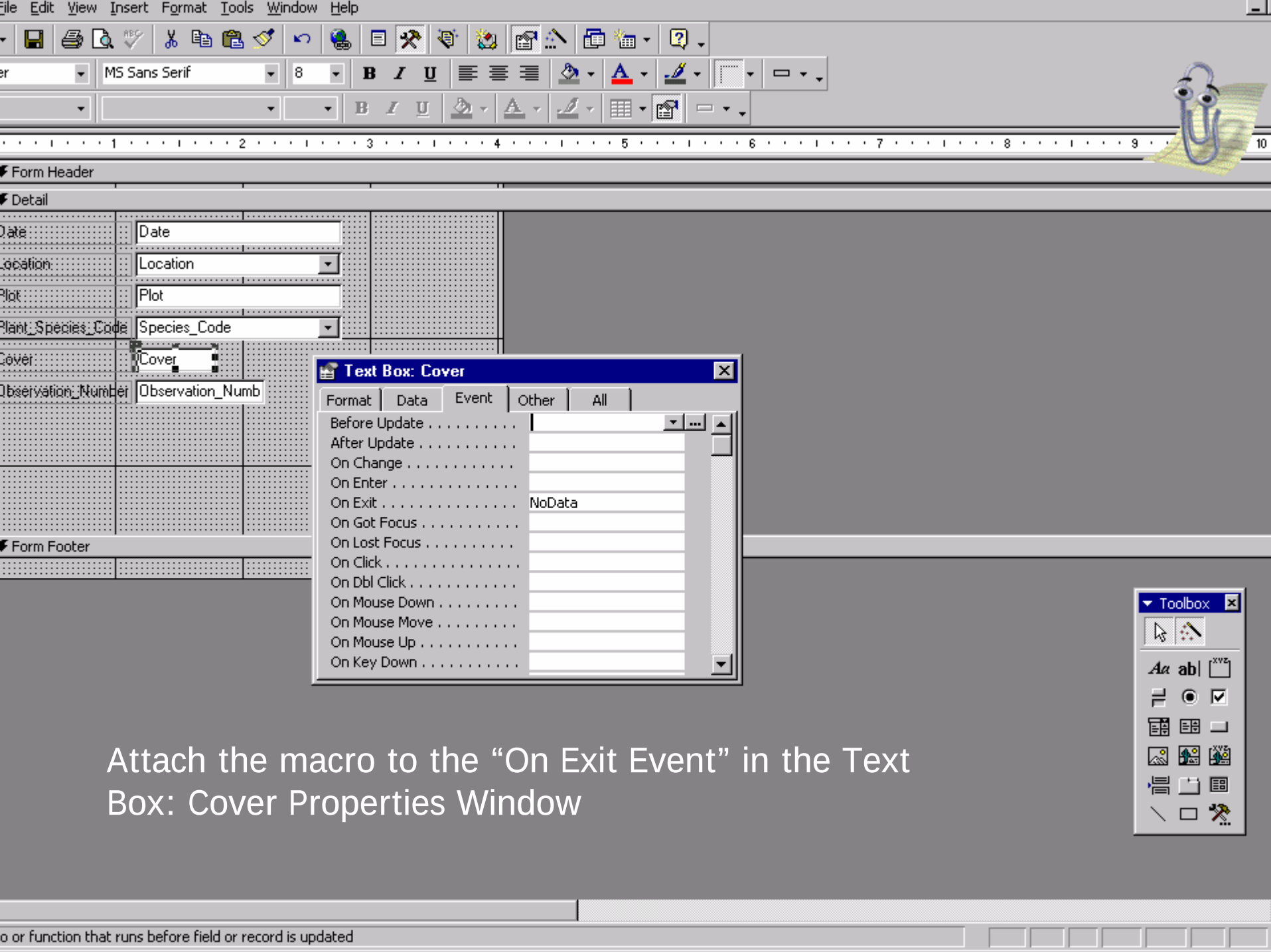
Macros

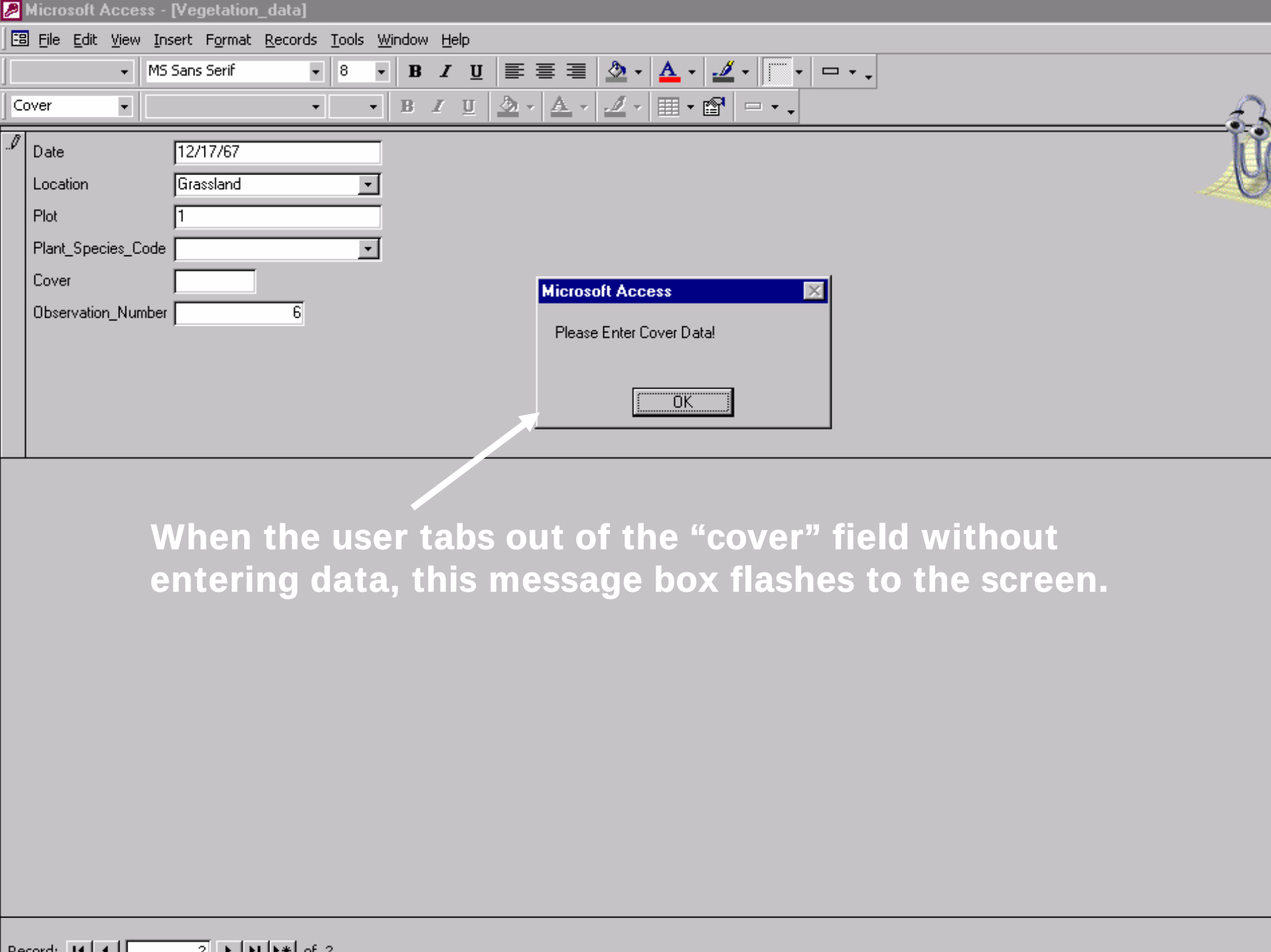
- Validate data based on conditional statements

You want to make sure that a value for vegetation cover is entered in every record. To do this, create a macro called “NoData” that will examine the contents of the cover field whenever the field is exited.




File Edit View Insert Run Tools Window Help
Condition
Action
Comment
IsNull([Forms]![Vegetation_data]![Cover])
MsgBox
IsNull([Forms]![Vegetation_data]![Cover])
This is what the “NoData” Macro looks like.
Action Arguments
Message
Please Enter Cover Data!
Beep
Yes
Type
None
Title
Displays a message box containing a warning or informational message. A common use is a message that appears when
validation fails. Press F1 for help on this action.
F6 = Switch panes. F1 = Help.


File Edit View Insert Format Tools Window Help
MS Sans Serif
8
Form Header
Detail
Date
Location
Plot
Plant_Species_Code
Cover
Observation_NumBer
Date
Location
Plot
Species_Code
Cover
Observation_Numb
Form Footer
Text Box: Cover
Format
Data
Event
Other
All
Before Update
After Update
On Change
On Enter
On Exit
NoData
On Got Focus
On Lost Focus
On Click
On Dbl Click
On Mouse Down
On Mouse Move
On Mouse Up
On Key Down
Toolbox
Attach the macro to the “On Exit Event” in the Text Box: Cover Properties Window
o or function that runs before field or record is updated

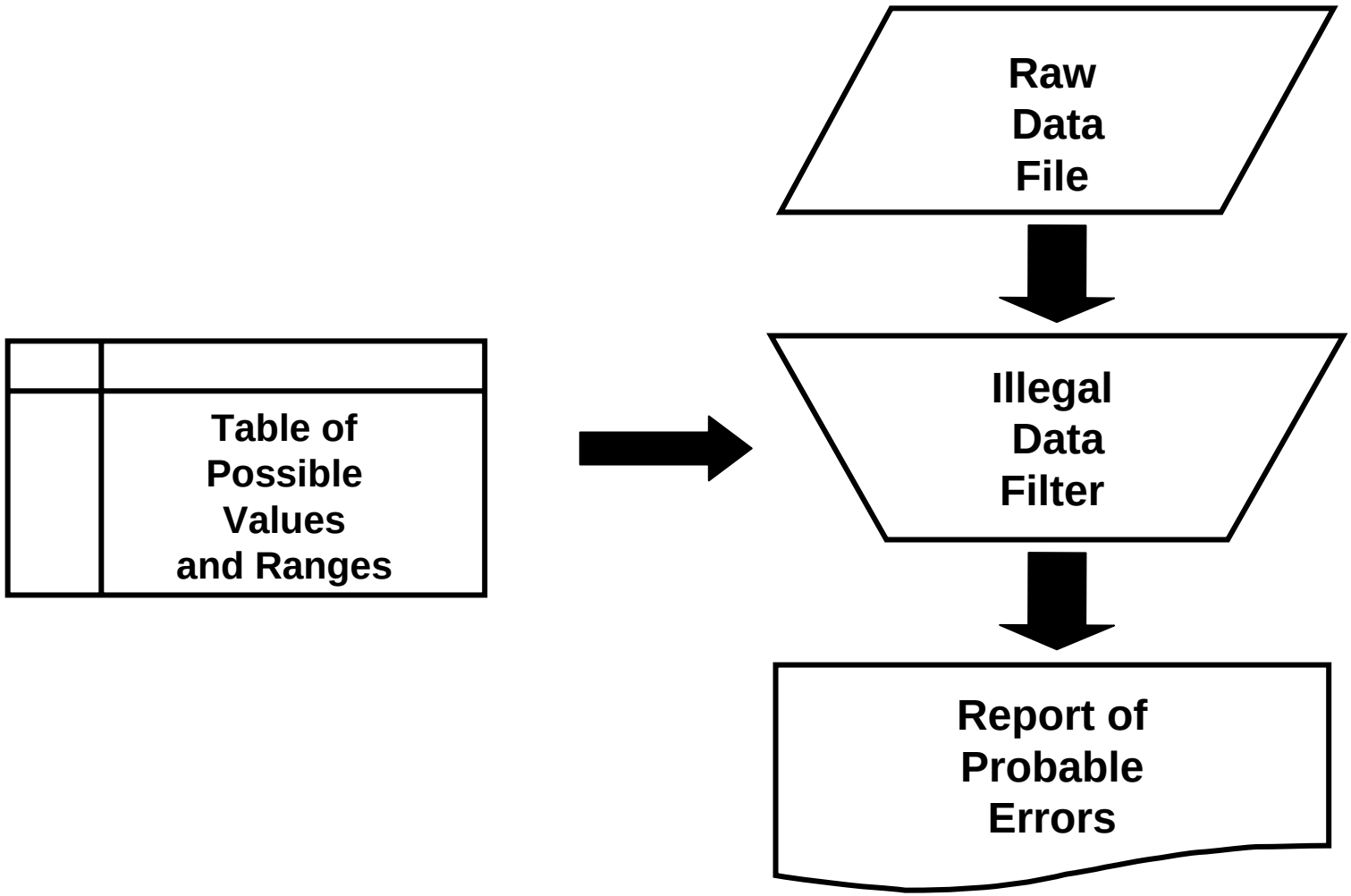

Microsoft Access - [Vegetation_data]
File Edit View Insert Format Records Tools Window Help
MS Sans Serif
8
Cover
Date
12/17/67
Location
Grassland
Plot
1
Plant_Species_Code
Cover
Observation_Number
6
Microsoft Access
Please Enter Cover Data!
OK
When the user tabs out of the “cover” field without entering data, this message box flashes to the screen.

Other methods for preventing data contamination

- Double-keying of data by independent data entry technicians followed by computer verification for agreement
- Use text-to-speech program to read data back
- Filters for “illegal” data
  - Statistical/database/spreadsheet programs
    - Legal range of values
    - Sanity checks

Edwards 2000

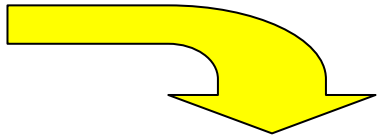
Flow of Information in Filtering “Illegal” Data



Edwards 2000

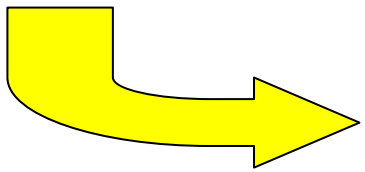
Tree Growth Data

Tree_ID	Cover (%)	DBH_1998 (cm)	DBH_1999 (cm)
a	43	300	200
b	231	300	400
c	46	530	480
d	109	200	300



A filter written in SAS

```
Data Checkum; Set tree;
        Message=repeat(“ ”,39);
        If cover<0 or cover>100 then do; message=“cover is not in the interval [0,100]”; output; end;
        If dbh_1998>dbh_1999 then do; message=“dbh_1998 is larger than dbh_1999”; output; end;
        If message NE repeat(“ ”, 39);
        Keep ID message;
Proc Print Data=Checkum;
```



Error report

Obs	ID	message
1	a	dbh_1998 is larger than dbh_1999
2	b	cover is not in the interval [0,100]
3	c	dbh_1998 is larger than dbh_1999
4	d	cover is not in the interval [0,100]

Spreadsheet column statistics: *Peromyscus truei* example

id#	mass	body	tail	foot
1	22.5	81.0	85.6	23.0
2	25.0	81.0	90.0	23.0
3	21.0	76.0	80.0	22.0
4	26.0	86.0	90.2	22.0
5	23.6	101.0	92.0	22.5
6	22.0	86.0	87.0	23.0
7	23.0	94.0	83.0	23.0
8	23.0	89.0	82.0	22.0
9	30.0	9.9	91.0	23.0
10	28.1	97.0	100.0	23.0
11	22.0	96.0	81.0	24.0
12	25.0	98.0	91.0	23.0
13	29.0	97.0	102.0	22.0
14	51.0	75.0	90.0	21.5
15	23.0	81.3	89.0	21.0
16	29.0	85.0	88.0	23.0
17	33.0	89.0	84.3	21.0
18	67.0	90.0	85.0	22.0
19	21.0	86.2	87.0	24.0
20	25.0	78.0	91.7	22.5
21	32.0	80.0	90.0	22.0

mean	28.6	83.6	88.6	22.5
median	25.0	86.0	89.0	22.5
standard deviation	11.0	18.5	5.5	0.8
variance	120.7	343.9	30.2	0.7
minimum	21.0	9.9	80.0	21.0
maximum	67.0	101.0	102.0	24.0

Spreadsheet range checks

id#	mass	body	tail	foot	rangecheck_mass
1	22.5	81.0	85.6	23.00	0
2	25.0	81.0	90.0	23.00	0
3	21.0	76.0	80.0	22.00	0
4	26.0	86.0	90.2	22.00	0
5	23.6	101.0	92.0	22.50	0
6	22.0	86.0	87.0	23.00	0
7	23.0	94.0	83.0	23.00	0
8	23.0	89.0	82.0	22.00	0
9	30.0	9.9	91.0	23.50	0
10	28.1	97.0	100.0	23.00	0
11	22.0	96.0	81.0	24.00	0
12	25.0	98.0	91.0	23.00	0
13	29.0	97.0	102.0	22.00	0
14	51.0	75.0	90.0	21.50	1
15	23.0	81.3	89.0	21.00	0
16	29.0	85.0	88.0	23.00	0
17	33.0	89.0	84.3	21.00	0
18	67.0	90.0	85.0	22.00	1
19	21.0	86.2	87.0	24.00	0
20	25.0	78.0	91.7	22.50	0
21	32.0	80.0	90.0	22.00	0

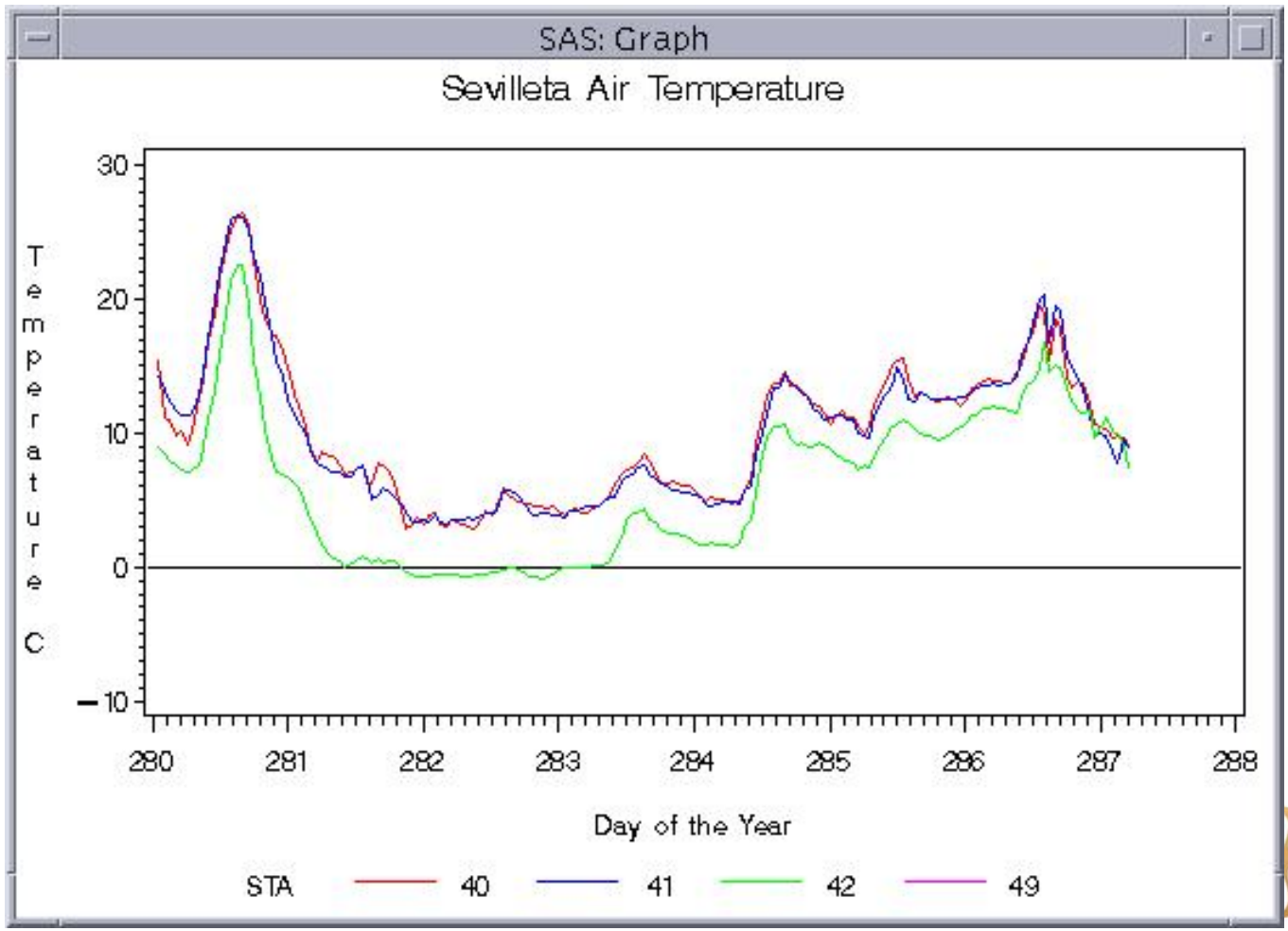
=if(mass>50,1,0)

mean	28.6	83.6	88.6	22.52
median	25.0	86.0	89.0	22.50
standard deviation	11.0	18.5	5.5	0.84
variance	120.7	343.8	30.2	0.71
minimum	21.0	9.9	80.0	21.00
maximum	67.0	101.0	102.0	24.00

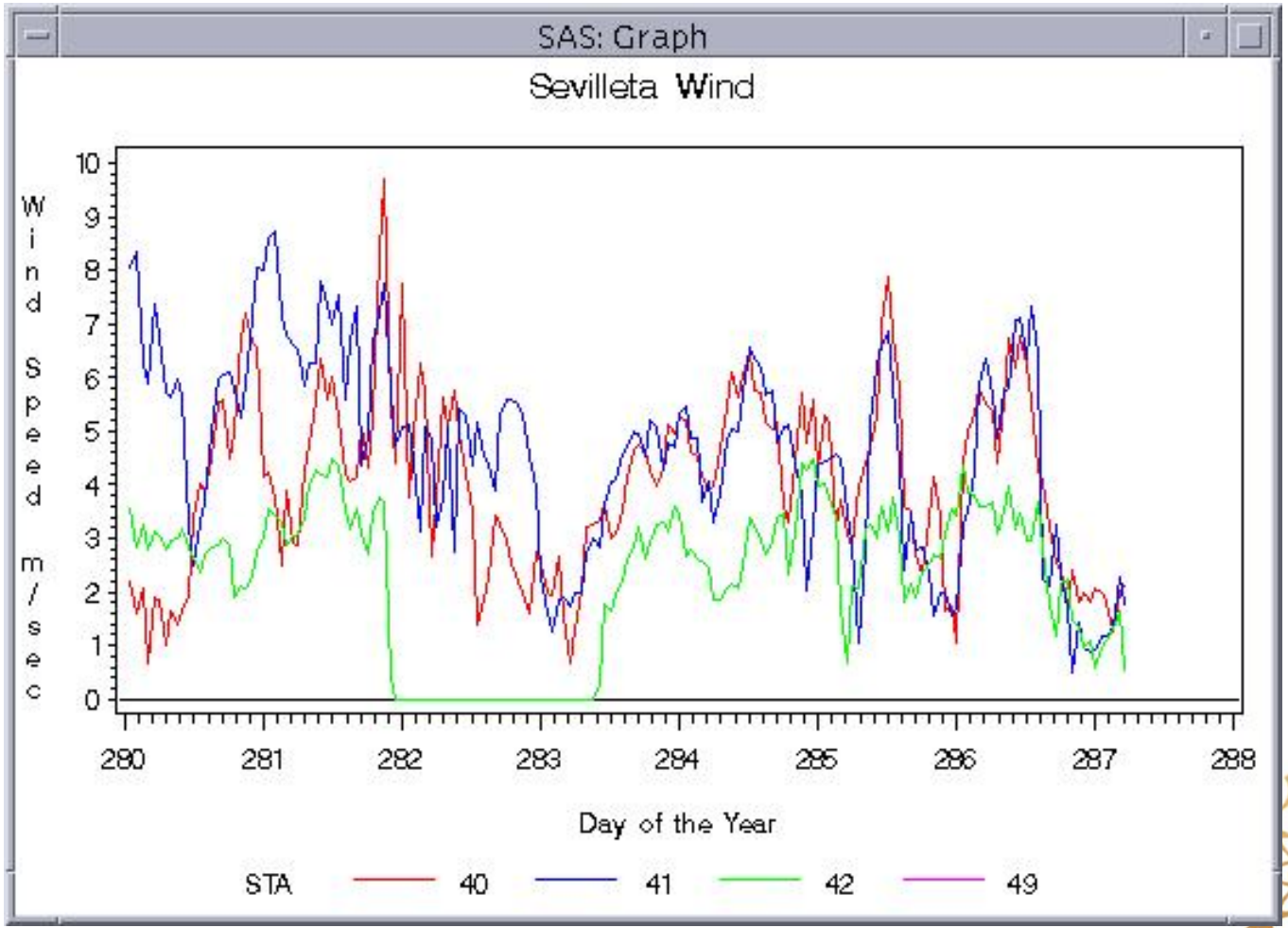
Outline:

- Define QA/QC
- QC procedures
  - Designing data sheets
  - Data entry using validation rules, filters, lookup tables
- QA procedures
  - Graphics and Statistics to find:
    - Unusual patterns
    - Outliers

Identifying Sensor Errors: Comparison of data from three Met stations, Sevilleta LTER

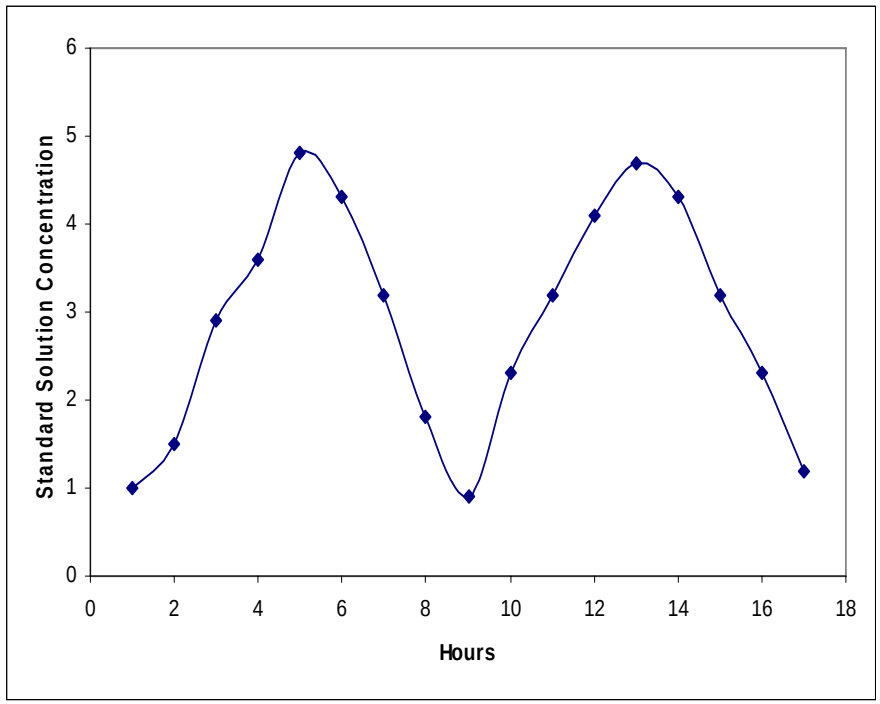


Identification of Sensor Errors: Comparison of data from three Met stations, Sevilleta LTER



Checking instruments for systematic errors

- Measure the concentration of a known standard solution every hour or so



Outliers

- An outlier is “an unusually extreme value for a variable, given the statistical model in use”
- The goal of QA is NOT to eliminate outliers! Rather, we wish to detect unusually extreme values.

Edwards 2000

Outlier Detection

- "the detection of outliers is an intermediate step in the elimination of [data] contamination"
  - Attempt to determine if contamination is responsible and, if so, flag the contaminated value.
  - If not, formally analyse with and without "outlier(s)" and see if results differ. Or use robust statistical methods.

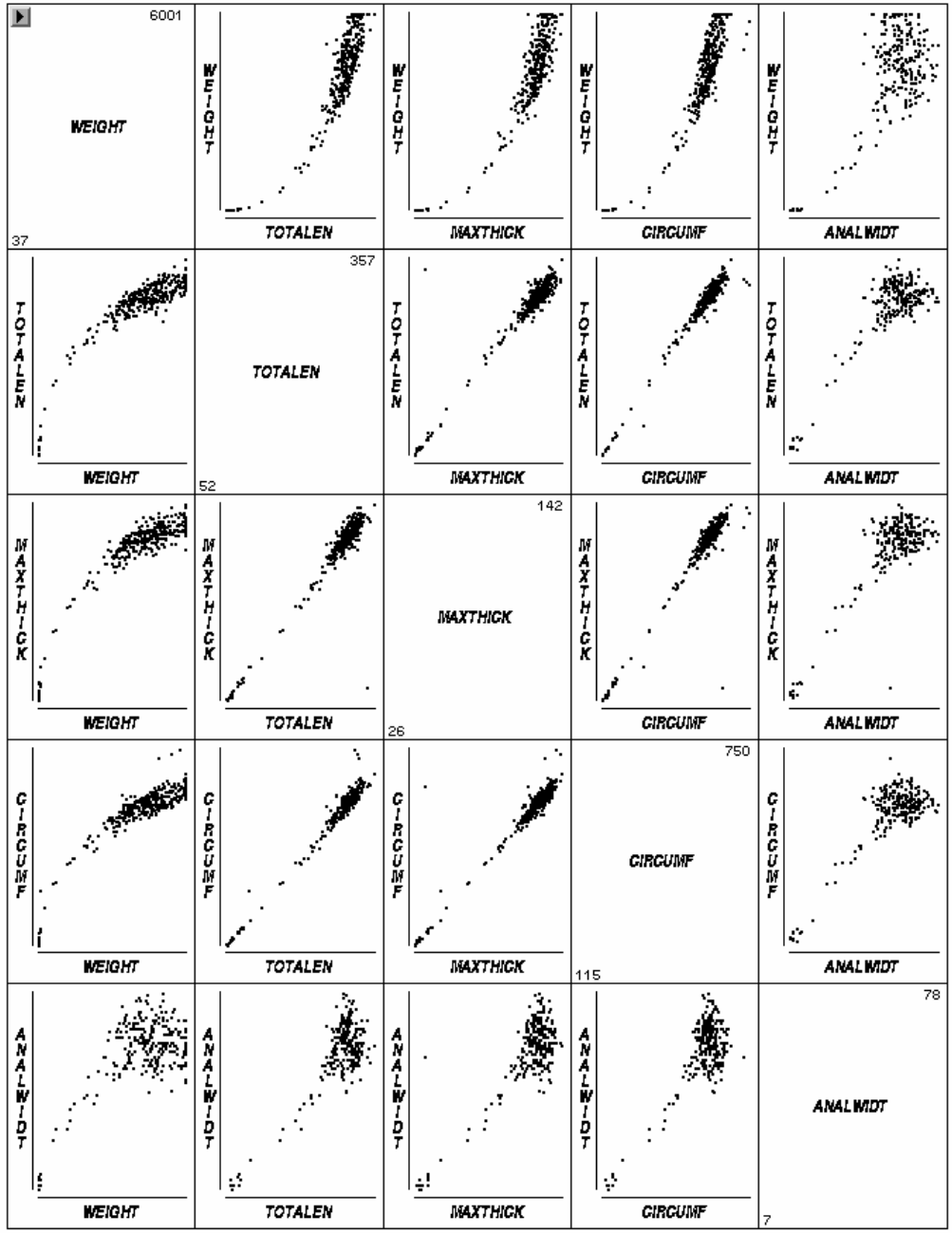
Methods for Detecting Outliers

- Graphics
  - Scatter plots
  - Box plots
  - Histograms
  - Normal probability plots
- Formal statistical methods
  - Grubbs' test

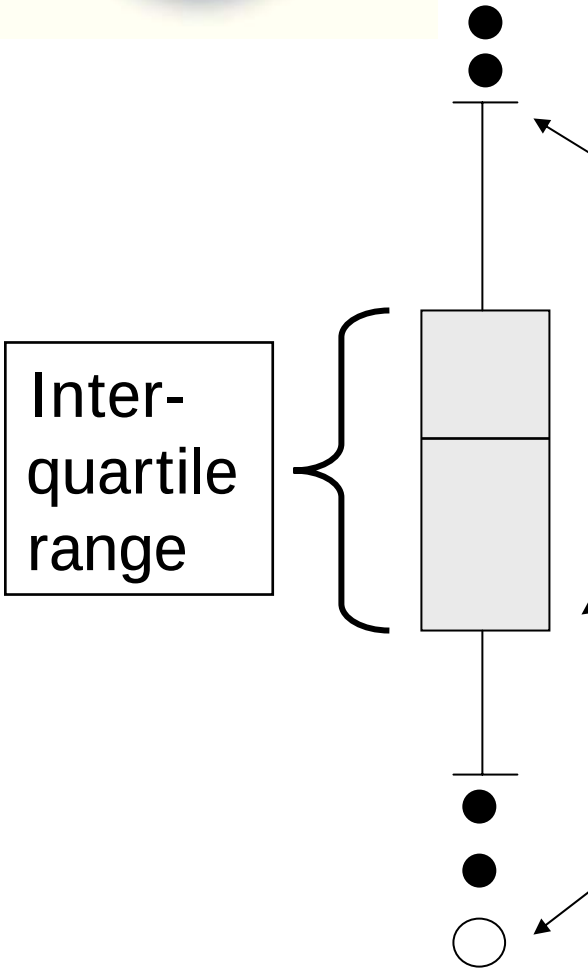
Edwards 2000

X-Y scatter plots of gopher tortoise morphometrics

Michener 2000



Box Plot Interpretation



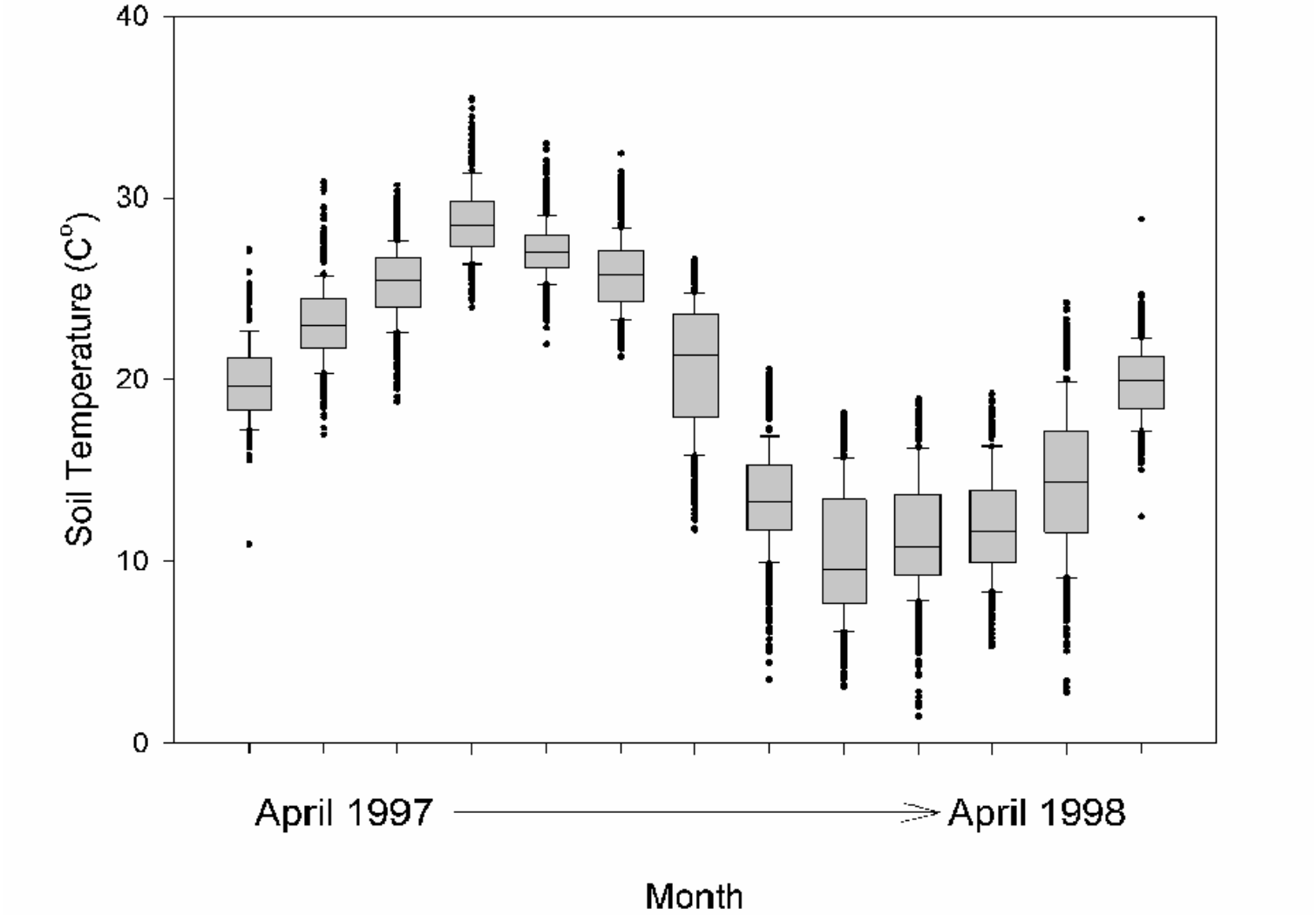
IQR = Q(75%) – Q(25%)

Upper adjacent value = largest observation ≤ (Q(75%) + (1.5 X IQR))

Lower adjacent value = smallest observation ≥ (Q(25%) - (1.5 X IQR))

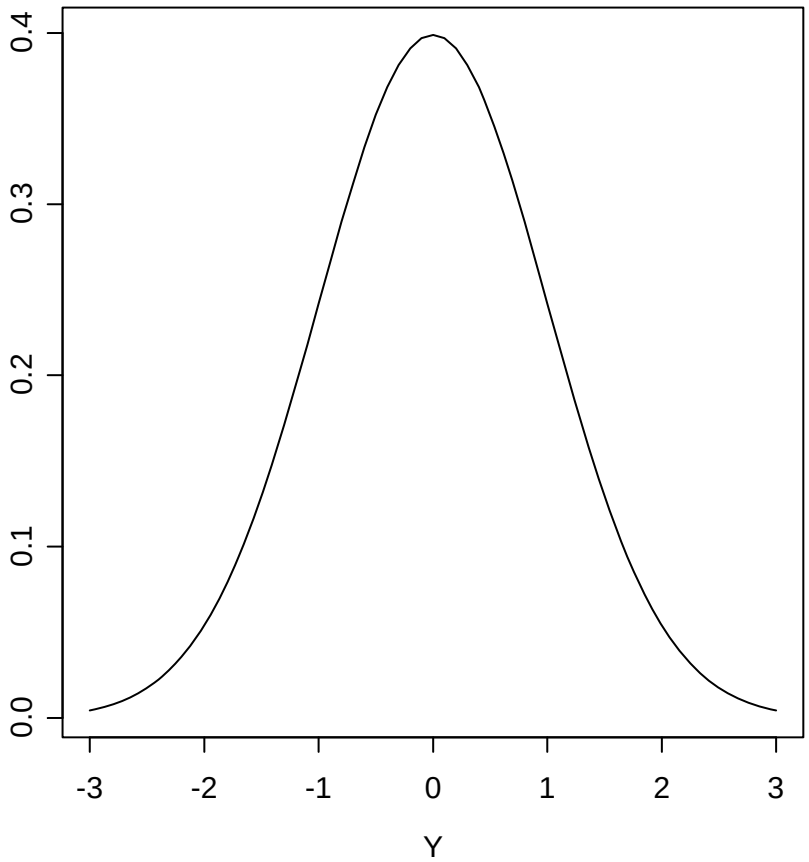
Extreme outlier: > 3 X IQR beyond upper or lower adjacent values

Box Plots Depicting Statistical Distribution of Soil Temperature

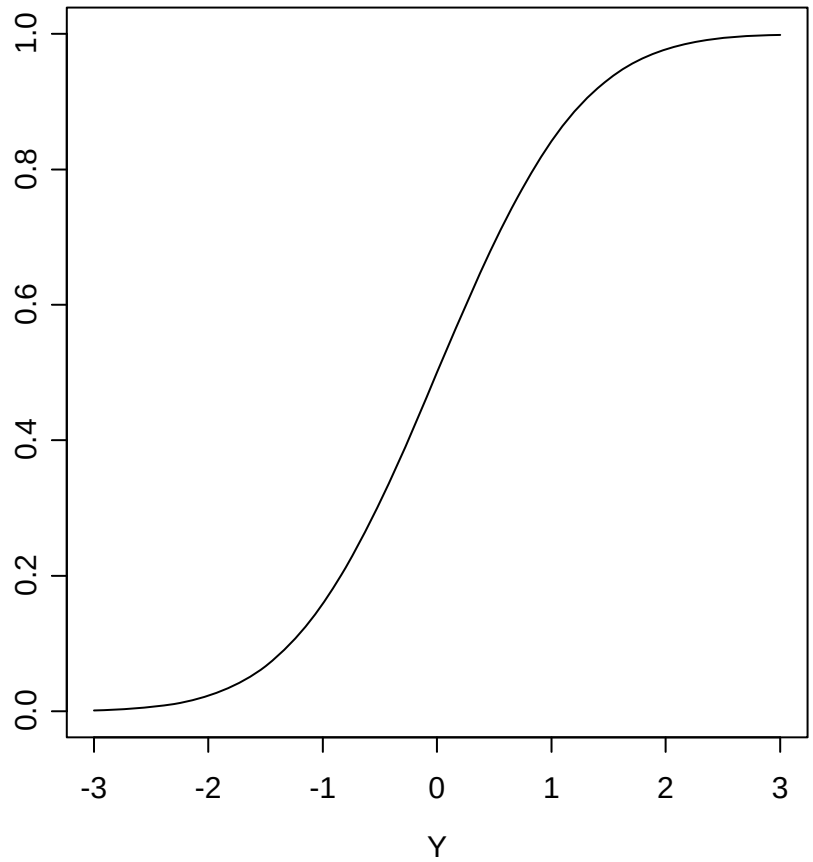


Normal density and Cumulative Distribution Functions

a. The Normal Frequency Curve

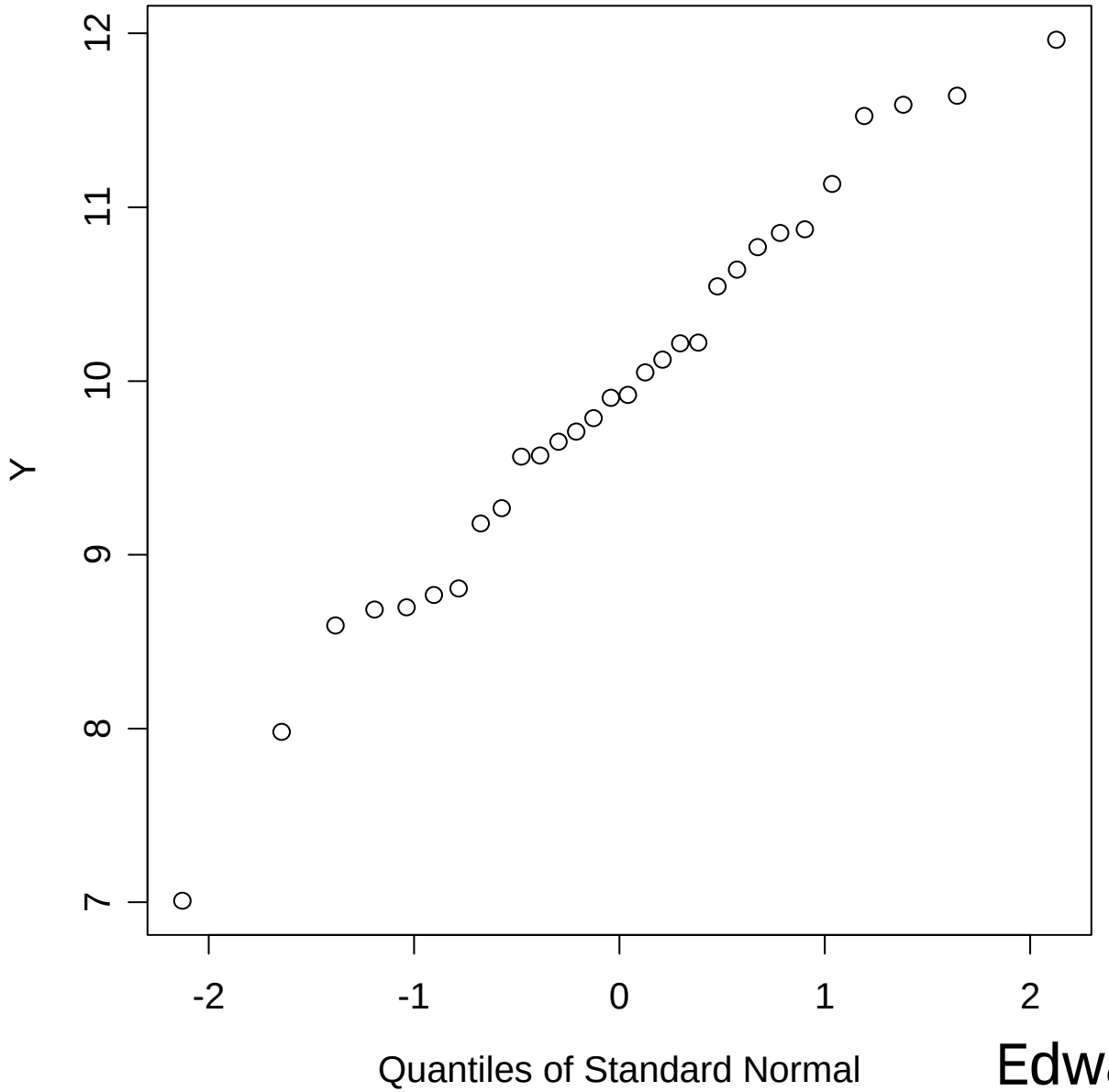


b. Cumulative Normal Curve Areas



Edwards 2000

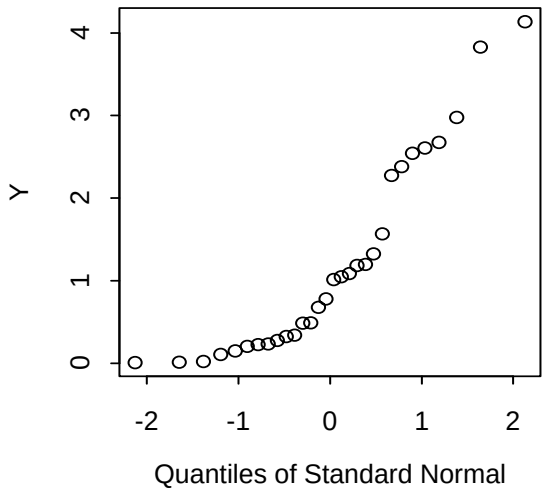
Normal Plot of 30 Observations from a Normal Distribution



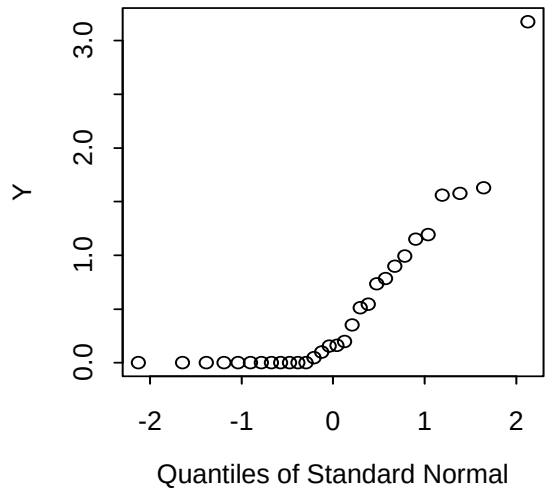
Edwards 2000

Normal Plots from Non-normally Distributed Data

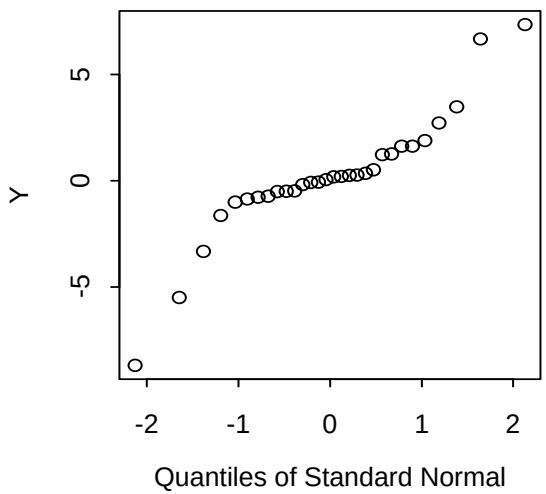
a. a right skewed distribution



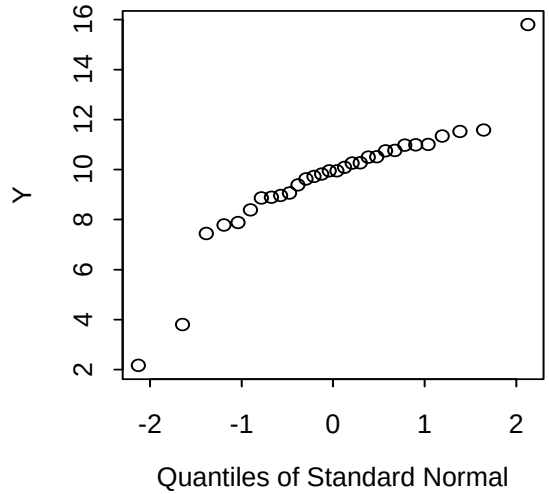
b. a left-truncated Normal distribution



c. a heavy-tailed distribution



d. a contaminated Normal distribution



Edwards 2000

Statistical tests for outliers assume that the data are normally distributed....

CHECK THIS ASSUMPTION!

Grubbs' test for outlier detection in a univariate data set:

$T_n = (Y_n - Y_{bar})/S$

where Y_n is the possible outlier,

Y_{bar} is the mean of the sample, and

S is the standard deviation of the sample

Contamination exists if T_n is greater than $T_{.01[n]}$

Grubbs, Frank (February 1969), Procedures for Detecting Outlying Observations in Samples, Technometrics, Vol. 11, No. 1, pp. 1-21.

Example of Grubbs' test for outliers rainfall in acre-feet from seeded clouds (Simpson et al. 1975)

4.1	7.7	17.5	31.4
32.7	40.6	92.4	115.3
118.3	119.0	129.6	198.6
200.7	242.5	255.0	274.7
274.7	302.8	334.1	430.0
489.1	703.4	978.0	
1656.0	1697.8	2745.6	

$T_{26} = 3.539 > 3.029$; Contaminated

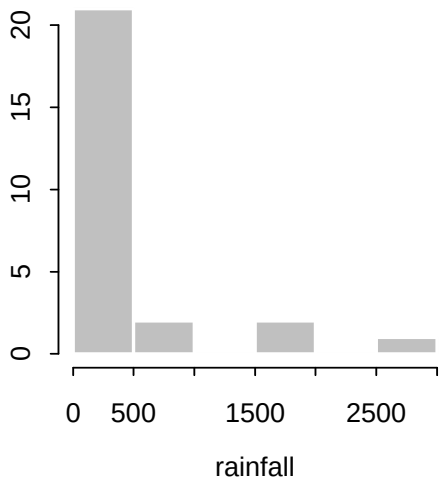
But Grubbs' test is sensitive

to non-normality.....

Edwards 2000

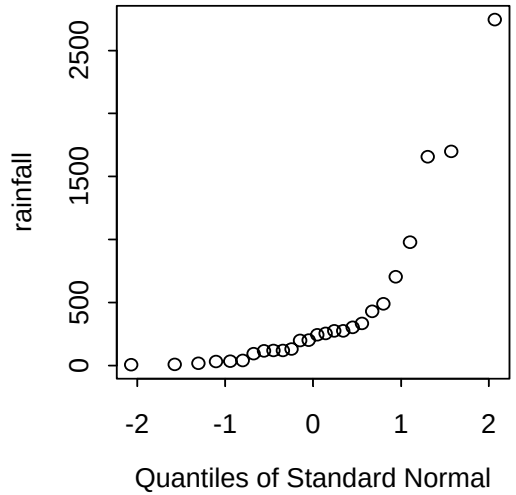
Checking Assumptions on Rainfall Data

a. rainfall

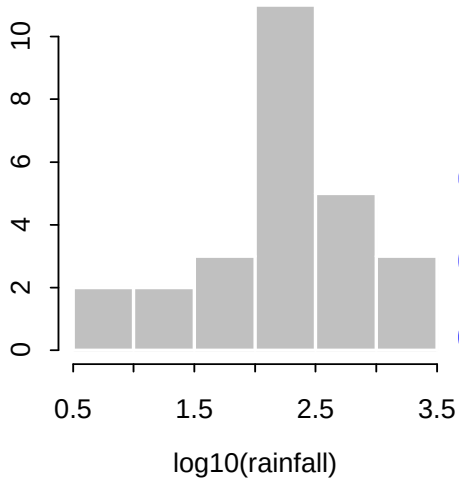


Skewed distribution: Grubbs' Test detects contaminating points

b. Normal plot

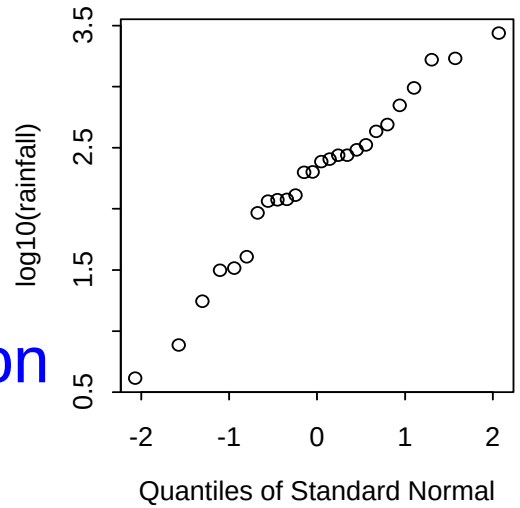


c. log10(rainfall)



Normal Distribution: Grubbs' test detects no contamination

d. Normal plot



Edwards 2000

References about outliers:

- Barnett, V. and Lewis, T.: 1994, *Outliers in Statistical Data*, John Wiley & Sons, New York
- Iglewicz, B. and Hoaglin, D. C.: 1993 *How to Detect and Handle Outliers*, American Society for Quality Control, Milwaukee, WI.

Simple Linear Regression: check for model-based……

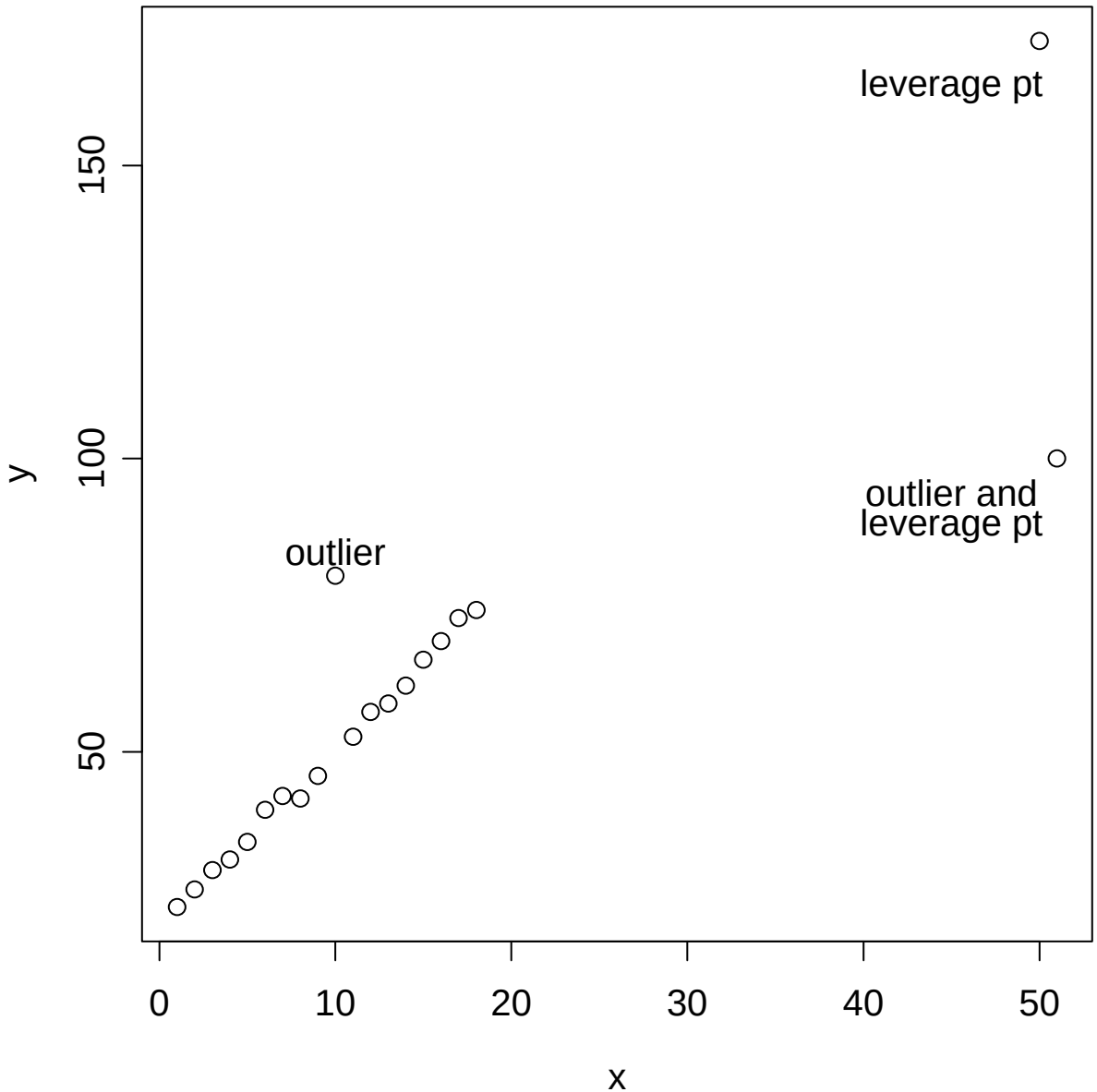
- Outliers
- Influential (leverage) points

Influential points in simple linear regression:

- A “leverage” point is a point with an unusual regressor value that has more weight in determining regression coefficients than the other data values.
- An “outlier” is an observation with a response value that does not fit the X-Y pattern found in the rest of the data.

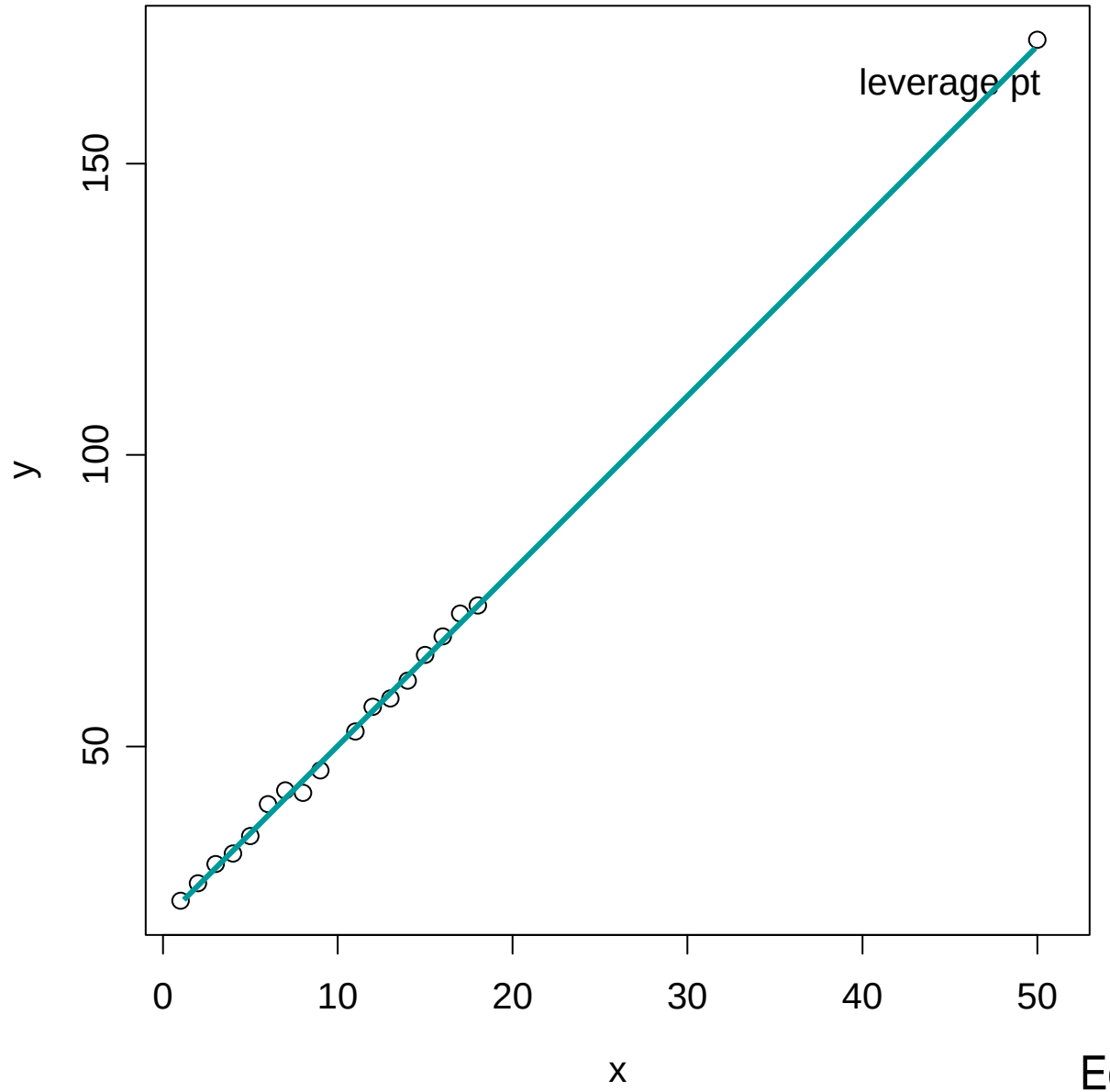
Edmonds 2000

Influential Data Points in a Simple Linear Regression



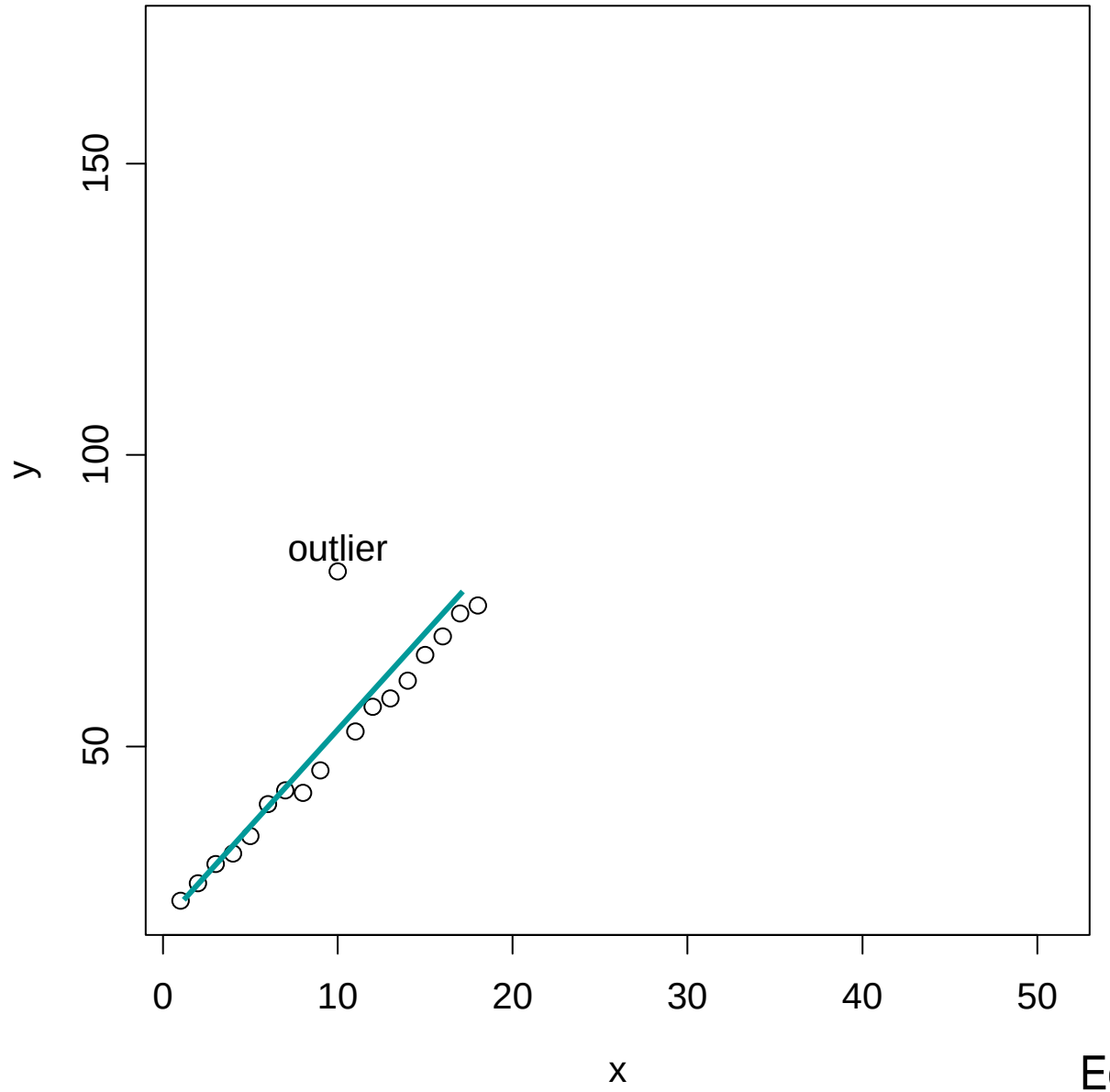
Edwards 2000

Influential Data Points in a Simple Linear Regression



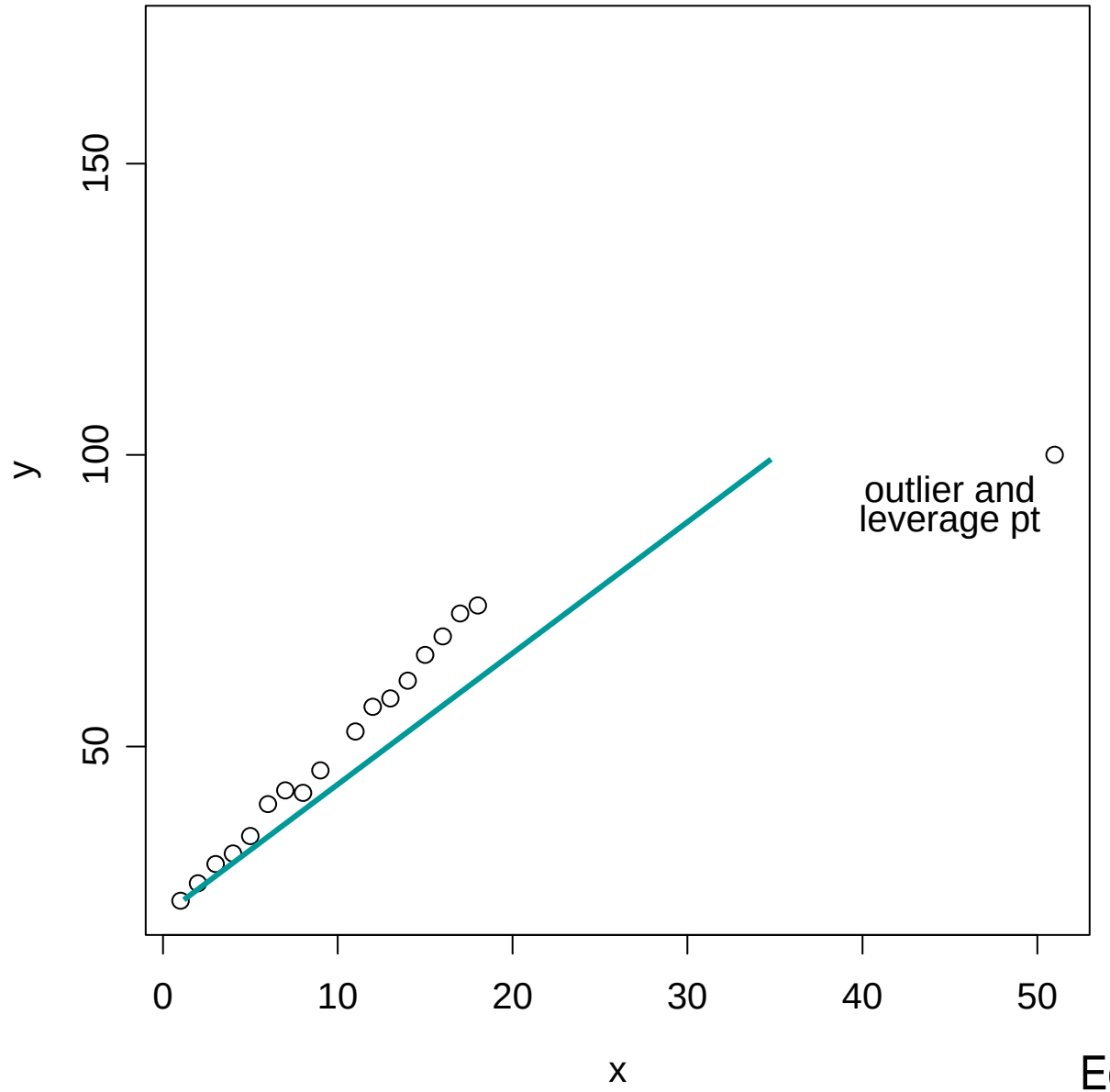
Edwards 2000

Influential Data Points in a Simple Linear Regression



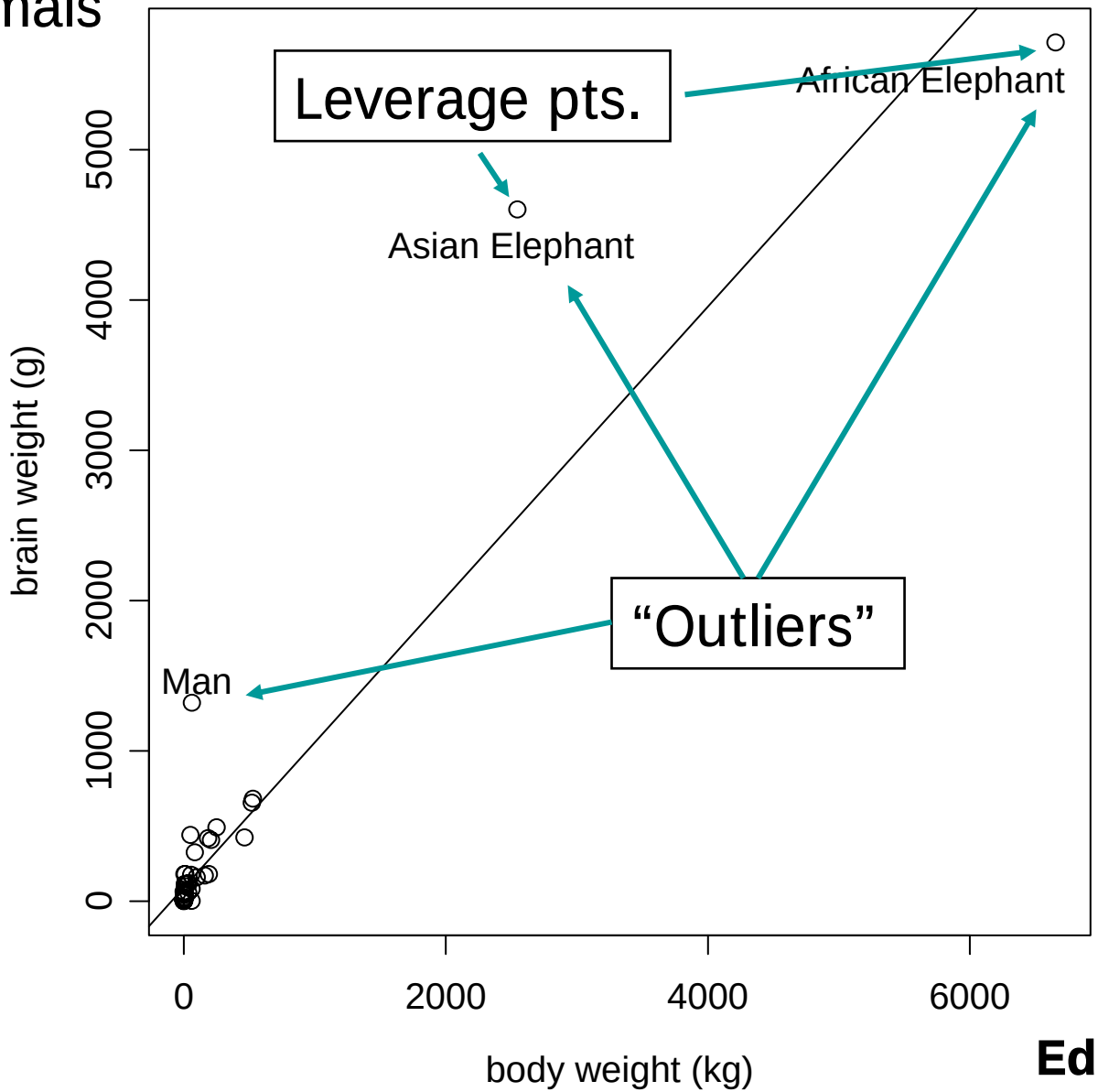
Edwards 2000

Influential Data Points in a Simple Linear Regression



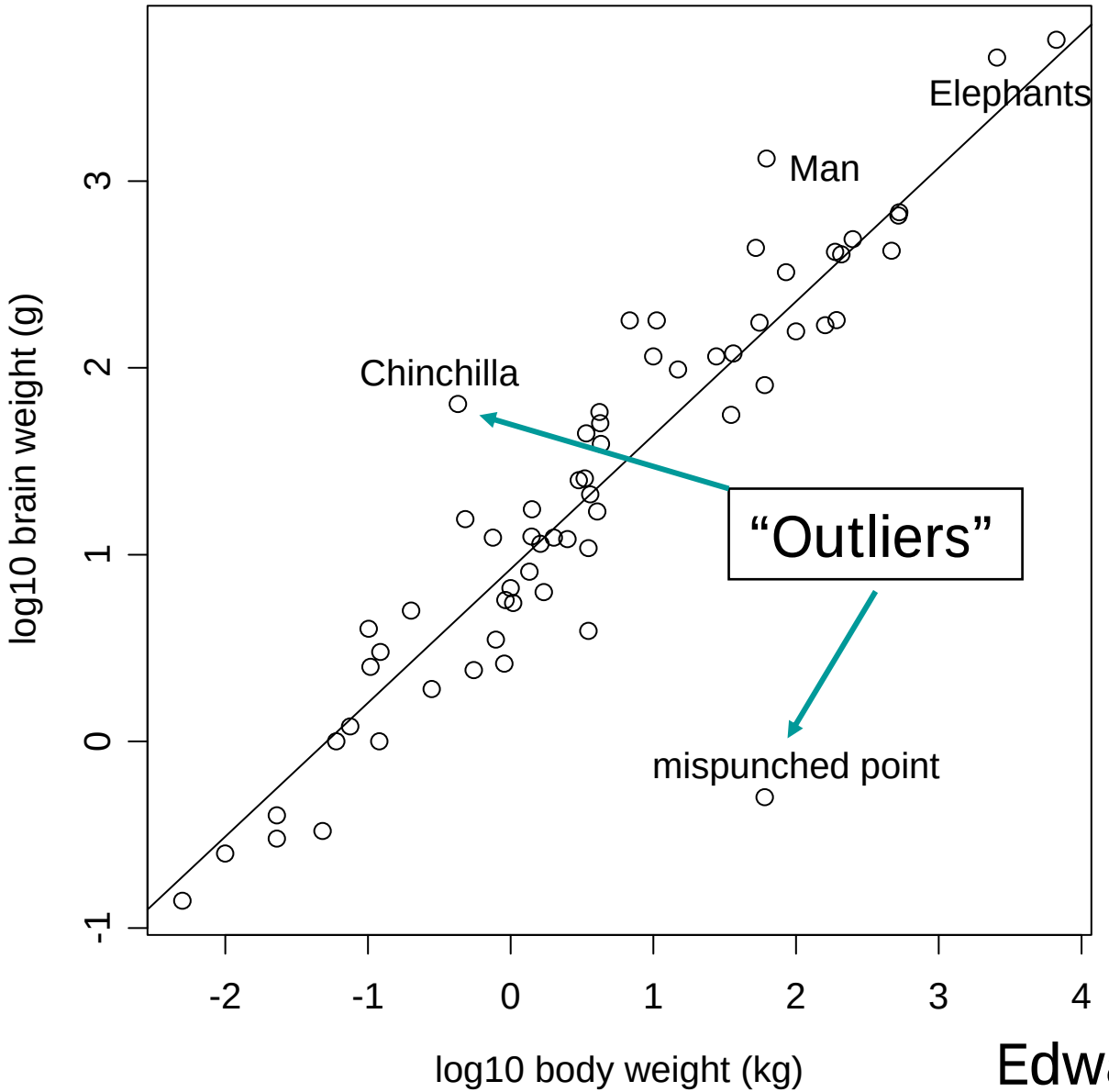
Edwards 2000

Brain weight vs. body weight, 63 species of terrestrial mammals



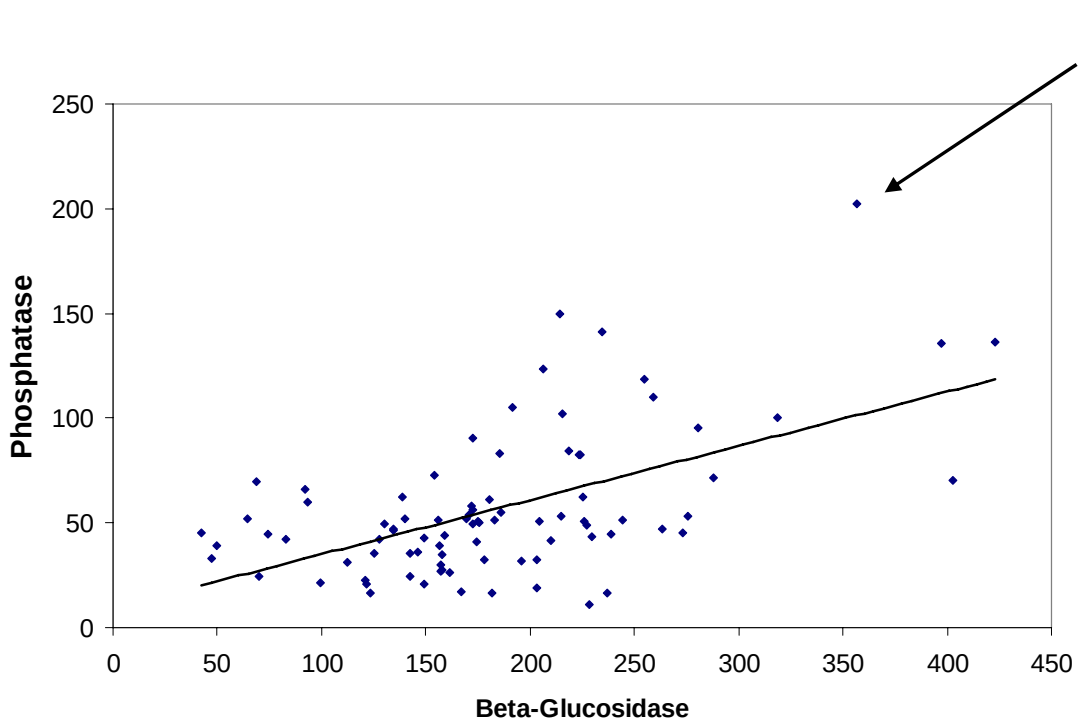
Edwards 2000

Logged brain weight vs. logged body weight



Edwards 2000

Outliers in simple linear regression



Outliers: identify using studentized residuals

- Contamination may exist if

$$|r_i| > t_{\alpha/2,\, n-3}$$

$\alpha = 0.01$

Simple linear regression:
Outlier identification

n = 86

$t_{\alpha/2},83 = 1.98$

Obs	Dep Var PHOS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual
49	82.9000	166.1	7.290	-83.1835	62.045	-1.341
50	238.6	169.2	7.114	69.4246	62.066	1.119
51	215.1	179.5	6.765	35.6463	62.105	0.574
52	166.8	136.0	10.205	30.8387	61.633	0.500
53	157.0	151.0	8.531	6.0259	61.887	0.097
54	142.2	157.4	7.932	-15.2357	61.966	-0.246
55	202.9	154.3	8.215	48.6407	61.929	0.785
56	228.4	128.2	11.183	100.2	61.463	1.631
57	145.9	158.2	7.866	-12.3208	61.975	-0.199
58	218.4	216.5	8.624	1.8552	61.874	0.030
59	156.8	162.5	7.532	-5.6964	62.016	-0.092
60	210.2	164.9	7.364	45.2760	62.036	0.730
61	225.7	176.2	6.833	49.4711	62.097	0.797
62	402.9	199.8	7.250	203.1	62.050	3.273
63	161.3	146.4	9.001	14.8672	61.820	0.240
64	227.3	174.2	6.896	53.1002	62.090	0.855

Simple linear regression: detecting leverage points

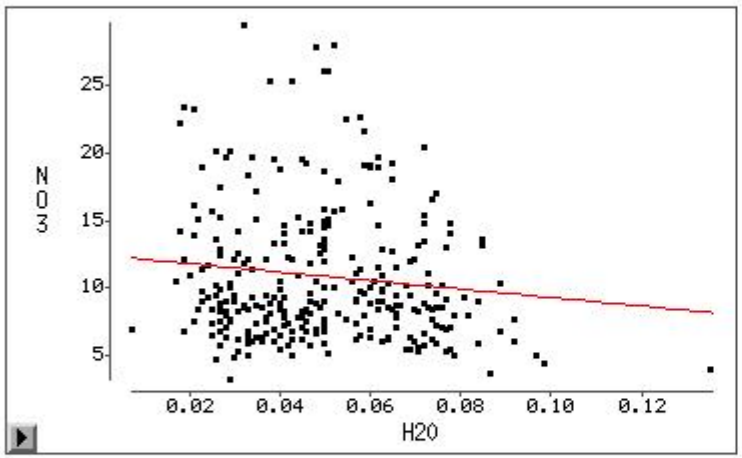
$$h_i = (1/n) + (x_i - x)^2/(n-1)S_x^2$$

A point is a leverage point if $h_i > 4/n$, where n is the number of points used to fit the regression

Regression with leverage point: Soil nitrate vs. soil moisture

NO3 = H20
Response Distribution: Normal
Link Function: Identity

Model Equation
NO3 = 12.3348 - 31.3432 H20



Parametric Regression Fit

Curve	Degree(Polynomial)	Model DF	Model Mean Square	Error DF	Error Mean Square	R-Square	F Stat	Prob > F
	1	1	107.9918	290	24.2399	0.0151	4.4551	0.0357

Summary of Fit

Mean of Response	10.7858	R-Square	0.0151
Root MSE	4.9234	Adj R-Sq	0.0117

Regression without leverage point

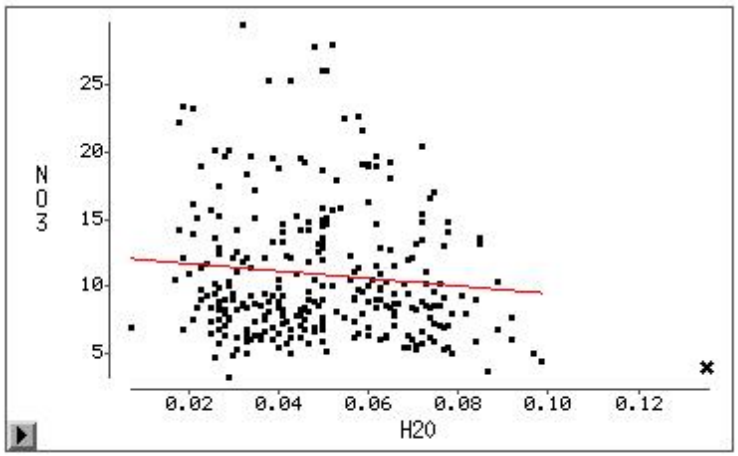
NO3 = H20

Response Distribution: Normal

Link Function: Identity

Model Equation

NO3 = 12.1791 - 27.8885 H20



Observation 46

Parametric Regression Fit

Curve	Degree(Polynomial)	Model DF	Model Mean Square	Error DF	Error Mean Square	R-Square	F Stat	Prob > F
	1	1	79.6479	289	24.2620	0.0112	3.2828	0.0710

Summary of Fit

Mean of Response	10.8091	R-Square	0.0112
Root MSE	4.9256	Adj R-Sq	0.0078

Output from SAS:
Leverage points

n = 336

h_i cutoff value: 4/336=0.012

The SAS System 155
16:12 Wednesday, October 11, 2000

Obs	Residual	Rstudent	Hat Diag H	Cov Ratio	Dffits	INTERCEP Dfbetas	H20 Dfbetas
33	-3.8319	-0.7795	0.0068	1.0095	-0.0645	0.0264	-0.0460
34	-4.8160	-0.9806	0.0076	1.0079	-0.0855	0.0387	-0.0638
35	-4.9625	-1.0199	0.0256	1.0260	-0.1652	0.1217	-0.1539
36	-0.7222	-0.1473	0.0141	1.0211	-0.0176	0.0112	-0.0154
37	-0.7019	-0.1426	0.0068	1.0136	-0.0118	0.0048	-0.0084
38	-1.6159	-0.3283	0.0058	1.0120	-0.0251	0.0083	-0.0164
39	0.6302	0.1279	0.0050	1.0118	0.0091	-0.0022	0.0052
40	-3.4884	-0.7141	0.0197	1.0235	-0.1013	0.0708	-0.0923
41	-4.8933	-0.9952	0.0052	1.0053	-0.0723	-0.0614	0.0434
42	-5.6034	-1.1396	0.0042	1.0022	-0.0737	-0.0543	0.0325
43	-4.4392	-0.9029	0.0058	1.0071	-0.0690	-0.0608	0.0449
44	-4.8692	-0.9906	0.0058	1.0060	-0.0757	-0.0667	0.0492
45	-3.8633	-0.7852	0.0052	1.0079	-0.0570	-0.0485	0.0343
46	2.2328	0.4693	0.0711	1.0823	0.1299	-0.1079	0.1268
47	-3.3892	-0.6889	0.0058	1.0094	-0.0527	-0.0464	0.0342
48	-0.9312	-0.1893	0.0071	1.0138	-0.0161	-0.0149	0.0117

References:

- Rousseeuw, P.J. and Leroy, A.M.:1987 *Robust Regression and Outlier Detection*, John Wiley & Sons, New York.
- Cook, R. D. (1977). "Detection of influential observations in linear regression" Technometrics 19, 15-18


Questions?