Investigating the effect of rising levels of atmospheric CO_2 on Earth's global surface temperature

In the early 20th century, scientists began to suspect that the increasing levels of green house gases such as CO_2 in the atmosphere might be the cause of the increase in global surface temperature. Scientists have been recording global surface temperatures and CO_2 levels in the atmosphere since before 1960. The table below shows data recorded since 1960.

Year	CO_2 Level (ppm)*	Global surface temperature anomaly (°C)**
1960	316.91	-0.02
1961	317.64	0.06
1962	318.45	0.04
1063	318.99	0.07
1964	319.62	-0.2
1965	320.04	-0.2
1966	321.38	-0.05
1967	322.16	-0.02
1968	323.04	-0.07
1969	324.62	0.07
1970	325.68	0.03
1971	326.32	-0.09
1972	327.45	0.01
1973	329.68	0.16
1974	330.18	-0.08
1975	331.11	-0.02
1976	332.04	-0.11
1977	333.83	0.17
1978	335.4	0.06
1979	336.84	0.16
1980	338.75	0.27
1981	340.11	0.33
1982	341.45	0.13
1983	343.05	0.31
1984	344.65	0.16
1985	346.12	0.12
1986	347.42	0.18
1987	349.19	0.33
1988	351.57	0.41

1989	353.12	0.28
1990	354.39	0.44
1991	355.61	0.41
1992	358.45	0.22
1993	357.1	0.24
1994	358.83	0.31
1995	360.82	0.44
1996	362.61	0.33
1997	363.73	0.47
1998	366.7	0.62
1999	368.38	0.4
2000	369.55	0.4
2001	371.14	0.54
2002	373.28	0.62
2003	375.8	0.61
2004	377.52	0.53
2005	379.8	0.67
2006	381.9	0.62
2007	383.79	0.64
2008	385.6	0.52
2009	387.43	0.63
2010	389.9	0.7
2011	391.65	0.57
2012	393.85	0.61
2013	396.62	0.64
2014	398.65	0.73
2015	400.83	0.86
2016	404.21	0.99
2017	406.53	0.9

* Temperature data source: NASA's Goddard Institute for Space Studies (GISS). The data represent the change in mean global surface temperature relative to 1951-1980 average temperatures. Seventeen of the 18 warmest years in the 136-year record all have occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record. (https://climate.nasa.gov/vital-signs/global-temperature/)

** CO_2 data source: Earth System Research Laboratory, Global Monitoring Division. The data were recorded at the Mauna Loa observatory on the big island of Hawaii. (https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html)

Group Work (submit one copy per group):

1- What type of science is represented in this study? (experimental, observational, theoretical)
2- Identify the following:

   a. Independent variable:
   b. Dependent variable:

3- What type of data were collected for the:
   a. Independent variable:
   b. Dependent variable:
4- State your null hypothesis:
5- State your alternative hypothesis:
6- Perform a statistical test to determine whether there is a significant correlation between atmospheric CO_2 levels and global surface temperature. Include the Excel analysis output in your answer.
7- Do you have evidence to reject/accept the hypothesis? Justify your answer using the result of your statistical analysis.
8- State your conclusion.
9- Use Excel to present the data (graph) of this study in a proper scientific way and make sure to label your graph appropriately.

Statistics Case 1

In a clinical trial, a population of patients was given two different types of anti-coagulants, drug A and drug B. Anti-coagulants are chemical agents that inhibit blood clotting and are used to treat patients with heart disease and stroke. Each patient was assigned a unique number and given drug A on day 1 and drug B on day 2 of the test. Thirty minutes after each drug administration, a blood sample is drawn from the patient and the time for the blood to clot is recorded as shown in the table below.

Patient number	Drug A (s)	Drug B (s)
1	61.6	39.3
2	64.6	26.3
3	55.6	32.4
4	45.2	21.5
5	50.6	60.3
6	70.5	24.3
7	67.7	36.4
8	57.5	47.4
9	66.5	33.2
10	42.3	57.2
11	51.3	35.7
12	54.7	40.2
13	59.2	37.8
14	61.4	42.5
15	58.7	38.6

1. What type of data is presented in this table?
2. Using Excel calculate the descriptive statistics for both samples.
3. What is the null hypothesis?
4. What is the alternative hypothesis?
5. Using Excel perform a statistical test to determine if there is a significant difference between the 2 treatments. Which test would you choose?
6. Can the null hypothesis be rejected? Justify using the results of the statistical analysis.
7. Use Excel to present the data (graph) of this clinical trial in a meaningful way.

Statistics Exercise 2

A biology student measured the frequency of chirps (the number of wing vibrations per second) made by ground crickets, at various ground temperatures. Since crickets are ectotherms (cold-blooded), the rate of their physiological processes and their overall metabolism are influenced by temperature. Consequently, there is reason to believe that temperature would have a profound effect on aspects of their behaviour, such as chirp frequency. The following data were obtained.

Temperature (º C)	Chirps/Second
21	**14.7**
21.5	**15.4**
22	**16.0**
24	**15.5**
25	**14.1**
26	**15.0**
26.5	**17.1**
27	**16.0**
28	**17.1**
28.5	**17.2**
29	**18.4**
29.3	**18.6**
29.6	**19.0**
31	**20.0**
34	**20.8**

1. What is your hypothesis? Null hypothesis?
2. Perform a statistical test to determine whether there is a significant correlation between temperature and chirp frequency? Justify your answer using the result of your statistical analysis.
3. Do you have evidence to reject/accept the hypothesis?
4. Use Excel to present the data (graph) of this study in a meaningful way.

Statistics Exercise 3

The type of browse (tender shoots, twigs, and leaves of trees and shrubs used by animals for food) favoured by the mule deer of Mesa Verde National Park is shown in the table below. An ecologist wanted to determine whether the deer feeding habits are related to the distribution of browse in this park. Using binoculars, volunteers observed the feeding habits of a random sample of 400 deer. The following results were obtained.

Type of browse	Plant composition in study area	Observed number of deer feeding on this plant
Sage brush	32.0%	117
Rabbit brush	38.7%	160
Salt brush	12.0%	68
Service berry	9.3%	32
Other	8.0%	23

1. What is the null hypothesis?
2. What is the alternate hypothesis?
3. Use Excel to perform a statistical analysis to test your hypothesis. Which test would you use?
4. Can the null hypothesis be rejected? Justify your answer using the results of your statistical analysis.
5. Use Excel to graphically show any relationship between the distribution of browse and deer feeding pattern.

Investigating the effect of rising levels of atmospheric CO_2 on Earth's global surface temperature

In the early 20th century, scientists began to suspect that the increasing levels of green house gases such as CO_2 in the atmosphere might be the cause of the increase in global surface temperature. Scientists have been recording global surface temperatures and CO_2 levels in the atmosphere since before 1960. The table below shows data recorded since 1960.

Year	CO_2 Level (ppm)*	Global surface temperature anomaly (°C)**
1960	316.91	-0.02
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1968	323.04	-0.07
1969	324.62	0.07
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1973	329.68	0.16
1974	330.18	-0.08
1975	331.11	-0.02
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1977	333.83	0.17
1978	335.4	0.06
1979	336.84	0.16
1980	338.75	0.27
1981	340.11	0.33
1982	341.45	0.13
1983	343.05	0.31
1984	344.65	0.16
1985	346.12	0.12
1986	347.42	0.18
1987	349.19	0.33
1988	351.57	0.41

1989	353.12	0.28
1990	354.39	0.44
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1993	357.1	0.24
1994	358.83	0.31
1995	360.82	0.44
1996	362.61	0.33
1997	363.73	0.47
1998	366.7	0.62
1999	368.38	0.4
2000	369.55	0.4
2001	371.14	0.54
2002	373.28	0.62
2003	375.8	0.61
2004	377.52	0.53
2005	379.8	0.67
2006	381.9	0.62
2007	383.79	0.64
2008	385.6	0.52
2009	387.43	0.63
2010	389.9	0.7
2011	391.65	0.57
2012	393.85	0.61
2013	396.62	0.64
2014	398.65	0.73
2015	400.83	0.86
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* Temperature data source: NASA's Goddard Institute for Space Studies (GISS). The data represent the change in mean global surface temperature relative to 1951-1980 average temperatures. Seventeen of the 18 warmest years in the 136-year record all have occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record. (https://climate.nasa.gov/vital-signs/global-temperature/)

** CO_2 data source: Earth System Research Laboratory, Global Monitoring Division. The data were recorded at the Mauna Loa observatory on the big island of Hawaii. (https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html)

Group Work (submit one copy per group):

1- What type of science is represented in this study? (experimental, observational, theoretical)
2- Identify the following:

a. Independent variable: **CO_2 levels in atmosphere (ppm)**
b. Dependent variable: **Global surface temperature anomaly (°C)**

3- What type of data were collected for the:
   a. Independent variable: **numerical, continuous**
   b. Dependent variable: **numerical, continuous**

4- State your null hypothesis: **There is no causal relationship between atmospheric CO_2 levels and global surface temperature anomaly.**

5- State your alternative hypothesis: **There is causal relationship between atmospheric CO_2 levels and global surface temperature anomaly.**

6- Perform a statistical test to determine whether there is a significant correlation between atmospheric CO_2 levels and global surface temperature. Include the Excel analysis output in your answer.

Regression analysis:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.945778
R Square	0.894496
Adjusted R Square	0.892612
Standard Error	0.096549
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.425789	4.425789	474.7856	5.02E-29
Residual	56	0.522013	0.009322		
Total	57	4.947802			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-3.3925	0.170527	-19.8942	4.62E-27	-3.73411	-3.05089	-3.73411	-3.05089
CO2 Level (ppm)*	0.010462	0.000478	21.78958	5.02E-29	0.009501	0.011424	0.009501	0.011424

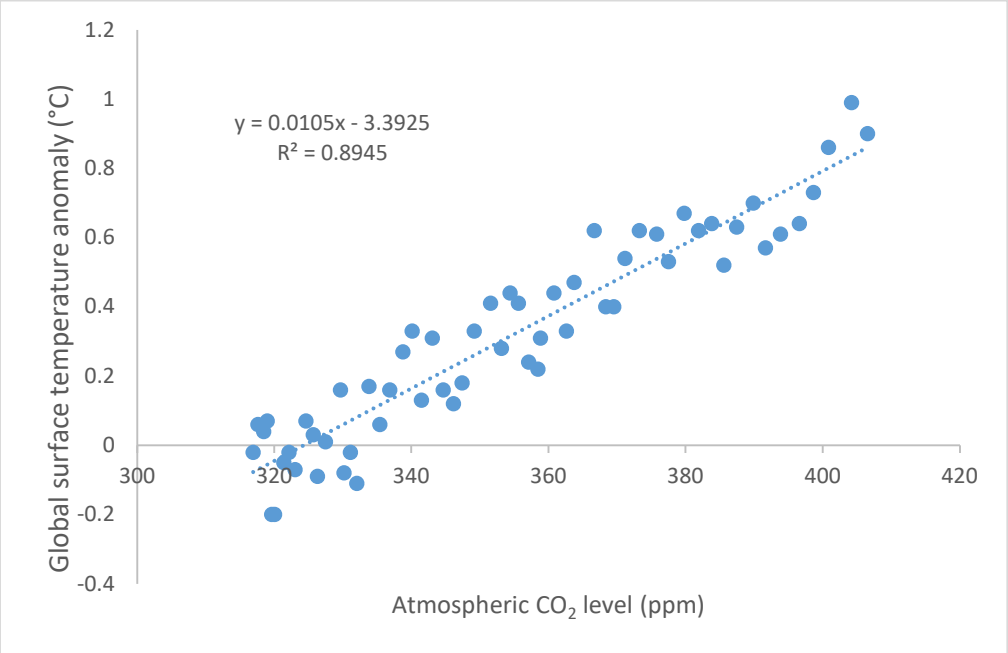
7- Do you have evidence to reject/accept the hypothesis? Justify your answer using the result of your statistical analysis.

There is evidence to support the hypothesis that an increase in atmospheric CO2 levels is causing the increase in global surface temperature anomaly. Since the sig. F value is <<<<0.05 (5.02E-29), the slope of the resulting line is significantly different from a slope of zero.

8- State your conclusion.

There is evidence for a positive linear relationship (y=0.0105x – 3.3925; R^2= 0.89) between the rise in atmospheric CO2 levels and global surface temperature anomaly over the recorded period of time (1960-2017).

9- Use Excel to present the data (graph) of this study in a proper scientific way and make sure to label your graph appropriately.



Effect of change in atmospheric CO_2 levels on global surface temperature. Each data point represents the change in mean global surface temperature relative to 1951-1980 average temperatures. Global surface temperatures and CO_2 levels in the atmosphere were recorded between 1960 and 2017. The levels of atmospheric CO_2 has been steadily increasing since 1960 (316.81 ppm), reaching a mean level of 406.53 ppm in 2017.

Statistics Exercise 1

In a clinical trial, a population of patients was given two different types of anti-coagulants, drug A and drug B. Anti-coagulants are chemical agents that inhibit blood clotting and are used to treat patients with heart disease and stroke. Each patient was assigned a unique number and given drug A on day 1 and drug B on day 2 of the test. Thirty minutes after each drug administration, a blood sample is drawn from the patient and the time for the blood to clot is recorded as shown in the table below.

Patient number	Drug A (s)	Drug B (s)
1	61.6	39.3
2	64.6	26.3
3	55.6	32.4
4	45.2	21.5
5	50.6	60.3
6	70.5	24.3
7	67.7	36.4
8	57.5	47.4
9	66.5	33.2
10	42.3	57.2
11	51.3	35.7
12	54.7	40.2
13	59.2	37.8
14	61.4	42.5
15	58.7	38.6

1. What type of data is presented in this table? Quantitative (1pt)
2. Using Excel calculate the descriptive statistics for both samples. (1 pt)

Drug A (s)		***Drug B (s)***	
Mean	58.0625	Mean	38.275
Standard Error	1.971016552	Standard Error	2.614885
Median	58.95	Median	38.2
Mode	61.6	Mode	39.3
Standard Deviation	7.88406621	Standard Deviation	10.45954
Sample Variance	62.1585	Sample Variance	109.402
Kurtosis	-0.244274808	Kurtosis	0.542251
Skewness	-0.465735176	Skewness	0.584776

Range	28.2	Range	38.8
Minimum	42.3	Minimum	21.5
Maximum	70.5	Maximum	60.3
Sum	929	Sum	612.4
Count	16	Count	16
Confidence Level(95.0%)	4.201122335	Confidence Level(95.0%)	5.573496

3. What is the null hypothesis? There is no difference between the means of the time for the blood to clot for drugs A and B. (1 pt)
4. What is the alternative hypothesis? There is a significant difference between the means of the time for the blood to clot for drugs A and B. (1 pt)
5. Using Excel perform a statistical test to determine if there is a significant difference between the 2 treatments. Which test would you choose? Paired t-test. (2 pts)

t-Test: Paired Two Sample for Means		
	Drug A (s)	*Drug B (s)*
Mean	58.0625	38.275
Variance	62.1585	109.402
Observations	16	16
Pearson Correlation	-0.419251063	
Hypothesized Mean Difference	0	
df	15	
t Stat	5.101607121	
P(T<=t) one-tail	6.50742E-05	
t Critical one-tail	1.753050356	
P(T<=t) two-tail	0.000130148	
t Critical two-tail	2.131449546	

6. Can the null hypothesis be rejected? Justify using the results of the statistical analysis. No, the null hypothesis is rejected. One-tail t-test returned a p value of 0.00006 (<0.05). Therefore,

there is a significant difference between the 2 means. Drug A is associated with a slower time of coagulation compared to drug B. (2 pts)

7. Use Excel to present the data (graph) of this clinical trial in a meaningful way. (2 pts)

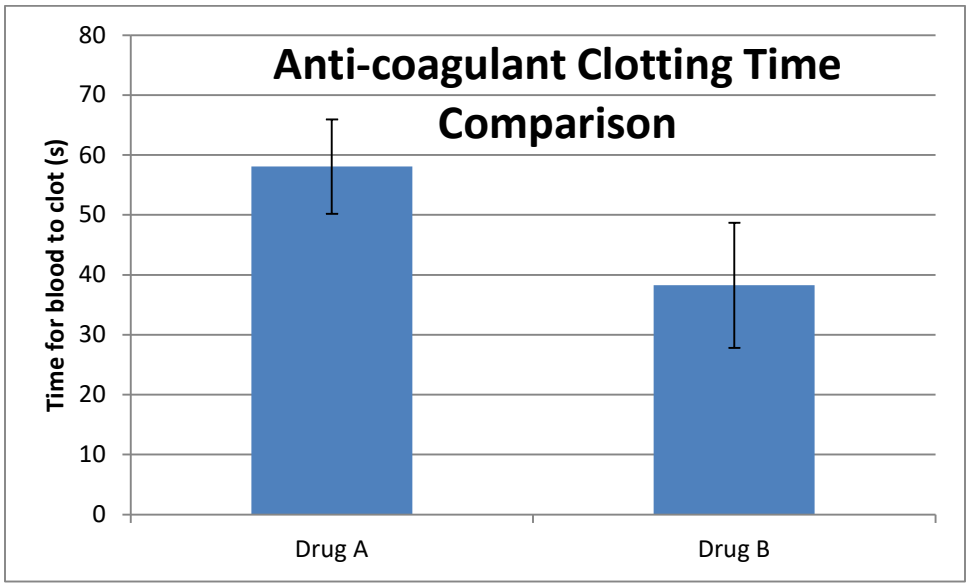


Figure 1. Anti-coagulant clotting time for drugs A and B. Data represent means ± sd, N=15.

Statistics Exercise 2

A biology student measured the frequency of chirps (the number of wing vibrations per second) made by ground crickets, at various ground temperatures. Since crickets are ectotherms (cold-blooded), the rate of their physiological processes and their overall metabolism are influenced by temperature. Consequently, there is reason to believe that temperature would have a profound effect on aspects of their behaviour, such as chirp frequency. The following data were obtained.

Temperature (º C)	Chirps/Second
21	**14.7**
21.5	**15.4**
22	**16.0**
24	**15.5**
25	**14.1**
26	**15.0**
26.5	**17.1**
27	**16.0**
28	**17.1**
28.5	**17.2**
29	**18.4**
29.3	**18.6**
29.6	**19.0**
31	**20.0**
34	**20.8**

1. What is your hypothesis? Null hypothesis?
   There is a positive correlation between environmental temperature and chirp frequency in crickets. (1 pt)
   There is no positive correlation between environmental temperature and chirp frequency in crickets. (1 pt)
2. Perform a statistical test to determine whether there is a significant correlation between temperature and chirp frequency? Justify your answer using the result of your statistical analysis.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.874864
R Square	0.765387
Adjusted R Square	0.74734
Standard Error	1.010046
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	43.26682	43.26682	42.4104	1.97E-05
Residual	13	13.26252	1.020194		
Total	14	56.52933			

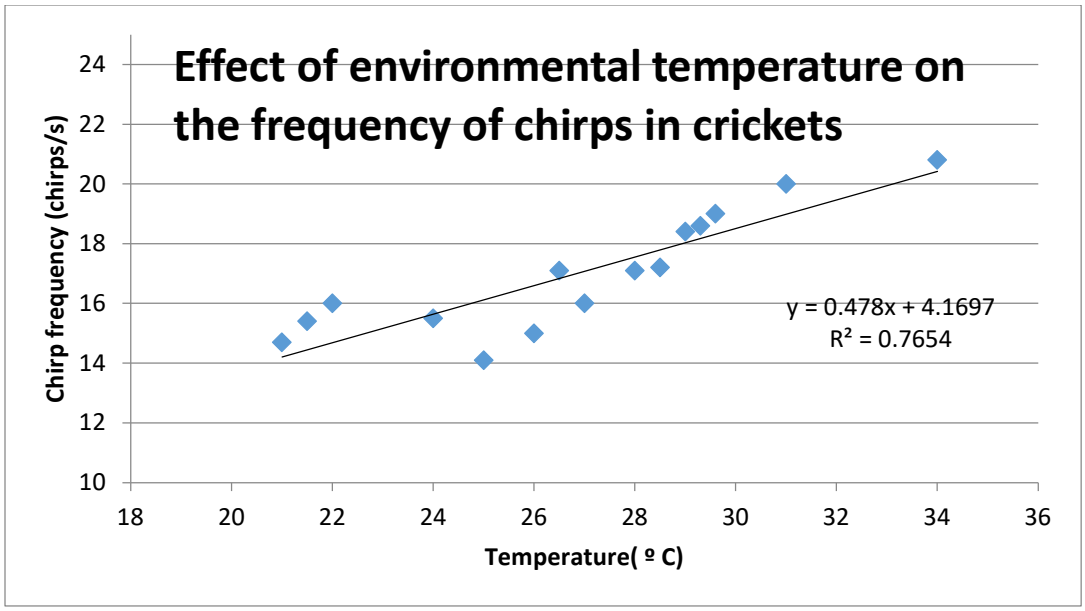
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4.169665	1.986333	2.099178	0.055896	-0.12155	8.460875	-0.12155	8.460875
Temperature (º C)	0.478019	0.073402	6.512327	1.97E-05	0.319444	0.636595	0.319444	0.636595

Linear regression analysis returns a significance of F value of 0.00002 (<0.5), indicating that the slope of the function of the relationship between environmental temperature and frequency of chirp is significantly different from a slope of zero.

3. Do you have evidence to reject/accept the hypothesis?

   Since the slope of the function is significantly different from zero, we can conclude that there is a positive correlation between environmental temperature and frequency of chirp, thus accepting the hypothesis and rejecting the null hypothesis.

4. Use Excel to present the data (graph) of this study in a meaningful way.


Effect of environmental temperature on the frequency of chirps in crickets
Chirp frequency (chirps/s)
24
22
20
18
16
14
12
10
18
20
22
24
26
28
30
32
34
36
Temperature(º C)
y = 0.478x + 4.1697
R² = 0.7654

Statistics Exercise 3

The type of browse (tender shoots, twigs, and leaves of trees and shrubs used by animals for food) favoured by the mule deer of Mesa Verde National Park is shown in the table below. An ecologist wanted to determine whether the deer feeding habits are related to the distribution of browse in this park. Using binoculars, volunteers observed the feeding habits of a random sample of 400 deer. The following results were obtained.

Type of browse	Plant composition in study area	Observed number of deer feeding on this plant
Sage brush	32.0%	117
Rabbit brush	38.7%	160
Salt brush	12.0%	68
Service berry	9.3%	32
Other	8.0%	23

1. What is the null hypothesis? Mule deer feeding habits are related/influenced to/by the distribution of browse in the Mesa Verde National Park. No difference between observed and expected. (1pt)
2. What is the alternate hypothesis? Mule deer feeding habits are not related/influenced to/by the distribution of browse in the Mesa Verde National Park. Difference between observed and expected. (1pt)
3. Use Excel to perform a statistical analysis to test your hypothesis. Which test would you use? Chi-square test is used. (3 pts)

Type of browse	Plant composition in study area	Observed number of deer feeding on this plant	Expected number of deer feeding on this plant	
Sage brush	32%	117	128	Total * 32%
Rabbit brush	38.70%	160	155	
Salt brush	12.00%	68	48	
Service berry	9.30%	32	37	
Other	8.00%	23	32	
Total	100%	400	400	

	Sage brush	Rabbit brush	Salt brush	Service berry	Other	Total

Observed	117	160	68	32	23	400
Expected	128	155	48	37	32	400

P= 0.013

4. Can the null hypothesis be rejected? Justify your answer using the results of your statistical analysis. The null hypothesis is rejected. The Chi-square test returned a p value of 0.013 (<0.05), therefore there is a significant difference between observed and expected values. The mule deer feeding habits are not influenced by the distribution of browse in the park. (2 pts)
5. Use Excel to graphically show any relationship between the distribution of browse and deer feeding pattern. Bar chart or pie chart (3 pts)