Analysis of Scarlet Macaw Data

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Presented To:
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Preliminary Note: This paper was written to be simple and directly useable by Mark McReynolds for his dissertation work. Mark's original question has been copied, with the results of our analysis of the data he provided, with remarks, following. The remarks may be quoted verbatim or adapted as necessary for the dissertation.

#1 Determining Abundance of Scarlet Macaw Food Plants and Phenology

Seasonal variation between the dry and wet seasons will be analyzed in each vegetation type by two-way ANOVA on the number of trees and sum of DBH of fruiting trees in each plot (Renton 2001), p 64. I will also use the Kruskal-Wallis test to compare seasonal and elevational variations in fruit production of each vegetation type, and individual species of food plant (Ragusa-Netto 2006), p 496.

To test for the difference in vegetation between the wet and dry seasons, we ran a paired t-test on the sum of the fruiting scores of each plot (12 plots—Polewood removed) between the wet and dry seasons. ANOVA assumes the two groups are independent, whereas they are not since they are the same plot in each season, and so a paired t-test was used. To meet the normality assumption of the test, a log-transform was applied to the differences.

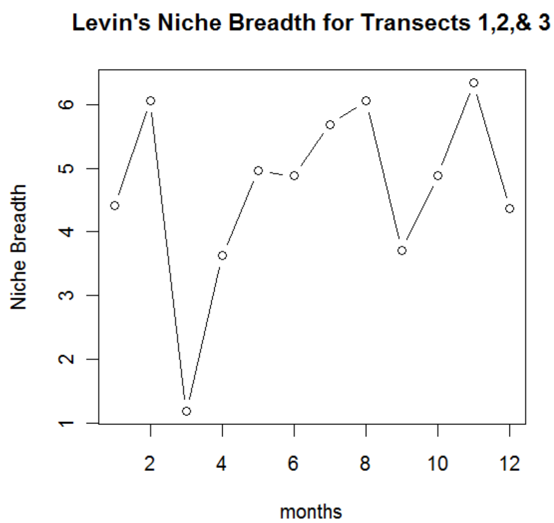
```
Updated:
        One Sample t-test

data:  diff
t = 11.8256, df = 11, p-value = 1.352e-07
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 2.495245 3.636488
sample estimates:
mean of x
 3.065866
```

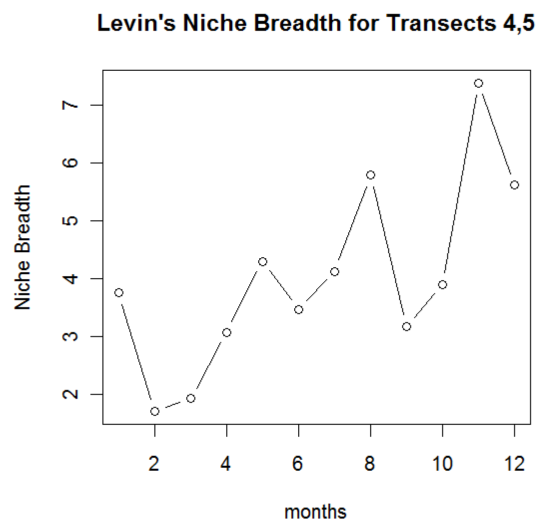
The difference between the two fruit scores between the two seasons is highly significant (p-value = 1.352e-07).

#2 Scarlet Macaw Abundance, Seasonal Movement and Diet Studies

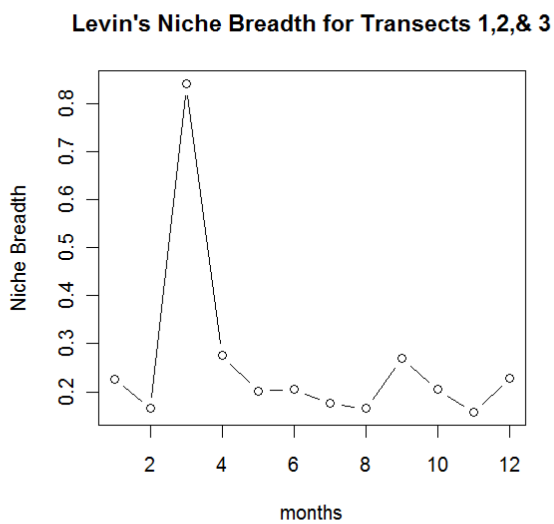
I will determine niche breadth for the fruit scores using the standardized Levin's niche breadth index (Levins 1968) as was done by (Colwell & J.Futuyma 1971) and (Renton 2006).

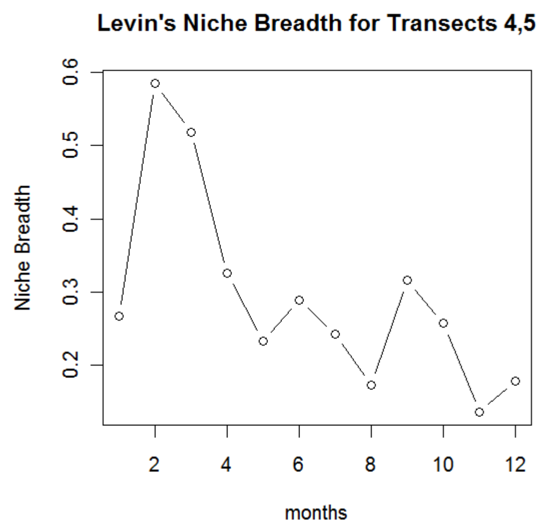
For the niche breadth index, B, we used the formula $1/B = \sum p_i^{\,2}$. Here are the graphs of B itself:





And here are the graphs of 1/B:





Where month 1 is July 08 and month 12 is June 09.

To determine if macaw diet significantly shifts between the dry and wet seasons I will use the Morisita index of similarity, as did (Renton 2001), comparing the uniformity or clustering of records of specific plant use with the months. Seasonal variation in the macaws' diet will also be analyzed by month and season with the Kruskal-Wallis test (Galetti 1993) and by Spearman's Rank Analysis (Bonadie & Bacon 2000).

There was no information on specific plant use.

#3 ????It is possible that some vegetation types may be preferred over others within certain seasons. I will use Chi-square contingency analysis to test for temporal differences in the number of feeding bouts observed in each of the six vegetation sampling transects (Renton 2001). More feeding bouts in a particular transect may indicate that the surrounding habitat is preferred over others in a particular time period.????

1- Bladen Area = Bladen and Maya Mtn
2- Red Bank Village = Guesthouse and Macaw Valley
3- Cockscomb Wildlife Sanctuary = Snook Eddy and Mx Branch
4- FCD Chiquibul Guardhouse = Guacamallo Bridge and Caracol Road
5- Las Cuevas Research Station = Las Cuevas and Monkey Tail and Cubetas and San Pastor
The test between transsects does not achieve statistical significance.

(3.2) Request for a redo of part (3.1), but with transsects separated into plots.

```
       x  y diff  log(diff+0.5)
 [1,]  0  0    0 -0.6931472
 [2,]  4 17   13  2.6026897
 [3,]  0  0    0 -0.6931472
 [4,]  5 15   10  2.3513753
 [5,] 41  0   41  3.7256934
 [6,]  0  3    3  1.2527630
 [7,] 34  0   34  3.5409593
 [8,]  0  0    0 -0.6931472
 [9,] 19 73   54  3.9982007
[10,]  3  0    3  1.2527630
[11,]  1  0    1  0.4054651
[12,]  0  0    0 -0.6931472
```

The Shapiro-Wilk normality test on “diff” gives p-value = 0.002.   (H0: diff is normally distributed), indicating the data is not normal. Square root and log transformations do not help much. Therefore, the non-parametric Wilcoxon signed rank test was employed:

```
data:  diff
V = 36, p-value = 0.01415
alternative hypothesis: true location is not equal to 0
```

Thus, the p-value = 0.01415, which is below 0.05.

(3.3) Request for an analysis of the relationship between low and high elevation differences.

	Plot.Name	Sightings	Season	Elevation
1	Bladen	0	dry	low
2	Maya Mountain Forest Reserve	0	dry	low
3	Macaw Valley	34	dry	low
4	Guesthouse Ridge	41	dry	low
5	Snook Eddy	0	dry	low
6	Mexican Branch Trail	3	dry	low
7	Guacamallo Bridge Road	5	dry	high
8	Caracol Road	4	dry	high
9	Cubetas	0	dry	high
10	Las Cuevas	0	dry	high
11	San Pastor	1	dry	high
12	Monkey Tail Trail	19	dry	high
13	Bladen	0	wet	low
14	Maya Mountain Forest Reserve	0	wet	low
15	Macaw Valley	0	wet	low
16	Guesthouse Ridge	0	wet	low
17	Snook Eddy	0	wet	low
18	Mexican Branch Trail	0	wet	low
19	Guacamallo Bridge Road	15	wet	high
20	Caracol Road	17	wet	high
21	Cubetas	0	wet	high
22	Las Cuevas	3	wet	high
23	San Pastor	0	wet	high
24	Monkey Tail Trail	73	wet	high

The issue of interest is the interaction of both the season and the elevation effects. This is a 2-way ANOVA:

```
> Anova(AnovaModel.2)
Anova Table (Type II tests)

Response: Sightings
                  Sum Sq Df F value  Pr(>F)
Elevation          145.0  1  0.4832 0.49495
Season               0.0  1  0.0001 0.99072
Elevation:Season 1027.0  1  3.4219 0.07917 .
Residuals         6002.8 20
---
Elevation       dry wet
     high  4.833333  18
     low  13.000000   0

         Season
Elevation       dry      wet
     high  7.250287 27.95711
     low  19.141578  0.00000

         Season
Elevation dry wet
     high   6   6
     low    6   6
```

There is no detected difference between Low and High elevation (p-value = 0.49; explanation: birds are Low during the dry season and High during wet, so the two cancel). There is no detected difference between Dry and Wet seasons (p-value = 0.99; explanation: same as previous). There is, however, an interaction between Elevation and Season, which is being signaled (p-value = 0.07917). This can be seen in the table of means (Dry/Low and Wet/High are the two places with the dramatically highest mean sightings).

Regarding assumptions, ANOVA also requires a normality assumption, which is also not met here. However, ANOVA is highly robust to violations of this assumption, particularly when the design is balanced (this design is balanced because there are 6 observations in each treatment).

 # 4 Comparing Scarlet Macaw Abundance & Seasonal Abundance of Food Plant Fruit/Flowers

Using Spearman's Rank analysis I will determine if there is a significant correlation between individual abundance of major food species i.e. (*Xylopia*, *Schizolobium*, *Pera*, *Slonea*) and the maximum numbers of macaws seen on a daily basis (Symes & Perrin 2003); (Ragusa-Netto 2006); and (Bonadie & Bacon 2000), at any one location. Graphs will be prepared with fruit availability per month on one axis and number of macaw sightings per month along vegetation transects, and number of other macaw sightings per month along the other axis.

For this part, we conducted two separate analyses. The first was correlation for each species by month. The second was a more specific analysis of Xylopia.

Here are the correlations for each species by month:

Species	Overall	Wet	Dry
22	0.70064905	0.774596669	0.654653671
28	0.691691498	0.664211164	0.657142857
66	0.662222631	0.664211164	0.707106781
33	0.617914381	NA	0.774596669
20	0.527220648	0.257247878	0.777541914
40	0.500158582	0	0.898645105
60	0.463109123	NA	0.676123404
69	0.414644214	0.685994341	NA
29	0.400912202	NA	0.654653671
9	0.4	NA	0.654653671
54	0.35824886	-0.5	0.5
92	0.34271505	NA	0.529640898
43	0.306235047	NA	0.392792202
103	0.294241211	NA	0.212511859
106	0.260983363	0.2	NA
104	0.25819889	0	NA
61	0.251312345	NA	0.292770022
16	0.243902439	0.948683298	0.057977104
71	0.189206466	NA	0.338061702
31	0.18445719	0.548795472	-0.392792202
38	0.174607574	NA	0.130930734
101	0.154115823	0.260896966	0.142857143
3	0.129777137	0.420084025	NA
49	0.115853659	-0.210818511	-0.085714286

85	0.113084786	NA	-0.03380617
95	0.1	0.353553391	NA
37	0.089087081	0.866025404	-0.774596669
52	0.083355043	0.398526698	-0.030358837
1	0.069354198	NA	0.18516402
11	0.043747864	0.132842233	NA
41	0.032444284	0.105021006	NA
2	0.018847464	-0.531368931	0.654653671
100	0	NA	-0.371428571
65	0	0	NA
24	-0.045856021	-0.277218497	-0.371428571
32	-0.10022805	0	NA
57	-0.131243592	-0.132842233	NA
72	-0.178599907	-0.184812331	-0.028571429
105	-0.205238415	-0.060633906	NA
39	-0.277498374	-0.707106781	0.338061702
67	-0.384210526	-0.661764706	-0.485714286
79	-0.481266711	-0.544331054	NA
74	-0.495165473	-0.677645214	-0.304255532

The common name of each species was given a number- sorted alphabetically, and each tree is named in the plots. A plot was made for each of the correlations that are not NA, they can be found in the PDF files, ProbFourTreeGraphs for Overall correlation, ProbFourTreeGraphsW for correlations in the wet season, and ProbFourTreeGraphsD for correlations in the dry season.

The data below consists of two time series variables, Xylopia ripeness scores and number of Scarlet Macaw sightings. If the variables were not time series, then the usual measures of correlation (Spearman or Pearson) would be considered. However, since the variables are time series, the appropriate measure of correlation is called "cross-correlation". When the two series occur at the same time (i.e. there is no time lag between them), then the value of cross-correlation is the same as Pearson's r, 0.962. The test of significance for cross-correlation, however, involves "prewhitening" the two individual time series to white noise by application of suitable filters, which is complicated. Therefore, two alternative solutions have been devised.

The first, and simplest, alternative is to ignore the time series information of the two variables, compute Spearman's correlation coefficient and test:

```
     Spearman's rank correlation rho

data:  Xylopia$V2 and Xylopia$V3
S = 102.1351, p-value = 0.02414
alternative hypothesis: true rho is not equal to 0
sample estimates:
      rho
0.6428844
```

This works (p-value = 0.024 < 0.05), but the p-value is much larger than one senses it should be from looking at the data or its graph.

The second alternative is to use a non-parametric bootstrap. The elements of each variable were randomly permuted, and the cross-correlation computed. This was repeated 100,000 times and the rank of the actual cross-correlation within the bootstrap cross-correlations found. The bootstrap p-value obtained was 0.00049. The null hypothesis of the test is

H0: There is no cross-correlation between Xylopia and Macaw sightings

The p-value means that there is a 49 in 100,000 chance that the data would be observed if there really were no cross-correlation. This is extremely unlikely, so the null hypothesis should be rejected, concluding that the cross-correlation of 0.962 is highly statistically significant.

	Xylopia frutescens (N = 13 Ripe)	Number of Scarlet Macaw Sighting (stationary and flying) in ST and TO
Jul-08	16.51304	4
Aug-08	0	6
Sep-08	0	0
Oct-08	0	0
Nov-08	0	2
Dec-08	30.71312	5
Jan-09	30.71312	45
Feb-09	93.31457	118
Mar-09	226.1481	177
Apr-09	0	9
May-09	4.128259	4
Jun-09	0	5

The Kruskal Wallis test will be used to compare the amount of feeding on any particular plant species with the 6 locations/vegetation types (Bonadie & Bacon 2000).

No information on particular plant feedings were recorded.

Bonadie, W. A., and P. R. Bacon. 2000. Year-round utilisation of fragmented Palm Swamp Forest by Red-bellied Macaws (*Ara manilata*) and Orange-winged Parrots (*Amazona amazonica*) in the Nariva Swamp (Trinidad). Biological Conservation **95**:1-5.

Colwell, R. K., and D. J.Futuyma. 1971. On the measurement of niche breadth and overlap. Ecology **52**:567-576.

Galetti, M. 1993. Diet of the Scaly-headed parrot (*Pionus maximiliani*) in a semi-deciduous forest in southeastern Brazil. Biotropica **25**:419-425.

Levins, R. 1968. Evolution in changing environments. Princeton University Press, Princeton, New Jersey.

Ragusa-Netto, J. 2006. Dry fruits and the abundance of Blue-and-Yellow Macaw (*Ara ararauna*) at a cerrdao remnant in central Brazil. Ornitologia Neotropical **17**:491-500.

Renton, K. 2001. Lilac-crowned Parrot diet and food resource availability: resource tracking by a parrot seed predator. The Condor **103**:62-69.

Renton, K. 2006. Diet of adult and nestling Scarlet Macaws in southwest Belize, Central America. Biotropica **38**:280-283.

Symes, C. T., and M. R. Perrin. 2003. Feeding biology of the Greyheaded Parrot, *Poicephalus fuscicollis suahelicus* (Reichenow), in northern province, South Africa. Emu **103**:49-58.