

T(auk)ing about Auks: A Temporal and Quantitative Analysis of Dive Parameters

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Introduction

Cassin's auklets (*Ptychoramphus aleuticus*) are diving seabirds which feed on primarily krill in the Pacific North [1]. Our objectives were **1**) to find if there were correlations between certain dive parameters and krill levels and **2**) to test the hypothesis that auklets dive deeper during midday (as more sunlight penetrates the ocean surface, the krill can congregate at deeper depths).



Figure 1: A Cassin's auklet on the Farallon Islands [2]

Methods

For this project, seven years of data were collected during the summer months from 2008 to 2015 on the Farallon Islands, off the San Franciscan coast. We attached sensors measuring temperature and depth every half second to individual birds and retrieved raw data after a few days of tracking. In total, we recorded 98632 dives performed by 118 birds over 62 separate days (Figure 2). We then parsed the raw data into readable text files using the programming language Python. It was at this point that we started analyzing and visualizing the data with Python, R, and the graphing interface Plotly.

Figure 2: Distribution of dive data from 2008-2015.

Year	Days	Hours	Birds	Dives
2008	7	101	15	9252
2009	8	126	15	14898
2010	11	171	11	6885
2011	7	101	20	14183
2012	4	63	6	3603
2013	9	140	15	15700
2014	8	130	17	18015
2015	8	124	19	16096

Statistical Methods

We used three statistical methods to analyze the two sets of data for our objectives: linear regression analysis for parameter-krill analysis, and Tukey HSD (honest significant difference) and ANOVA (for linear mixed models) for temporal analysis of dive depth. For the former of these analyses, we averaged data at the individual bird level (n=118) while for the latter, we used data averaged at the individual dive level (n= 98632).

- Linear Regression: Finds the least-squares line of fit between two variables
- Tukey HSD: Compares differences between multiple means (similar to a t-test)
- ANOVA (linear mixed models): For this specific case, ANOVA takes the least-squared quadratic equation (the full model) and tests if a reduced model is sufficiently similar and if it can effectively approximate full model values
 - Full model: dive depth ~ (hour+hour²) * year
 - Reduced model: dive depth ~ hour*year + hour²

Results

Dive Parameters vs. Krill

There were quantitative relationships between the yearly krill levels and seven parameters: maximum dive depth (dive pressure), dive length, dive PDI (rest time between dives), dive efficiency, dive bottom (time spent at >80% maximum depth), bout diving (% time spent diving in a cluster of dives), and bout efficiency. All these were significant with a p-value ~.01 or less.

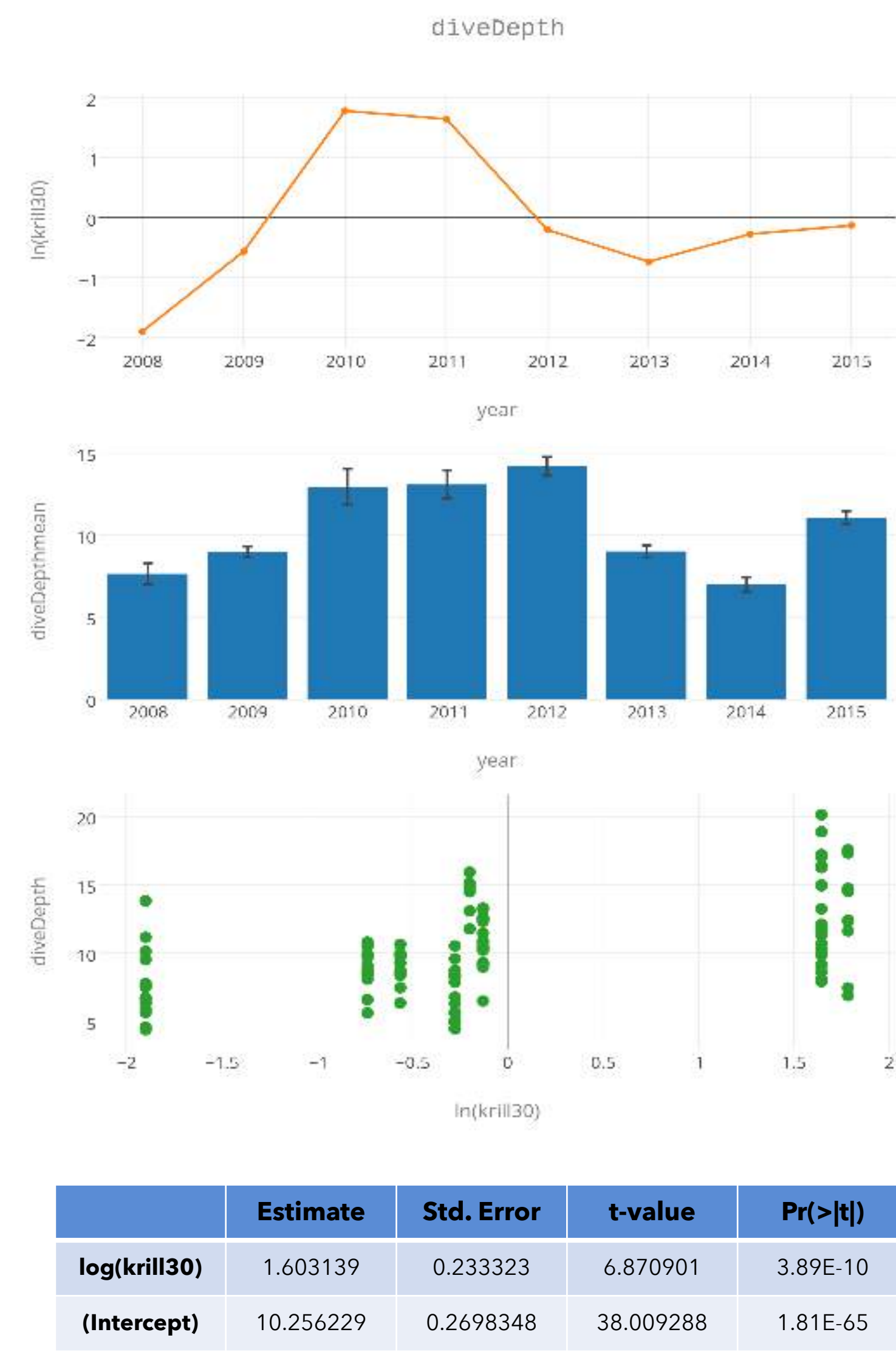


Figure 3: Comparison of maximum dive depth and krill levels 30 m underwater. Top) Ln(krill30) by year. Middle) Average maximum dive depth by year. Bottom) Dive depth vs. Ln(krill30) and the corresponding linear regression analysis.

Temporal Dive Depth

It appears that there is a correlation between dive maximum pressure and the time of day. A Tukey HSD analysis shows that dives during midday(11-4 PM) are deeper than dives during other times with a high level of statistical significance. However, ANOVA illustrates that we cannot describe the yearly relationship between dive depth and hours using a generalized equation.

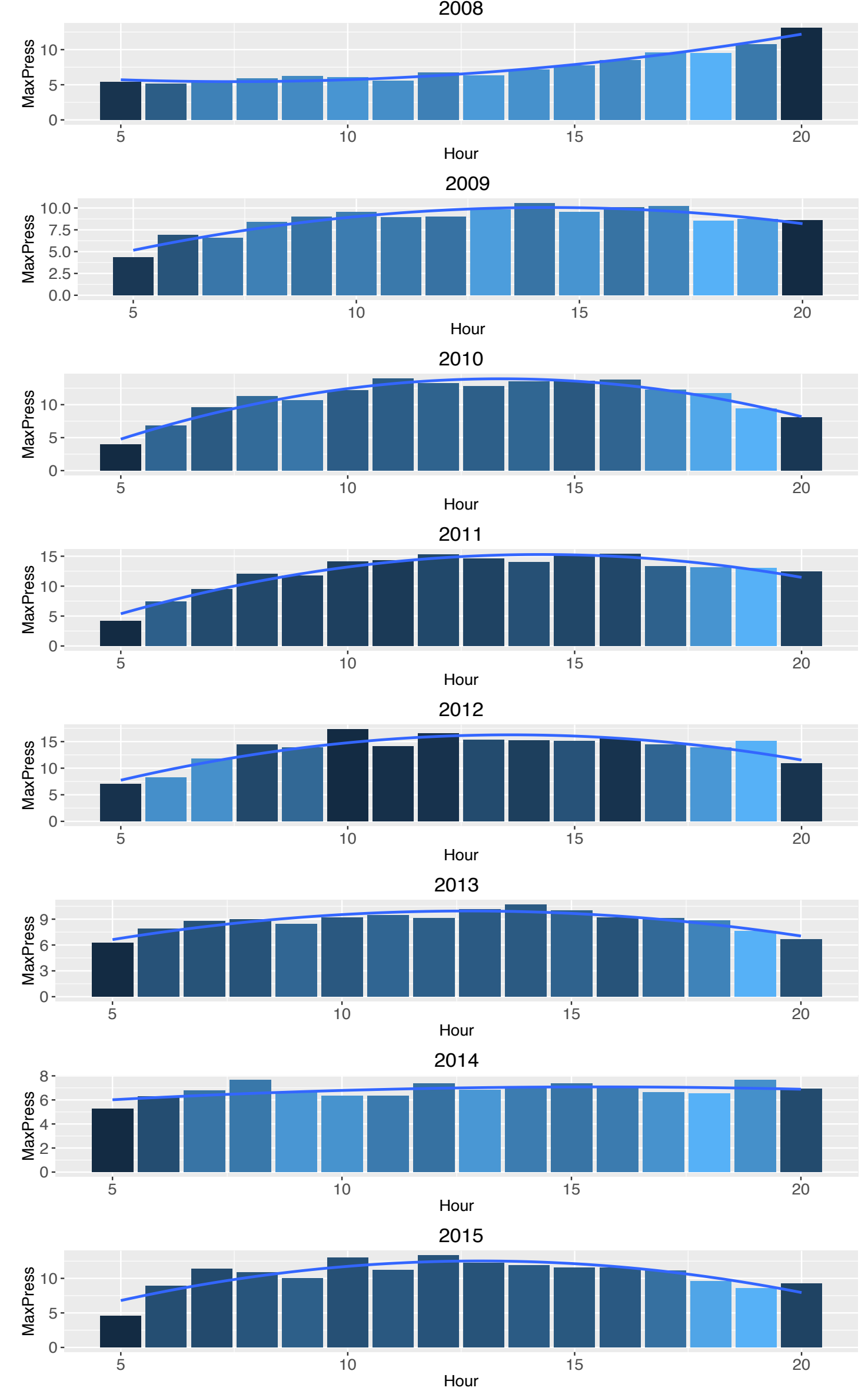


Figure 4: A set of bar charts comparing the maximum dive depth by year. The charts are colored by the total number of dives by hour for each year.

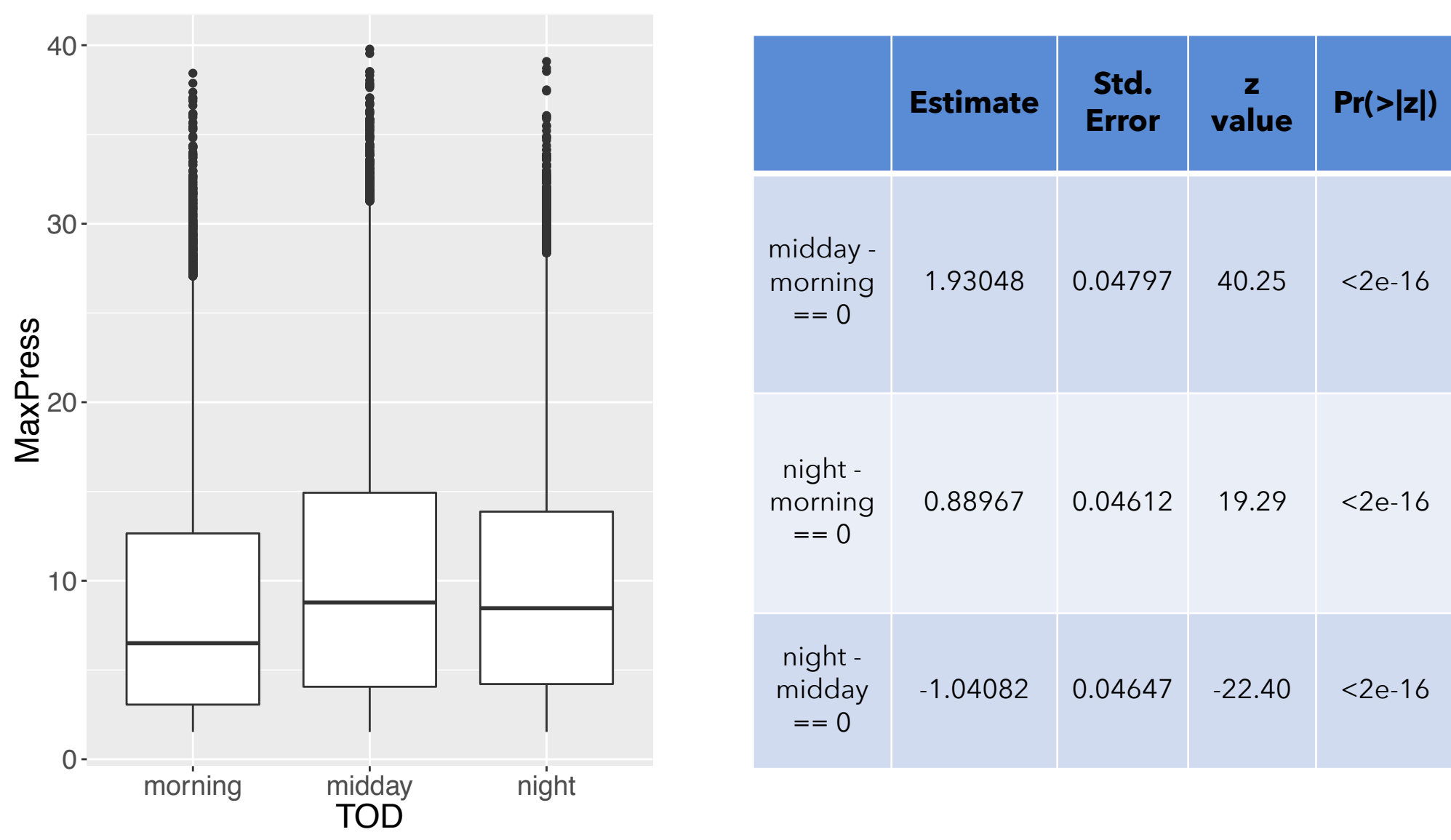


Figure 5: Cumulative boxplots of maximum dive pressure by time of day and the corresponding Tukey HSD analysis.

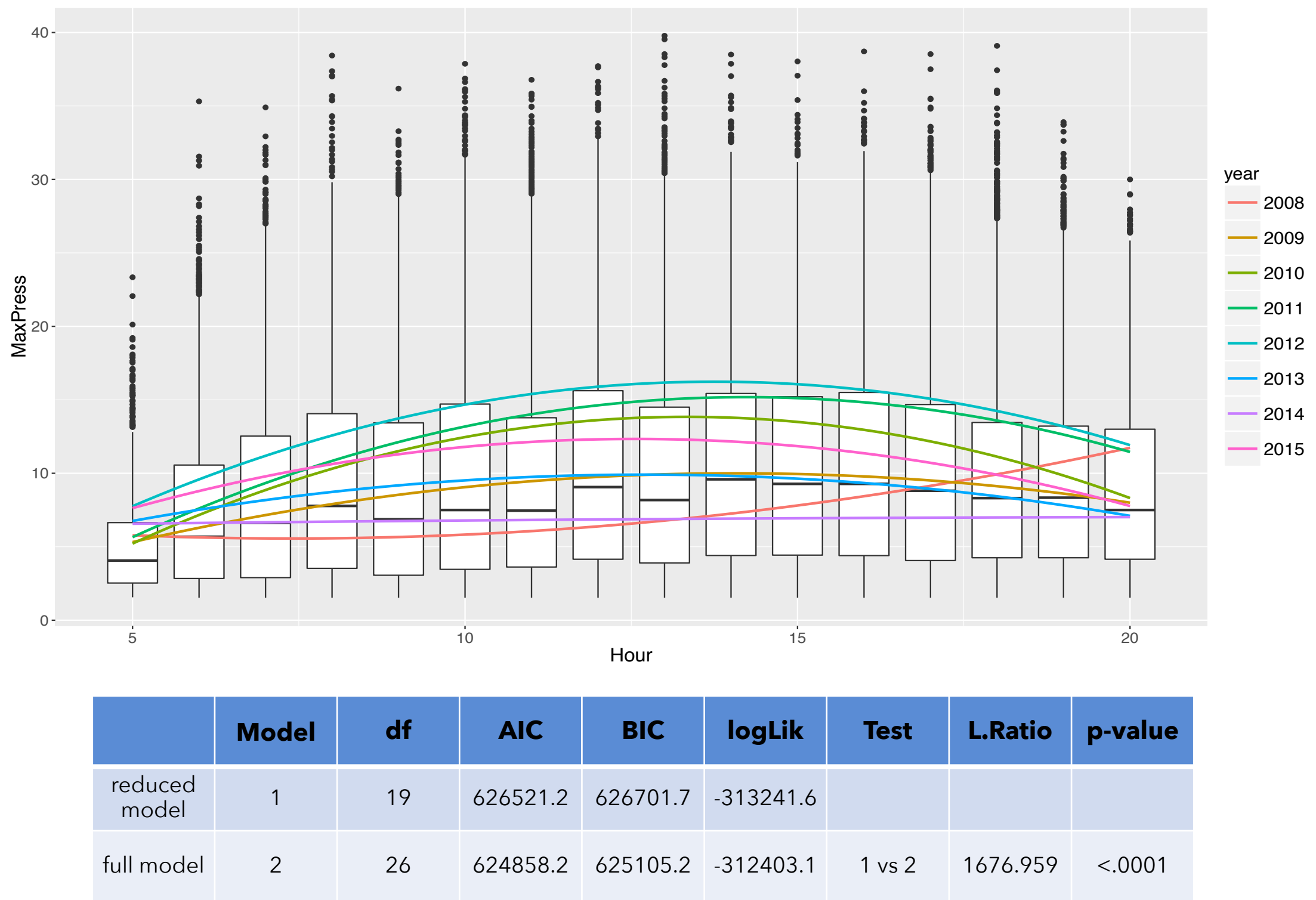


Figure 6: Cumulative boxplots of average maximum dive pressure by hour. Each year's least-squares polynomial fit to its specific data is graphed in a different color. The ANOVA table summarizes the similarity of the full and reduced model: the p-value of the models being similar is <.0001.

Conclusion

There are statistically significant correlations between certain dive and bout parameters and krill levels throughout the years. We didn't find a specific quantitative relationship between hours and dive depth, but generally, auklets dive deeper during midday.

Future Work

We plan to analyze the data for more correlations and trends. For example, we can compare individual years to others to see if abnormal trends correspond to low-krill years (2008, for instance, had little krill and auklets were forced to change their diet).

Acknowledgments

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