Evaluate Hypotheses using R-Studio and Excel  Student Sample

Included:

3 Preparatory Data Assignments
1 Final Data Assignment
The goal of this assignment is to learn how to organize and analyze data in a basic spreadsheet software program (Microsoft Excel). Using a ‘raw’ data spreadsheet (Fish Length Data downloaded from Blackboard), you will learn how to initiate a series of key commands (e.g., cut, copy, paste, insert/delete rows, etc.) and basic functions (e.g., average, sum, max, min, standard deviation, etc.), as well as how to create various types of data figures (e.g., bar chart, scatter plots, etc.). Collectively, these skills are essential for preparing spreadsheet data that is in a format suitable for secondary analysis using R-Studio. In addition to manipulating these data in Excel, each student is required to submit a written report (2-3 pages maximum, single-spaced) explaining their results. The deadline to complete this assignment is January 22, 2015.

**Basic Guidelines:**

1. Combine transect data and determine mean fish length and standard deviation (note: could also look at total counts, max and min sizes, standard errors, etc.)

2. Organize these data into discrete columns (i.e., DATE, LENGTH)

3. Plot data with either bar chart or scatter plot

4. Submit written report (via Bb) explaining/evaluating results
Using the supplied data on four species of fish, I calculated the mean, standard deviation, and other values seen in Table 1. Standard deviation is abbreviated as S.D., while standard error is abbreviated as S.E. The raw data for all species in the study included points for which total length was recorded but weight was not. In those cases I removed those points from all calculations. Outliers were not removed from calculations.

<table>
<thead>
<tr>
<th>Species</th>
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<tr>
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<td>208</td>
<td>30</td>
<td>239</td>
<td>143.16</td>
<td>62.21</td>
<td>4.31</td>
<td>0.3</td>
<td>295</td>
<td>88.99</td>
<td>80.88</td>
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<tr>
<td>Bluntnose Minnow (Pimephales notatus)</td>
<td>100</td>
<td>46</td>
<td>84</td>
<td>61.57</td>
<td>8.04</td>
<td>0.80</td>
<td>0.5</td>
<td>5</td>
<td>2.01</td>
<td>1.05</td>
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<tr>
<td>Iowa Darter (Etheostoma exile)</td>
<td>31</td>
<td>38</td>
<td>56</td>
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<td>68</td>
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Table 1. Length and weight data on four species of fish.

Blue Gill were the most abundant in the study (n=208), while Iowa Darter were least abundant (n=31). Largemouth Bass had both the highest mean length (296.98 mm) and highest maximum length (429 mm). Iowa Darter had the lowest mean length (47.22 mm). The shortest fish observed was a 30 mm Blue Gill. The Bluntnose Minnow maximum length (84 mm) falls outside two standard deviations from the mean, as does the Iowa Darter minimum length and the Largemouth Bass maximum length.

The least massive fish observed was a Blue Gill (0.3 g), while the heaviest fish was a Largemouth Bass (1070 g). The Largemouth Bass had the highest mean weight (352.66 g), while the Iowa Darter had the lowest mean weight (0.83 g). One item to note is that the S.D. of Blue Gill weight is 90.8% of the mean weight, indicating unreliability in this data. The Blue Gill
minimum weight falls outside two standard deviations of the mean, as does the Bluntnose Minnow minimum weight, Iowa Darter maximum weight, Largemouth Bass minimum weight, and Largemouth Bass maximum weight.
All four species in the study exhibit a positive relation between total length and weight, indicating that as they become heavier, they also grow longer. Trendlines for all four species are included; Figures 1a and 1d are modeled with a logarithmic trendline, while Figures 1b and 1c have a linear trendline; the trendlines chosen were the best-fitting lines for each data set. The $R^2$ values for 1a and 1d are above 0.91, while the $R^2$ values for 1b and 1c are below 0.6. The trendlines for 1a and 1d indicate that there is a logarithmic relation between total length and weight for Blue Gill and Largemouth Bass, meaning the ratio between length and weight is higher when the fish are small and becomes lower as the fish grows. The trendlines for the remaining figures are less indicative of linear relations between total length and weight for Bluntnose Minnow and Iowa Darter, but do suggest that the rates of increase for these species’ lengths are constant throughout their lives.

Future steps and directions for this study on lake fish should first include gathering more data and ensuring that all the data for each fish is recorded (i.e. ensuring that both total length and weight are recorded). This will prevent any data from needing to be excluded from analysis due to missing information. Larger sample sizes would be useful for all four species, but especially for the Iowa Darter, whose total count was only one-third of the next highest sample size. Future analysis should consider whether to remove outliers from the data, as they may be skewing the mean. Future studies should investigate why the relationship between total length and weight of Blue Gill and Largemouth Bass is logarithmic. Studies could be used to determine if there is an upper limit of the length and weight these species can attain. Studies of these species’ habitats and life cycles could be used to better understand if limited resources, competition between individuals, or some factor in the life cycles (e.g. age limit) are capping the growth of these fish.
The goal of this assignment is to learn how to organize and analyze data in a basic spreadsheet software program (Microsoft Excel). Using a ‘raw’ data spreadsheet (Fish Length Data downloaded from Blackboard), you will learn how to initiate a series of key commands (e.g., cut, copy, paste, insert/delete rows, etc.) and basic functions (e.g., average, sum, max, min, standard deviation, etc.), as well as how to create various types of data figures (e.g., bar chart, scatter plots, etc.). Collectively, these skills are essential for preparing spreadsheet data that is in a format suitable for secondary analysis using R-Studio. In addition to manipulating these data in Excel, each student is required to submit a written report (2-3 pages maximum, single-spaced) explaining their results. The deadline to complete this assignment is January 29, 2015.

**Basic Guidelines:**

1. Determine mean ± SD total length (mm) and weight (g) for four different lake fish (i.e., Blue Gill, Bluntnose Minnow, Iowa Darter, and Largemouth Bass, respectively). Note: could also include total counts, max and min sizes, standard error, etc.

2. For each species of fish, plot data with scatter plot (i.e., total length versus weight).

3. Submit written report (via Bb) explaining/evaluating results
Using the supplied data on four species of fish, I calculated the mean, standard deviation, and other values seen in Table 1. Standard deviation is abbreviated as S.D., while standard error is abbreviated as S.E. The raw data for all species in the study included points for which total length was recorded but weight was not. In those cases I removed those points from all calculations. Outliers were not removed from calculations.

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Figure 1. Total Length vs. Weight of four fish species

a) Blue Gill Total Length vs. Weight

b) Bluntnose Minnow Total Length vs. Weight

R² = 0.5112

R² = 0.957

c) Iowa Darter Total Length vs. Weight

d) Largemouth Bass Total Length vs. Weight

R² = 0.5838

R² = 0.9147
All four species in the study exhibit a positive relation between total length and weight, indicating that as they become heavier, they also grow longer. Trendlines for all four species are included; Figures 1a and 1d are modeled with a logarithmic trendline, while Figures 1b and 1c have a linear trendline; the trendlines chosen were the best-fitting lines for each data set. The $R^2$ values for 1a and 1d are above 0.91, while the $R^2$ values for 1b and 1c are below 0.6. The trendlines for 1a and 1d indicate that there is a logarithmic relation between total length and weight for Blue Gill and Largemouth Bass, meaning the ratio between length and weight is higher when the fish are small and becomes lower as the fish grows. The trendlines for the remaining figures are less indicative of linear relations between total length and weight for Bluntnose Minnow and Iowa Darter, but do suggest that the rates of increase for these species’ lengths are constant throughout their lives.

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Several different .csv files are attached below. The file titled: kelp_abund_example.csv will be used as part of an in-class exercise (I'll hand-out copies of the code in class and it will be attached below). The other files (eelgrass_density_BFC.csv and eelgrass_density_CatH.csv) are for Data Assignment #4 (due March 5). Using R, I'd like you to analyze the eelgrass_density_BFC.csv data using a BARPLOT and REGRESSION. All of the information you need to complete the basic components of this assignment (#4) is available in the example code (below) and the code from Data Assignment #3 (also attached below). Specifically, you will need to do add the following to your barplot and regression plots: 1) Axis and Title Labels, 2) Bar/Data Point Colors, 3) Modify Axes Scale/Range, 4) Horizontal Line with Color Showing Mean (Barplot), 5) Regression Line with Color (Regression Plot). As usual, you will submit a written report (via Bb) explaining/evaluating the results from your barplot of regression data. Bonus Points if you can do the following: Add a Legend, Include Coefficient and/or R-Squared Values on Regression Plot. Super Bonus Points if you can simultaneously plot both the eelgrass_density_BFC.csv and eelgrass_density_CatH.csv on a single regression (with a legend and all of the other stuff mentioned previously).

A few notes on the data being analyzed: Both the eelgrass_density_BFC.csv and eelgrass_density_CatH.csv spreadsheets are organized into 4 columns (MO=Month, YR=Year, SGDEN=Seagrass Density (Mean Number of Shoots per Square Meter), and FISHabun=Fish Abundance (Mean Number of Calico Bass Observed)). Let me know if you have questions!
Figure 1 shows density of eelgrass (*Zostera spp.*) observed at Big Fisherman’s Cove from September 2013 to January 2015. The mean density of eelgrass shoots was 26.1 shoots/m². Grass density in 2013-09 was above the average (mean =42.8). Grass density was then below the mean value from October through December 2013 (means = 23.2, 13.2, 20.4). Eelgrass density in January 2014 was slightly above the mean with a value of 26.8 shoots/m². Following this increase in eelgrass density, the observed values fell below the mean February 2014 through June 2014 (means = 18.4, 19.2 18.8, 20.0, 19.6). Then, there was a period lasting six months (from July 2014 - December 2014) where eelgrass density was again above the mean; the means for these months are chronologically as follows: 35.6, 31.2, 28.4, 35.2, 33.2, 40.0. Finally, the eelgrass density fell below the mean in January 2015, with a value of 18.0 shoots/m². The highest eelgrass density was observed in September 2013 (mean = 42.8), while the lowest eelgrass density was observed in November 2013 (mean = 13.2).

Figure 2 plots abundance of calico bass (*Paralabrax clathratus*) versus density of eelgrass (*Zostera spp.*) observed at Big Fisherman’s Cove. There is a positive correlation between fish abundance and eelgrass density. The line describing this relationship is $y=0.9237 - 7.5521$; this line does not pass through the origin. The R² value for this linear regression line is 0.344. Seven data points fall above this line, while ten data points fall below this line. The largest cluster of data (n=6) is found below the linear regression line, where eelgrass density is approximately 20 shoots/m², and fish abundance is less than 10 individuals observed.
As discussed in class, each group will analyze multiple parameter data set (posted below). Data include information on seagrass habitat, kelp bass abundance, and NOAA temperature data. Each group will independently analyze and interpret data using R. Final projects include written report (4-5 pages) and oral presentation (10-15 min). Projects will be evaluated for originality, accuracy and thoroughness of research, attention to detail, and overall quality of the finished product. Note: Data posted on Bb in Excel Spreadsheet (organized within three separate tabs: Kelp Bass Data; Seagrass Data; and Temp Data -- you will need to save each set of data separately as a .csv file). Come see me ASAP if you have questions!
Final Data Assignment

Introduction

Each month between September 2013 and December 2014 researchers at the University of Southern California’s Wrigley Marine Science Center conducted surveys in Big Fisherman’s Cove off of Catalina Island to record kelp bass, *Paralabrax clathratus*, lengths. Belt transects were also conducted over seagrass beds with the intent to understand how seagrass density, as well as abiotic factors such as temperature and time of year, affect the abundance and distribution of kelp bass. Kelp bass lengths were collected in centimeters and seagrass density was recorded as shoots per square meter. After 16 months of data were recorded they were analyzed to understand kelp bass population dynamics.

From length, we were able to determine the age of kelp bass using the Von Bertalanffy growth equation. The Von Bertalanffy equation, \( L_t = L_\infty \left(1-e^{-K(t-t_0)}\right) \), was used to find age dependent on the length of the kelp bass observed in Big Fisherman’s Cove. For our report, \( L_t \) is the length of individual kelp bass observed, \( L_\infty (69.8) \) is the maximum possible length (in centimeters) for the species of fish, \( K \) is the rate of growth (in centimeters per year), \( t \) is the age (in years) we are solving for, and \( t_0 \) is the theoretical length of the fish at age 0 (or birth). The constants \( L_\infty \), \( K \), and \( t_0 \) were taken from a scientific report done by Love in 1996. R-Studio was used to run this equation and find the ages of fish observed. Next, biomass was calculated using the equation \( \text{biomass} = a(L)^b \), with the constants \( a=6.6359E-05 \) and \( b=3.23655 \) as defined by Quast (1968). Once biomass and age were determined, we were then able to calculate age classes and sort fish by biomass into these bins.

Ocean temperature data were taken from pre-existing NOAA data and used to see how temperature may affect seagrass density. Finally, several figures were created to help visualize, and compare and contrast these data. The goal of the study was to determine secondary productivity and aspects of kelp bass population dynamics within the seagrass ecosystem of Big Fisherman’s Cove. To guide our data analysis we posed five questions: How does seagrass density affect population dynamics of kelp bass? How do kelp bass biomass, water temperature, and seagrass density vary over time? How can temperature affect seagrass density? How does seasonality affect kelp bass abundance and age class distribution? Finally, how does seagrass density affect secondary productivity?

Results

To begin, bar plots of monthly averages for water temperature, seagrass density, and kelp bass biomass are plotted in Figure 1. Water temperature and seagrass density were recorded
monthly from September 2013 - March 2015, while kelp bass biomass was calculated for each month from September 2013 - December 2014. The average water temperature (Figure 1a) throughout the period of study was 18.13 °C. The maximum temperature (22.42 °C) was observed in September 2014, while the minimum temperature (15.16 °C) was observed in April 2014. Eight months had monthly means above the global mean, while ten months had monthly means below the global mean; one month’s mean temperature (December 2014) was equal to the global mean. September and October 2013 had mean temperatures above the global mean, followed by a seven-month stretch of monthly means below the global mean. June 2014 - November 2014 were above the global mean temperature, and December 2014 had a mean temperature equal to the global mean of 18.13 °C. The study period concluded with the final three monthly mean temperatures below the global mean temperature.

Similar information is plotted for monthly mean seagrass densities from September 2013-March 2015 (Figure 1b). The global mean seagrass density was 6.38 shoots/square meter. The maximum seagrass density (10.7 shoots/square meter) was observed in September 2013, while the minimum seagrass density (3.3 shoots/square meter) was observed in November 2013. Eight months had monthly means above the global mean, and eleven months had monthly means below the global mean. September 2013 had a mean seagrass density (10.7 shoots/square meter) above the global mean, and was followed by three months where seagrass density was below the global mean. Seagrass density in January 2014 (6.7 shoots/square meter) was above the global mean, but the following five months’ means were all below the global mean. Then, beginning in July 2014 and lasting through December 2014, monthly mean seagrass density was above average. Finally, the last three months of the study had mean seagrass density values below average.

Lastly, monthly biomass values were calculated using the Von Bertalanffy equation from observations of fish length, and a mean biomass for the period of study was calculated at 229.97g (Figure 1c). Unlike Figures 1a and 1b, data were only available from September 2013 - December 2014. The maximum fish biomass for a given month occurred in September 2013 (1010.08 g), and the minimum fish biomass occurred in February 2014 (8.36 g). Four months had fish biomass above average, while twelve months had below-average biomass. The maximum fish biomass value of September 2013 preceded a nine-month span of below-average monthly fish biomass. Biomass in July 2014 (596.15 g) was above average. Biomass in August 2014 (209.22 g) was below average, followed by September 2014 (355.22 g) and October 2014 (329.29 g) above average. The last two months of observations—November and December 2014—yielded fish biomass calculations that fell below the average (203.24 g and 75.32 g, respectively).

In exploring the relationship between monthly mean seagrass density and monthly mean water temperature, a positive correlation was found (Figure 2). Monthly data were plotted and a
linear trendline applied \((y = 0.5456x - 3.5120)\); the \(R^2\) value is 0.325. For minimum and maximum monthly values for temperature and seagrass density, see Figures 1a and 1b. Two points lie along the trendline, while ten points lie below the line and seven lie above it.

We note a few apparent trends revealed by these figures. First, the peaks and valleys in all three bar plots of Figure 1 suggest a seasonality to the data collected near Catalina Island. In general, monthly mean values of water temperature, seagrass density, and fish biomass tended to be above the global average during late summer through late fall, and below the global average during winter and spring. This is logical considering the high heat capacity of water; the heating throughout the summer months allows water temperatures to persist above average for many months after the air begins cooling, leading to warmer waters even into late fall and winter. This stretch of above-average water temperatures was more apparent in 2014 than in 2013; similarly, the periods of above-average seagrass density and fish biomass were also more apparent and lasted for a longer period of time in 2014. The positive correlation between temperature and seagrass density was confirmed (Figure 2), indicating that seagrass in this area is most abundant when waters are warmer. The correlation between seagrass and biomass indicated by Figure 1 was explored subsequently.

Figure 3 shows both the abundance (frequency) of kelp bass in seagrass depending on age and the average biomass of kelp bass depending on age from September 2013 to March 2015. The abundance was sorted depending on the age class, and can be followed via the pink plot points. What we have learned in class is that seagrass is a nursing ground for kelp bass. The average number of kelp bass as newborns (0 years of age) is 14.2 individuals. Then, the frequency of the fish decreased in the age class of 1 year to about 1 individual. Age 2 had the highest average frequency of kelp bass in the seagrass with about 24.6 individuals. Age 3 had the second highest average abundance at 19.4, which is followed by age 4 at 13.3 individuals. The likelihood of kelp bass being in the seagrass after age 4 went down as the graph shows a trend of less kelp bass being in the seagrass as they age.

The biomass, which is marked by the brown dots, has a different trend because older kelp bass have much more biomass. At birth, the biomass is about 0.3 grams. The biomass continues to increase with age exponentially until about age 15, when the rate slows down. Because the graph is an S curve, the biomass does continue to grow, but kelp bass gain the most biomass between the ages 8 and 15. These two sets of data show that individual fish with higher biomass do not frequent seagrass as much as fish with low biomass. However, the younger fish are highly abundant in seagrass, whereas older kelp bass are rarely observed in the area.

Figure 4 shows that as the density of seagrass (measured by shoots/square meter from September 2013 to March 2015) increases, so does the total kelp bass biomass (measured in grams). Data plotted deviates from the regression line quite a bit as the value of \(R^2\) is 0.14, which is fairly low, but it does show that there is a positive correlation between seagrass density and
fish biomass. We expected the kelp bass biomass to increase with seagrass density; however, by comparing these data to Figure 3, we get a better sense of the relationship between the density of seagrass and the population structure of kelp bass. Despite the younger fish having much lower biomass, they are abundant in seagrass compared to the older fish with higher biomass per individual.

If biomass increased with seagrass density, but fish with lower biomass are more common in the seagrass, then the seagrass is mainly a habitat for high numbers of young fish. Figure 3 shows that there were spikes in kelp bass abundance from ages 2 to 11. The age for sexual maturity for kelp bass is between 2 and 5 years of age (Canterbury and Pyper, 2013). This supports what we discussed in class about seagrass being an essential fish habitat. We suspect that the highest frequencies of kelp bass were between ages 0 and 4 because the sexually mature kelp bass return to the seagrass in order to spawn. Eventually the eggs hatch, which causes the high number of newborns.

Figure 5 depicts the number of kelp bass found in each age class each month for the 16-month study period. The highest frequency of fish was seen in November of 2014 with 85 individuals recorded in age class 2. The next highest frequency of fish was recorded in October 2014 with 66 individuals recorded again in age class 2. Finally, September 2014 also saw a high frequency of fish with 59 individuals recorded in age class 3. September, October, and December of 2013 also experienced high frequencies of fish in young age classes. However, the abundance of fish in these frequencies was not as high as the amount of fish seen near the end of the study, in 2014. September 2013 experienced a high frequency of 26 individuals in age class 3, and again in age class 12. October 2014 experienced a high of 39 individuals in age class 0. Finally, December of 2014 experienced a high of 40 individuals in age class 0. With the exception of September 2013, the highest abundances of fish throughout the study were recorded in low age classes, defined as age classes 0 to 3 (Figure 5).

Nearly every month throughout the study experienced a low frequency of fish in at least one age class. With the exception of September 2013, every month experienced low fish frequencies in higher age classes, defined as age classes 10 and above. Each month there were one or more age classes with a fish frequency between 1 and 3. Overall, lower frequencies of fish were seen in higher age classes, indicating that most fish from the study belonged to lower age classes. Months January through June of 2014 saw particularly low fish frequencies across every age class recorded. In February of 2014 only one fish, belonging to age class 9, was recorded. In April of 2014, just two months later, only two fish were recorded, one each belonging to age classes 9 and 10 (Figure 5).

Over the course of the entire study fish frequencies seem to be highest in lower age classes and in months September through December in both 2013 and 2014. January of 2014 experienced a sharp decline in fish abundance across all age classes. This low fish abundance
then continued for several months until July 2014. The trends revealed by these data describe several aspects of the kelp bass population dynamics in seagrass beds in Big Fisherman’s Cove at Catalina Island. Overall, more fish of younger age classes were seen in this area, especially in months of September through December. This indicates that this area serves a nursery for young kelp bass with peak reproduction seasons in the fall to early winter. In the Spring and Summer very few kelp bass were present across all age classes, indicating that either these kelp bass are leaving the area, or falling victim to predation or some other ill (Figure 5).

Discussion

Our ultimate goal in analyzing these data was to determine if there was a connection between water temperature, seagrass density and the ability for kelp bass to survive and grow. We began by exploring how water temperature, seagrass density, and kelp bass biomass vary over time and found that all three variables exhibit some degree of seasonality. Based on these initial findings, we correlated seagrass density and temperature, as well as kelp bass biomass and seagrass density, and found that both relationships have a positive correlation. We found that the kelp bass observed in the study region were mostly young fish with low biomass, and that fish biomass increased with fish age. While the biomass of these young fish was low, their abundance was high, which suggests this area is important for the development of young fish. The density of seagrass, which is related to water temperature and seasonality, is a contributing factor to the growth of these fish. Lastly, when we plotted the age classes of the fish observed each month, the finding of our initial bar plots were confirmed and expanded—the highest numbers of fish off Catalina Island are found during the late summer and fall months, when waters are warmest and seagrass is most abundant, and these fish are in young age classes.

This leads to a number of conclusions. First, a higher density of seagrass increases secondary productivity of *Paralabrax clathratus*. This area is most productive during the summer through late fall, and is a prime nursery ground for kelp bass, as indicated by the predominance of low age classes and high frequency of young fish observed. From this, we ultimately conclude that seagrass off Catalina Island is essential fish habitat, and must be protected. Future research could be directed at recording more data on water temperature, seagrass density, and kelp bass length over a longer period of time to determine if there are inter-annual fluctuations in temperature that may cause trends or fluctuations in seagrass density or kelp bass biomass.
Figure 1. Bar plots of mean monthly water temperature (a), seagrass density (b), and kelp bass (*Paralabrax clathratus*) biomass (c) observed in Big Fisherman’s Cove. Monthly observations for temperature and seagrass span September 2013 - March 2015, while biomass calculations span September 2013 - December 2012. Mean values over the entire study period are shown as horizontal lines.
Figure 2. Seagrass density versus water temperature as observed at Big Fisherman’s Cove from September 2013 - March 2015.
Figure 3. Kelp bass frequency (average number of individuals depending on age) and biomass compared to age. Data was observed in Big Fisherman’s Cove at the USC Wrigley Marine Institute.

Figure 4. Kelp bass biomass in relation to density. R² was calculated as 0.14. Data was observed in Big Fisherman’s Cove at the USC Wrigley Marine Institute.
Figure 5. Depiction of the frequency of fish (measured as number of individuals) in each age class, each month.
Works Cited