**Project EDDIE: Biodiversity module**

**Student Handout**

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Learning objectives:

* Explain and define species richness, Shannon diversity index and Pielou’s evenness index
* Analyze a large data set, using a pivot table, to determine species richness, Shannon diversity index and Pielou’s evenness index
* Explore how different reef types and hurricanes impact abundance and diversity indices
* Communicate and summarize findings clearly and effectively using quantitative evidence

Why this matters:

Biodiversity can be measured at many levels (e.g. gene, species, ecosystem). Species diversity is a major component of biodiversity and can contribute to ecosystem stability (e.g. Tilman 2006). Diversity measures such as species richness (the number of different species present) and evenness (the relative abundance of each species) are useful quantitative metrics for understanding how communities are structured. Diversity indices such as the Shannon index and the Pielou’s evenness index (Pielou 1966) incorporate both richness and evenness into a single measure of species diversity and can be useful for comparing biodiversity between sites and/or over time.

In this module, you will analyze data from the [Florida Keys Reef Visual Census](https://myfwc.com/research/saltwater/reef-fish/monitoring/fim-fl-keys-visual-sampling/) (FKRVS), a long-term monitoring effort of key reef fish populations in the Florida Keys National Marine Sanctuary. Coral reefs support more species per unit area than any other marine environment (NOAA) and have significant economic and recreational value. Unfortunately, climate change, pollution, habitat destruction and disease have threatened many coral reefs and the communities that inhabit them. You will calculate the species richness, Shannon index and Pielou’s evenness index across different years of data that vary in hurricane frequency and between different benthic habitat types (strata). The module will culminate with you investigate how different benthic reef habitats and hurricane frequency influence biodiversity in the FL Keys and a synthesis of all of your data into a summary finding.

Outline:

* *Activity A*: Determine the species richness, Pielou’s evenness and Shannon index for a given year of data from the FKRVS
* *Activity B*: Analyze and compare diversity measures to a different year of data that followed a hurricane intensive year
* *Activity C*: Investigate how benthic reef habitat and hurricane frequency influence biodiversity in the FL Keys and synthesize all of the data into a summary finding.

**Diversity Metrics**

This learning module focuses on three different measures of diversity - species richness, Shannon index and Pielou’s evenness index. Before you start analyzing the data from the Florida Keys Reef Visual Census, let’s take a moment to review what each of these terms tells you about the community you are studying.

*Species richness*

Species richness is the number of unique species present. Consider the simple data set below of four common reef fish in the FL Keys:

|  |  |  |
| --- | --- | --- |
| Species | Common Name | Abundance |
| *Archosargus probatocephalus* | Sheepshead | 2 |
| *Orthopristis chrysoptera* | Pigfish | 25 |
| *Mycteroperca venenosa* | Yellowfin grouper | 1 |
| *Seriola dumerili* | Greater amberjack | 1 |

What is the species richness? \_\_\_\_\_\_\_\_\_\_

*Shannon Diversity Index*

The Shannon diversity index () is a quantitative measure that allows you to simultaneously take into account species richness and evenness and is calculated as follows:

ln

Calculations are done by:

1. Using the proportional abundance of species i (pi). (For example, if species i makes up 15% of the individuals, pi = 0.15).
2. The value pi is then multiplied by the natural log of pi
3. Sum across all species (Σ)
4. Multiply by -1.

For example, H’ = -1\*[p­1\*ln(p1)+ p­2\*ln(p2)+ p­3\*ln(p3)+…+ p­n\*ln(pn)]

The Shannon diversity index assumes that all species are represented in the sample and that species are randomly sampled. A community with a single species would have a H’ of 0 and H’ values increase with increasing species richness and evenness. The Shannon diversity index for ecological data ranges typically from 1.5 to 3.5.

Diversity indices, such as the Shannon index, have faced criticism as they are not sampled from a known distribution (in ecological applications) so there are no statistical means to evaluate the probability of particular *H’* values or the statistical difference between *H’* of two different communities (Gotelli and Graves 1996). Still, despite this limitation, particularly for large data sets, Shannon diversity continues to be used as a measure of diversity in a number of different fields.

Using the simple data set from before, calculate the Shannon index.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | Abundance | Relative abundance (pi) | lnpi | pi\*lnpi |
| *Archosargus probatocephalus* | 2 |  |  |  |
| *Orthopristis chrysoptera* | 25 |  |  |  |
| *Mycteroperca venenosa* | 1 |  |  |  |
| *Seriola dumerili* | 1 |  |  |  |
|  |  |  | Sum across all species |  |

What is the Shannon index?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Pielou’s Evenness Index*

Pielou’s evenness takes into account the relative abundance of each of the species that is present in a community. Low evenness means that the community is dominated by one or more species whereas high evenness means that species occur in similar numbers. In the example above, the community has low evenness because *Orthopristis chrysoptera* is dominant compared to the other reef fish species.

Related to the Shannon index, Pielou’s evenness index also simultaneously measures species richness and evenness. The index is constrained between 0 and 1, where 0 means that there is no evenness and 1 means that all species occur in equal abundance. The Pielou’s evenness index is calculated as follows:

Here, *H’* is the Shannon index for a given community and Hmax is calculated as:

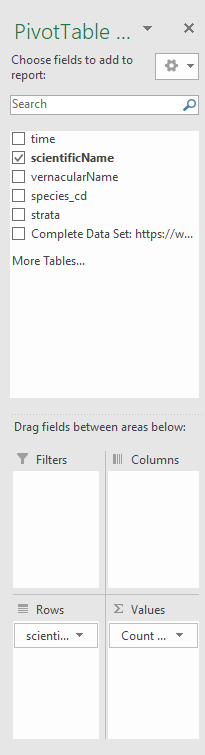
Here, ln the natural log and *S* is the species richness.

Calculate the evenness index for the simple data set above:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Activity A: What is the species richness, Shannon index and Pielou’s evenness index for one year of the Florida Keys Reef Visual Census?**

The data set you will be using in this module is from the Florida Keys Reef Visual Census. The Florida Fish and Wildlife Conservation Commission's (FWC) Fisheries Independent Monitoring (FIM) program began a long-term monitoring effort of key reef fish populations in the Florida Keys National Marine Sanctuary in 1998. Concerns over habitat degradation and recent increases in recreational and commercial fishing in the FL Keys led to the establishment of an annual census of reef fish populations. The visual census, using a stationary point count method, evaluates the relative abundance, size structure, and habitat utilization of specific reef fish species that are targeted by commercial and recreational fisheries (Smith, S.G., et al. 2011) and allows for more accurate assessment of the ecosystem condition.

In this activity, you will determine the species richness, Shannon index and Pielou’s evenness index for the reef visual census from the year 2000.



**Data Organization**

1. Start by downloading the data set ([available here](https://docs.google.com/spreadsheets/d/16QNYlqgnIB7jsnhRVWrktIQik9k3cS1I/edit?usp=sharing&ouid=102931111693466191346&rtpof=true&sd=true)). A scaled down version has been provided to you in the data link but all of the data is publicly [available here](https://www.sciencebase.gov/catalog/item/57fe9bf5e4b0824b2d14ebf4).
2. Examine the columns of the data
   1. Column A – Date and time of data collection
   2. Column B – Scientific name of reef fish
   3. Column C – Common name of reef fish
   4. Column D - Species code (consist of three letters of genus and four letters of the specific epithet, note some species are only identified to genus and have SPEC. for the specific epithet)
   5. Column E - Identifies the reef strata type (discussed later)
3. A pivot table is a helpful tool to quickly summarize your data. In this case, we need to know how many individuals of each species were present for the 2000 census.
   1. Click on cell 1A
   2. Go to - “insert”, “pivot table”
   3. Use the default settings of “Select a table or range” and “New Worksheet” and click ok
   4. You should now have a new worksheet where you can choose the fields for your pivot table.
   5. You will do this by dragging the field “scientificName” to the “rows” and “values” boxes (should look like image to the right)
   6. What you should see now are all of the species identified in the census (Column A) with a count of the number of each species observed in the census (Column B).

**Total Abundance**

1. Total abundance can be found by scrolling to the bottom of the species list. You should see 35,549. Meaning that 35,549 individual reef fish were sampled during the year 2000.

**Species Richness**

1. You can calculate the species richness by using the “count” function and highlighting the column with the number of different species present. It may be helpful to create a table on your excel worksheet of all of the species diversity measures you will be calculating. There is a table at the bottom of this page where you can enter the species richness as well.

**Shannon Diversity Index**

1. You will need to calculate the relative abundance of each species (pi).
   1. Create a column called valuesin Column C
   2. Use the “cut”, “paste values” function to copy your count data from column B
   3. Create a column called pi in Column D
   4. To calculate the relative abundance of the first species listed, *Abudefduf saxatilis*, you will type “=C4/35,549”. The relative abundance tells you what proportion of the total reef fish sampled were *Abudefduf saxatilis.*
   5. You can then copy the formula to the subsequent rows (if you click on D4 and then place your cursor on the bottom right corner of D4 and double click when it becomes a plus sign, it will populate the subsequent rows with the same formula from D4)
   6. Create a column called lnpi in Column E
   7. To calculate the natural log of the relative abundance of *Abudefduf saxatilis* you will type “=ln(D4)”, copy to subsequent rows as you did above.
   8. Create a column called pilnpi in column F where you multiply column D and E together “=D4\*E4”
   9. The last step to calculate the Shannon index is to sum pilnpi across all species and multiply by -1. Choose a cell where you want your Shannon index (once again a labelled table in the worksheet is helpful) and type (or highlight)

“=-sum(F4:F201)”

**Pielou’s Evenness index**

1. You need to determine Hmax, which is the natural log of the species richness.
   1. Once you have Hmax, choose a cell where you want your evenness index and divide your calculated Shannon diversity index by Hmax
2. Record your results in the table below:

|  |  |
| --- | --- |
| Diversity measure | Calculated value |
| Abundance | 35,549 |
| Species Richness |  |
| Shannon Index |  |
| Pielou’s Evenness Index |  |

1. What do the values presented in the table above tell you about reef fish diversity?

Abundance:

Species Richness:

Shannon Index:

Pielou’s Evenness Index:

1. Why might your interpretation of the data be limited? (Hint – think about how the indices are meant to be used).

**Activity B: How does species richness, Shannon index and Pielou’s Evenness Index change in years following high hurricane frequency in the FL Keys?**

The Florida Keys are prone to hurricanes that can cause massive structural damage (Gardner

et al. 2005) and, among many other impacts, have consequences for reef fish species diversity

(Rogers 1993). In this activity you will calculate the same species diversity measures

but for a different year of the visual census. You can choose to analyze either the

census data from 2005 or 2006 (each year is a separate tab in the excel spreadsheet). These

two years were chosen because 2004 and 2005 were particularly hurricane intensive years

with seven storms occurring within 100 nautical miles of the FL Keys (Table 1). The reef fish

census occurred prior to the hurricanes in 2005 so this year just reflects the storm damage

from 2004 and the 2006 data set would capture the 2005 storm/hurricane damage.

*Table 1 - Hurricanes coming within 100 miles of the FL Keys in 2004 and 2005*

|  |  |  |
| --- | --- | --- |
| 2004 | Census data collected before Hurricane Charley (Category 2) | August 13th |
|  | Census data collected before Hurricane Frances (Category 2) | September 4th |
|  | Census data collected before Tropical Storm Ivan | September 21st |
| 2005 | Census data collected before Hurricane Dennis (Category 2) | July 9th |
|  | Census data collected before Hurricane Katrina (Category 2) | August 27th |
|  | Census data collected before Hurricane Rita (Category 2) | September 21th |
|  | Census data collected before Hurricane Wilma (Category 3) | October 24th |

1. Decide which year data (2005 or 2006) you will use for your analysis and complete the table below:

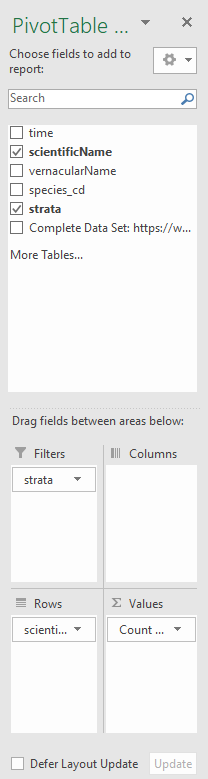
|  |  |  |
| --- | --- | --- |
| **Diversity measure** | **2000 (copy from activity A)** | **2005 or 2006**  **(circle year analyzed)** |
| Abundance |  |  |
| Species Richness |  |  |
| Shannon Index |  |  |
| Pielou’s Evenness Index |  |  |

1. How does hurricane frequency impact the species diversity measures you examined?

**Activity C: How does reef fish diversity differ between habitat strata?**

Each annual census partitions the Florida Keys domain into 7 cross-shelf benthic habitat strata that are defined by environmental characteristics such as bottom depth, reef morphology, and topography (drivers of variance of fish density) (Luckhurst & Luckhurst, 1978; Gratwicke & Speight, 2005; Smith et al., 2011, Brandt et al. 2009). The 7 strata are:

|  |  |
| --- | --- |
| **Strata** | **Description** |
| Forereef Deep Linear Reef | Continuous reef that runs parallel to the shore with outside part of the reef facing the open sea, 18-33m deep |
| Forereef Midchannel Linear Reef | Continuous reef that runs parallel to the shore with outside part of the reef facing the open sea, 6-18m deep |
| Forereef Shallow Linear Reef | Continuous reef that runs parallel to the shore with outside part of the reef facing the open sea, <6m deep |
| High Relief Reef (Spur & Groove) | Spur and groove formations are features of many coral reefs that consist of ridges of reef formed by coral (spurs) separated by channels (grooves) which often have sediment or rubble bed. High relief reefs are reefs with >2m vertical relief. |
| Inshore Patch Reef | Small, isolated reefs that are close to shore – used extensively for recreational activities and more vulnerable to coastal pollution |
| Midchannel Patch Reef | Small, isolated reefs found in between inshore and offshore reefs |
| Offshore Patch Reef | Small, isolated reefs that are diverse and vary in relief |

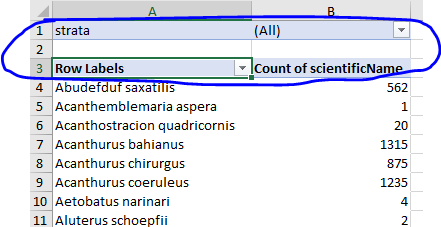
**Analysis by strata**

1. Choose two strata (out of the seven) that you will investigate for the year 2000 and 2005 or 2006 data set.

\*Note you will examine the same two strata across both years of data

**Write a hypothesis about how you expect the two reef types you chose to differ in the biodiversity metrics you will examine:**

1. Use the filter function in your pivot table to select the stratum that you want to investigate (see image to the right) – This can be done by dragging “strata” to the Filters box.
2. Once you add the strata filter, you will be able to use the dropdown menu on your pivot table to filter for the strata you selected for study (see image below).



1. Record your results in the table below (**be sure to label the column with the year and strata that you examined):**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year/stratum | 2000/ | 2000/ | / | / |
| Abundance |  |  |  |  |
| Species Richness |  |  |  |  |
| Shannon Index |  |  |  |  |
| Hmax |  |  |  |  |
| Pielou’s Evenness Index |  |  |  |  |

1. Based on your data analysis above, explain how reef biodiversity is impacted by both strata and tropical storms/hurricanes for the different years of data. Provide quantitative evidence to support your explanation.
2. Discuss your results with at least two other students that examined different strata. What were their results? How did their results compare to your biodiversity metrics?
3. If you were asked to write a report for NOAA on the vulnerability of different benthic habitat strata to climate change, what other data would you want to build an evidence-based report?
4. How could your analysis and future analyses of the FL Keys Reef Visual Census inform management and/or conservation decisions in the FL keys?

**Works Cited**

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