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Beachcomber Biology: The Shannon-Weiner Species Diversity Index

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Introduction

Species richness, evenness, and diversity are all fun concepts to teach biology students. I like them because they are somewhat intuitive, easy to calculate, and can be used to compare different populations. Species richness is simply the number of species present in an area. Species evenness refers to the proportion that each species comprises of the whole. The Shannon-Weiner Species Diversity Index is calculated by taking the number of each species, the proportion each species is of the total number of individuals, and sums the proportion times the natural log of the proportion for each species. Since this is a negative number, we then take the negative of the negative of this sum. The higher the number, the higher is the species diversity. In the ideal situation, one should compare populations that are the same size in numbers of individuals.

The formula is as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where H' is the species diversity index, s is the number of species, and p_i is the proportion of individuals of each species belonging to the ith species of the total number of individuals.

After a spring break in which I traveled to Florida, I needed something snappy for my Ecology class to do on the first day back. Actually, I conceived of this exercise while I was walking the beach in Florida. I walked twenty paces or so in an informal "rectangle" and collected all the shells I could find in that spot. This was to be a "simulation" of what the ocean floor "population" might look like at that point in time. (Of course, I "cheated" by adding a few extra shells that I collected during the week to increase the sample diversity.)

Upon my return to the classroom, I took a large tray and randomly mixed the seashells, sand and all, on the tray. I gave the students a couple of shell field guides (see below) and told them to identify the shells by their Latin names and to write the list on the board. This is easier to do with the shell guides as it was done mostly pictorially, but there are brief written descriptions as well. There was quite a lot of argumentation about which was which species, "No, I think it's that one---can't you see the shape of the hinge??" This made for a lot of good interaction and team work. Once all the shells were sorted into piles, they counted the number of each and placed that number next to the Latin species name on the board. They next made a table similar to the results below in which they calculated the total number of shells, total proportion that each species contributed to the total, the log of the proportion, the log of the proportion times the proportion, and the sum of these log of proportion times proportion values.

On this wintry day in New York that we did this, we were all able to reminisce as to what our sunshiny vacations were like, or what was yet to come in the summer.

We have also used this exercise for four student classes in the St. Francis College Summer Science Academy for high school students. We have expanded our shell collections to include a beach on the campus of Kingsborough Community College near Coney Island in Brooklyn, New York, the shores of the Salt Marsh Nature Center on Jamaica Bay in Brooklyn, New York, a beach in Cape Cod, and a beach in Wildwood, New Jersey, better known as the Jersey shore.

The best thing about the Salt Marsh collection, was that the students helped to collect the shells. Again, we have to add the mud snails in as “ghosts” because those don’t keep well (often these animals are alive and when the animals die and they start to smell). We sometimes include fragments of shells if it is possible to figure out what organism it is from the pictures. Another thing we did was divide the number of bivalve shells in half, as each shell represents only one half of an organism.

This exercise slows the students down and makes them really look at the organisms and think about them and their ecology. Hopefully, it will illicit a sense of wonder and cause them to ask questions: Why do some species have a more narrow distribution range than others? Why do organisms come in different sizes? What is it related to? Habitat? Density-dependent or density-independent factors? Could you differentiate them genetically? Are there clinal differences in size, genetics, etc.? You may add your own questions here.

The students like to “compete” with each other to see which group has the highest species diversity. Below we give you an example of results from two populations of shells.

Materials and Methods

Two sea shell collections were made of a 20 pace by 20 pace area within a month of each other. The first collection site was in New Smyrna Beach, Florida. The second site was at the beach behind Kingsborough Community College, Brooklyn. The shells were then sorted to species, sized, counted, and the Shannon Wiener Diversity Index was calculated. To do this, the proportion of each species of the total is calculated, the natural log of each is determined, and then multiplied by the proportion. This calculation for each species is then summed.

Results

Table 1. Seashell collection from New Smyrna Beach, Florida. Total number of specimens = 75.5; Shannon-Weiner species diversity index = 2.00.

	Species name	Common name	Geographic range	Size range In mm	# of specimens in sample	Proportion of total (p)	Ln p	p Ln p
1	***Noetia ponderosa***	Ponderous ark	VA-TX	20-40L x 15-30W	57/2 = 28.5	0.377	-0.976	-0.368
2	***Anadara ovalis***	Blood ark	MA-W. Indies	20-60L x 18-45W	39/2 = 19.5	0.259	-1.351	-0.350
3	***Crepidula fornicata***	Slipper shell	Nova Scotia-Gulf of Mexico	40L x 30W	6	0.079	-2.538	-0.201
4	***Anadara brasilana***	Incongruous ark	NC-Brazil	28-33L x 28-32W	8/2 = 4	0.053	-2.937	-0.156
5	***Anadara transverse***	Transverse ark	Nova Scotia-Gulf of Mexico	24-28L x 14-18W	7/2 = 3.5	0.046	-3.079	-0.142
6	***Labiosa plicatella***	Channeled duck	NC- FLA-TX	45L x 35W	1 + 2 frags = 1.5	0.020	-3.912	-0.078
7	***Busycon spiratum***	Fig whelk	NC-FLA+gulf sts.		2 frags	0.026	-3.650	-0.095
8	***Anomia simplex***	Jingle shell	Nova Scotia-West Indies	30L x 30W	2/2 = 1	0.013	-4.343	-0.056
9	***Busycon carica***	Knobbed whelk	MA-FLA		1 frag	0.013	-4.343	-0.056
10	***Dinocardium robustum***	Great heart cockle	VA-TX	160L x 160W	1 (not in survey)/2=.5	0.007	-4.462	-0.055
11	***Oliva sayana***	Lettered olive	SC-FLA	60L x 40W	1 (not in survey)	0.013	-4.343	-0.056
12	***Mercenaria mercenaria***	Quahog	Gulf of St. L--FLA	64L x 64W	1/2 = .5	0.007	-4.462	-0.035
13	***Aquipecten gibbus***	Calico shell	NC-W. Indies	20L x 20W	1/2 = .5	0.007	-4.462	-0.035
14	***Trachycardiu m maricatum***	Common cockle	NC-W. Indies	60L x 60W	1/2 = .5	0.007	-4.462	-0.035
15	***Cyrtopleura costata***	Angel wing	Cape Cod-Gulf of Mex; W. Indies-Brazil	150L x 40W	3/2 = 1.5	0.020	-3.912	-0.078
16	***Natica canrena***	Colorful moon snail	NC-W. Indies		1 frag	0.013	-4.343	-0.056
17	***Sinus maculatum***	Spotted earshell	NC-FLA		1 frag	0.013	-4.343	-0.056
18	***Phalium cicatricosum***	Scotch bonnet	Bermuda; FLA-W. Indies		1 frag	0.013	-4.343	-0.056
19	***Crassostrea virginica***	Common oyster	Gulf of St. L--FLA	80L x 40W	2/2 = 1	0.013	-4.343	-0.056

Table 2. Seashell collection from Kingsborough Community College Beach, Brooklyn, NY, 4/12/02. Total number of specimens = 250; Shannon-Weiner species diversity index = 0.872.

	Species name	Common name	Geographic range	Size range In mm	# of specimens in sample	Proportion of total (p)	Ln p	p Ln p
1	***Mytilius edulis***	Blue mussel	Greenland-SC ALAS-CA, Europe	38-68L x 12-23W	268 + 50 frags-extap 318/2 = 159	0.636	-0.45	-0.288
2	***Ensis directus***	Common razor clam	Labrador-FLA	110-135L x 23W	17/2 = 8.5	0.034	-3.38	-0.115
3	***Crepidula fornicata***	Slipper shell	Nova Scotia-Gulf of Mexico	40-50L x 10-12W	77	0.308	-1.17	-0.363
4	***Spisula solidissima***	Surf clam	Nova Scotia-SC	47-122L x 35-95W	7/2 = 3.5	0.014	-4.27	-0.06
5	***Anomia simplex***	Jingle shell	Nova Scotia-West Indies	30L x 30W	2/2 = 1	0.004	-5.52	-0.022
6	***Pitar albida***	White venus	W. Indies (?)	22L x 30W	1/2 = .5	0.002	-6.215	-0.012
7	***Petricola pholadiformis***	False angel wing	Prince Ed. Is.-FLA-Gulf of Mex	40L x 20W	1/2 = .5	0.002	-9.07	-0.012

Discussion

The Florida collection, although lower in density, depicted higher species diversity. The most abundant species were the ark species. The Brooklyn collection was dominated by *Mytilus edulis*, and was much less diverse (even though the shells were found at a greater density).

The Florida collection had a greater species richness (19) and greater species evenness. The Brooklyn collection numbered only 7 species.

The reasons for these differences could be as follows: warmer climates tend to be more speciose. The less harsh climate perhaps permits greater survival rate. Greater pollution in the Northeast might foster greater populations of more opportunistic species.

References

Rehder, H. 1981. National Audubon Society Field Guide to North American Seashells. Alfred A. Knopf Pub.

Morris, P. 1973. A Field Guide to Shells of the Atlantic and Gulf Coasts and the West Indies. Peterson Field Guide Series

Web site references

A number of people at the workshop requested keys to use for identifying shells. Although we feel that looking at pictures of shells is the quickest and easiest way to identify the specimens, an on-line search was conducted that unearthed a few web sties that may prove to be helpful.

One such web site, http://lamer.lsu.edu/classroom/edonahalfshell/dicotkey1.htm contains an exercise that includes pictures of shells that are numbered and questions in the form of a dichotomous key that allows the participant to plug the correct number into a blank. The shells are not named; however, the instructor could do that as an additional activity.

Another web page: http://clem.mscd.edu/~simmonse/SEASHELL_KEY.doc , written by Beth Simmons, describes an activity in which students are given a bag of mostly shells and a dichotomous key and are asked to identify the shell species. This key included some, but not all, of our species. They included the oyster, ribbed mussel, blue mussel, jingle, scallop, quahog, and slipper shells.

The Education Project of the New Jersey Marine Science Consortium (http://www.njmsc.org) describes a classification and identification activity (click on "education", "lesson plans" and "classification and idenfication" that contains a key to the common shells of the Jersey shore.

About the Authors

Kathy Nolan has been teaching biology labs at St. Francis College for the past eleven years, and prior to that she taught at Columbia and Yeshiva Universities. This is the third mini-workshop she has presented. She has also presented three major workshops (one twice!) and has been recently elected to the ABLE board.

Jill Callahan graduated from St. Anselm College and has been teaching at and developing labs at St. Francis College for the past two years. She previously taught at Barnard College. Jill has taken some graduate courses, and will be pursuing graduate work in biology full time in 2006.