Chapter 8

Species Diversity, Island Biogeography, and the Design of Nature Reserves

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Introduction

This open-ended investigation involves a combination of field and laboratory experiences to test predictions derived from island biogeography theory, using various-sized fragments of leaf litter arthropod communities as "island" systems. Two common models for undergraduate ecology focus primarily on process (how we "do" ecology) or content ("what we know" about the natural history of organisms and communities), but rarely do equal justice to both. This lab is intended to be an example of integrating process and content, as well as an opportunity for students to learn both field and lab skills, and to use several quantitative models for comparing biodiversity measures. As part of the final report, students are charged with writing well-supported recommendations for land preservation to the local county parks commission, with special attention to the preservation of biodiversity in leaf litter arthropod communities.

We have successfully employed various modified versions of this exercise in our introductory biology courses for majors, in our general education ecology course for non-science majors and in our sophomore-level "Ecology and Evolution" course for majors. Typically, island fragments are constructed in a nearby deciduous forest 2-4 weeks in advance of the field

portion of the lab. During one 3-hour lab, students collect leaf litter fragments from the field and place them in the Berlese funnels. Students return to retrieve and seal their samples 24 hours later. During the second 3-hour lab in the following week, students identify and tally the litter arthropods present in their samples, calculate diversity indices, and construct graphical measures of diversity (dominance-diversity curves and species-area curves).

Materials

To construct leaf litter "island" fragments (amounts given are for 1 large island of 2 x 1.5 m and 12 small islands (0.5 x 0.5 each) that equal the same total area as the large island):

- 1 piece of bird netting mesh cut to 2 x 1.5 m (e.g. Bird d-fence™ protective netting, available from garden supply centers)
- 12 pieces of bird netting mesh cut to 0.5 x 0.5 m each
- 60 6-inch lengths of plastic-coated aluminum clothesline wire (solid, not stranded), bent at one end to form small
- stakes for securing mesh over leaf litter layer
- plastic bags to store/transport mesh
- work gloves (1 pair per participant)
- garden rakes
- meter tape and 2 meter sticks (used for laying out islands)

For construction and operation of Berlese funnel apparatus (instructions given are for 4, 3-funnel units, 12 units is appropriate for class sizes of 24 or more, with students working in pairs - for multiple lab sections simply stagger use of the funnels):

- paneling wood for 4 units as shown in Fig. 5A, Appendix A: Berlese Funnel Units; the units measure 1.15 meters long x 0.75 meters high x 2 pieces of each length
- 3 holes cut in the middle shelf of each unit are 13 cm diameter
- each unit is fitted with 3 mounts for 50-watt lightbulbs, each bulb mount requires 2 screws
- each of the bulb mounts are wired to a single cord for the unit to be plugged in to an electrical socket
- 12 large plastic funnels (26 cm diameter)
- 12 circular pieces of hardware cloth (approx 1.2 cm x 1.2 cm mesh) cut to 12 cm diameter
- 12 widemouth chromatography jars (w/lids) to catch specimens beneath funnels
- approx. 2 liters of 70% ethanol *per lab section of 24 students, working in pairs*
- an alternate, more economical Berlese funnel apparatus uses recycled plastic milk jugs and a wooden unit that can accomodate 5 funnels (see Appendix A: Figure 5B); the only disadvantage of the milk jug units we have noticed is that some insects, such as ants, may be able to more easily crawl up the sides of the milk jugs and escape.

For the field lab: collection of leaf litter samples from the "island" fragments (amounts given are for a lab section of 24 students, working in pairs):

- 12 plastic buckets with handles, bucket top diameter of about 25 cm (exact size is not important, as long as the diameter is smaller than a small island, but all buckets must be the same size)
- optional: 12 inexpensive, serrated steak knives work well for *marking a perimeter* around the
- inverted bucket; they should not be used for digging up leaf litter, however.
- 12 plastic, sealable bags and paper/pencils for making labels

For identification and counting during the laboratory (amounts given are for a lab section of 24 students working in pairs):

- 6-12 insect field guides, arthropod keys, or any other supplementary materials for identification of a range of invertebrates that are likely to include annelids, crustaceans, arachnids, millipedes, centipedes, and insects. In addition to using such printed material, we have begun a website of litter arthropods common to our Michigan dune forest community in the form of a photographic identification key. Please visit: *http://www.hope.edu/academic/biology/leaflitterarthropods/* for further information.
- 12 prs. insect forceps
- 12 dissecting microscopes
- 24 sorting dishes (we use plastic petri dishes, including the sectioned petri dishes)
- data sheets (see Table 1)
- 1 large jar with lid for discarding used specimens, debris, used alcohol
- 12 plastic disposable pipets
- small bottle of liquid soap
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Additional materials for starting a voucher collection of arthropod specimens (highly recommended if you wish to compare changes in diversity from one year or one semester to the next):
- 70% ethanol in squeeze bottles
- supply of 2-dram glass vials with screw-top lids
- paper slips and pencils for making labels

Notes for the Instructor

Timing of the Field and Lab Components

Typically, we set up our litter islands in the early fall, before significant leaf-fall threatens to re-create "bridges" between islands that we are trying to keep isolated. Alternatively, island fragments can be created after leaves have fallen (late fall) and we have even collected litter samples in February in Michigan and found dozens of thriving arthropods in them. Set up the litter island fragments at least 2 weeks before the students will collect litter samples. Return to the site once a week prior to the collection date to re-rake the leafless spaces between and around islands. You will want to keep the islands isolated from each other and from leaf litter "mainland" until after students have collected their samples. At Hope College, students use one lab period to make the field trip to the site, receive background information while examining the island treatments, and then collect their litter samples. Students return to the lab, place litter samples in the Berlese funnels (one sample per funnel), add 70% ethanol to the collecting jar and leave for 24 hours. Students receive instructions on sealing their sample when they return to the lab in 24 hours (this takes only 5 min., so we have students do this on their own, outside of lab time). This also frees up the funnels before they are needed for another lab section. The time in the Berlese funnel can be adjusted to fit your needs, but should be at least 18 hours or so, and if left for longer than 24 hours, make sure the alcohol does not evaporate or the specimens will dry out and become unidentifiable!

During the next week's lab, students retrieve their samples, identify all of the animals in the sample, and begin the data analysis. We collect information from the students before they leave the lab for compilation.

Creating Litter "Islands," or Fragments

Any arrangement or combination of small vs. large islands can be used. We find it instructive to create three experimental treatments from which students sample leaf litter:

1) intact forest leaf litter, several meters removed from trails and from the island treatments, but in the same general area of the forest so that soil conditions are similar throughout;
2) a single, large island (usually a 2 x 1.5 m rectangle surrounded by a 2 meter wide border of raked, leaf-less soil;
3) an archipelago of 12 small islands (each 0.5 x 0.5 m squares) arranged in a 3 x 4 grid, with 0.5 meters of bare soil between all islands, and a 2-meter border of bare soil around the archipelago.

This design allows the students to test the effects of fragment size on diversity (single small vs. single large island), of insularity on diversity (islands vs. mainland), and of "packaging" of the habitat chunks on diversity (the single large island vs. the combined data from the 12-island archipelago, which has the same total area as the large island). Creation of additional sets of

large islands and archipelagos would allow the students to replicate the entire model if desired. Select an area of forest with a low density of emerging seedlings and saplings and other obstacles (large dead logs, etc.).

Island fragments are created by measuring the area needed with the meter tape, marking the corners, and then using the meter sticks to align pieces of the netting. For the archipelago, lay down one small island netting onto the first corner and stake down, using the plastic-coated wire, at each of the four corners. Leave a space of 0.5 meters, and then stake down the next island, and so on. The large island net just needs to be staked down around the edges. Make sure there are several meters of intact leaf litter between the archipelago site and the large island site. Remove all large sticks, fallen limbs, and rocks from in and around the islands by hand. Green vegetation emerging from the litter islands or between them (such as tree seedlings) should be left intact. Seedlings that fall within islands can be gently pulled through the net and the island net staked down around it. Within the archipelago, use a small rake and gloved hands to carefully clear the spaces between the islands, taking care not to pull leaves out from under the net. It helps to place your hand as a straight-edge, on top of the island edge itself, while you use the other hand to clear a neat edge, by breaking off leaves and small sticks. All litter must be cleared down to bare soil. Next, create the 2-meter wide border around the archipelago and the large island, using a large rake, again removing all litter down to bare soil.

Identification Consistency

None of the instructors who teach this lab are entomological experts, but when possible, we invite one to be around during the identification part of the lab for a lot of reasons. First, so we can actually get correct names associated with creatures, and second, because these kinds of systematic biologists are incredibly knowledgeable people and impress our students with the depth of their observation skills. Nonetheless, to estimate species diversity, we must categorize, to the best of our ability, different animals *at the species level*, and this means that we usually resort to creating names for creatures at some taxonomic level (*e.g.,* below the Order or Family level). We call them "morphospecies," and creating the utmost consistency in the naming of "morphospecies" within the group of students that will be sharing data (whether this be within the lab or between different lab sections) is very important. We attempt to determine the actual Class (e.g. Annelida, Insecta), Order (e.g. Coleoptera, Lepidoptera), and Family (e.g. Scarabidae, Curculionidae) wherever possible and then let the first students who discover a "new" morphospecies give it a name. Descriptive names that cue the students in to distinguishing morphological features (*e.g.,* "red-clawed pseudoscorpion") are tremendously more useful than ambiguous names ("Joe") and will help a great deal in keeping consistency from one student group to another. It becomes the instructor's job to maintain this consistency, by constantly visiting microscopes with "new finds" and matching them to those found in other students' samples. Encourage and coerce the students to visit each other's microscopes to confirm matches, and to note similarities and differences (besides, this is what scientists *really* do; nobody would ever be naming a new species without first comparing with what other scientists in that field have already collected and named). In all cases, the entire classification of the animal should be retained in the naming procedure, *e.g.,* "Insecta, Curculionidae, yellow-black striped weevil." Insect larvae present a particular challenge. There tend to be a lot of them in leaf litter (discuss the importance of the leaf litter habitat in the life cycle of many kinds of animals that may be more conspicuous when they move to a different, more visible habitat, later

in their life) and their differences are less striking. The identification part of the lab should be highly social and there should be a lot to view at neighboring lab tables, so there should be lots of visiting going on.

A few "rules" we have found very useful:

1) Don't count body parts or molted exoskeletons (which look like ghost arthropods).

2) Set a lower magnification limit (don't count creatures smaller than mites at 40X, for example.)

3) Nobody gets to name a new species until the instructor confirms it *is* a new species. In our experience, students quickly learn that naming a new species requires much less time than carefully comparing the specimen with other specimens. The result is mass inconsistency in naming (same species ending up with 4, 5 or 12 different names).

4) Create a voucher specimen (a preserved, labeled specimen in a separate vial) of each new species and organize them by groups (Coleoptera adults, Coleoptera larvae, Annelids, etc.) so that students can more quickly compare their specimens and use the same names previous students have used. Before long, you will have a growing voucher specimen collection specific to your field site and future labs will benefit tremendously.

Student Outline

Objectives
1. To understand the concept of species diversity, including the contribution of both species richness and "equitability" or "evenness" to it.
2. To understand some of the ways in which species diversity is measured and/or quantitatively modeled.
3. To understand the relationship between species diversity and area sampled.
4. To understand the equilibrium theory of island biogeography and its potential application to the design of nature preserves.
5. To enhance your appreciation for the value of litter arthropod communities in the functioning of forest ecosystems, and the tremendous diversity that characterizes these micro-scale communities.
6. To gain some familiarity with identification of leaf litter arthropods.

Background
If Ottawa County had some money to buy land for new parks, would you (as their highly paid consultant) suggest that they spend it all on one big parcel or on several smaller ones having the same total area?

One of the primary purposes of national parks, national forests, and other kinds of nature reserves is to protect and conserve biological diversity - different kinds of living things. And while we all agree that conserving biological diversity is a good thing, we also realize that doing so comes only at some cost - development, timber harvest, mining, *etc.* all promote economic well-being (at least over the short term) by providing jobs, even though they often result in serious environmental degradation. So in the real world, we have to be able to give more practical advice to policy makers than "protect everything!" This two-week field/lab problem is meant to give you some basic background on species diversity and island biogeography, as well as to get you to think about the above problem. In doing so, you should see some important contributions that ecological theory can make to very practical problems. Such contributions form the basis of a relatively new science: conservation biology.

Species Richness (S): This is simply the number of different species present in a given area. This is a good first approximation to diversity, but it doesn't allow us to distinguish between a community that has 10 species represented by 10 individuals each, and one that has one species represented by 91 individuals and nine other species represented by one individual each. To do that, ecologists have developed other measures, because we feel that the former community is more "diverse."

Reciprocal form of Simpson's Index: Simpson's Index is a mathematical model that takes into account both the number of species and the "evenness" or "equitability" of distribution of total individuals among the species. The reciprocal form of Simpson's index simply converts the index to a form in which a higher index value indicates higher species diversity,

$$\frac{1}{D} = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

where S is species richness (the total number of species present in the community), and p_i is the proportion of total individuals in the sample made up by individuals of species i. Values can vary from one (low diversity) to S (high diversity).

Dominance-diversity curves: A graphical way of representing species diversity is to plot the log of each species' abundance vs. its rank (from most abundant to least abundant). If we had 10 species, represented by 100, 80, 53, 41, 35, 33, 29, 14, 9, and 6 individuals, respectively, our dominance-diversity curve would look like Figure 1 to the right. Though it doesn't yield a simple number for comparison, this way of representing diversity is perhaps the best of all, since it conveys the most information. Note that the *greater the slope of the line, the less diverse* (especially less "even") the sample, and the smaller the slope, the more "even" the sample.
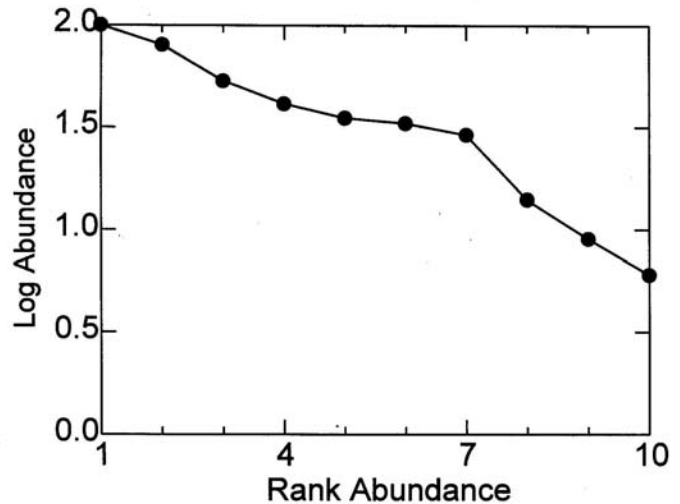
Figure 1. Sample Dominance-Diversity Curve

Species-Area Curve: It should be obvious that larger areas generally contain more species than smaller areas, all else being equal. For example, starting with an area of about $10m^2$ in a forest, we might find only one species of tree (just one individual). As we expand the area sampled, however, we begin to pick up more and more individuals, and hence the probability of finding more *species* increases. At first, we generally find that even small increases in area sampled yield considerable increases in number of species encountered. But as we consider larger and larger areas, the rate at which we pick up new species declines. We can represent this graphically with a so-called *species-area curve*, as shown in Figure 2 at right.
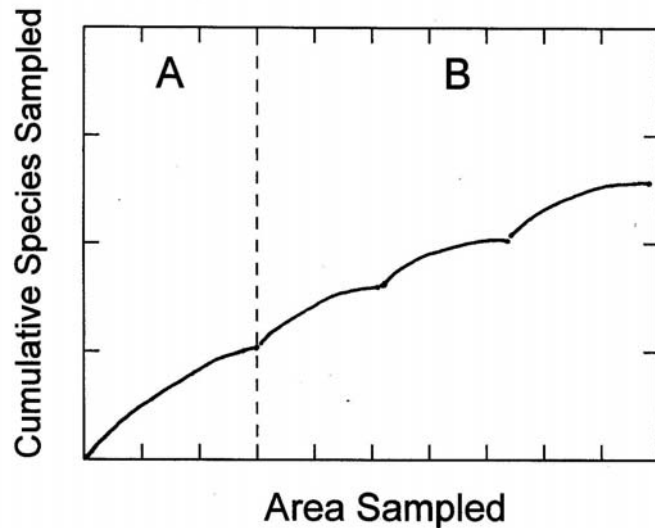
Figure 2. Hypothetical Species-Area Curve

The sort of relationship in region A of this graph can generally be found within a given habitat, and is called *within-habitat diversity* (MacArthur 1965) or *alpha diversity* (Whittaker 1960). The asymptote approached in this region of the graph should be the total number of species present within this particular habitat. If we continue to increase our sampling area so that

we now take in *different habitats*, we will of course start picking up more species (region B of graph). The kind of diversity across a variety of habitats was called *between-habitat diversity* by MacArthur and *beta diversity* by Whittaker. If we continue sampling over an extremely large geographic area, we start picking up even more, because we cross into the geographic ranges of completely different species. Cody (1975) calls this aspect *gamma diversity*.

In general, nature reserves can only be large enough to include aspects of alpha and beta diversity. Furthermore, since reserves are often isolated patches of natural habitat surrounded by human-altered landscapes (i.e., they are effectively *islands*), we can take advantage of a body of theory developed by MacArthur and Wilson (1967) and others that seeks to predict the species diversity of islands as a function of their size and distance from the mainland.

The essence of MacArthur and Wilson's "*Equilibrium Theory of Island Biogeography*" is simple. They assume that the number of species on an island is determined by a balance between the rate of *immigration* of new species from the "source pool" (generally the nearby mainland) and the rate of local *extinction*. Both processes are assumed continuous, with species continually going (locally) extinct and being replaced through immigration, although not necessarily by the same species. The theory is represented in Figure 3 below.
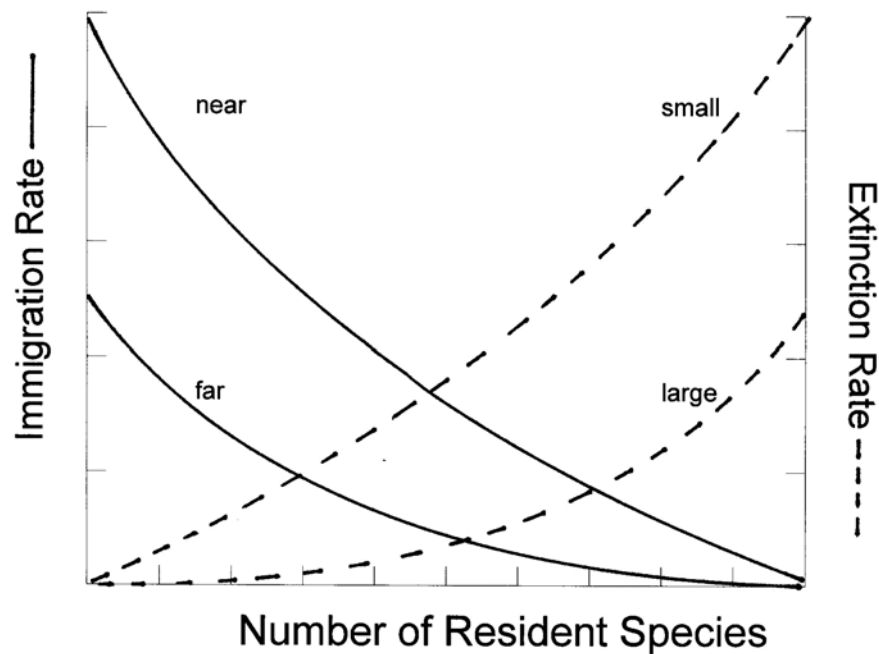

Figure 3. Island equilibrium theory, a model.

Consider immigration first. At first, immigration rate will be high, since each new individual reaching the island will represent a new species. As more and more individuals arrive, however, fewer and fewer represent new species. The immigration rate reaches zero when all of the "source pool" species (*i.e.,* those present on the adjacent mainland) are present on the island. Immigration rate should also vary as a function of the island's "remoteness," *i.e.,* its distance from the mainland. So the graph has two immigration curves - one for a near island and one for a far one.

Now consider extinction rate. It is bound to be zero when there are no species present, but will increase in proportion to the number of species already present, due to exclusion of species that are poor competitors. Extinction should also be a function of island size, both because larger islands support larger populations (which are less vulnerable to extinction through density independent factors like weather extremes, etc.) and because larger islands are likely to contain a greater diversity of habitats and microhabitats than small ones (remember the driving force behind beta diversity above). Superimposing the immigration and extinction curves for near, far, large and small islands on the same graph allows us to make predictions about the number of species present as a function of both factors, size and distance from the mainland. We can now make several predictions:

1) Species richness will become roughly constant through time, even though there will be continual *turnover* in species composition. Thus, the *equilibrium* reached is dynamic rather than static.
2) Large islands should support more species than small islands.
3) Near islands (to the mainland source pool) should support more species than far islands.

There are lots of data from real communities that support the above predictions. The potential application of this for the design of nature reserves is not so simple, however. On the one hand, it seems very clear that we should expect a decline in species diversity when a patch of land is separated from the "mainland" by human-altered habitat, since distance from the mainland is by definition increased from zero. In addition, a larger preserve should support more species than a smaller one. *On the other hand, if we consider the question of whether to make a single large reserve or several smaller ones with the same total area, things get complicated.* Small reserves might be more insulated against the spread of an epidemic disease. Small reserves might also allow for survival of poor competitor species in patches that just happen (by chance) to be without superior competitors. Similarly, small reserves might allow for the survival of prey species in patches that happen to lack major predators (Huffaker 1958). So it isn't at all clear whether a single large reserve should contain more species than several smaller ones. When ecologists first contemplated the application of island biogeography theory to reserve design, this "single large or several small" debate became known by its acronym, SLOSS. Most ecologists now probably consider island biogeography theory to be useful in designing reserves, but they don't think that it provides *all* of the answers. In the end, we probably need detailed knowledge of the biology of all the species involved, as well as of the particular pieces of land (*e.g.,* their topography, habitat diversity, etc.) in question. So there won't be any "correct" result from this week's field problem, and it's probably more important at this point to ponder the question anyway. As we've said before, if we already knew the answer, we wouldn't bother to do the lab! Now back to the specific problems...

The Questions
1. How does species diversity of litter arthropods vary with *number* of samples taken (Species-Area Curves)?
2. How does species diversity vary with the *size* of litter fragments? (Comparison of Reciprocal Simpson's Index and Dominance-Diversity Curves for "mainland" samples, large fragment samples, and small fragment samples).

3. How do Species-Area Curves differ for fragments of different sizes? (Comparison of Species-Area Curves for "mainland," small fragments, and large fragments).
4. If your goal were to maximize species diversity of litter arthropods, would it be better to preserve one large fragment, or several small fragments having an equivalent total area?

The good news is that Ottawa County is going to spend some money for (a) nature preserve(s)! The bad news is that they're only allocating enough to buy 3 m^2! Obviously, you can't buy enough land to conserve trees, deer, or even bunny rabbits with that amount of money. In fact, dune forest land near the Hope College Nature Preserve currently goes for about $10,000/acre! Undaunted, you resolve to design reserves to preserve species diversity of leaf litter invertebrates. There are lots of these little buggers, including ants, millipedes, centipedes, springtails, beetles, slugs, and others. Some time ago, we created "islands" of leaf litter at the field station in two treatments: a single large island 1.5 x 2 meters and an "archipelago" of 12 smaller islands, each 0.5 x 0.5 meters. Thus the large island and the archipelago have the same total area. We created these islands by raking away the leaf litter between the islands and the "mainland" (about 2 m in a border around the islands). We then covered these islands with plastic netting (mesh size approx. 2 cm) that allows free movement of air, water, and arthropods, but keeps the leaf litter in place. When we collect leaf litter from these islands, each bucket-sample will comprise 0.05m^2 of leaf litter *area* sampled (bucket diameter = 0.25 m; area sampled $=\pi r^2 = \pi (0.125)(0.125)$; several of these samples will be collected from each treatment. The "mainland" is the intact leaf litter on the other side of the surrounding bare area (see Figure 4).
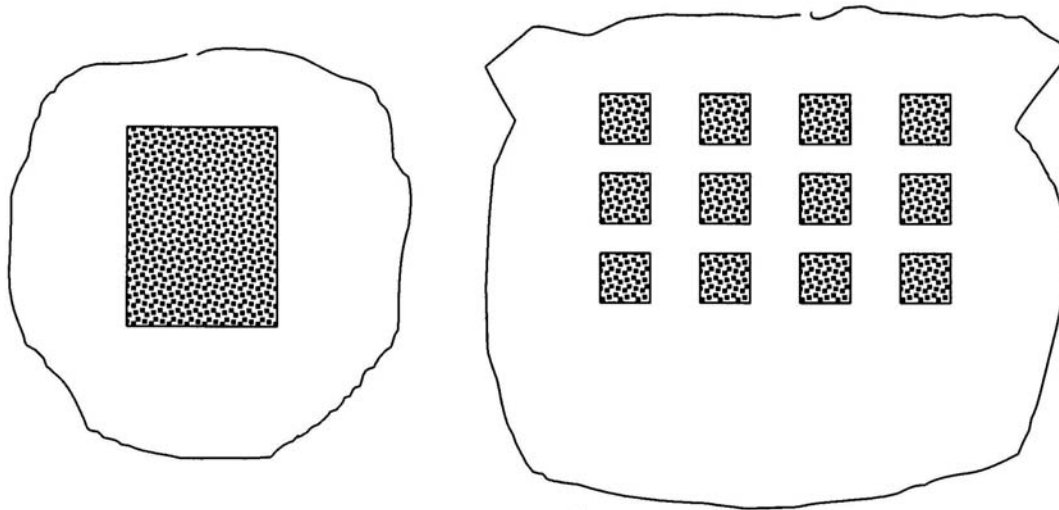

Figure 4. Schematic of Litter Islands.

For further information on the theory and applications of island biogeography and island equilibrium theory, please see Diamond and May (1981), Harris (1984), Knowlton (2001), Krebs (1989), Magurran (1988), Meffe and Carroll (1994), Primack (1993), Simberloff and Abele (1976, 1982), Soule and Wilcox (1980) and Watchman *et al.* (2001).

Procedure for week one: Collection of Litter Samples

We'll collect the litter samples the first week and put them into Burls Funnels to extract the organisms, and then identify and count the organisms in the samples the second week. Each lab group will take one sample from the large island, one from one of the small islands, and one from the nearby "mainland."

To collect a sample from one of the treatments, place your plastic bucket over the area of litter desired (open end down, of course) and quickly use a small hand shovel or a steak knife to cut through the litter around the edge of the bucket. Then, tip the bucket over, using your hands to retain all of the litter in the bucket. Collect the litter all the way down to a depth where the substrate is mostly sand and fine tree roots, so that you get even the fine litter. Then dump the litter sample into a plastic bag, along with a label containing the *day/time* of your lab section, the *names* of all members of your group, and the *treatment* (large island, small island, or mainland). Then seal the bag. *Be sure to write the label with pencil*, since ink will run later when we put the label into ethanol. After collecting your sample, be sure to replace the plastic netting over the island.

Back in the lab, put each sample, *with its paper label*, into a separate Burleys funnel that empties into a jar of ethanol (+ 1 drop of liquid soap). Much less dirt will fall through into the ethanol if you first put a layer of large leaves over the screen in the Berlese funnel and then pour the rest of the sample on top of it. Litter organisms will still be able to crawl down through cracks between the leaves. Be sure to turn on the light above the funnel. As the heat from the light dries the litter, any invertebrates will go lower to escape desiccation until they drop through the screen into the ethanol. The soap will break the surface tension of the liquid to that the animals can't climb back out. After 24 hours, discard the litter, drain off the liquid in the jar, and place all invertebrates collected into a vial of fresh 70% ethanol *with the label identifying the sample*.

Procedure for Week 2: Identifying and Counting the Extracted Invertebrates

In the lab, carefully pour aliquots of each sample into sorting dishes (work on one treatment sample at a time so as not to mix different kinds of islands). Rinse the jar with a small amount of 70% ethanol to be sure you have retrieved even the smallest, microscopic things in the bottom of the jar. Examine your sample first under the lowest power on the dissecting scope to get a feel for the range of sizes of different animals present and to begin to discern animals from debris. It won't take long to become an expert at this! Sort through the invertebrates under a dissecting microscope, naming and counting each of the distinct "morphospecies" (organisms that appear to the observer to be different species) you find. It may help to start extracting similar things (*e.g.,* all of the beetles in one pile, all of the springtails in one pile, etc.) and sorting them into sectioned petri dishes. Your instructor will help you identify major groups (Class and Order) and perhaps Families of some large insect Orders. For an excellent, easy-to-use insect identification guide, see Dunn and Dunn (1998). Use the voucher specimens and resource material your instructor provides. Take your time and be careful. It makes a big difference! Be consistent. Check with other groups constantly! Don't give a new name to a species until you check with the instructor and get verification. If you are verified as having a "new" species, *collect at least one voucher specimen of it in a small vial of 70% ethanol and add it to the reference collection*. Be sure to put a paper label (in pencil) in with each voucher specimen with its name (or number, *etc*.) and the treatment, sample, course number and date, including the year

in which it was collected. Descriptive names that include some aspect of the creature's observable morphology will help other members of your class know if they have the same species (*e.g.,* use names like "red-clawed pseudoscorpion" and "two-spined, bicolored ant" rather than "Joe"). After you've identified and counted all of the organisms in your sample, save them and the original label in a smaller jar of ethanol in case we need to take a second look at any of them.

As you're recording the morphospecies present in your sample, give some thought to the *food habits* (*i.e., detritivore* (consumer of rotting vegetation, bacteria, fungi, *etc.*), *herbivore* (living plants), or *carnivore* (other animals) of each species encountered. This may also take some library work; an excellent appendix with insect food habits is found in Hogan (1994). Doing so will help you to interpret your results (*e.g.,* you might find that small fragments with spiders (which are predatory) lack other species commonly found in fragments without spiders). When your counts are completed, *hand in your data to the instructor before you leave lab***.**

Data Analysis

1. Determine S and 1/D (the reciprocal form of Simpson's Index) for each of the three treatments (mainland, large island, and small island) using the compiled class data your instructor will provide.
2. The following example should help you to understand the calculations necessary for 1/D. Suppose our samples contained 400 individuals in 10 species, and that species 1 through 10 were represented by 100, 80, 53, 41, 35, 33, 29, 14, 9 and 6 individuals, respectively. The following table shows the values of p_I, and p_i^2 for computing the diversity index.

Table 1. Sample calculation of the reciprocal form of Simpson's Index.

I =	1	2	3	4	5	6	7	8	9	10
n_i	100	80	53	41	35	33	29	14	9	6
p_i	.25	.20	.1325	.1025	.0875	.0825	.0725	.035	.0225	.015
p_i^2	.0625	.04	.0176	.0105	.0077	.0068	.0053	.0012	.0005	.0002

1/D = 1/(sum of the entire last row = 0.1523) = 6.566

3. Use a computer graphics program (*e.g.,* EXCEL, SYSTAT) to produce a dominance-diversity plot with a different line for each of the three treatments, again using the compiled data for your class. Remember that the y-axis should be on a log scale, and be sure to label the axes and provide a legend.
4. Use a computer graphics program to plot the species-area relationship for each of the 3 treatments, using the compiled data for your class. Remember that a species-area curve uses the *cumulative* number of unique species sampled. Although we could theoretically enter each of the samples into the count in any order (and thus get at least slightly different curves), you should just enter them in the order in which they appear on the combined class data sheet that you get from your instructor. Also, be aware that the x-axis will be *area sampled*, rather than island area *per se*. The relationships you plot thus won't be exactly species-area curves for the entire islands

of different size, but they will reveal any differences in patterns of diversity in the three treatments.

Table 2: Data Sheet for Island Biogeography and The Design of Nature Preserves

Group members: _____

Lab Day and Group NUMBER: _____

Treatment: _____

MORPHOSPECIES NAME	NEW?	# IN SAMPLE

Worksheet Report
Group Members:

Lab Day and Group Number:

1. Score on Table 2, turned in at the end of week 2 of this lab: _____
2. Attach a copy of the combined data for all three treatments (the one your instructor handed out to you) at the end of this worksheet.
3. What is your working hypothesis for the relationship between species diversity of the three treatments (large island, archipelago of small islands, and "mainland"), and why do you think so?
4. Reciprocal form of Simpson's Index for the combined class data.
    Simpson's Index: mainland _____

    large island _____

    small islands _____

    Include the Dominance-Diversity Curve for the compiled data sets for the three leaf litter treatments (small island, large island, "mainland"). Attach your single graph, with a legend for curves representing the different treatments.
5. Explain the relationship between the reciprocal form of Simpson's Index and the Dominance-Diversity Curve. What information is conveyed by each model? How is that information similar? Different?
6. Compare your results from parts 4 and 5 with your working hypothesis stated in 3. Which litter fragment type has the highest diversity? Is this result consistent for both models of diversity (reciprocal form of Simpson's Index, and the Dominance-Diversity curves)? Does this result provide evidence in support of your working hypothesis, or not? Explain the patterns in diversity observed among the three litter fragment treatments - does the size of the fragment make a difference in species diversity? Does the packaging of the leaf litter area make a difference in species diversity?
7. Construct a Species-Area Curve for each fragment type, on the same graph. This will be the *cumulative number of species sampled (y axis) as a function of cumulative area sampled (x axis).* For consistency, the instructor will provide you with the sequential order in which to add samples, in each case. Attach your graph here.
8. Which treatment - mainland, large island, or small island, has the *greatest species richness* sampled at a given area, for example, at $0.5m^2$ or $1.0m^2$? What is the *asymptote*, or the maximum species richness, that is predicted for each treatment, and how do they compare with one another? Do the *shapes* of the species-area curves suggest that we have taken enough samples from each of the 3 treatments to have a good idea of species richness in them, i.e. do the curves appear to be close to asymptotic numbers of species? Explain.
9. Describe the *ecological* reasons why you think the species-area curves are different (if they are) for mainland, large islands, and small (archipelago) islands. Consider things like: degree of isolation, proximity to source pool, size, rate of desiccation of habitat, abundance or lack of food, abundance or lack of predators, etc. Be specific and refer to the names of actual arthropod groups as much as possible, rather than generalizing over all species. Spiders are very different ecologically than are springtails!
10. Based on all three types of information you have gathered about species diversity in these litter fragments, summarize your recommendation to the Ottawa County Planning Commission. Your most important goal with this essay is to convey the *evidence* you have for which type preserve will best maximize species diversity for this particular ecological community.

Acknowledgments

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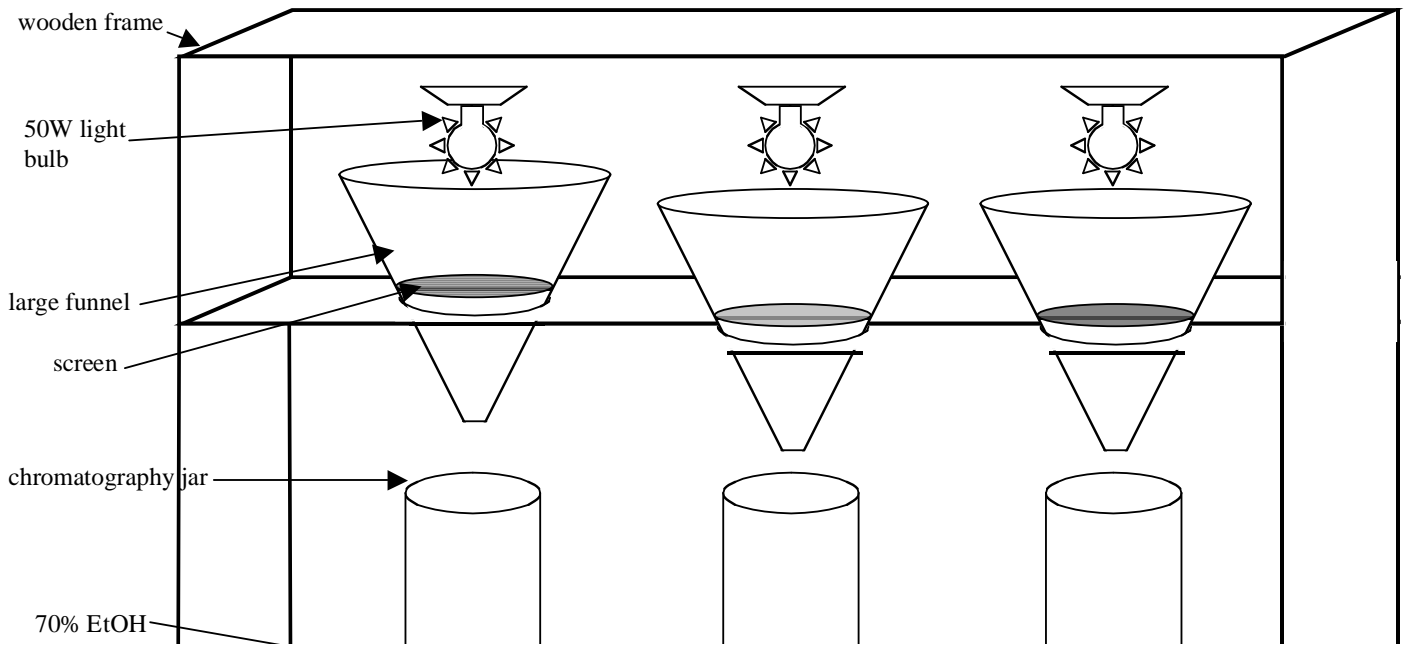## APPENDIX A: Schematics for Two Types of Berlese Funnel Set-ups

Figure 5A. Berlese Funnel apparatus with large funnels. Typically, four are needed for a lab section size of 24 students.
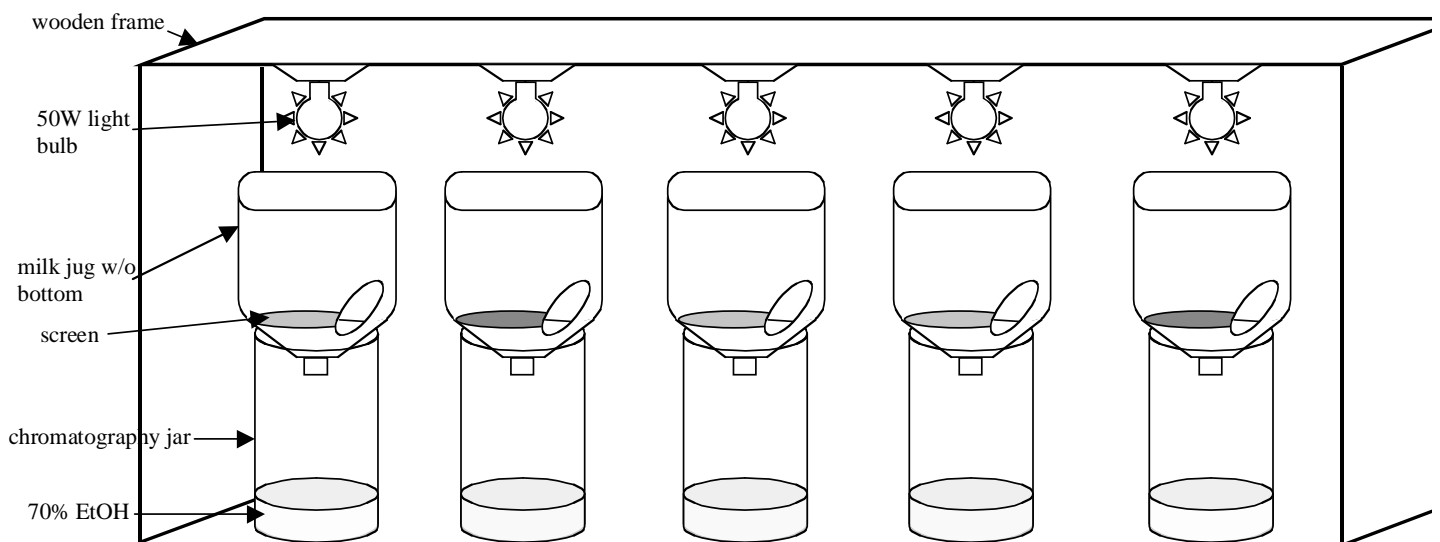

Figure 5B. Economical Berlese Funnel apparatus using inverted plastic milk jugs. Typically, 2 or 3 are needed for a lab section.

APPENDIX B: Sample data sets and graphs.

All data collected from the Fall 2000 class of Biology 280: Ecology and Evolutionary Biology, Hope College, Instructor: K. Greg Murray. Updated information from this class is posted each fall at: *http://www.hope.edu/academic/biology/classdata/bio280/labs/datasets.htm*

Table 3. Species richness and reciprocal form of Simpson's Index, Fall 2000, Hope College Nature Preserve, Holland, MI.

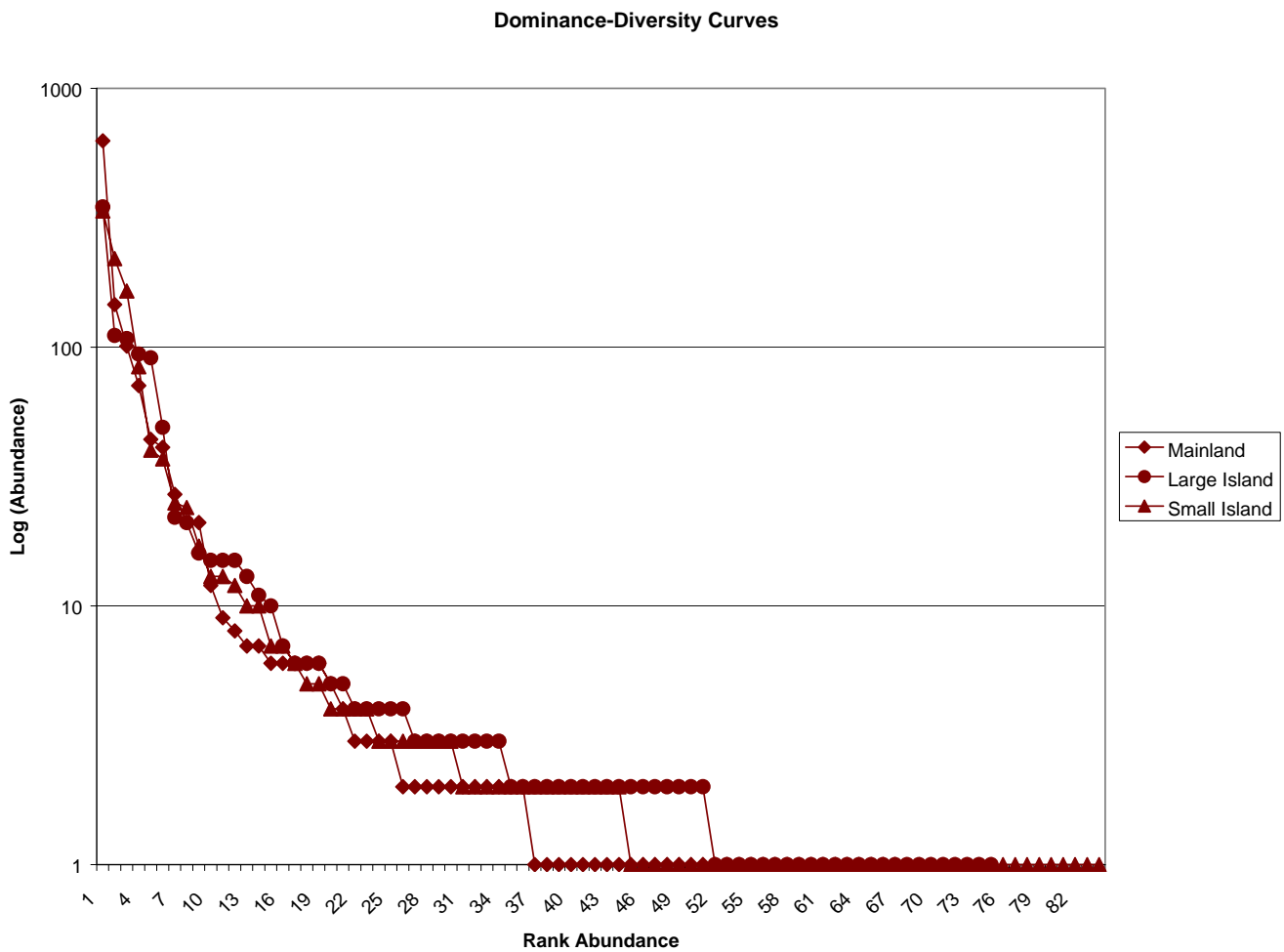| TREATMENT	S	1/D
"Mainland"	67	3.564
Large Island	75	6.920
Small Islands	84	6.473

Dominance-Diversity Curves

Figure 6. Dominance-diversity curves constructed from Fall 2000 data, Hope College Biology Nature Preserve, Holland, MI.
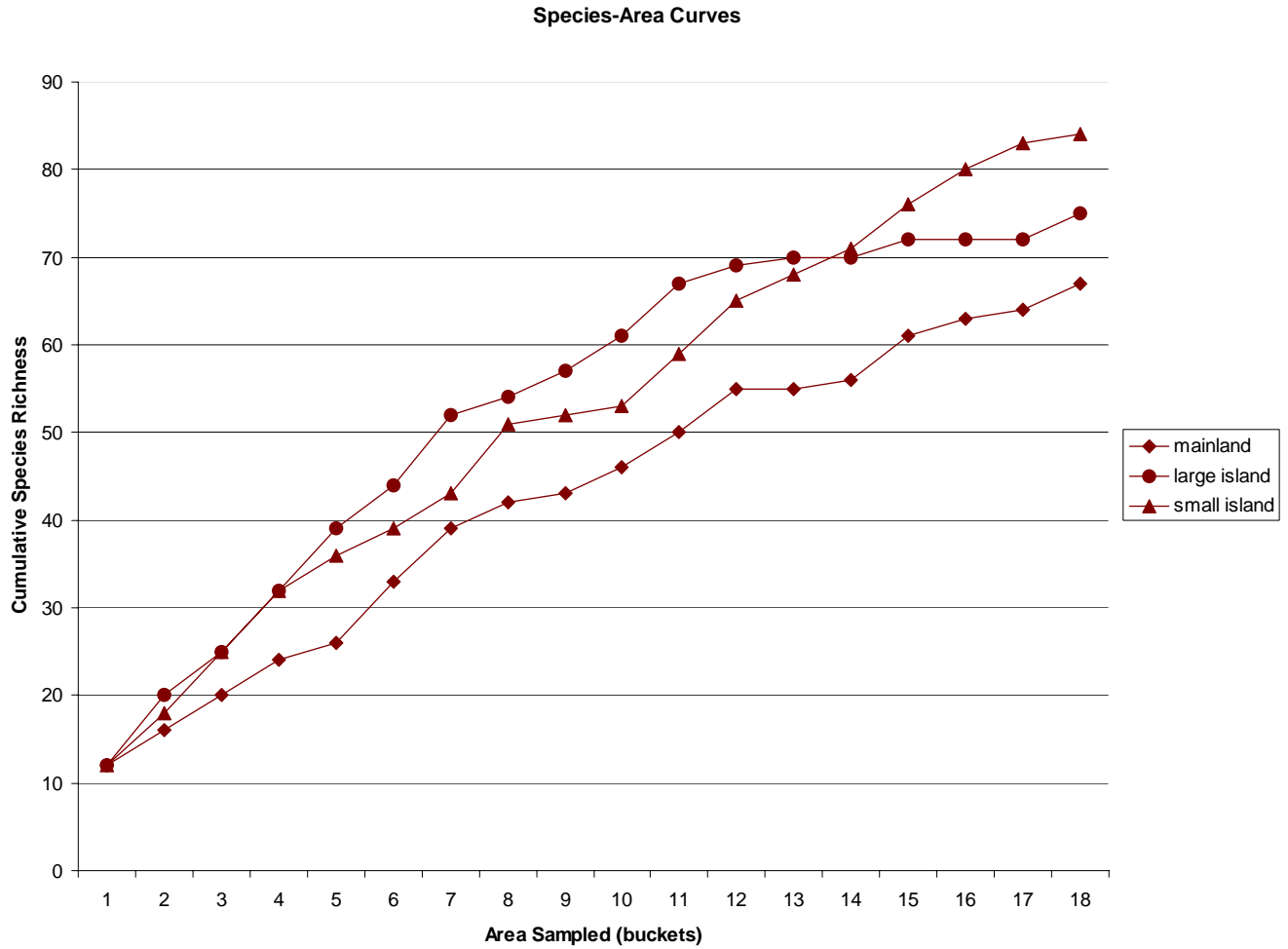
Figure 7. Species-Area Curves for Fall 2000 data collected at the Hope College Biology Nature Preserve, Holland, MI.