The Biodiversity Invasion

(Species Diversity and Invasive Species)

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NGSS Middle School Performance Expectations

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Objectives

Upon completing this lesson the students will be able to:

1. Demonstrate focused observations of organisms through detailed descriptions, sketches, and naming of species.
2. Describe species diversity as a measure of the biodiversity in a particular habitat.
3. Define species richness as the total number of different species in a particular habitat.
4. Define species evenness as the relative abundance of species in a particular habitat.
5. Construct and interpret species-area curves to compare the species diversity of different habitats.
6. Explain how invasive species can affect the species diversity of a habitat.

Materials and Setup

Engage:

Arrange students in groups of two, and go outside to a selected habitat such as a wooded area, a pond, or even the schoolyard, where they can observe different species. The materials required for this portion of the lesson are listed below (masters attached).

- Diversity Log – one per student (cut along dotted line and staple half-sheets into booklet)
- the schoolyard or a nearby natural habitat
- terms written on the board in the following format

BIODIVERSITY
Species Diversity

Explore:

The materials required for this portion of the lesson are listed below (masters attached). Students should *not* be given handouts for the Explore section of the lesson until Step 3.

- meadow diagrams (Meadows A and B) – one copy of each per group
- meadow diagram transparencies (Meadows A and B) – one copy of each for teacher
- species diversity worksheet – one per group
- species diversity worksheet transparency – one for teacher
- *species richness* and *species evenness* added to terms written on the board in the following format

BIODIVERSITY
Species Diversity
species richness
species evenness

Explain:

The materials required for this portion of the lesson are listed below (masters attached).

- habitat diagrams (Habitats A and B) – one copy of each per group
- habitat diagram transparencies (Habitats A and B) – one copy of each for teacher
- data table I (Habitats A and B) – one per group
- data table I transparency (Habitat A) – one for teacher
- species-area curve worksheet – one per group
- species-area curve worksheet transparency – one for teacher
- data table II – one per group
- data table II transparency – one for teacher
- *species-area curve* added to terms written on the board in the following format

BIODIVERSITY
Species Diversity
species richness
species evenness
Species-Area Curve

Elaborate:

The materials required for this portion of the lesson are listed below (masters attached).

- diversity over time diagram – one per group
- diversity over time diagram transparency – one for teacher
- changes in diversity worksheet – one per group
- changes in diversity worksheet transparency– one for teacher
- *invasive species* added to terms written on the board in the following format

BIODIVERSITY
Species Diversity
species richness
species evenness
Species-Area Curve

INVASIVE SPECIES

Evaluate:

Formally assess student understanding (quiz and key attached). Materials required for the quiz are listed below. Prepare two different reef habitats with the candy marine species in *Swedish Fish: Aqua Life*. Reef 1 should have more species diversity, including a higher species richness and greater species evenness (8 blowfish, 7 red snapper, 9 seahorse, 7 seastar, 9 dolphin). Reef 2 should have both a lower species richness and species evenness (8 blowfish, 13 red snapper, 5 seahorse, 14 seastar).

- two packages of *Swedish Fish: Aqua Life* candies (approximately 60 per package)
- if not in local store, purchase online at www.swedishfish.com

Safety

Encourage students to turn over rocks, logs, and other forms of shelter for smaller organisms when exploring the selected habitat, but remind them to minimize the disruption they cause, putting everything back the way they find it. Survey the habitat prior to the lesson for any potentially harmful animals or plants (poison ivy), and remind students to wash their hands back in the classroom.

Requisite Knowledge/Skills for Students

Students should be comfortable with the distinction between an individual organism and a species. Students should also understand the coordinate plane and be able to construct and interpret line graphs.

Procedure

Engage:

60-90 minutes. Students will carefully observe different organisms on or near the schoolyard and document each species they discover in their Diversity Log. A subsequent classroom discussion will introduce students to the concept of species diversity as a measure of biodiversity in a particular habitat.

1. Inform students that today they will explore the topic of biodiversity. Ask if they have heard of this term, and if so, what it means. If students are slow to respond, prompt them by asking what two words, or parts of words, make up the term, and what they mean. Students should recognize that "bio" means life and combining it with "diversity" refers to the diversity of living things. Describe *biodiversity* as the diversity of living organisms in different ecosystems on Earth, directing students to the term on the board. Point out that biodiversity includes all the different plants, animals, fungi, and various microscopic organisms that exist on the planet. Tell students that they will act as scientists by investigating the biodiversity of a habitat you have chosen, looking for different species. Instruct them to focus on making detailed observations of each organism they find. Tell students to document their observations in their Diversity Logs. They should describe and sketch each species in as much detail as possible, labeling defining characteristics that they observe. For example, they might label "needles" as one defining characteristic of pine trees. Or they may identify the possession of six legs as distinguishing insects from other invertebrates. They should also record a name for each species in their Diversity Log. Assure students that it is not important to know the actual names of species they discover. If a student does know the name of an organism they find, such as a squirrel, they should record it. However, if a student discovers an unfamiliar species, they should create their own descriptive name and document it in their Diversity Log. For example, if a student finds a plant with fuzzy, soft leaves, and he or she does not know its name, "tissue plant" would suffice. Providing descriptive names, as well as constructing detailed sketches and written descriptions, will emphasize the need for focused observation. Motivate students by encouraging them to act as scientists, exploring and documenting the biodiversity of a local habitat. Tell them to find and record as many different species as they can. Once students understand their task, provide each of them with their own Diversity Log, lead them outside to the selected habitat, and have them begin their investigation.

2. When you notice that students are finished discovering new species, or when they have filled up their Diversity Logs, return to the classroom for a short discussion regarding their findings. Ask questions such as, how many different species were present in the habitat they explored, what their names were, and what characteristics helped distinguish them. Celebrate their investigation of biodiversity by showing genuine interest for each additional discovery of a species. Introduce the concept of species diversity, directing students to the term written on the board. Tell them that scientists are often interested in the species diversity of a habitat. Ask students how they would define species diversity based on their investigation outside. They should recognize that species diversity describes the various species found in some habitat,

and they may define it as “how many” species exist. If needed, remind them that biodiversity is a broad term for the diversity of all living organisms on Earth. Guide students to the understanding that *species diversity* is a measure of the biodiversity in a particular habitat.

3. *Evaluate*: Throughout the Engage, students should develop an understanding that species diversity is a measure of the biodiversity in a particular habitat. Students should also demonstrate focused observations of organisms when exploring the selected habitat. Their careful observation and documentation of species should be illustrated in detailed descriptions and sketches in their Diversity Logs. Descriptive names of unknown species are further evidence of focused observations made by students. They should be able to provide distinguishing characteristics in their descriptions, sketches, and names of species. For example, students might discover a fungus growing from a fallen log or branch, which they name the “pancake fungus,” sketching and describing the flat pancake-like structures protruding from the decomposing wood. Students should record a variety of species in their Diversity Logs, including plants, animals, fungi, and even algae if exploring an aquatic habitat. These are all organisms easily seen with the naked eye.

Explore:

30-45 minutes. Students will carefully examine the meadow diagrams (Meadows A and B), collecting and analyzing data to develop an understanding of species richness and species evenness, two different components of species diversity.

1. Inform students that they will continue their investigation of species diversity, by examining two diagrams representing different meadows. Using a transparency of Meadow A, point out that plants with different shapes and shading represent different species in each meadow. Begin this portion of the lesson by quickly alternating transparencies of Meadows A and B on the overhead projector several times, instructing students to compare the meadows. Assure students that each meadow contains the same number of plants (35). Briefly displaying the two diagrams, in rapid succession, will prevent students from counting individual plants or the number of different species. Note that students should *not* be given handouts for the Explore section of the lesson until Step 3; student views of Meadows A and B should be restricted to brief alternating glimpses on the overhead.

2. *Evaluate*: While quickly alternating transparencies of Meadows A and B, ask students if one meadow seems more diverse than the other. They will likely reply that Meadow A appears more diverse. However students answer, make sure they explain their reasoning. Encourage them to consider how they described "diversity" in the habitat they investigated during the Engage. Students should recall that species diversity is a measure of the biodiversity in a particular habitat. They should also recognize, that to determine which meadow has a higher species diversity, they will need to count the number of species in each.

3. While passing out the meadow diagrams (Meadows A and B) and a species diversity worksheet to each group, inform students that scientists who investigate the species diversity of natural habitats are called ecologists. Remind them that, as scientists, ecologists reach conclusions based on evidence. Again, ask students which meadow is more diverse, highlighting this as the central question of this portion of the lesson. Tell students to use the species diversity worksheet to record their observations, placing an "X" next to the species that are present in each meadow. One partner in each group should examine Meadow A, while the other focuses on Meadow B, sharing their findings.

4. After analyzing their results, students should respond that the meadows are equally diverse. Remind students to provide evidence for their conclusions. They should report that both meadows are composed of the same seven plant species. Inform students that they have discovered the component of species diversity called species richness. Define *species richness* as the total number of different species in a particular habitat, directing students to the term on the board. Tell students that ecologists report species richness as a numerical value, 5 or 12, for example. Ask them what the species richness is for each of their meadows. Students should reply that both meadows have a species richness of 7.

5. Express confusion to students about species richness and the diversity of a habitat. Point out that Meadow A still seems more "diverse" than Meadow B, even though they have the same species richness. Ask students if they can explain why Meadow A seems more diverse. They may point out that Meadow B is dominated by one species (2^{nd} species down on the species diversity worksheet), whereas the species of Meadow A are more balanced, or even, giving the impression of being more diverse. If not, bring up this possibility, asking students how many individual plants of each species are present in the meadows. Tell students to record their observations for each meadow in the species diversity worksheet, in the third column (grayed out with dotted lines). They should report that there are 5 of each species in Meadow A, while there are 20 individuals of the dominant species and 2 or 3 of the remaining plant species in Meadow B. Inform students that they have discovered another component of species diversity called species evenness. Define *species evenness* as the relative abundance of species in a particular habitat, directing students to the term on the board. Point out that Meadows A and B are similar in two respects: 1) they have the same total number of individual plants (35); and 2) they have the same species richness (7). They differ, however, in the relative abundance of these seven species. Tell students that species evenness can be an important characteristic distinguishing two different habitats. Have students try to imagine walking through Meadows A and B in a straight line. Ask them in which meadow they are likely to encounter more species on their walk. They should recognize that, because of the relative abundance of species, they would encounter more species on a walk through Meadow A. Point out that this component of species diversity (species evenness) is exactly what makes Meadow A appear more diverse, even though both meadows have the same number of species (species richness). Explain that habitats with a more even distribution, or relative abundance, of species are considered more diverse than those dominated by one or a few species.

6. *Evaluate*: Throughout the Explore, students should develop their understanding of species diversity by collecting and analyzing data. Students should carefully examine and compare the diversity of each meadow, recording their observations on a worksheet. Based on their results, students should discover the concepts of species richness and species evenness. Have each student write a paragraph or two describing the concept of species diversity, specifically defining species richness and species evenness. Tell students to use their exploration of meadow diversity to explain why it is important to look at more than the number of species when investigating the species diversity of a habitat. They should be able to describe how two habitats can have the same species richness, but a different species evenness, making one more diverse than the other.

Explain:

45-60 minutes. Students will emulate ecologists, choosing 15 sample plots to survey species in the habitat diagrams (Habitats A and B). They will then demonstrate their understanding of species diversity by constructing and analyzing species-area curves for the two habitats. Students will also explore how species-area curves can be used to compare the species diversity of different habitats.

1. Handing out the habitat diagrams (Habitats A and B) to each group, tell students they will continue to act as ecologists investigating species diversity, by examining two new habitats. Use a transparency of Habitat A to introduce students to the habitat diagrams. Point out how both habitats contain an assortment of species, each represented by a particular geometric shape (circle, square, or triangle) with one of four different patterns (clear, solid, striped, or stippled). Tell students they are going to survey the species in each habitat using a technique called sampling. Explain to students that, when investigating species diversity, ecologists usually do not have time to count every individual organism in a habitat. Instead, they divide the habitat into equally-sized sections, or sample plots. Then they survey, or sample, the species in a few of the plots, attempting to estimate the species diversity of the habitat. Using the transparency of Habitat A, direct students' attention to the dotted lines partitioning each habitat into 35 equally-sized squares. Tell students that each partitioned square represents a 10 m^2 sample plot, containing four or five different organisms (the geometric shapes). Caution students not to confuse a sample plot (dotted lines) with the squares that represent a particular species (clear square, solid square, striped square, or stippled square). Point out that each of the 35 sample plots contains more than one kind of species, but may or may not include a "square" species.

2. Have students begin collecting data. Tell them they are going to survey the species in 15 different sample plots for each habitat. Using a transparency of Data Table I for Habitat A, show students how they can record their observations. Explain that they could choose any one of the plots in Habitat A to sample first. Once they have identified a plot to sample, they should draw each species contained in the plot in the column labeled, "Species Present." For example, if they selected the plot in the upper left-hand corner, they would draw a striped square, stippled circle, striped circle, and clear triangle on the data table. These are the four different species present in the upper left-hand plot of Habitat A. Tell students to record the cumulative number of different species they find in each habitat in the column labeled, "Running Total." This would mean recording a "4" in the data table for the four species found in the first sample of Habitat A (upper left-hand corner). Show students how to accurately record the running total of different species by choosing the plot in the lower right-hand corner as a second sample. A striped square, striped triangle, stippled square, stippled circle, and solid triangle would be drawn in the "Species Present" column, and a "7" should be recorded in the "Running Total" column. Although the second sample contained five different species, only three of these were new additions to those found in the first sample (4 + 3 = 7). Tell students to continue this process for all 15 of their samples, pointing out that with some samples, their running total may

not change. Explain that the running total for any sample with no new species will be the same as the previous sample. When this occurs, the species found in the sample should still be recorded in the "Species Present" column. Tell students to choose 15 different samples in each habitat. Have them place a small "X" in the upper left-hand corner of each plot they sample to avoid sampling it more than once. Again, one partner in each group should examine Habitat A while the other focuses on Habitat B, sharing their findings.

3. Once they have surveyed the species in 15 sample plots, tell students they are going to construct species-area curves for the habitats they sampled. Directing students to the term on the board, describe a *species-area curve* as a line graph representing the total number of different species found in a habitat plotted against the total area sampled. Tell students that a species-area curve is a tool ecologists use to compare the diversity of two or more habitats. Using a transparency of the species-area curve worksheet, show students how to use their data tables to create species-area curves for each habitat. Tell students that the y-axis represents the running total of different species in the habitat, and the x-axis represents the running total of area sampled, with each of the 15 plots surveyed. Since each sample plot in Habitats A and B is 10 m^2, the total area sampled in each habitat is 150 m^2 (10 m^2 x 15 = 150 m^2). To check for understanding, ask students what the coordinates (x,y) would be on the species-area curve for Habitat A if the first sample came from the plot in the upper left-hand corner. They should respond with (10, 4). The first coordinate (10) corresponds to the total area sampled (10 m^2), and the second coordinate (4) represents the four different species present in the plot. Graph this point on the transparency for students to see. Have students identify the coordinates of a second point on the species-area curve, assuming a second sample from the plot in the lower right-hand corner of Habitat A. They should answer (20, 7). The first coordinate (20) corresponds to the running total of area sampled (10 m^2 x 2 = 20 m^2), and the second coordinate (7) represents the running total of different species (4 + 3 = 7). Plot these coordinates (20,7) on the transparency as well, connecting this point and the first point (10, 4) with a line. Have students use a similar procedure to construct species-area curves for both habitats from the information they collected in their data tables.

4. Ask students to compare their species-area curves for Habitats A and B, looking for as many differences between the two as they can find. An obvious difference is likely to be that curves for Habitat A all reach a total of 10 different species, while curves for Habitat B may only reach a total of 8 or 9 different species. Even if a species-area curve for Habitat B does reach 10 different species, curves for Habitat A always have a steeper slope; students have to sample more plots in Habitat B to discover the same number of species sampled in Habitat A. Students will likely notice any difference in height between their species-area curves for the two habitats (if only 8 or 9 species found in Habitat B). If a curve for Habitat B happens to reach 10 different species, ask students if it took more or less samples to do so. Make sure students notice the difference in slope between the curves for the two habitats. Ask students to provide an explanation for the differences in the two species-area curves. Students may suggest that one of the habitats has more individual organisms or possibly fewer

species. Remind them to use the new terms they are learning, referring to the possibility that one habitat has a lower species richness. Students may suggest that species are not equally represented in the two habitats, that some species are relatively rare in one habitat. Again remind them to use ecological terms, suggesting the possibility that one habitat may have a greater species evenness. Remind students that scientists reach conclusions based on evidence, and that they can explore all of these possibilities by investigating the presence and abundance of each species in the two habitats.

5. After passing out Data Table II, tell students to investigate and record the presence and abundance of species in Habitats A and B (not just their 15 samples, but the entire habitat). Use a transparency of the data table to show students how to use tally marks in the column labeled, "Abundance" to indicate how many individuals of each species are found in each habitat. When finished, ask students if there is a difference in the total number of individual organisms or the species richness between Habitats A and B. They should report that both habitats consist of 160 individual organisms with a species richness of 10 (the same 10 species in both habitats). Ask students about the relative abundance of the species in each habitat. They should respond that Habitat A has a greater species evenness than Habitat B; the 10 different species are more equally represented in Habitat A than in Habitat B. Students should recognize that Habitat B contains some species that are particularly common (stippled circle and clear square) or rare (striped circle and clear triangle). Ask them to explain how having rare species may affect a species-area curve. They should recognize that a species that only occurs in a few sample plots is likely to be missed in any survey of the habitat. Putting the transparency of Habitat B on an overhead, point out that the striped circle and clear triangle species each occur in only two plots in Habitat B. Have students locate them. Point out that stippled circles and clear squares are especially common in Habitat B, and have students specifically notice the abundance of these species. Ask what the effect of having a particularly common species in a habitat is on a species-area curve. Have students look at their results in Data Table I and at their species-area curves for both habitats. They should recognize that abundant species show up more often in sampling and, after being recorded a first time, do not contribute to the growing total of different species in a habitat.

6. *Evaluate*: Have students add to their paragraph(s) from the Explore, describing how species-area curves can be used to compare the species diversity of two habitats. Remind them to use the ecological terms they have learned, providing relevant examples from our fictitious habitats to illustrate their understanding.

7. *Optional Extension*: Ecologists use a number of different diversity indices to estimate the species diversity of various habitats. The Shannon diversity index is one such measure that students could explore if appropriate. The Shannon index takes into account both species richness and species evenness in assessing the "diversity" of a particular habitat, but requires more advanced mathematical expertise (logarithms).

Elaborate:

20-30 minutes. Students will carefully examine the changes in species diversity of a lake's fish species over time (Diversity Over Time). Students will discover how an invasive species can enter a habitat and affect both species richness and species evenness, to the detriment of the habitat's native species.

1. Ask students if they think the species diversity of a habitat can change over time, and if so, how. Students may suggest that disturbances to a habitat like logging, natural disasters, pollution, or even climate change could decrease the species diversity of a habitat by eliminating individuals, or even entire species. Inform students that a number of factors can impact a habitat's diversity and that they will act as ecologists, investigating changes in the species diversity of a fictitious lake over time. Distribute the Diversity Over Time diagram and the Changes in Diversity worksheet to each group. Placing a transparency of the Diversity Over Time diagram on an overhead projector, tell students to investigate the lake's fish species during each of the four time periods. Show students how to record their observations on the Changes in Diversity worksheet. Have students identify the species present (species A, B, C, D, or E) in each time period in the columns labeled, "Species Present" and specify how many individuals of that species they find in the columns labeled, "Abundance." Point out that they should document the lake's species richness during each time period, below each table on the worksheet.

2. When finished, ask students to describe the changes that occurred in the lake from time 1 to time 2. Students should respond that a new species (E) is present in the lake during the second time period and that the species richness of the lake increased from 4 to 5. Students should also notice that two species decreased in abundance (B and C). Ask students to describe what happened in the lake from the second to the third time periods. They should notice that the species richness remained the same (5), but that the new species (E) increased in abundance, while three species decreased in number (A, B, and C). Ask students to describe what happened to the lake from the third to fourth time periods. They should respond that the new species (E) increased in abundance again, and the same three species (A, B, and C) decreased in number, as well. They should also report that the species richness decreased to 3 since two of the original species (B and C) are missing. Ask students why they think species B and C are missing from the fourth time period. They will likely conclude that species E had something to do with it. Tell students that when a new species invades a habitat, it can be a new competitor or predator for some of the original, or native, species. Students should recognize that species B and C went locally extinct because of the introduction of species E to the habitat. Tell students that ecologists refer to species E as an invasive species.

3. Directing students to the term on the board, describe an *invasive species* as a non-native species that can enter a habitat and negatively impact native species, even leading to the local extinction of some from the habitat. Ask students how they think invasive species enter new habitats. Ask them if they know of any invasive species in Michigan. Tell students that they will explore these two questions next.

4. Have students use the library and Internet to investigate invasive species found in the Great Lakes Region. Provide related books or articles about invasive species in the classroom. Some well-known invasive species students may discover include the zebra mussel, sea lamprey, round goby, purple loosestrife, and spotted knapweed. (We intended that species E resemble the sea lamprey, and some students may make this connection after researching invasive species of the Great Lakes).

5. *Evaluate*: In the Elaborate portion of the lesson students should be able to apply their understanding of species diversity, specifically species richness and species evenness. They should be able to correctly record species present, abundance, and species richness for each time period on the Changes in Diversity worksheet. Through discussion, students should conclude that invasive species can have a negative impact on the species diversity of a habitat. They should recognize that, although invasive species initially increase species richness by one, they eventually decrease species evenness, even leading to local extinction of native species. After investigating invasive species in the Great Lakes, have students write a paragraph or two on the species of their choice. They should include its name, a short description of the species, where it came from, how it reached the Great Lakes, and what effect it has had on native species.

Evaluate:

During the Engage (Diversity Log): Students record observations of various species in their Diversity Log when exploring the selected habitat. Their focused observation of organisms should be apparent in detailed descriptions and sketches in their Diversity Logs (Objective 1). Descriptive names given to unknown species is also evidence of focused observation. Through discussion, students should demonstrate their understanding of species diversity as a measure of biodiversity in a particular habitat (Objective 2), sharing their observations of organisms discovered in the selected habitat.

During the Explore (Species Diversity worksheet): Students collect and analyze data from the meadow diagrams to develop an understanding of two components of species diversity, species richness and species evenness (Objectives 3-4). They should conclude that Meadow A is more diverse than Meadow B even though both meadows contain the same seven plant species.

After the Explore (written paragraph): Students explain the concept of species diversity (Objective 2) in a paragraph or two, using the meadows as examples to illustrate their understanding. They should be able to define species richness as the total number of different species (Objective 3), and species evenness as the relative abundance of species in a particular habitat (Objective 4).

During the Explain (Data Tables I & II and Species-Area Curve worksheet): Students use data collected from the habitat diagrams to construct and interpret species-area curves (Objective 5). They use the species-area curves to compare the species diversity of Habitats A and B, applying the concepts of species richness and species evenness (Objectives 2-4). Students add to their paragraph(s) from the Explore, expanding on their understanding of biodiversity by describing how species-area curves can be used to compare the species diversity of two habitats. They should be able to provide evidence to support their conclusions about the diversity of Habitats A and B, incorporating relevant concepts and appropriate terminology.

During the Elaborate (Changes in Diversity worksheet): Students collect and analyze data from the Diversity Over Time diagram to develop an understanding of how an invasive species can affect the species diversity of a habitat (Objective 6). They should conclude that invasive species have a negative impact on biodiversity, decreasing species evenness and potentially causing the local extinction of native species (species richness).

After the Elaborate (written paragraph and Quiz): Students research invasive species of the Great Lakes and report on a species of their choice in a paragraph or two. They should be able to apply their new understanding of biodiversity in assessing their selected species' impact on native species. The quiz formally assesses students' understanding of species diversity, specifically species richness and species evenness (Objectives 2-4), including the use of species-area curves to compare the diversity of different habitats (Objective 5). It also evaluates students' understanding of the impact invasive species can have on species diversity (Objective 6).

Scientific Background for the Teacher

In general, biodiversity is the diversity of life and encompasses all living organisms on Earth, including plants, animals, fungi, bacteria, and other microscopic organisms. In addition to describing the variety of species, biodiversity includes the variability (genetic diversity) both within and among species. Scientists have named and described approximately 1.8 million different species. Estimates vary on how many species remain undiscovered. This vast diversity of living organisms is related to the great variety of environments found throughout the planet. Biodiversity is an invaluable treasure, a legacy of evolution, reflecting billions of years of natural selection on an ever-changing Earth.

This lesson focuses on the concept of species diversity and how scientists attempt to measure the diversity of various habitats. Species richness is the total number of different species in a particular habitat. Students can simply count how many species they find in any given habitat to determine its species richness. The more species they discover the higher the species richness. Species evenness is the relative abundance of species in a particular habitat. This measure of species diversity takes into account how rare or common various species are. To determine species evenness students must estimate the number of individuals of each species. Habitats with a greater species evenness are considered to be more diverse.

The use of species-area curves represents one method that scientists employ to compare the diversity of different habitats. The number of different species encountered in a habitat is plotted against the increasing amount of area sampled, resulting in a line graph. A line that reaches a larger point value on the y-axis (number of species) indicates a higher species richness. The slope of a line reflects the species evenness of a sampled habitat, with a steeper slope resulting from a greater species evenness. The higher the relative abundance of species in a habitat, the more species will be found in sampling, producing a species-area curve with a steeper slope. When comparing two different habitats, a species-area curve with a steeper slope that reaches a higher point value on the y-axis, either altogether or in fewer samples, depicts a higher species diversity.

Species introduced to a habitat from elsewhere, either purposefully or unintentionally, are referred to by a variety of names, including exotic, non-native, nonindigenous, or alien. Not all introduced species are necessarily considered invasive or harmful. Some of these species, however, are particularly aggressive, taking over and substantially changing a habitat. These biological invaders are referred to as invasive species. They act as competitors, predators, or parasites, cause disease or alter habitats, and impact pre-introduction diversity by decreasing the relative abundance of native species (species evenness) or even causing the local extinction of species (species richness). Endemic species are at a disadvantage because they have not evolved defenses to the novel features that these biological invaders acquired through their evolutionary backgrounds in different environments. Invasive species are a serious concern and may follow loss of habitat as a second leading threat to the conservation of biodiversity.

This lesson emphasizes data collection and analysis inside the classroom. We recommend using the lesson as a primer for students before any ecological investigation outside the classroom, as a way to help students develop a deeper understanding of species diversity and the potential impact of invasive species.

Misconceptions

Students may have a preconceived belief that simply counting species (species richness) is a good estimate of species diversity. This lesson addresses the potential misconception by helping students understand the importance of assessing the relative abundance of species (species evenness) in any particular habitat. Students may also initially misinterpret the arrival of an invasive species as having a favorable impact on species diversity, since it increases the number of species in a community. This lesson helps students see how invasive species can negatively impact diversity by decreasing species evenness over time, potentially even leading to the local extinction of species.

Interdisciplinary Components

This lesson incorporates the math concepts of plotting ordered pairs of integers on the coordinate plane, and using a line graph to represent the relationship between number of species and area of habitat sampled. Although not the primary focus of the lesson, these content expectations are addressed in developing a deeper understanding of species diversity. Specifically, species-area curves are used to illustrate how habitats with a higher species richness and greater species evenness are more diverse.

Acknowledgements

We would like to thank Kara Manning for her illustration on the cover of the Diversity Log.

Diversity Log

Name: _____

Species Name: _____

Description:

_____

_____

_____

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_____

Sketch of Species:

Species Name: _____

Description:

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Sketch of Species:

Species Name: _____

Description:

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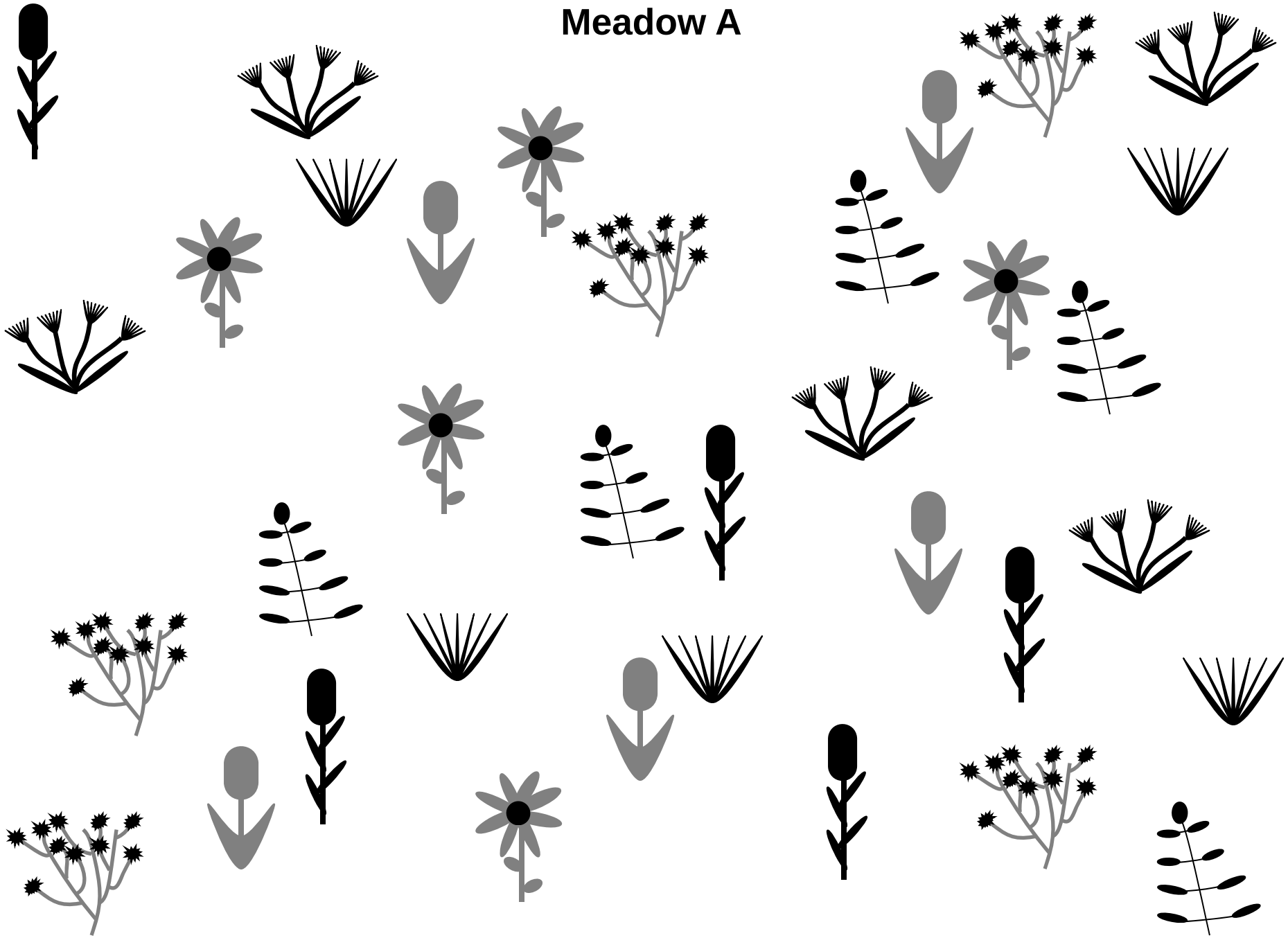
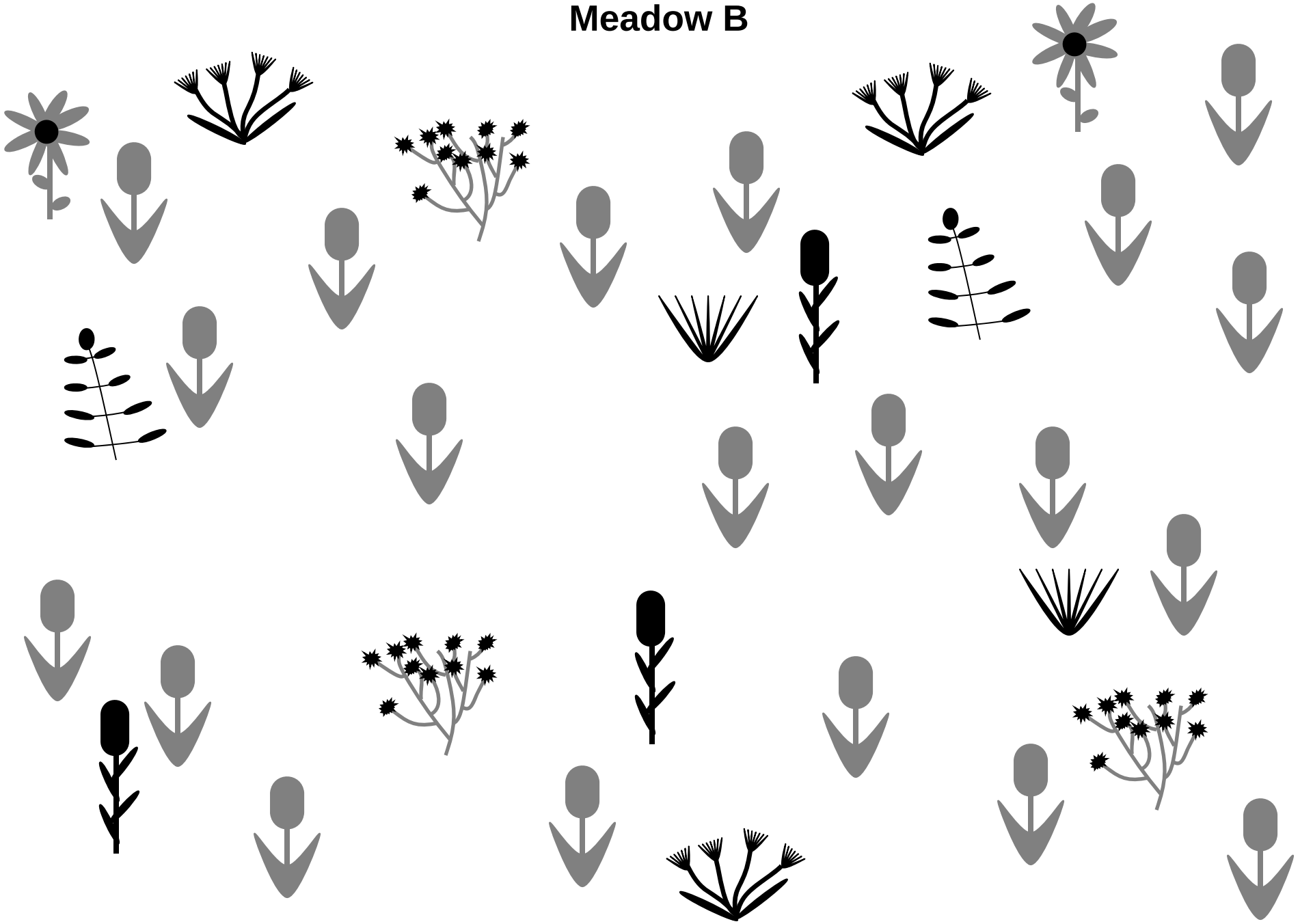
Sketch of Species:

Meadow A



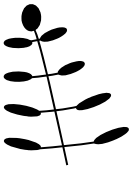
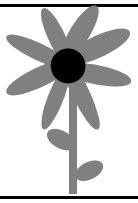
Meadow B



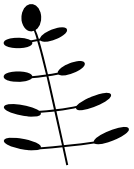
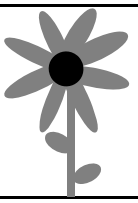
Species Diversity

Directions: Place an “X” in the middle column next to the species that are present in each meadow. Record the total number of different species found in each meadow at the bottom of the middle column.

Meadow A

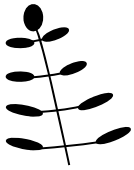
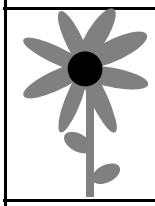
	
	
	
	
	
	
Total	

Meadow B

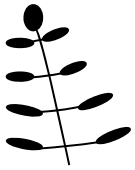
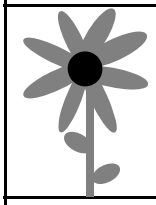
	
	
	
	
	
	
Total	

Species Diversity (Key)

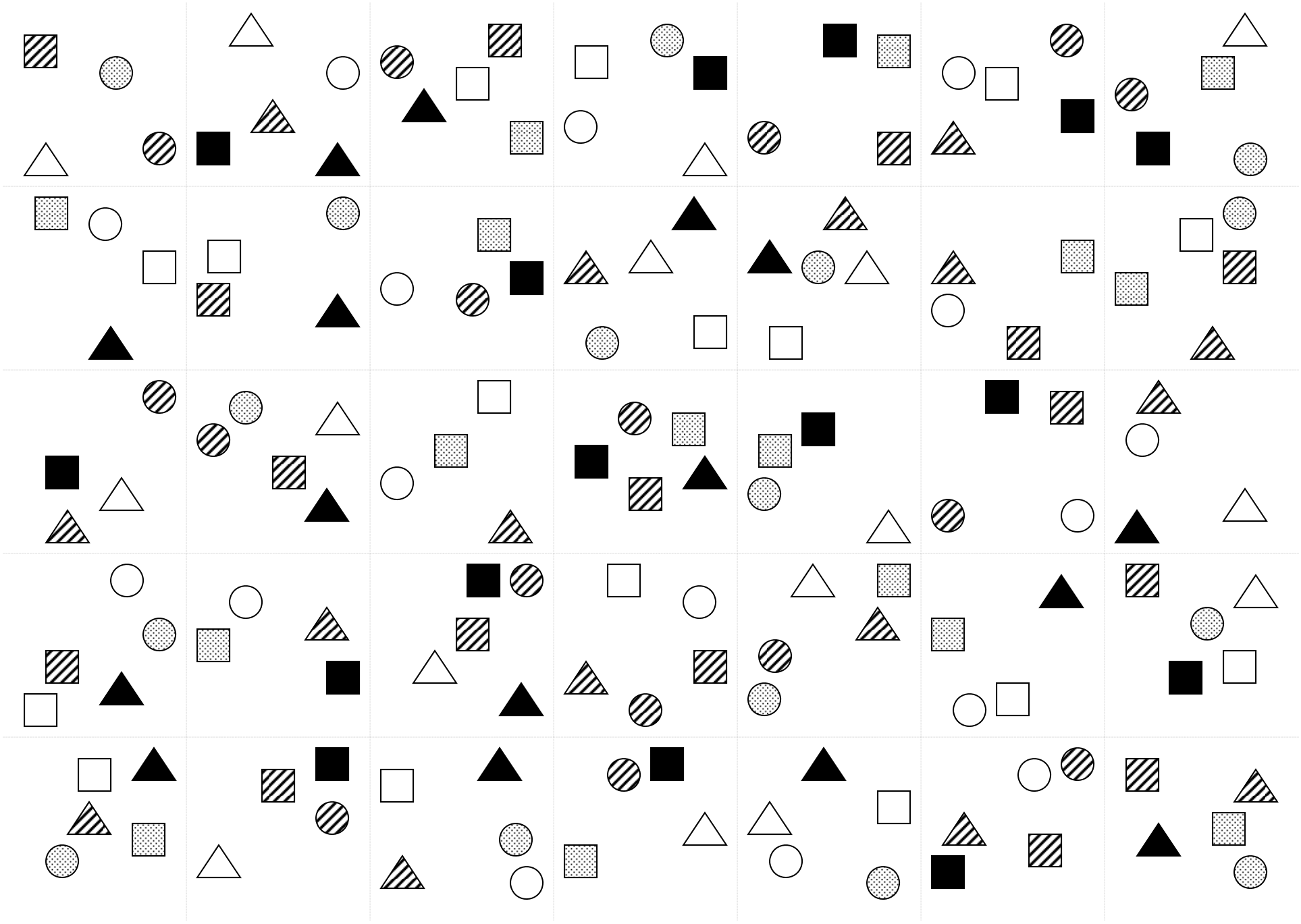
Meadow A

	x	5
	x	5
	x	5
	x	5
	x	5
	x	5
	x	5
Total	7	35

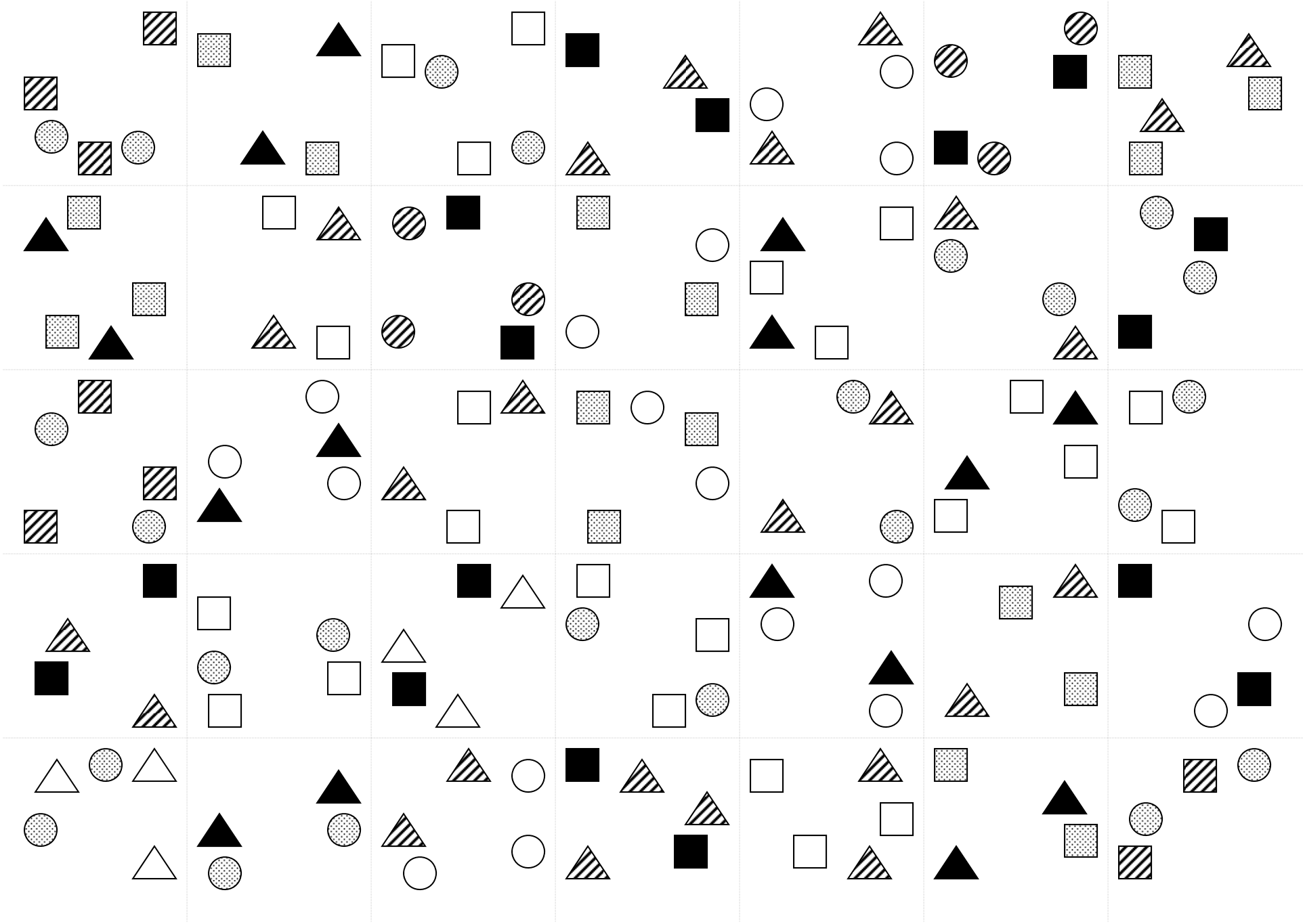
Meadow B

	x	2
	x	20
	x	2
	x	3
	x	3
	x	2
	x	3
Total	7	35

Habitat A



Habitat B



Data Table I (Habitat A)

Directions: Draw the species that were located in each plot sampled under “Species Present.” Specify the total number of different species you have discovered in the habitat while sampling under “Running Total.”

Sample #	Species Present	Running Total
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Data Table I (Habitat B)

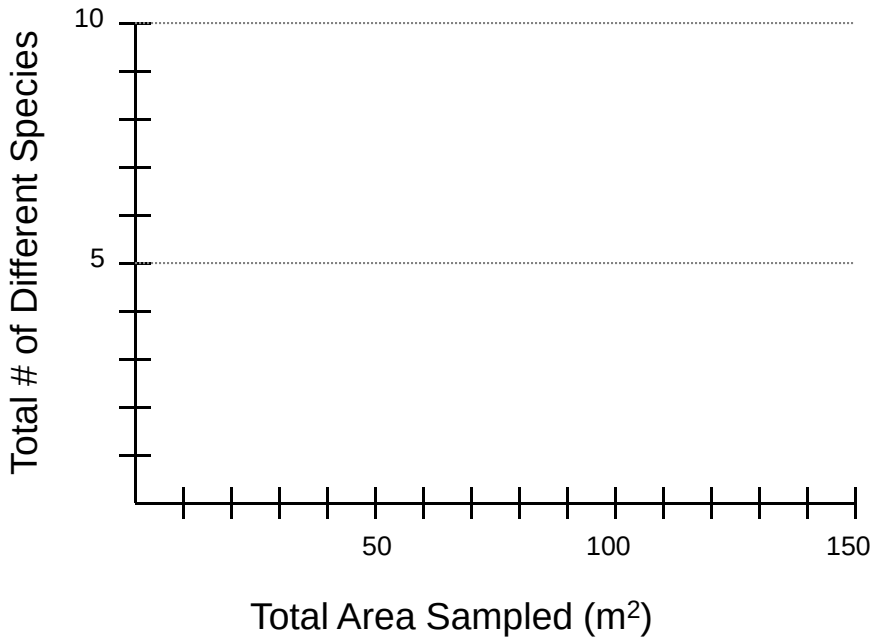
Directions: Draw the species that were located in each plot sampled under “Species Present.” Specify the total number of different species you have discovered in the habitat while sampling under “Running Total.”

Sample #	Species Present	Running Total
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

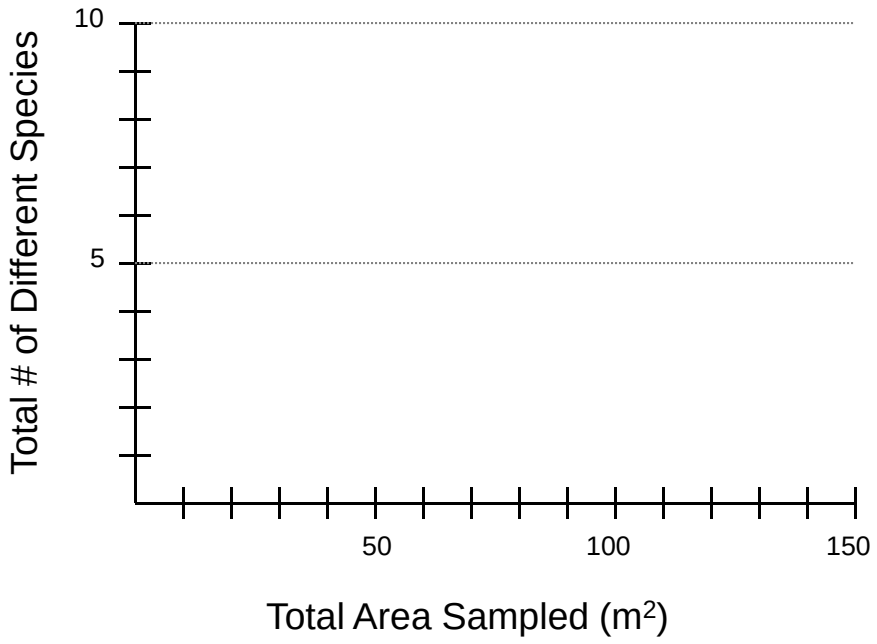
Species-Area Curve

Directions: Use the data you recorded in the habitat data tables to create species-area curves for Habitats A and B.

Habitat A



Habitat B



Data Table II

Directions: Record organisms with tally marks under “Abundance.” Then total the number in each species, as well as all organisms combined (gray box).

Habitat A

Species	Abundance	Total
		
		
		
		
		
		
		
		
		
		

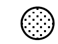
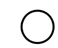
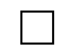
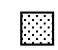
Habitat B

Species	Abundance	Total
		
		
		
		
		
		
		
		
		
		

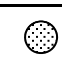
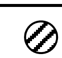
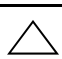
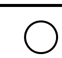
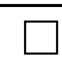
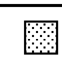
Data Table II (Key)

Directions: Record organisms with tally marks under “Abundance.” Then total the number in each species, as well as all organisms combined (gray box).

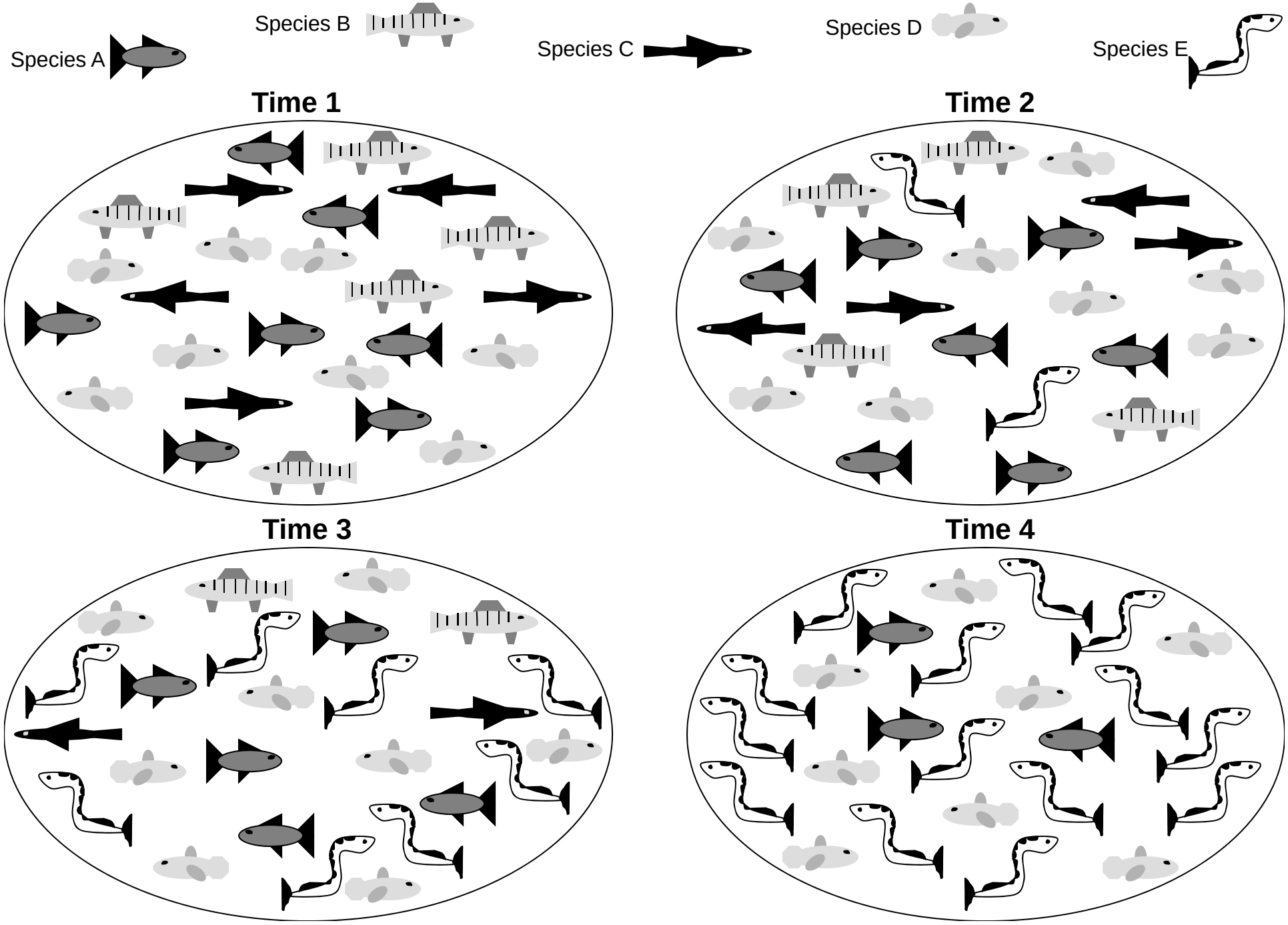
Habitat A

Species	Abundance	Total
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 |	16
		160

Habitat B

Species	Abundance	Total
	𝍸 |||	8
	𝍸 𝍸 𝍸 𝍸 ||||	24
	𝍸 |	6
	𝍸 |	6
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 𝍸 𝍸	25
	𝍸 𝍸 𝍸 |||	18
	𝍸 𝍸 𝍸 |	16
	𝍸 𝍸 𝍸 𝍸 ||||	24
	𝍸 𝍸 𝍸 ||	17
		160

Diversity Over Time



Changes in Diversity

Directions: Identify the species present (A, B, C, D, or E), their abundance, and the species richness in each time period of *Diversity Over Time*.

Time 1

Species Present	Abundance

Species Richness: _____

Time 2

Species Present	Abundance

Species Richness: _____

Time 3

Species Present	Abundance

Species Richness: _____

Time 4

Species Present	Abundance

Species Richness: _____

Changes in Diversity (Key)

Time 1

Species Present	Abundance
A	7
B	5
C	5
D	8

Species Richness: 4

Time 2

Species Present	Abundance
A	7
B	4
C	4
D	8
E	2

Species Richness: 5

Time 3

Species Present	Abundance
A	5
B	2
C	2
D	8
E	8

Species Richness: 5

Time 4

Species Present	Abundance
A	3
D	8
E	14

Species Richness: 3

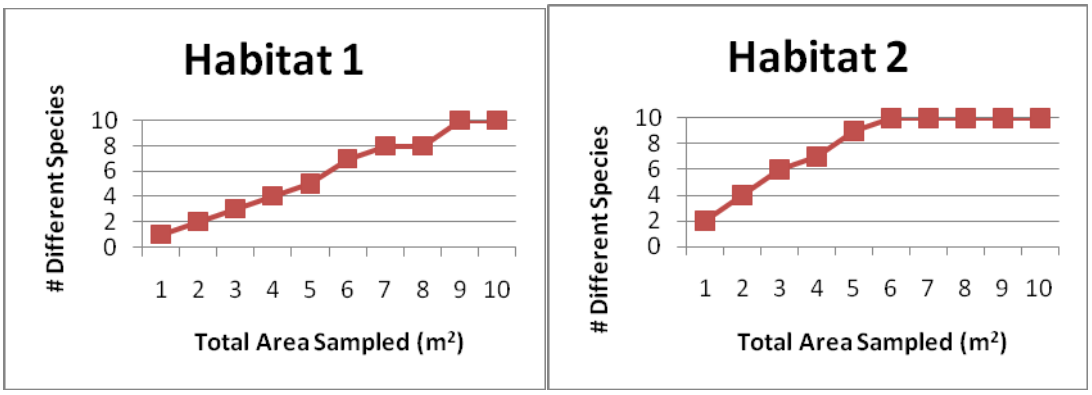
Quiz

(1) Use the data tables below to help determine which reef (*Swedish fish* species) is more diverse. Explain your answer, using relevant ecological terms related to diversity.

Reef 1			Reef 2	
Species	Abundance		Species	Abundance
Total			Total	

Species Richness: _____ Species Richness: _____

(2) Compare the diversity of Habitats 1 & 2 based on the species-area curves below.



(3) What would you say to someone who claimed that invasive species are a good thing for biodiversity because they increase the number of species in a habitat?

Quiz (Key)

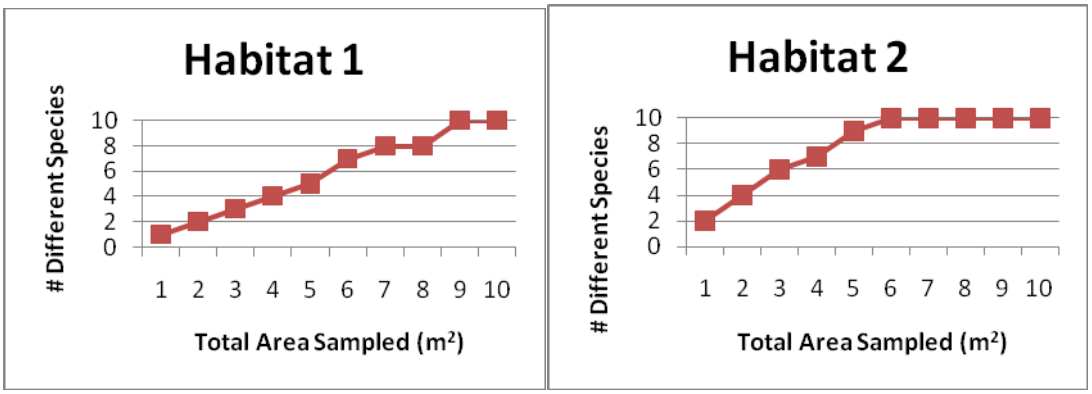
(1) Use the data tables below to help determine which reef (*Swedish fish* species) is more diverse. Explain your answer, using relevant ecological terms related to diversity.

Reef 1			Reef 2	
Species	Abundance		Species	Abundance
blowfish	8		blowfish	8
red snapper	7		red snapper	13
seahorse	9		seahorse	5
seastar	7		seastar	14
dolphin	9			
Total	40		Total	40

Species Richness: __5__ Species Richness: __4__

Reef 1 has a higher species diversity than Reef 2. Although both habitats consist of 40 total individuals, Reef 1 has a higher species richness, as well as a greater species evenness. Reef 2 is dominated by two species, the red snapper and seastar.

(2) Compare the diversity of Habitats 1 & 2 based on the species-area curves below.



Habitat 2 has a higher species diversity than Habitat 1. Although both habitats consist of 10 different species (species richness), Habitat 2 has a greater species evenness. The species-area curve for Habitat 2 reaches 10 different species in fewer samples (steeper slope).

(3) What would you say to someone who claimed that invasive species are a good thing for biodiversity because they increase the number of species in a habitat?

Although it is true that an invasive species initially increases species richness by 1, over time it can negatively impact species diversity by decreasing species evenness, and even causing the local extinction of some species (a decrease in species richness).