hhmi | BioInteractive

Seed Dispersal in Tropical Forests

Activity
Educator Materials

OVERVIEW

Although plants are immobile, they use a number of different mechanisms to disperse offspring. This activity investigates differences in seed dispersal between two tropical tree species, one whose seeds are dispersed by wind and one whose seeds are dispersed by birds. Students explore authentic data from the literature and apply their ideas to a practical problem. In an optional section of the activity, students examine the degree to which results from the study support the Janzen-Connell hypothesis. This activity is designed to accompany the BioInteractive *Scientists at Work* video *Seed Dispersal and Forest Fragmentation*.

KEY CONCEPTS

- Plants produce different types and shapes of seeds and fruit, which are shaped by natural selection for specific dispersal mechanisms.
- Wind dispersal results in more seeds being clustered around the parent plant with diminishing numbers farther from the plant.
- When seeds are dispersed by animals eating fruit, seeds are distributed in groups or clumps farther from the parent plant.

STUDENT LEARNING TARGETS

- Explain how fruit structure can affect the function of seed dispersal.
- Predict seed shadows for plants with different seed dispersal mechanisms.
- Interpret seed dispersal and seedling establishment patterns from experimental data.
- Infer patterns from seed dispersal and seedling establishment experimental data.
- Apply an understanding of seed dispersal patterns to the design of conservation areas.

CURRICULUM CONNECTIONS

Standards	Curriculum Connections
NGSS (2013)	HS-LS2-2; SEP1, SEP4
AP Bio (2015)	4.A.5, 4.B.3; SP3, SP5
IB Bio (2016)	9.4
AP Env Sci (2013)	II.A, III.A, IV.B
IB Env Systems and Societies (2017)	2.1
Common Core (2010)	ELA.RST.9–12.7, WHST.6–12.1 Math.S-IC.3; MP2
Vision and Change (2009)	CC5; DP1, DP2

KEY TERMS

abiotic, angiosperm, biotic, dispersal vector, fruit, seed, seed shadow

TIME REQUIREMENTS

One 50-minute class period. The video should be viewed beforehand.

SUGGESTED AUDIENCE

- High School: Biology (General, AP/IB), Environmental Science (AP/IB, with modifications)
- College: Introductory Biology, Ecology, Plant Biology

PRIOR KNOWLEDGE

Students should be familiar with:

- basic concepts related to seed dispersal, including different seed types
- how to develop a research question and experimental design
- interpreting graphs showing proportions or percentages

BACKGROUND

The seeds of flowering plants are dispersed in a number of ingenious ways. Different dispersal mechanisms (vectors) can be broadly grouped into two categories: abiotic and biotic. Among abiotic vectors, wind dispersal is the most common. In wind dispersal, fruit structures encasing or attached to the seed carry the fruit some distance away from the maternal (parent) plant. Many species whose seeds are dispersed by wind have a type of winglike structure attached to the seed. This type of fruit is called a samara (see Figure 3 in the "Student Handout"). The samaras produced by maple trees in temperate regions are a familiar example. This dispersal mechanism tends to disperse many offspring in the immediate vicinity of the parent plant, where competition with the much larger parental plant and with many siblings can be intense. High fruit density around the parental plant can also attract animals that eat the seeds and fruit, further reducing survival and establishment. Fewer seeds are dispersed to greater distances away from the parent tree, causing a decrease in seed density at increased distances from the parent tree.

Species whose seeds are dispersed by biotic vectors either use hooks, barbs, or sticky substances to adhere to an animal's body, or they produce fleshy, nutritious fruit to attract animals to act as dispersers. The animal will either remain where it fed or travel some distance before passing the seed through its digestive system or regurgitating the seeds. This type of seed dispersal typically results in a pattern in which seeds are distributed in groups or clumps farther from the parent plants. These plants risk having their seeds damaged during feeding by the animal.

In this activity, students explore seed dispersal patterns in two different species. *Platypodium elegans* are large trees in tropical forests that form part of the forest canopy. They produce wind-dispersed samaras. As they fall from the tree, the wing causes the samaras to spin and carries them away from the parent tree. *Ficus cyrtophylla* are relatively small trees and lianas (climbing vines) that live in the understory of tropical forests. They produce small, fleshy fruits in a cluster, and each fruit contains many tiny seeds. Bats and birds often eat the fruits and fly to a roost tree, where they eventually defecate the seeds.

TEACHING TIPS

- Provide a copy of the "Student Handout" for each student. This activity works well with students working together in pairs or small groups. Each student should complete their own copy of the handout.
- The seed dispersal plots in Figures 1 and 2 of the handout serve as a convenient pause point for classroom discussion of student predictions and plotting results before resuming the rest of the activity.
- For Step 8 of the "Student Handout," you may refer to the BioInteractive activity "Asking Scientific Questions" to help students develop their research questions.
- Decide whether you want students to complete the optional Part 4 of the activity. This section would be especially useful if you plan to have students learn about the Janzen-Connell hypothesis in your course.
- Consider implementing an additional inquiry-driven activity. Ask students to collect different representative wind-dispersed seeds with different structural adaptations for wind dispersal. For example, some trees make samaras in which the shape and size of the wing cause the fruit to spin as it falls, spiraling away from the parent plant. Dandelions and other members of the sunflower family have a structure attached to the top of the fruit called a pappus (Figure 1). It acts like a parachute to lift the fruit into the air and carry it away on the breeze. Students can drop them from different heights and measure how far they travel from the point of release. Students can also use a fan to determine how wind affects dispersal. With the fan on, will the seeds stay where they land?

Dispersal when seeds are released from the parent plant is called *primary dispersal*. Movement after seeds have landed on the ground, such as when the wind blows them, is called *secondary dispersal.*

- If you want students to have more practice developing their own graphs, consider downloading the data for Figures 4 and 5 from the Dryad Digital Repository (the "Seed seedling sapling distributions" data set).

Figure 1. The common dandelion makes "parachute" fruits. The pappus is attached to the top of the fruit.

ANSWER KEY

PART 1: Predicting Patterns and Developing Ideas

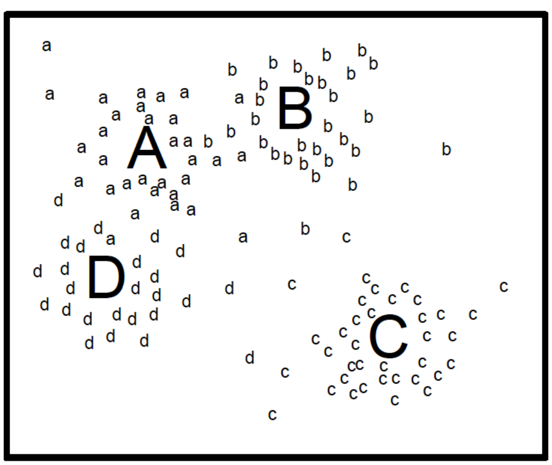
1. What fruit or seed adaptations might plants have for dispersal using **abiotic vectors** such as wind?

Examples include wings like on maple fruits (samaras); plumes (pappus) like on dandelion fruits or milkweed seeds; and husks that allow fruit to float, as in coconuts.

2. What fruit or seed adaptations might plants have for dispersal using **biotic vectors** such as birds or small mammals?

Examples include fleshy, sweet fruit (apples, cherries) that animals eat and transport internally, or hooks and barbs (such as those of cocklebur or sandbur) that attach to an animal's coat and are transported externally.

3. The box in Figure 1 below represents a hypothetical forest with four adult trees of the same species, labeled A, B, C, and D. There may be more trees from other species around them, but those trees are not shown. Assume that these trees do not affect wind direction in a consistent way.
   a. If **wind** disperses the seeds of this species, what pattern of seed dispersal would you expect to observe for each tree? Draw multiple lowercase letters a–d to show where you expect seeds to land for each of these four individuals. (Note that you are drawing a **seed shadow**, the pattern of seed dispersal away from the parent plant.)
   b. In space next to the figure, explain why you made the prediction you did.

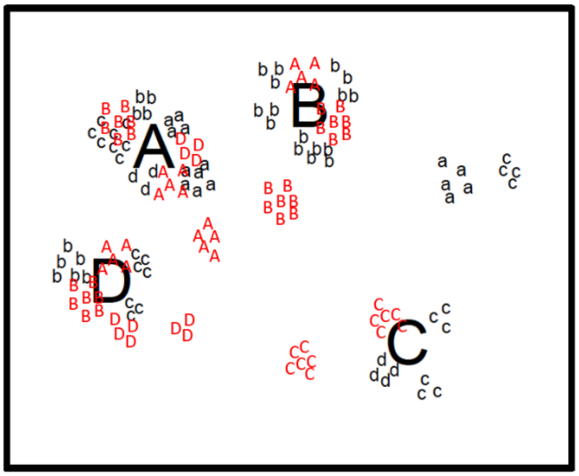


A possible student answer is shown in the figure. With wind dispersal, it is expected that most seeds will land near the parent tree and a decreasing number of individuals will be dispersed farther away.

4. The box in Figure 2 represents the same hypothetical forest. This time, however, imagine that the trees' seeds are dispersed by **animals**.
   a. What would the seed shadow look like if **birds** dispersed the seeds of the hypothetical tree species in Figure 2? Use multiple lowercase letters a–d to show the seed shadow you would expect for each of these four individuals.

b. What would the seed shadow look like if **monkeys** dispersed the seeds of the hypothetical tree species in Figure 2? Use multiple uppercase letters A–D (in a different color, if possible) to show the seed shadow you would expect for each of these four individuals.

c. In the space next to the figure, explain why you made the predictions you did.



A possible student answer is shown in the figure. It is expected that most seeds will be dispersed in clumps wherever the animals deposited their feces — whether under the parent tree, a different tree of the same species, or under a tree from another species. Birds typically travel farther than monkeys do, so the seeds dispersed by monkeys (shown in red here) may have a shorter distribution range.

5. Describe the similarities and differences in the predicted seed shadows you drew for the wind-dispersed seeds (Figure 1) versus the bird-dispersed seeds (Figure 2).

Student answers will depend on their specific predictions, but they may describe that for both wind-dispersed and bird-dispersed seeds, the seeds move beyond the parent tree, but bird-dispersed seeds may move farther. Bird-dispersed seeds are clumped, whereas wind-dispersed seeds are more broadly distributed.

6. Imagine that the forest in Figure 2 gets bisected by a road that isolates the trees near tree "C" and creates two forest fragments. Describe the similarities and differences in how seeds dispersed by birds would be affected by forest fragmentation compared to seeds dispersed by spider monkeys.

Seeds dispersed by monkeys will still likely show a clumped distribution, similar to seeds dispersed by birds. However, the monkey-dispersed seeds are not likely to travel as far as bird-dispersed seeds. This is because monkeys require uninterrupted forest canopy to move between locations, so they would not be able to move between forest fragments as easily.

7. As shown in the video *Seed Dispersal and Forest Fragmentation*, biologists have developed creative ways to use insects to help them find seeds that animals have dispersed. However, when these clues are not available, biologists use different approaches to investigate seed dispersal. What other tools or sources of information do you think biologists could use to study seed dispersal?

Answers may include performing genetic analyses on seeds and possible parents, direct observations, and collecting animals and examining stomach contents.

8. Time to brainstorm ideas!
   a. How would you conduct a study to investigate seed dispersal by **wind**?
      i. State a research question you would investigate.
      ii. Describe the kinds of data you would need to answer the research question.
      iii. What experimental design would you use to study this question?

Various answers are possible. Evaluate the extent to which students describe the design of the experiment, whether the data can be reasonably collected, and how well the data would answer questions about seed dispersal by wind. [You may also want to use the BioInteractive activity "Asking Scientific Questions" to help students develop their research questions.] Some possible research questions include "To what extent does the distribution of wind-dispersed seeds from a tree match the pattern of the prevailing wind?" and "Do wind-dispersed seeds from a tree *with many neighbors land closer to the parent tree than those of one with few neighbors?" Students may suggest mapping the location of seeds and comparing the map to a map of the prevailing wind directions or measuring the distance of seeds from trees that differ in their number of neighbors*.

b. How would you conduct a study to investigate seed dispersal by **birds**?
   i. State a research question you would investigate.
   ii. Describe the kinds of data you would need to answer the research question.
   iii. What experimental design would you use to study this question?

Various answers are possible. Evaluate the extent to which students describe the design of the experiment, whether the data can be reasonably collected, and how well the data would answer questions about seed dispersal by birds. Some possible research questions include "Does the distribution of bird-dispersed seeds differ by the size of the bird species eating the seeds?" and "Are the bird-dispersed seeds more common under trees in which the birds perch?" Students may suggest measuring the distance at which seeds are found for seeds eaten by birds of different sizes or observing birds to see where they perch and comparing the number of seeds found under those spots to the number found in other areas.

PART 2: Comparing Plants with Different Vectors

9. What do the data in Figure 4 indicate about survival of seedlings and saplings at different distances from the parental tree?

Seedling and sapling survival are low near the parental tree. Beyond 25 meters, the survival rate of seedlings and saplings increases.

10. Summarize the claim or claims the graph in Figure 5 is communicating.

Representing the number of seedlings and saplings formed per seed at various distances makes it clear that the seeds that disperse farther from the tree have a higher probability of successfully establishing and growing into saplings, though the effect may start to drop off at 90 meters.

11. Considering Figures 4 and 5, summarize what the combination of seed, seedling, and sapling data tells you about seed dispersal by wind.

Although most seeds are distributed near the parental tree, establishment of a seedling and growth to a sapling are more likely at greater distances.

12. What can you determine about the seed shadow for *Ficus cyrtophylla* based on the data in Figure 7?

Seeds are dispersed long distances by birds and show a clumped distribution.

13. What do the results indicate about survival of seedlings at different distances from the maternal tree?

Establishment can occur near the parent tree but also at great distances. Also, the largest increase in seedling frequency compared to seed frequency occurs at larger distances, suggesting seedling establishment is more successful at greater distances.

14. Describe **similarities** in the seed shadows of the wind-dispersed and bird-dispersed tree species.

In both cases, most of the seeds were dispersed relatively close to the parent tree with decreasing numbers farther from the tree.

15. Describe **differences** in the seed shadows of the tree species with different dispersal vectors.

In wind-dispersed Platypodium*, many seeds are deposited near the parent tree, less than 30 m away. Bird-dispersed* Ficus *seeds moved much farther from the parent tree compared to the seeds dispersed by the wind (up to 30 times farther). The seed shadow is larger for the bird-dispersed seeds and the pattern is more uneven or clumped.*

16. How do the observed patterns compare to the predictions you drew in Figures 1 and 2?

Student answers will vary based on their initial predictions.

17. Why do you think that the researchers studied not only seed dispersal distances but also the distances of seedlings?

Studying the seedlings shows not only how far the seeds moved but also where dispersal successfully resulted in a new individual being established.

18. Do the data support the claim made by the representation in the video? Why or why not?

The representation suggests that as distance from the parent tree increases, so does the survival rate of seeds. The data in Figures 5 and 7 generally support this claim, though the case is stronger in the wind-dispersed example.

19. Estimate the range over which about 70% of the *Platypodium* seeds are likely to fall. Do the same for the *Ficus* seeds.

    Estimated *Platypodium* seed dispersal range (m) for about 70% of the seeds ***10–40 m***

    Estimated *Ficus* seed dispersal range (m) for about 70% of the seeds ***30–2500 m***

20. How does the distance that most seeds are moved compare to the distance where most seedlings establish?

Most Platypodium *seeds will be dispersed relatively close to the parent tree (less than 40 m). Seedling establishment peaks at 25–30 m and decreases rapidly after 45 m. Saplings, which indicate seeds that have survived longer, showed an establishment peak at 45 m. Establishment was low but consistently evident at distances up to 90 m, and the survival rate per seed improved as distance increased. No seedlings close to the adult tree survived. These data suggest that establishment improves at greater distances from the adult tree.*

Most Ficus *seeds were dispersed 30–150 m from the parent tree, but there were still many seeds found at large distances such as 2500 m. Seedling survival was highest from 30–90 m and was consistently evident up to 240 m. Peaks of seedling establishment could be found at 1200 m and as far as 2400–3000 m.*

21. What do you think causes this pattern?

Competition, shading, or predation may be high near the parent tree, which limits seedling establishment and growth to a sapling. The increase in the survival rate away from the tree indicates that perhaps competition or other issues are not as big a factor at these distances.

22. The video *Seed Dispersal and Forest Fragmentation* describes seed dispersal by spider monkeys. In the introduction to this handout, you learned that small monkeys typically travel 100–400 m before depositing feces that contain seeds from several different species. Birds often travel two to three times that distance before depositing seeds. Use this information and the data from the previous experiments to make a prediction in the form of a graph for where you would expect to find fruit tree seeds and seedlings dispersed by monkeys as a function of distance.

Based on the results for bird-dispersed seeds, students are likely to predict that many seeds will be close to the parent tree with a clumped pattern farther away from the parent tree. The distance should be one-half to one-third of the longest distance for bird-dispersed seeds (a maximum distance of about 1000 m). Seedling survival should increase with increasing distance from the parent tree.

PART 3: Applying What You've Learned

23. Can seeds from the individuals of the three different species disperse naturally to the conservation areas? Draw letters to indicate where you expect seeds from the nine indicated trees could disperse from the forest to the conservation areas.

Answers will vary. Given the information in the introduction of the "Student Handout," about seed dispersal by monkeys requiring continuous forests, seeds from plants M_1–M_3 will not move outside of their forest clusters. Seeds from W_1–W_3 will likewise be restricted, though a few seeds from W_1 may make it to the new habitat. The birds dispersing seeds from trees B_1–B_3 should be able to get seeds to the fragments if there are perches that would attract them such as existing trees.

24. Suppose you have funds to be able to purchase seven additional 100 m × 100 m plots. Which seven would you purchase? Indicate them on the map. Why would you purchase those plots? How would they help achieve your conservation goal?

Students should consider different patterns for the seven additional squares to make corridors that connect existing forest to the new conservation areas. Corridors should give a route that monkeys or wind-dispersed seeds can use to access the new areas.

PART 4 (Optional): Exploring a Mechanism that Explains the Pattern

25. Is this hypothesis consistent with the results of the studies on *Platypodium* and *Ficus*? If so, how? If not, why not?

The distribution patterns in the study — more seeds close to the parent tree, but more seedlings and saplings farther from the parent tree — seem generally consistent with the hypothesis. However, the two studies did not try to investigate what mechanisms drive this pattern beyond differences in seed dispersal.

26. List possible mechanisms leading to this pattern.

Possible mechanisms include increased numbers of herbivores closer to parent plants, increased numbers of seed predators, depletion of soil nutrients close to the parent tree, and increases in disease-causing organisms near the parent tree.

27. Pick one mechanism from your list and describe how you could test whether the mechanism is causing the pattern.

One possibility would be dropping seeds at different distances from the parent tree, observing the factor that causes mortality (e.g., pathogens or herbivores), and classifying the herbivores or pathogens as specialists or generalists that will attack a variety of tree species. Another test would be to measure the amount of nutrients at a set of distances from the parent tree.

28. How might this mechanism support the diversity of pathogens, herbivores, biotic dispersers, and trees found in tropical forests?

Seeds that disperse farther from the parent plant are more likely to survive and grow, leading to a forest with many species of trees, with individuals from the same species spaced widely apart. If each tree species is host to particular herbivores, biotic dispersers, and pathogens, the tree diversity helps support the diversity of other species that depend upon the tree as well.

REFERENCES

Augspurger, Carol K., Susan E. Franson, Katherine C. Cushman, and Helene C. Muller-Landau. "Intraspecific variation in seed dispersal of a Neotropical tree and its relationship to fruit and tree traits." *Ecology and Evolution* 6, 4 (2016): 1128–1142. https://doi.org/10.1002/ece3.1905.

Zhou, Hui-Ping, and Jin Chen. "Spatial genetic structure in an understorey dioecious fig species: the roles of seed rain, seed and pollen-mediated gene flow, and local selection." *Journal of Ecology* 98, 5 (2010): 1168–1177. https://doi.org/10.1111/j.1365-2745.2010.01683.x.

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