Seed Dispersal in Tropical Forests

hhmi | BioInteractive

Activity
Student Handout

INTRODUCTION

The goal of this activity is to use concepts of plant dispersal mechanisms to better understand how plants are distributed. A second goal is to make predictions about how forest fragmentation may affect plants with different dispersal mechanisms in unique ways. Let's get started!

What is dispersal, and why is it important?

A key challenge faced by flowering plants (angiosperms) is dispersal: spreading their offspring, which are packaged in seeds, to different locations where they can grow into new plants. If the seeds are not dispersed, too many plants may grow in the same place. These plants may compete for resources or attract predators, which makes them less likely to survive. Understanding how seeds are dispersed can help explain patterns of tree diversity in tropical forests and the potential impact of changes, such as fragmentation, on a forest.

How does dispersal happen?

Flowering plants have evolved to use a wide array of mechanisms, called dispersal vectors, to move seeds away from the parent (maternal) plant. Dispersal vectors can be either abiotic (nonliving, such as wind, gravity, or water) or biotic (living organisms, such as animals). The specifics of how various dispersal vectors move fruit and seeds determine how seeds, and ultimately individuals, are distributed on the landscape. Depending on the vector, some seeds will be dispersed close by the parent tree, and others will be moved further away.

How do animals affect dispersal?

The seeds of over half of woody tropical plant species are dispersed by animals. Birds and small mammals, such as spider monkeys, may eat the fruit from a tree and swallow the seeds in the fruit. The seeds can then pass through the animal's digestive tract and be deposited later in feces. Seeds dispersed in this way are typically "clumped" together wherever the feces were deposited.

Different animals disperse seeds differently. Small monkeys typically travel 100–400 m before depositing feces that contain seeds from several different plant species. Birds often travel two to three times that distance before depositing seeds. Monkeys also require uninterrupted forest canopy to move from location to location, but birds typically do not have this limitation. Forest fragmentation may therefore affect plants whose seeds are dispersed by monkeys differently than those whose seeds are dispersed by birds.

PROCEDURE

After watching the *Scientists at Work* video *Seed Dispersal and Forest Fragmentation*, use your understanding of plant dispersal to complete the following questions and tasks.

PART 1: Predicting Patterns and Developing Ideas

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

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

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 the space next to the figure, explain why you made the prediction you did.

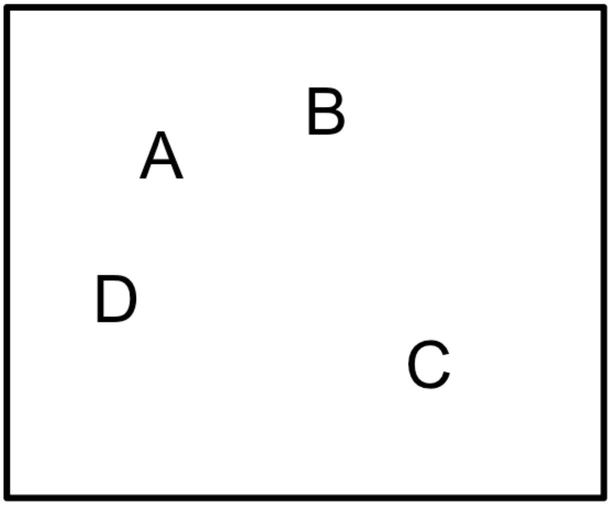


Figure 1. Hypothetical forest with seed dispersal by wind.

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.

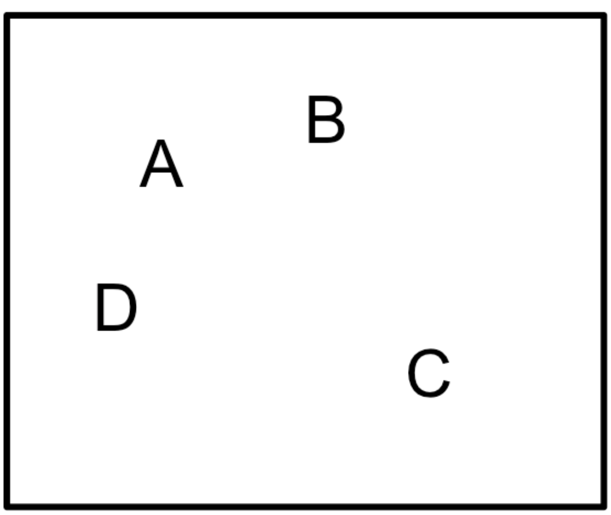


Figure 2. Hypothetical forest with seed dispersal by animals.

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).

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.

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?

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?

   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?

PART 2: Comparing Plants with Different Vectors

Figure 3. *Platypodium elegans* samaras. Note the single seed and long wing.

Wind dispersal

A group of researchers studied abiotic seed dispersal by wind in the tropical tree graceful platypodium (*Platypodium elegans*). This tree species is common in tropical forests from Panama to Brazil. It produces a single-seeded fruit called a samara (Figure 3). The seed has a large wing attached on one side, which causes the seeds to spin as they fall off the tree. *Platypodium* seeds "helicopter" away from the parent plant, much like the samaras produced by maple trees in many temperate forests.

Working in a forest on Barro Colorado Island in Panama, researchers identified six trees that were isolated from one another so any seeds or seedlings nearby were produced by that specific adult tree. After seed dispersal finished for the season, researchers counted the number of samaras found around each of the *Platypodium* trees. They also measured the distance from the parent tree to the samara. Next, they counted and measured the distance to all the germinated seedlings and the larger saplings (young trees) around the trees. Their results are presented in Figure 4.

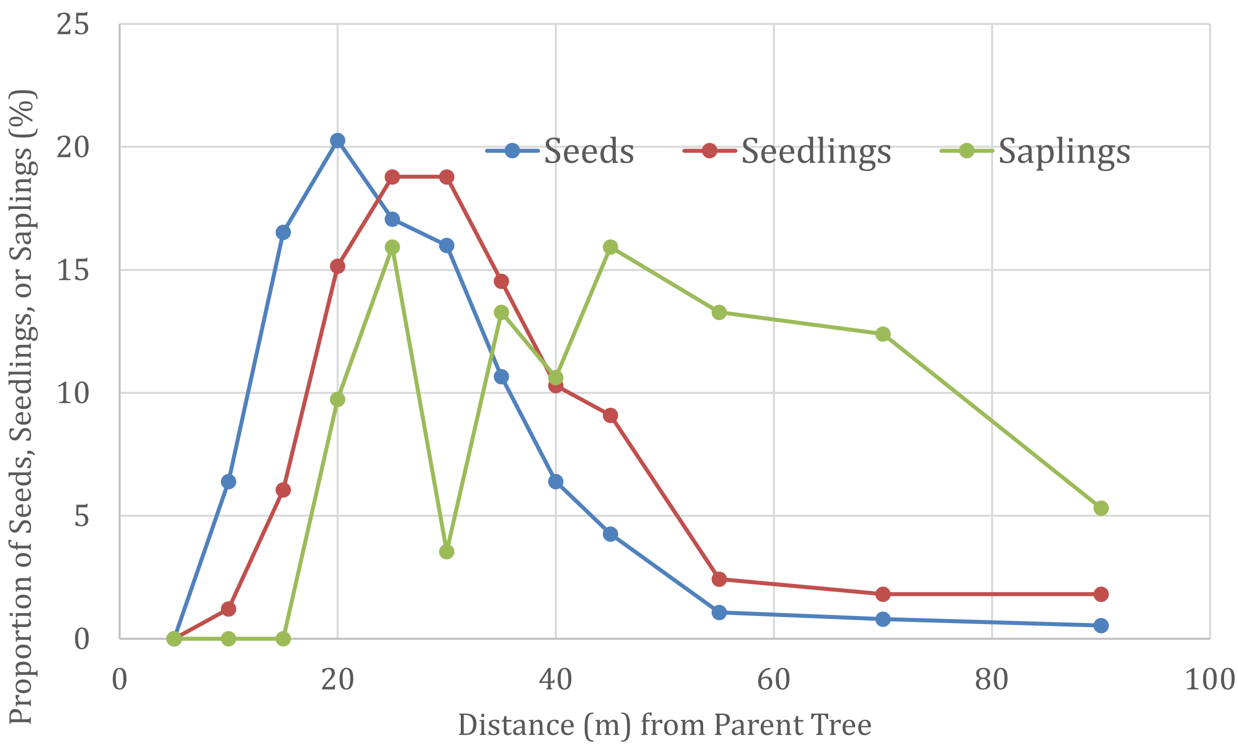


Figure 4. Proportion of seeds, seedlings, and saplings at different distances from six isolated *Platypodium elegans* trees. Adapted from Figure 8 in C. K. Augspurger, S. E. Franson, K. C. Cushman, and H. C. Muller-Landau. "Intraspecific variation in seed dispersal of a Neotropical tree and its relationship to fruit and tree traits." *Ecology and Evolution* 6, 4 (2016), 1128–1142.

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

Another way of presenting the data in Figure 4 is by dividing the number of seedlings and saplings by the total number of seeds at each distance to compute the number of individuals formed per seed. Those data are shown in Figure 5.

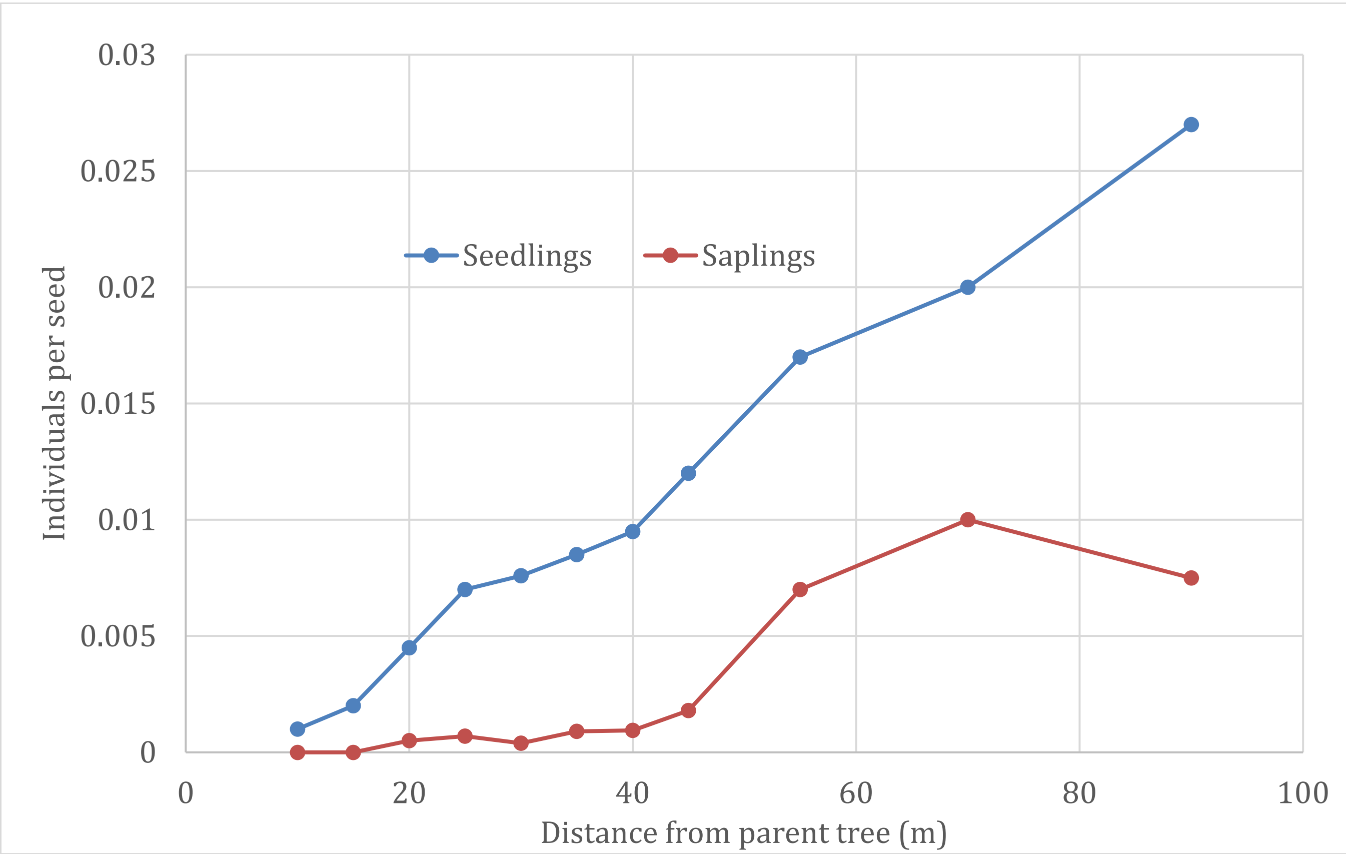


Figure 5. Number of seedlings per seed and the number of saplings per seed at various distances from six isolated *Platypodium elegans* trees. Adapted from Figure 8 in Augspurger et al. (2016).

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

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

Bird dispersal

Figs are common components of many tropical forests. In the limestone mountains of Yunnan Province in China, *Ficus cyrtophylla* grows in many of the moist valleys. This short evergreen tree produces clusters of small, seed-filled figs two or three times each year (Figure 6). Three species of birds called bulbuls eat the figs. The seeds pass through their digestive tract and are dropped on the forest floor in the birds' feces.

Because this fig species is so numerous, the research team used a different approach than the *Platypodium* researchers to study the seeds. They placed 46 1 meter (m) × 1 m mesh nets called seed traps around their study area. A **seed trap** is a container used to catch items that drop to the forest floor, such as seeds. Researchers checked the traps weekly for one year and removed and counted the fig seeds. It is not possible to determine whether a seed or seedling came from a specific parent tree based on its appearance (**phenotype**) because they all look similar. Instead, the researchers germinated some of the fig seeds and collected leaf tissue from the seedlings to determine their **genotype** (set of alleles for specific genes) using genetic markers. The researchers also used the same genetic markers to genotype the adults and seedlings throughout their study area. They used the genotypes to match the seeds and seedlings to the mother tree. The data for seed and seedling distances from the maternal tree are shown in Figure 7.

Figure 6. Seed-filled interior of typical figs. The fruits shown are from a fig species related to the one used in the study.

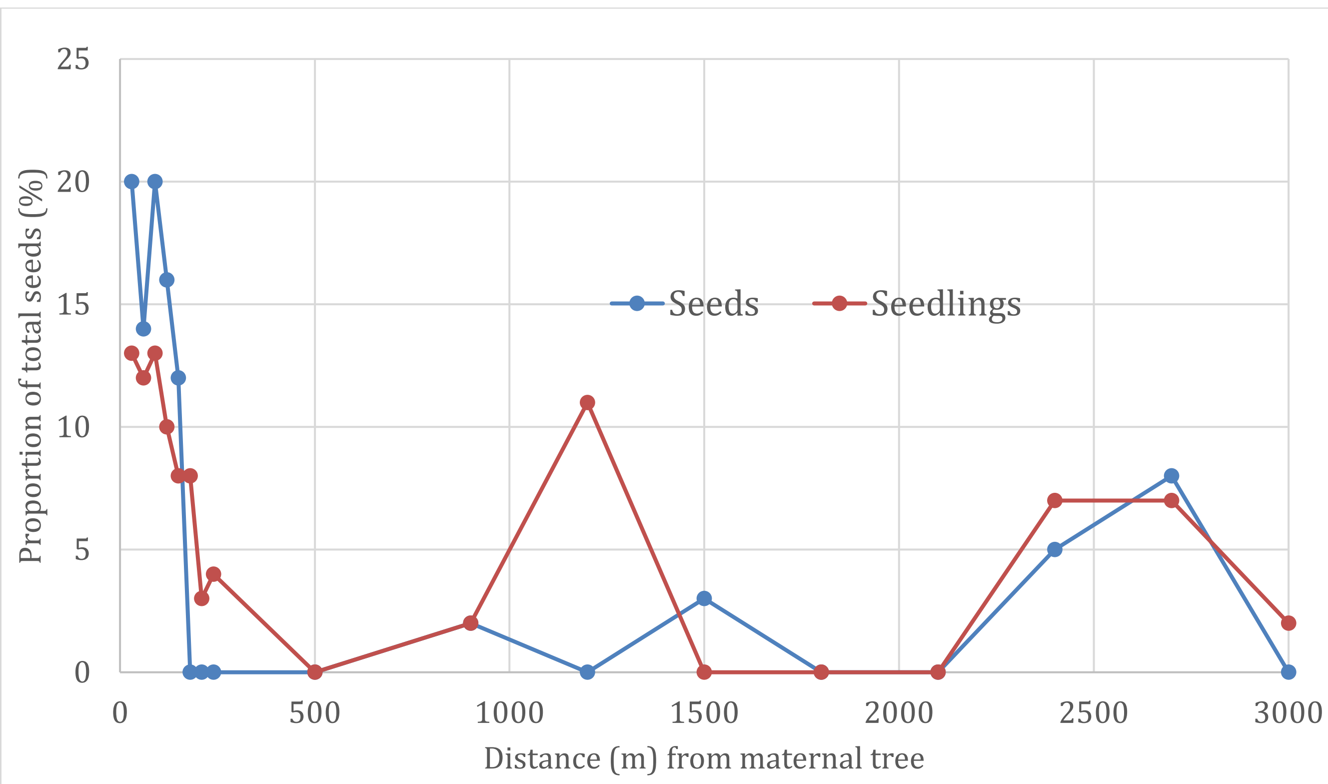


Figure 7. Proportion of seeds and seedlings at different distances from their maternal tree for *Ficus cyrtophylla.* Adapted from Figure 2 in H. P. Zhou and J. Chen. "Spatial genetic structure in an understorey dioecious fig species: the roles of seed rain, seed and pollen-mediated gene flow, and local selection." *Journal of Ecology* 98, 5 (2010): 1168–1177.

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

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

Comparisons

Now that you have seen the data from two separate studies, compare their results and draw conclusions.

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

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

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

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

In the video *Seed Dispersal and Forest Fragmentation*, the following image represents the survival rate of seeds as a function of distance.

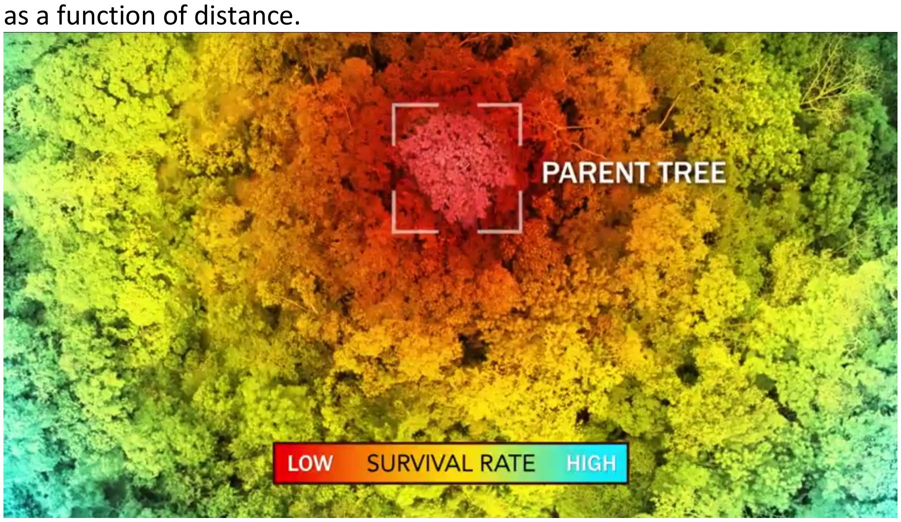


Figure 8. A representation of survival of seeds versus distance from the parent tree.

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

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

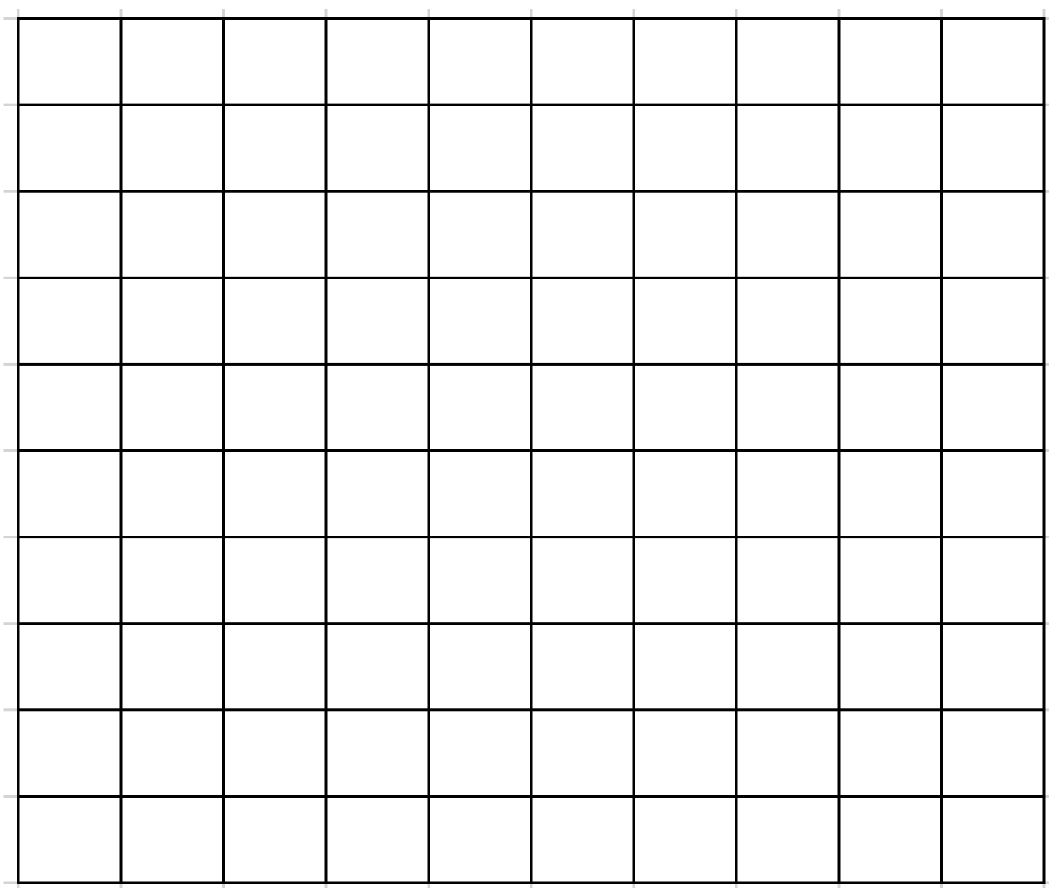
    Estimated *Platypodium* seed dispersal range (m) for about 70% of the seeds ______________________

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

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

21. What do you think causes this pattern?

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 seeds and seedlings from a monkey-dispersed fruit tree as a function of distance.



PART 3: Applying What You've Learned

Suppose the map in Figure 9 represents an area with intact tropical forest (dark stippled area) and two new tracts of land that you are managing for conservation (light stippled area). Spaces in between are inhospitable for seedling establishment. The new conservation area has sites that are suitable for germination of seeds from a monkey-dispersed (M), bird-dispersed (B), and wind-dispersed (W) tree species in each fragment. Your goal is to have seeds from the monkey-, bird-, and wind-dispersed species naturally disperse to the conservation areas to establish new individuals.

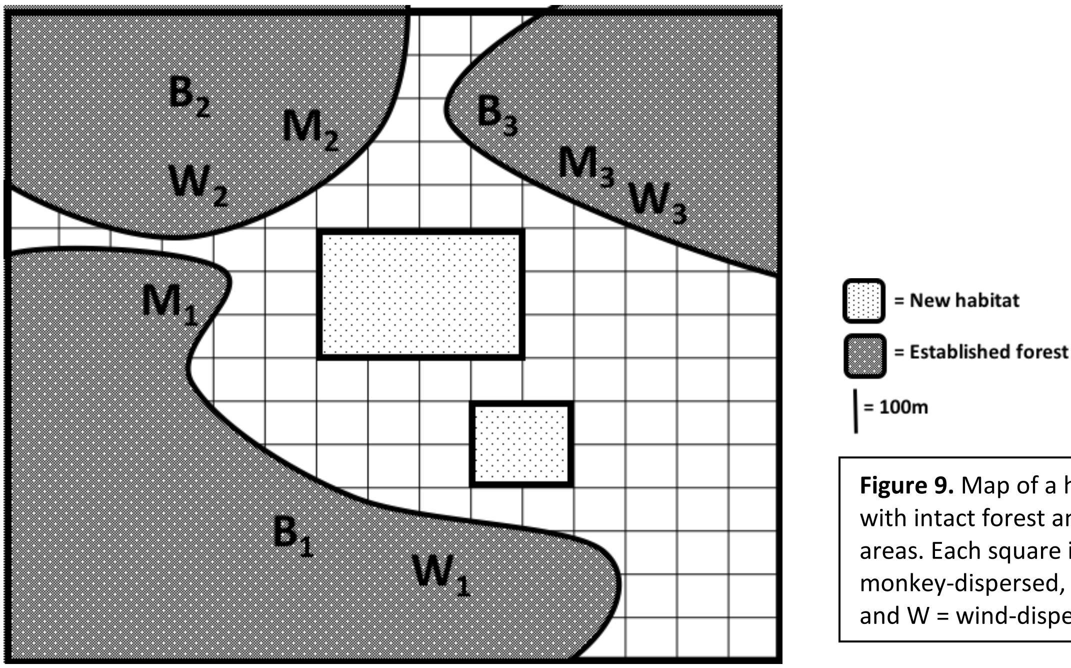


Figure 9. Map of a hypothetical forest with intact forest and new conservation areas. Each square is 100 m × 100 m. M = monkey-dispersed, B = bird-dispersed, and W = wind-dispersed tree species.

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.

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?

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

Two ecologists, Daniel Janzen and Joseph Connell, independently developed an explanation for seed dispersal and survival in tropical forests in the 1970s. Their explanation is referred to as the Janzen-Connell hypothesis, and many experiments today still try to support or refute its predictions. The hypothesis posits that seed survival is density dependent, with seeds farther from the parent being less likely to face pathogens (disease, fungal attack) and herbivores specific to that species. This leads to seedling survival increasing with increasing distance from the parent tree in a density-dependent fashion, as shown here.

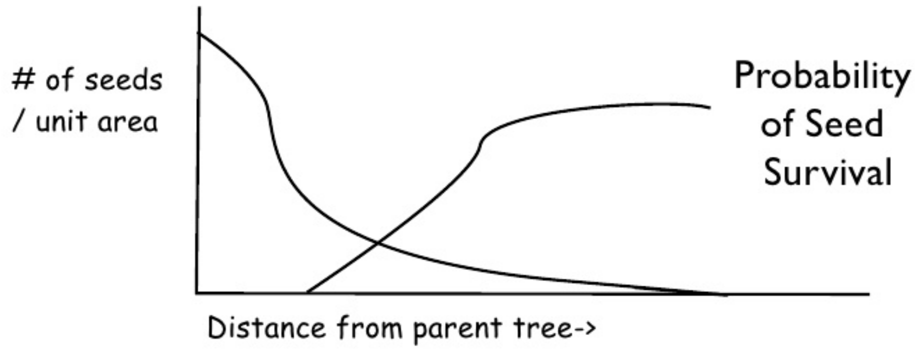


Figure 10. Probability of seed survival at various distances from the parent tree and the number of seeds per unit area. Figure based on the Janzen-Connell hypothesis.

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

26. List possible mechanisms leading to this pattern.

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

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