CHICAGO BOTANIC GARDEN

Activity 3.4: Seed Dispersal and Plant Migration

Grades 7 – 9

Description:
Part 1: Seed Dispersal Predictions: Students will make observations about different types of seeds, and based on those observations, make predictions about how those seeds are dispersed.

Part 2: Seed Dispersal Experiment: Students will put their predictions to the test by using a fan, water, and material to see which seeds float, stick to animal fur, or are wind-borne.

Part 3: How Far Can Seeds Travel? Students will calculate how far different dispersal mechanisms are likely to move seeds over a given period of time. Students use average range and migration distance to calculate how far animal-dispersed seeds might travel, experiment using a fan for wind-dispersed seeds, and consider how far water-dispersed seeds travel using a global map of ocean currents. They will also consider the constraints of their experiments and how those constraints (e.g. using a fan rather than wind) might affect the accuracy of their results.

Part 4: Assisted Migration: Students will consider the implications of the ability of plants to migrate in the context of changing climates and debate whether or not humans should use assisted-migration techniques to help plants migrate.

Time: Three 45-minute class periods

Materials:
Per Student
- Student handouts for parts, 1, 2, 3, and 4
- Pencils

Per group
- Calculator (optional)
- Tape measure
- A set of seeds of different dispersal types (at least three different seeds per group of students). Sets of seeds can be ordered from Carolina Biological Supply Company, item #157970, Seed Dispersal Set (http://www.carolina.com/)
- One box fan (if you don't have enough fans for each group, you can have student groups rotate to test wind-dispersed seeds)
- One bucket of water
- One stuffed animal, or other fuzzy fabric

National Science Education Standards
A1c Use appropriate tools and techniques to gather, analyze, and interpret data
A1d Develop descriptions, explanations, predictions, and models using evidence
A1h Use mathematics in all aspects of scientific inquiry
C5d Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival

AAAS Benchmarks
4B/H1 Life is adapted to conditions on the Earth…
5F/M2a Individual organisms with certain traits are more likely than others to survive and have offspring.
5F/M2b Changes in environmental conditions can affect the survival of individual organisms and entire species.
5F/M5 Reproduction is necessary for the survival of any species.

Guiding Questions:
- How is seed dispersal vital for plant survival?
- What are the different types of seed dispersal?
- How is seed dispersal related to changing climates?
- What is assisted migration? What are goals and risks associated with assisted migration?

Assessments
- Seed dispersal worksheets and lab report
- Colored hardiness zones map

Vocabulary
Seed dispersal is the movement or transport of seeds away from the parent plant.
Migration is the movement of living things over long distances to find an appropriate habitat.

Part 1: Seed Dispersal Predictions

Procedure:
1. Ask students what ways animals might have of coping with climate changes in their habitats. Write student responses on the board.

2. Suggest that in response to a changing climate, many animals are moving or **migrating** to new habitats (note: some Internet links will not display on Explorer, better on Google Chrome or Mozilla Firefox).
   - http://www.sciencedaily.com/releases/2012/02/120223142642.htm (peer-reviewed article on how climate change is modifying bird migration patterns)
   - http://www.washingtonpost.com/national/health-science/up-and-up-plants-and-animals-migrating-as-climate-changes/2011/08/18/gIQAzlTxNJ_story.html (*Washington Post* article on how plants and animals are migrating as a result of climate change)
   - http://news.discovery.com/animals/animals-migrating-north-global-warming-110818.html (Discovery channel feature on plants migrating from climate change)

3. Ask whether plants can move in the same way. Some questions you should have students consider might be:
   - Can plants move like animals?
   - Have you ever seen plants, or parts of plants, move from one habitat to another?
   - If plants can't walk, how can they migrate in response to climate change?

4. Start with a discussion of seeds. Seeds are the offspring of plants. When seeds are mature they are released from the parent plant. Seeds generally travel some distance away from the parent plant (this distance can range from centimeters to kilometers or more). The movement of seeds away from their parent plant is called seed dispersal.
   - Why might it be beneficial for seeds to move away from their parent plant?
   - What are some ways that seeds can disperse away from their parent plant?

5. Take student answers and write them on the board. Tell students they will investigate how seeds disperse, how far they might go, and whether that will be fast enough to keep pace with changing climates.

6. Break students into groups of three or four, and hand out individual student handouts and one seed dispersal kit to each group. Have students examine their seeds, make predictions about what dispersal method each seed might represent, and answer the questions on the handout.

7. Once groups are finished, have a whole class discussion reviewing their answers:
   - What seed characteristics did you focus on to predict how it was dispersed?
   - Why did you feel those were the most important in making your decision?
   - How could you determine if your predictions in the chart were correct?
   - What kind of experiment could you create to test your predictions?

8. Use student answers to guide them toward an experiment that would test dispersal efficiency using water, wind, and animal transportation. Tell students that they will now have an opportunity to put their ideas into action.

Part 2: Seed Dispersal Experiment

Procedure

1. Introduce the activity by reviewing students' seed-dispersal predictions and their answers to the questions on the handout.

2. Divide students into groups.

3. Hand out the Seed Dispersal Experiment handout and give each group:
   - Three seeds of different dispersal type
   - One bucket of water
   - One box fan (if you don't have enough fans for each group, you can have student groups rotate to test wind-dispersed seeds)
   - One stuffed animal or fuzzy piece of fabric

4. Tell students they are going to use their materials to determine what type of seed dispersal their plant uses. They should test each of their three seeds with different dispersal mechanisms (animal, wind, water) to see which is most effective for each seed.

5. Students who finish early can begin work on the questions on the data sheet.

6. Once students complete their chart you can either
   a. Bring the class back together for a discussion about how they made their determination of seed dispersal types and assign questions for homework.
   b. Have students complete the entire data sheet and use student responses to the questions as a discussion guide.

Part 3: How far can seeds travel?

Procedure

1. Review students' answers to the questions on their seed dispersal experiment datasheet. Ask them:
    - How far do you think each different type of dispersal could transport seeds?
    - Which would go the farthest?
    - Why do you think so?

2. Tell students they are going to use the average range and migration distance of a few different animals to calculate how far animal-dispersed seeds might travel, experiment using a fan for wind-dispersed seeds, and consider how far water-dispersed seeds travel using a global map of ocean currents.

Wind-Dispersed Seeds

3. Break students into groups, give each group:
    - One box fan
    - Wind-dispersed seeds from one plant species
        - You will want to have seeds from a number of different species, so that when students come back together to compare data, a variety of species are represented)
        - If you do not have enough box fans for each group, you can divide the class and have some groups work on animal-dispersed seeds and the other on wind-dispersed, and then switch.
    - "How Far Can Seeds Travel" data sheets
    - Tape measure

4. Each group of students will do ten trials with their species' seeds, record the distance the seeds go in meters, and calculate the average distance.

5. Once the groups have finished their calculations, bring the class back together as a group to complete Table 2 on the wind-dispersed seed data sheet and answer the calculations questions (these can be done in groups, as a class, or as homework). Discuss differences in dispersal distances of different species. Some discussion questions might be:
    - Why do some seeds go farther than others?
    - What are the characteristics of the seeds that go the farthest? The shortest?
    - What might this mean for the speed of plant migration for different species?

6. Conclude the activity by drawing attention to the constraints of the experiment by reviewing the calculations questions:
    - Is the calculation you performed above an accurate indicator of how far your plant population will travel in 50 years? Why or why not? What assumptions were made in the calculation that may not be true in nature?
    - Describe two improvements that could be made if you were to run this experiment a second time.

Animal-Dispersed Seeds

7. Ask students if they think animal-dispersed seeds can go as far as wind-dispersed seeds. Farther? Tell them they are going to do some calculations that will help them figure it out using the average home range size of a few different animals.

8. Have each student group choose an animal from the table below. First, they will answer the questions on the handout, and then they will calculate the distance a seed will travel based on the range of their chosen animal over a day, a week, and a month.

9. Once students have done the calculations for the different animals, create a table on the board to compare the distances that a seed might travel via different animals.

Animal	Distance/Day	Distance/Month	Distance/Year
Grey squirrel – male			
Grey squirrel – female			
Red wolf			
America robin			

Use this table to discuss the implications for seeds that are dispersed by different animals.

- Is there a relationship between the range of an animal and the distance seeds might be dispersed?
- Are the calculations you performed using animal range an accurate indicator of how far your seed will travel? Why or why not?
- What assumptions were made in the calculation that may not be true in nature?

10. Compare wind-dispersed seeds to animal-dispersed seeds:
    - Which can travel farther?
    - Is there a pattern or does it depend on the seed/animal?
    - What about water-dispersed seeds? How far do you think they might go? Why?

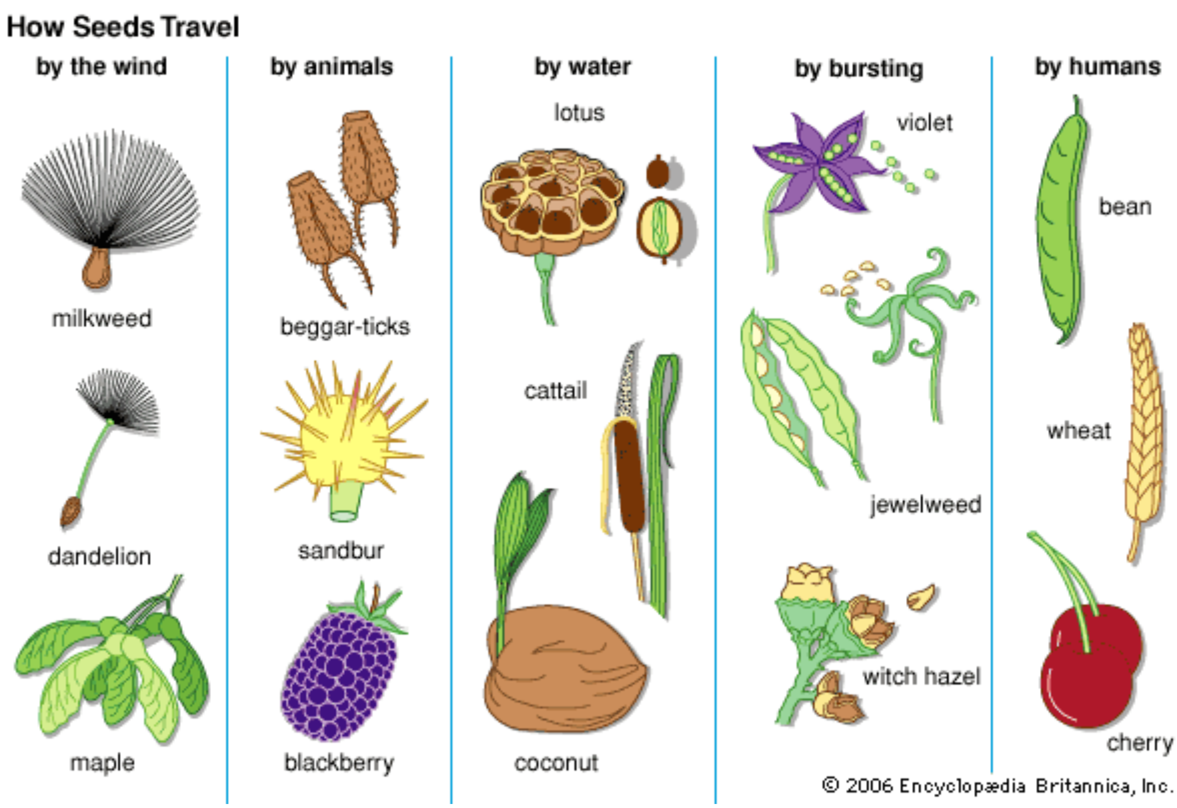
Water-Dispersed Seeds

11. Introduce the activity by reviewing wind- and animal-dispersed seeds. Ask students if they can think of any other ways that seeds might be dispersed? Do they recall their initial dispersal experiment? What were the methods they tested?

12. Have students look at the ocean currents map on the water-dispersed seeds handout. Depending on your students' prior knowledge, you may want to review the map. Explain that the arrows indicate ocean currents, which will determine how seeds move across the ocean, and then have students work in groups to complete the handout, or assign it as homework.

13. Discuss the following questions comparing the three dispersal methods.
  - What are the three different seed-dispersal types?
  - Compare the three methods of dispersal
    - Based on your calculations, which method will disperse seeds the farthest?
    - What are the benefits of each method? The problems?
    - Which seed would be most likely to be dispersed to a suitable habitat—a seed dispersed by wind, water, or animals?
  - Considering these dispersal types, can you make any predictions about which plants would most likely survive climate change? Tell students that in the next activity, they will test their predictions.

This image, from *Encyclopaedia Britannica,* (available: http://media-1.web.britannica.com/eb-media/15/92015-034-AC782CA2.gif) may be a helpful review of the dispersal types studied, as well as others (though your students may note that humans are also animals)!



Part 4: Assisted Migration: Can Plants Migrate with Changing Climates?

Procedure

1. Hand out part 4 of the lab. Introduce the concept of plant hardiness zones as a measure of the climate in a particular place. Have students look at the hardiness zone maps and describe the changes they see. In general, hardiness zones are migrating northward. Northern Illinois was in zone 5 in 1990, and in 2006 was in zone 6. This means that it may be too warm in Illinois for certain plants to survive here today that could have survived in 1990.

2. Next, students will calculate the distance that plant hardiness zones have shifted over the course of one year. They can do this in several ways. One way is to estimate the upper limit of a hardiness zone in 1990 and in 2006 and draw them onto the U.S. map with the legend. Then, students can measure the distance between these lines and convert to miles and kilometers. Students should divide this number by 16, because the hardiness zone map shows changes that occurred over 16 years. We will assume a consistent rate of shift based on that map. (Although this is a debatable assumption, it will have to do for this exercise.)

3. An animation of the shifting hardiness zones can be found here: http://www.arborday.org/media/mapchanges.cfm

4. Next, students will determine if one of the plant species they studied in parts A or B could migrate fast enough to keep pace with climate change. To do this, students should compare the distance they calculated for the seed dispersal with the distance they calculated for the movement of hardiness zones.

5. If their answer is farther than their seed can travel in a year, then this species could be in trouble and will need help through assisted migration to survive.

6. Introduce the concept of assisted migration, either through a class discussion or a reading: This process involves collecting seeds and storing them in seed banks (not unlike a Noah's ark for plants). These seeds are used to re-establish the population in new areas as their preferred climate drifts north. Assisted migration will help plants that cannot migrate quickly enough and may be at risk for extinction. It is hoped that the newly established population will thrive in their new area as the population further south may be struggling to maintain a viable population.

7. Show the assisted migration PowerPoint, or have students read the article about assisted migration from the *New York Times*. "A hunt to save species, perhaps by helping them move" http://www.nytimes.com/2009/11/10/science/earth/10plant.html)

8. Lead students in a discussion or a writing activity to guide their understanding of assisted migration and determine their position on its use. (See question 6 on student handout part 4.)

Extensions:

- Students may say that they would expect all plants to survive better if the weather is warmer. Examples of four plant species (and how they are threatened by climate change are available at the BGCI website, "How does climate change affect plants" (scroll down) http://www.bgci.org/climate/climate_change_effects/
- Students can research other species that are affected by climate change.
- You may introduce the topic of invasive plants, and how climate change can affect their range.

Literacy Connection*:*
"Charles Darwin & Ocean Dispersal of Seeds": The text in the activity has been modified to a 9th-grade reading level. If you have advanced students you may use the original, which is at a 12th-grade reading level. It can be found at http://waynesword.palomar.edu/pldec398.htm

Charles Darwin & Ocean Dispersal of Seeds

The dispersal of plant seeds by ocean currents has fascinated many famous explorers, including Charles Darwin. The U.S. Coast and Geodetic Survey has studied sea currents by using stoppered bottles containing a numbered postcard. When someone finds a bottle with a card on the beach, she is asked to fill out the card with the beach location, and drop it in the mail. They have found that it takes about a year for one of these bottles to float from the Yucatan in Mexico to Ireland. A bottle put in the ocean near Caracas, Venezuela, reached the Florida Keys four months later. It traveled at an average speed of 16 miles per day. They think that tropical seeds found on European shores have been adrift for a year or longer.

During Darwin's voyage around the world on the H.M.S. *Beagle,* he came up with the idea that drifting seeds and fruits reached distant islands and began growing. He felt that this was true for isolated volcanic islands, which have never been connected to the mainland. Darwin studied the role ocean currents played in the plants of the Cocos Keeling Islands in the Indian Ocean. He concluded that most of the plants found on those islands came from drift seeds and fruits.

After he returned to England, Darwin conducted experiments to see whether seeds from garden plants could float. Darwin stated:

> "I soon became aware that most seeds…sink in water; at least I have found this to be the case, after a few days, with the 51 kinds of seeds which I have myself tried; so that such seeds could not possibly be transported by sea-currents beyond a very short distance."

Darwin also wondered whether some seeds that don't generally float "hitched rides" on other floating objects such as driftwood to disperse in seawater. He also said that ocean currents might carry seeds contained within pods. These would wash ashore on distant beaches. In his book, *On the Origin of Species,* Darwin summarized his experimental data on seed dispersal in salt water. He expressed the view that dried seeds could float "across a space of sea 900 miles in width, and would then germinate."

Of all the 250,000 species of seed plants on Earth, only about 250 species (0.1 percent) are commonly collected as drift seeds on tropical beaches. Only about half of these plants produce seeds that can float in seawater for more than a month and still be able to germinate. Although the total number of viable drift seed may be relatively small, they form a floral flotilla with thousands of individual seeds riding the ocean currents of the world.

References

Animal Migration and Habitat Ranges:

Animal	Home Range Size/ Avg. Migration	Citation
Grey squirrel – male	2,810,000 m^2 (1676 x 1676 m)	http://wdfw.wa.gov/conservation/research/projects/western_gray_squirrel/north_cascades/
Grey squirrel – female	750,000 m^2 (866 x 866 m)	
Red wolf	760,000 m^2 (871 x 871 m)	http://www.dspace.rice.edu/bitstream/handle/1911/17882/1435730.PDF?sequence=1
American robin	60,800 meters (38 miles) per day	http://www.learner.org/jnorth/robin/

Water-borne Seed Dispersal Information:
For more information on drift plants, see Wayne's Word article "Drift Seeds and Drift Fruits" http://waynesword.palomar.edu/pldec398.htm.

Literacy Connection*:*
Charles Darwin & Ocean Dispersal of Seeds
Original: http://waynesword.palomar.edu/pldec398.htm**,**

Assisted Migration Links and References:
Assisted Migration article from the *New York Times:*
"A hunt to save species, perhaps by helping them move"
http://www.nytimes.com/2009/11/10/science/earth/10plant.html

Can "Assisted Migration" Save Species from Global Warming?
Scientific American, March 3, 2009
http://www.scientificamerican.com/article.cfm?id=assited-migration-global-warming

How does climate change affect plants?
http://www.bgci.org/climate/climate_change_effects/

Map credits
Plant Hardiness Map http://www.arborday.org/media/mapchanges.cfm
U.S. Map: http://www.yellowmaps.com/maps/img/US/blank-base/usstates1.jpg

Student Handout Part 1: Seed Dispersal Predictions

1. What are some ways that seeds can be dispersed away from their parent plant?

2. Observe three seeds and fill in the chart below. By looking at a seed's structure, try to predict how it might disperse.

	Plant name (if found)	Sketch	Dispersal type (wind, animal, other?)	Reason for dispersal choice
Seed 1				
Seed 2				
Seed 3				

3. What seed characteristics did you focus on to predict how it was dispersed?

4. Why did you feel those were the most important characteristics in making your decision?

5. Explain how you could determine if your predictions in the chart were correct.

Student Handout Part 2: Seed Dispersal Experiment

Using the box fan, bucket of water, stuffed animal, and any other available materials (check with your teacher first), determine the dispersal type for each of your three seeds.

	Dispersal type	How do you know?
Seed 1		
Seed 2		
Seed 3		

1. List and describe three differences between plant and animal migration.

2. List and describe three types of seed dispersal.

3. Which type of seed do you expect will disperse the farthest: a seed dispersed by wind, water, or animals? Explain your answer.

4. If a new island were to appear because of a volcanic eruption, which type of seed would you expect to arrive at the island first: a seed dispersed by wind, water, or animals? Explain your answer.

5. Which seed would be most likely to be dispersed to a suitable habitat: a seed dispersed by wind, water, or animals? Explain your answer.

Student Handout Part 3: How far can seeds travel?
In this part, you will determine how far seeds of different types can travel.

A. Wind-dispersed seeds:
Procedures:
1. Choose the species you will be testing.
2. Drop your seed into the wind from a height of 1 meter and then measure the horizontal distance to where the seed landed.
3. Record the distance (in meters) in the data table.
4. Calculate the average distance and record it at the bottom of the table.

Data Table 1: Seed Dispersal Distance

Plant Species: ________________________________

Trial #	Distance (m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Average	

Show average calculation work here:

Data Table 2: Class Seed Dispersal Distance Data

Species	Average Dispersal Distance

1. Looking at your class data, what were characteristics of the seed that dispersed the farthest? What about the seed that traveled the shortest distance? Explain.

2. **Calculate:** Assume your seed traveled the average number of meters you calculated in this lab after leaving its parent plant. Then, the seed landed in the soil, germinated, matured, and produced seeds the next year that also dispersed that distance. The next generation of seeds also landed in the soil and produced seeds. Overall, how many miles could your plant population travel in 50 years? (Hint: Assume the plant reproduces one time per year. 1 mile = 1600 meters). Show your work and circle your answer below:

3. Is the calculation you performed above an accurate indicator of how far your plant population will travel in 50 years? Why or why not? What assumptions were made in the calculation that may not be true in nature?

4. Describe two improvements that could be made if you were to run this experiment a second time.

B. Animal-dispersed Seeds:

1. There are at least two ways a seed can be dispersed by an animal. What are they? Explain the difference.

2. If you were walking in the woods and a burr got stuck to your shoe, where would the seed end up? Would the seed be able to germinate and grow in that location? Explain.

3. If you saw a blackbird eating a berry, and it ate the whole thing, seeds and all, and then flew away, where would the seeds end up? Would the seeds be able to germinate and grow in that location? Explain.

4. **Calculation:** Select (or your teacher will assign) an organism from the chart to the right. Assuming the organism can travel the length of its home range in one day, how far would a burr attached to that organism travel in:

Animal	Home Range Size/ Avg. Migration Distance
Grey squirrel – male	2,810,000 m^2 (1676 x 1676 m)
Grey squirrel – female	750,000 m^2 (866 x 866 m)
Red wolf	760,000 m^2 (871 x 871 m)
American robin	60,800 meters (38 miles)/day

   a. One week: ________________

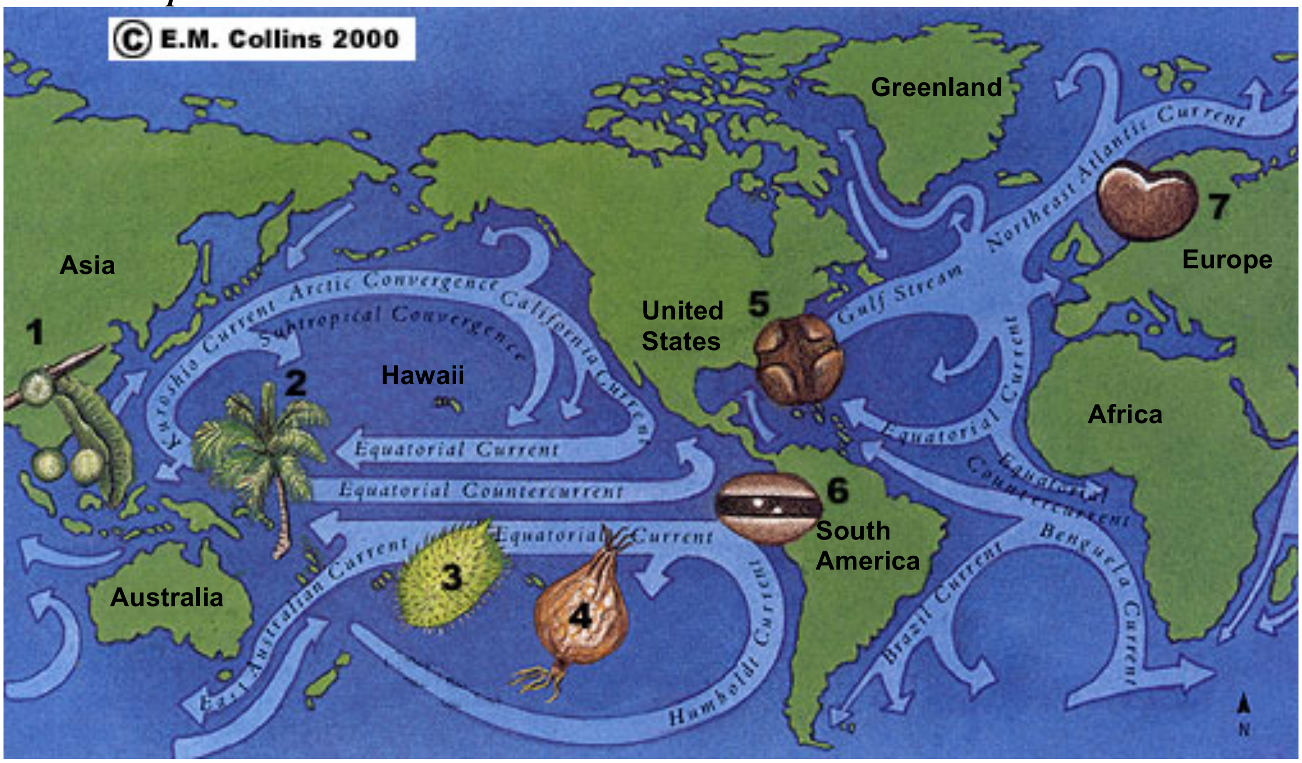
   b. One month: _______________

   c. One year: _________________

Show your calculations below:

5. Is the calculation you performed above an accurate indicator of how far your seed will travel? Why or why not? What assumptions were made in the calculation that may not be true in nature?

C. Water-dispersed Seeds:



1. Many plants on the Hawaiian Islands are closely related to plants from Asia, and South America. Considering the map above, how do you think the plants reached Hawaii?

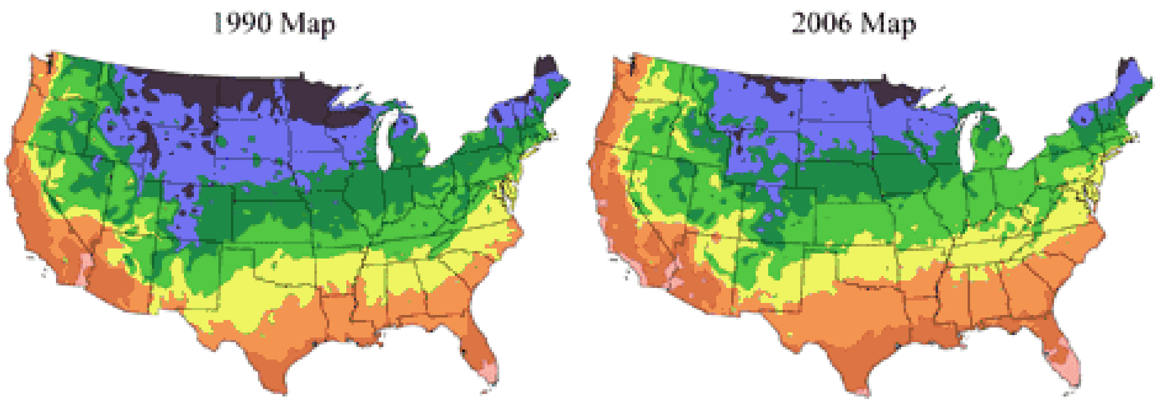
2. Where might seeds from Florida end up?

3. What properties are necessary for seeds to travel such a long distance in salt water?

4. Are you familiar with any seeds that fit this description? List them below.

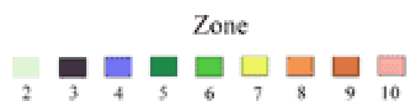
Student Handout Part 4: In a race against climate change, can these species survive?

1. Plant hardiness zones are a way to describe the climate. Gardeners, farmers, and others use plant hardiness zones to determine which species are likely to grow and survive in their area. However, plant hardiness zones are shifting. Using the maps below, describe the change in plant hardiness zones between 1990 and 2006.



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.



2. Using the maps above, and the U.S. map with a scale at the end of this activity, estimate the distance moved by a plant hardiness zone in your state over one year. Give the *ANNUAL* distance in both miles and kilometers. Show all work.

3. Select a species from part A or B of this lab. Would your species be able to migrate far enough over one year to keep up with the change in hardiness zones? Explain your answer.

4. Is the calculation you performed above an accurate indicator of whether your seed will be able to survive climate change? Why or why not?

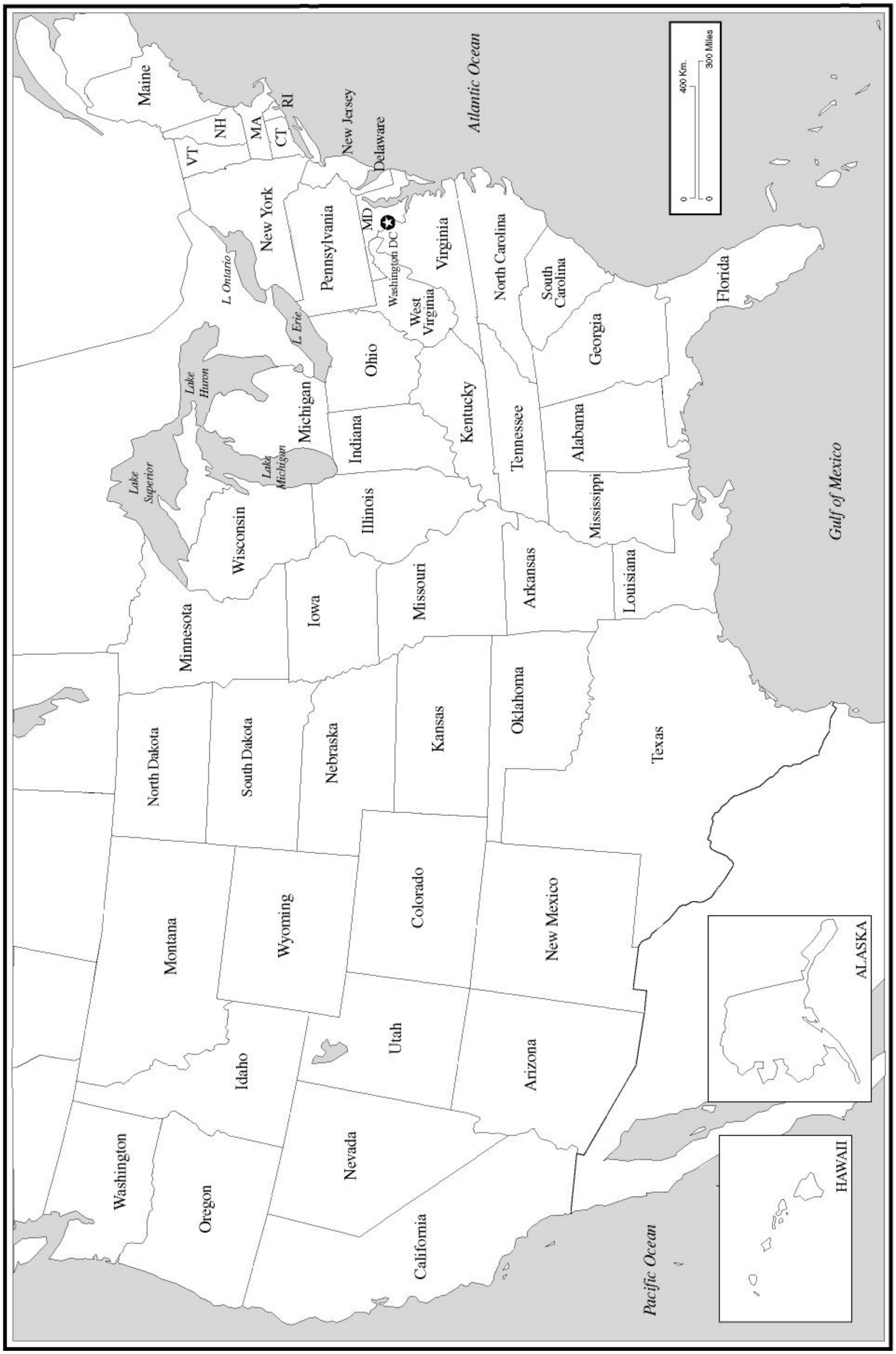
5. What assumptions were made in the calculation that may not be true in nature?
   a. What natural barriers might be in the way of effective dispersal?
   b. What human barriers might be in the way?

6. Assume your species is unlikely to survive climate change, what could humans do to help conserve the species? Do you think humans should work to save plant species? Why or why not?

7. After reading about/discussing the concept of assisted migration:
   a. Describe assisted migration in your own words.

   b. Give one benefit and one risk associated with assisted migration.

   c. What are your personal feelings about assisted migration? Do you believe it is a good strategy for our future? Explain your answer.



Produced by the Dept. of Geography
The University of Alabama

A Hunt for Seeds to Save Species, Perhaps by Helping Them Move

Anne Raver, New York Times, November 9, 2009

CHICAGO — Pitcher's thistle, whose fuzzy leaves and creamy pink puffs once thrived in the sand dunes along several of the Great Lakes, was driven by development, drought and weevils into virtual extinction from the shores of Lake Michigan decades ago.

But in the 1990s, seeds collected from different parts of the thistle's range were grown at the Chicago Botanic Garden and planted with the help of the Morton Arboretum along the lake, in Illinois State Beach Park, north of Chicago near the Wisconsin state line. The plants from Indiana's dunes to the south are doing well; the plants that had come from the north are failing.

With those mixed results in mind, scientists from the botanic garden are sending teams out across the Midwest and West to the Rocky Mountains and Great Basin to collect seeds from different populations of 1,500 prairie species by 2010, and from 3,000 species by 2020. The goal is to preserve the species and, depending on changes in climate, perhaps even help species that generally grow near one another to migrate to a new range.

"In 50 to 100 years, because habitats or climates are so altered, we might end up trying to move species in a restoration context, in assemblages of species," said Pati Vitt, a conservation scientist and curator of the Dixon National Tallgrass Prairie Seed Bank at the botanic garden.

The garden is seeking permits to test the concept with the thistle, by pushing it into new, colder territory along the shores of Lake Ontario. "It may be the best test case for moving an individual species outside its range," Dr. Vitt said.

But assisted migration, as it is called, is a hotly debated issue. On one side are those like the botanic garden scientists, who argue that the risks are better than doing nothing.

"We recognize that climate change is likely to be very rapid and that seeds only disperse a few hundred yards, half a mile at most, naturally," said Kayri Havens, the botanic garden's director of plant science and conservation. "They'll need our help if we want to keep those species alive."

Other scientists argue that tinkering with the complexity of habitats is courting disaster — and huge expense.

"Even given our best science, we're not good at predicting which species will be invasive," said Jason S. McLachlan, a biologist at the University of Notre Dame who has studied postglacial population spread. "And it's going to be especially complex as climates change."

The American beech, for example, was so rare during the ice age that it is rarely found in fossils. "It may have been one of those rare and unusual species we think about saving with approaches like assisted migration," Dr. McLachlan said. Now, the beech is so abundant in Eastern forests, he said, it is shading out "almost all other species."

Dr. McLachlan and other scientists have formed a working group on managed relocation, financed by the National Science Foundation and the Cedar Tree Foundation, to open up the discussion to citizens, economists, natural resource managers and policy makers.

While the debate proceeds, scientists at the botanic garden are building the seed collection and assessing the adaptability of different populations of species. Dr. Vitt and Dr. Havens recently showed off the new Rice Science Center, which has laboratories and a 420-square-foot seed vault with floor-to-ceiling stainless steel shelves.

When temperatures in the giant humidity-controlled freezer stabilized at minus 4 degrees Fahrenheit at the end of September, they moved collections of 800 Midwestern species — some made up of 300,000 seeds — from their old home in four large freezers, hardly different from the kind a large family might use to store home-grown produce and a side of beef.

"The first time I walked in here, I started to cry," Dr. Vitt said. "I know what having this will allow us to do in the future. It's the most important conservation work the garden can be doing."

The prairie effort is part of a Bureau of Land Management project called Seeds of Success, which intends to collect seeds of the entire flora of the United States, except for species already under protection and recalcitrant species, or those that cannot survive long-term storage.

That is 14,000 native plant species.

Seeds of Success, started in 2001 in response to a Congressional mandate to plant native seed in restoring public lands destroyed by wildfire, began its far more ambitious initiative in June 2008.

A consortium of botanic gardens and other institutions have sent 65 teams across the country, which so far have collected groupings of 3,200 species.

We hope to collect 20 populations across the species' range so we can get 95 percent of the genetic diversity of the species," said Peggy Olwell, the plant conservation program manager at the bureau. "Because frankly, we don't know what it is we're going to need when we're talking restoration in light of climate change. It's going to be one big experiment."

Seeds of Success sends one collection of every species to the Millennium Seed Bank Project, at the Royal Botanic Gardens, Kew, in Britain, which intends to collect 25 percent of the world's flora by 2020. Seeds are also stored at the National Center for Genetic Resource Preservation in Fort Collins, Colo., and the Western Regional Plant Introduction Station in Pullman, Wash.

The Dixon seed bank at the Chicago Botanic Garden houses not only species from the tallgrass prairie, but also natives of the bogs, dunes and other ecosystems in the prairie region. It also includes the working collections of species singled out for restoration.

"In the Midwest, we have about 200 that are going to be very important," Dr. Havens said. "These are the matrix species, the bread-and-butter species that can be used in restorations after disturbance to really stabilize the community."

Climate models all show temperatures rising, but they do not agree on the prairie's future climate.

"Some models show us with more Virginia-like ecosystem, some say more like Texas," Dr. Havens said.

In a paper to be published in the journal Biology Conservation and available now online, Dr. Vitt, Dr. Havens and three other scientists at the botanic garden outline a framework for assisted migration, calling first for a globally unified seed banking strategy, which involves collecting genetically diverse populations of each species, accompanied by provenance data like GPS coordinates, soil type and the structure of the surrounding plant community.

They also propose how to predict where species can be relocated. The scientists are just beginning to test their theories in seven climate change gardens planted this fall across the country. Each contains genetically identical clones of plants grown from seed collected in four hardiness zones (4, 5, 6 and 7). Three sites are in the Chicago area, with the others in Boston; Chapel Hill, N.C.; Seattle; and Washington.

Students and volunteers will collect data on the species, and can compare their gardens with others through a webcam system. "If plants grown from seed collected in Zone 4, 5 or 6 can't withstand Texas conditions," Dr. Havens said, "that's a good sign they're going to become extinct here, if there's no way for them to migrate on their own or human-assisted."

Collecting all the native species in the United States, as well as developing restoration techniques and growing huge amounts of seed will take about 10 years and cost about $500 million, Dr. Havens said — a cost that she argues is well worth it.

Dr. Vitt said: "I won't be around in 100 years, but if the research isn't there, we won't know how to do it on that scale. That's why the seed bank is so important.

"For now, we are trying to follow Aldo Leopold's maxim: 'The first rule of intelligent tinkering is to keep all the pieces.' "