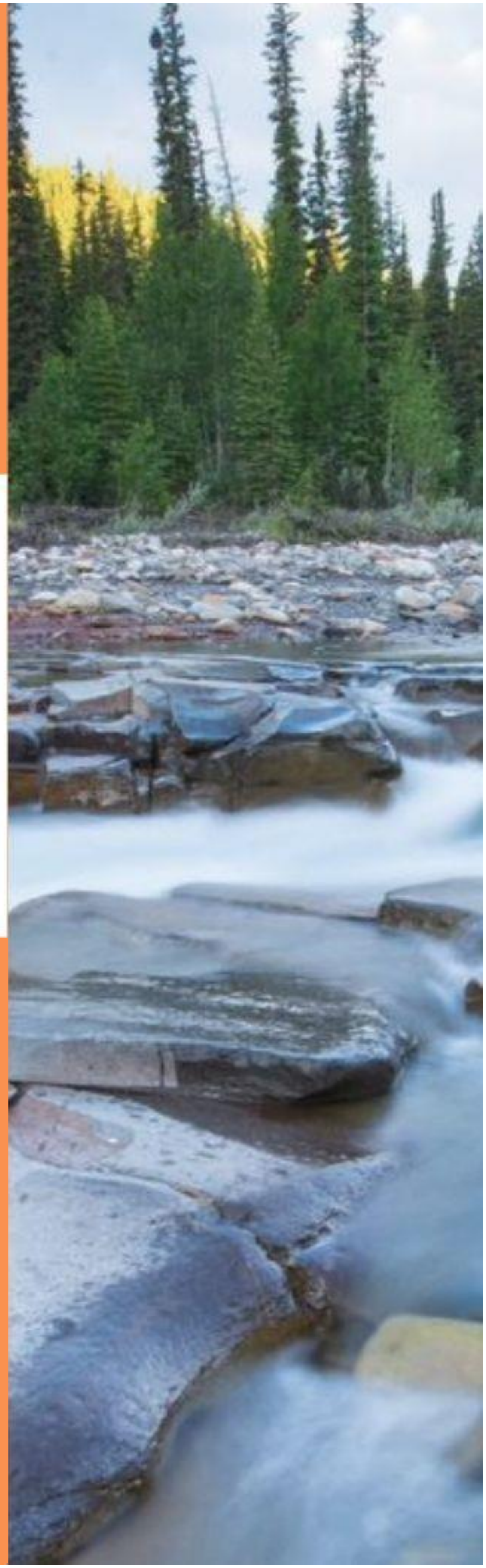
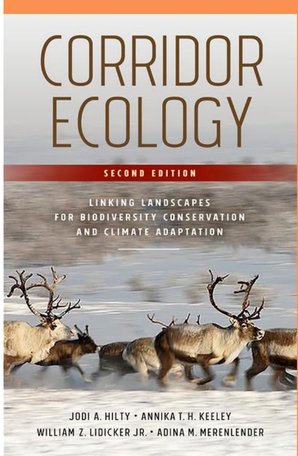
HABITAT FRAGMENTATION AND WILDLIFE CORRIDORS



SECONDARY SCHOOL ECOLOGY LESSON PLAN

CREATED BY LONI CANTU WITH THE SUPPORT OF THE YELLOWSTONE TO YUKON CONSERVATION INITIATIVE



BASED ON HILTY ET AL. 2019. CORRIDOR ECOLOGY: LINKING LANDSCAPES FOR BIODIVERSITY CONSERVATION AND CLIMATE ADAPTATION. ISLAND PRESS.

Overview – Students will discover how landscape patch size and proximity determine an organism's ability to disperse or successfully establish and colonize habitat patches, impacting extinction rates and overall biodiversity. Students will learn about the Theory of Island Biogeography, Metapopulation Theory, and habitat fragmentation.

Advanced Option – Students will collect data and measure habitat sizes and distances. Students will test the frequency of successful dispersal rates relative to habitat size and distance. Students will graph their results and discover colonization vs species extinction rates.

Note: *This activity is adapted from the Y2Y educational teachers guide entitled "Why the Y2Y?"*

Student Learning Targets - See Appendix

Time requirements – 1-2 hours, lesson can be adapted to fit multiple class periods

Suggested Audience - Middle or High School

Optional Pre/Post Evaluation – See Appendix

Background for the Teacher

In this lesson students will learn about the causes and impacts of habitat fragmentation on wildlife populations in the Canadian Rocky Mountain Region. (Facilitator/Teacher can adapt the animals and habitats in this lesson to represent the local landscape)

Small fragmented habitat patches are correlated with lower species biodiversity, which means lower species richness and lower abundance/number of individuals. Habitat fragmentation is caused by natural factors and human activities. Natural fragmentation such as fires, extreme weather, and glaciers change a landscape slowly. Over time forests have evolved with fires and extreme weather events, and if left to nature, restoration of these lands after natural fragmentation occurs quickly. However, human induced fragmentation generally changes landscapes at faster rates, over larger areas, and human changes are often harder to reverse. Some examples of human activities include agriculture, mining, housing development, industrial processing plants, and road construction.

Human activities not only exacerbate habitat fragmentation, but also change the climate. Climate Change is transforming our earth, forming novel ecosystems and communities that have never been observed before. This changing landscape is causing plants and animals to move in search of more favorable climates, but fragmented habitats restrict an animal's ability to migrate and adapt to changing ecosystems. Connecting habitats through corridors such as road overpasses and underpasses is one solution to restore fragmented patches, building more climate resilient landscapes, and restoring populations and overall biodiversity.

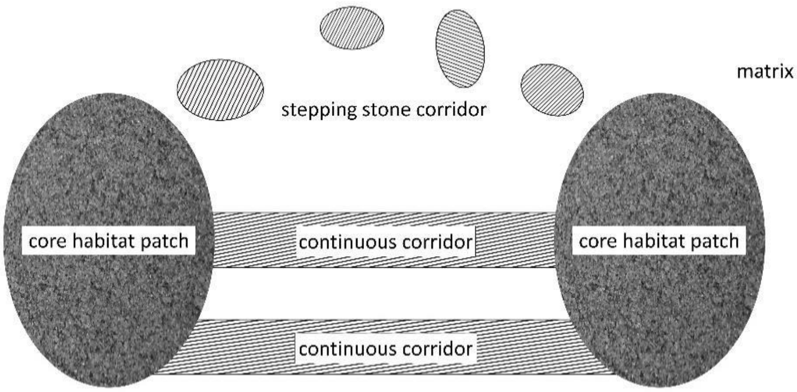


Figure 1 depicts habitat patches *connected through corridors. "**Stepping-stone**" corridors consist of patches of appropriate size and proximity can assist with the dispersal of species. The **matrix** is outside of healthy habitat areas and is typically altered by human activities. Corridors and habitat patches are embedded in the matrix.*

The Theory of Island Biogeography was published in 1967 by R.A. Macarthur and E.O. Wilson. This theory uncovered how organisms respond to disconnected patches of habitat, and what influences the diversity or number of species on islands. The authors observed four basic principles:

1. Larger islands will host more species than smaller ones because large islands are likely to have greater habitat diversity.
2. Islands close to the mainland will be more diverse than more distant islands.
3. Small islands will suffer high rates of species extinctions compared to larger islands.
4. Islands close to the mainland will experience lower extinction rates regardless of size because they will benefit from a larger input of new **colonists**, including individual species already present on the island.

Since the publication of this seminal paper, the principals of Island Biogeography have been adapted and expanded to the terrestrial environment with a new concept called **Metapopulation Theory**. **Metapopulations** are smaller population units connected at different levels by movements of individual species. Like Island Biogeography, Metapopulation theory explains how **dispersal**, or species movement, is influenced by different habitat patch configurations. Metapopulation Theory also contain the 4 basic area and distance principals as Island Biogeography.

Overall both theories explain how larger, closer, or connected habitat patches experience higher population numbers, greater overall diversity, and lower rates of extinction.

Metapopulation and Dispersal

Habitat fragmentation, resulting from human development, can also lead to isolated **metapopulations**, or smaller spatially separated population units connected at different levels by movements of individual species between populations. Habitat fragmentation is causing once continuous populations to shrink and often break up into smaller populations with various levels of connectivity between them, thus becoming a metapopulation. Shrinking habitats can also shrink and isolate remaining populations causing biodiversity loss such as through loss of smaller populations, genetic drift, or weakening. By maintaining connectivity among the smaller populations of a metapopulation, it is more likely that smaller patches of habitat will retain a population over the long term and avoid issues such as inbreeding in otherwise smaller populations. (Typically, it is the male mammals who disperse or travel long distances in search of a mate.)

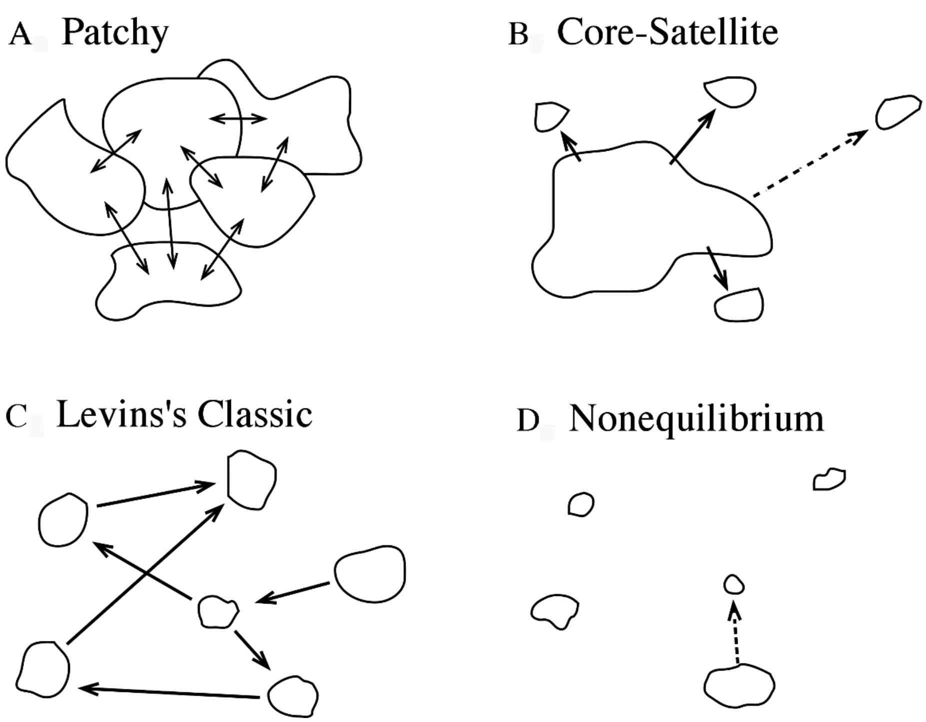


Figure 2 depicts the four configurations of metapopulations. Each patchy shape inside the meta-population is called a population, which can consist of a single, or multiple individuals of the same species within the population. The arrows show individuals dispersal movements among habitat patches. Extremely rare dispersal events are depicted as dashed arrows.

Metapopulations Key Concepts (Advanced)

A. Patchy Metapopulation – are so well connected that dispersal is easy and common. If a population becomes extinct in one patch it can quickly be recolonized (**rescue effect**). This is a common pattern and is the one most resistant to metapopulation extinction.
B. Core-satellite Metapopulation – also known as mainland island or source sink, consists of a large habitat patch with one or more large extinction-resistant populations plus one or more usually peripheral smaller patches of habitat. Dispersal is mainly in the direction of mainland to satellite. The smaller populations experience occasional extinctions, but eventually those patches are recolonized from the core population. This kind of metapopulation is relatively extinction resistant because of the relative security of the core or source population.
C. Levin's Classic Metapopulation – is a network of highly connected habitat patches of adequate size with dispersal from occupied to unoccupied habitats.
D. Nonequilibrium Metapopulation – this arrangement has the highest risk of overall extinction, because connectivity among populations is weak or absent and there is no large secure group among them. With minimal dispersal among populations, the rescue effect is unreliable or nonexistent. As populations, or individuals, suffer extinction, there is little prospect of these

habitat patches being recolonized, at least over reasonable time spans. Nonequilibrium metapopulations are in a sense moribund (declining). Key point: **Unfortunately, this pattern is also common and becoming more so with increased habitat fragmentation.** These situations are the ones to which most conservation efforts are directed.

Note: One way to teach the 4 Metapopulation Key Concepts is for your entire class to role play a metapopulation of species such as grizzly bears. Each student could represent an individual and stand in the patchy configurations depicted and described above, and practice moving or dispersing between the habitat patches. Barriers or obstacles should be created or described between patches that are far apart to represent the difficulty in dispersing to small, isolated, and far away habitat patches.

Key Terms

Biodiversity – variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexities they are part of, this includes diversity within species, between species, and of ecosystems.

Biogeography – study of the distribution of species and ecosystems in geographic space and through geologic time.

Calving – When certain large mammals give birth to their offspring, or calf (e.g. elk, whale, caribou)

Carrying Capacity – the number of living organisms that a region can support indefinitely; going over carrying capacity will create environmental degradation and/or cause a crash in the number of a specified species.

Colonist – a disperser that takes up residence in an unoccupied habitat patch. Colonization rate is the number of new colonies species expand to and establish per unit of time.

Connectivity – the ability of organisms to move among separated patches of suitable habitat.

Conservation – carefully planned protection of natural resources and wildlife for the health and sustainability of the humans and nature.

Core-Habitat – Area with suitable living conditions for a diverse, extinction resistant population of species.

Corridor **–** any space that facilitates connectivity over time among habitat patches.

Dispersal – the process of individuals leaving their residence, or home, to look for a new place to live. This behavior can occur both within and between habitat patches.

Dispersal Distance – the distance moved by a disperser from its current home to a new one. Many mammal species travel smaller distances with the presence of humans.

Disperser – individual in the process of dispersal. If the search for a new home is successful, such an individual would be a successful disperser.

Emigrant – a disperser that leaves its home population and represents a loss to that population. Emigration rate is the number of emigrants produced by a population per unit of time.

Excursion – an exploratory trip away from home including a return home. This movement could come before dispersal, but if an excursion ends in death of the individual, we cannot distinguish it from failed dispersal.

Fragmentation – smaller habitat patch sizes are correlated with lower overall species richness as well as lower biodiversity of native species.

Habitat Patches – a defined area used by species for breeding, socializing, or obtaining resources such as food, water, or shelter.

Individual – in this activity individual represents juvenile organisms, but this could mean any individual species within a population.

Immigrant – a disperser that enters and becomes established in a new population. Immigration rate is the number of new arrivals per unit of time.

Matrix – landscapes typically altered by human activities, but can also be a mosaic of natural and human systems. Corridors and Habitat patches are embedded in the matrix. (throughout the lesson an advanced option can be to replace uninhabitable landscape/human activities with Matrix.) **Note**: Some species can survive in the matrix while others cannot. Matrix is viewed anthropocentrically as the human landscape in which nature is embedded, but this could look different depending on cultures (e.g. could be viewed as humans embedded into natural landscapes).

Metapopulation – group of spatially separated populations of a single species which interact through dispersal or migration. (see figure 2 of the 4 types of metapopulations)

Metacommunity – a set of interacting communities (of different species) which are linked by the dispersal of multiple, potentially interacting species.

Migration – term typically used to refer to seasonal movements between breeding and nonbreeding animal ranges.

Rescue Effect – if one group within a habitat patch becomes extinct it can quickly be recolonized by nearby populations (see figure 2, A)

Spawning - the process of releasing or depositing eggs and or sperm by aquatic animals such as fish, frog, mollusk, and crustaceans.

Stepping-Stone – habitats or protected areas that are not physically connected but can facilitate dispersal or migration movements. Stepping-stones support metapopulations that are adapted to human activities and can disperse in fragmented (less specialized) or generalized habitats.

Prior knowledge

Students should understand how the following concepts relate to their lives and global systems:

- Biodiversity
- Climate Change
- Conservation
- Ecosystems
- Ecosystem Services
- Endangered Species

Materials

- 10 scraps of paper per student from the recycling bin (or small soft balls)

- 3-5 containers of dramatically different sizes (e.g. large boxes, the classroom garbage can, ice cream container, large mug, etc. All containers should be as deep as possible to fit at least one paper ball)
- 1 long rope or cord (approximately 30feet or 9m)– large enough to make a circle and fit your entire class inside. You can also use chalk to mark up the floor or sidewalk (you will use the rope for 2 activities)
- Old newspaper or planks (to represent corridors)
- Advanced Option – measuring tape or ruler (for distance and area)
- Optional - Blank name tags for every student (or half sheets of paper for every student)

Instructions for Teacher:

Warm Up Activity – Shrinking and Fragmenting Habitats

1. Place a large piece of rope or string on the floor in the shape of a circle (or draw a large circle with chalk on the floor to represent the core-habitat boundary). Say:

   "The area inside the rope represents a healthy and large habitat patch." (You can also name the patch after a local park, wilderness or protected area). "Each of you will represent a different species and stand in this habitat patch. Write the name of your species on your nametag, or piece of paper"

   Note: If students do not know the local animal species, ask students to create a list of species in the region.
   Note: It is fine if students choose the same species but ensure you have at least 10 different species to represent biodiversity. Say:

   "This habitat is healthy and diverse and contains (number of students) species."

2. Record this number in a place visible to all students. Say:

   "Surrounding the habitat patch is uninhabitable landscape. The uninhabitable landscape (matrix) is a combination of human development including homes, roads, industrial sites (manufacturing plants), oil and gas activity, ranching, and mining."

   Note: You can name the primary human activities that occur around your school or region. Say:

   "One day a real estate developer decided that your habitat patch was in the prime location for new homes they wanted to develop. They decided to cut down the forest and build their new subdivision."

3. Point to a specific part inside the rope. Say:

   "This part of your habitat can no longer support any species. I need the students standing in this section to step into the uninhabitable landscape."

   Note: When you are fragmenting your large habitat patch ensure to target specific species that cannot live on small patches (example: Wolverine, wolves, or Grizzly bears)

4. Close the rope into a smaller circle around the remaining students to show how the habitat is getting smaller (draw a smaller circle or new boundary with the chalk). Say:

"Unfortunately, this habitat has turned into new homes and these species (point to the students which moved) can no longer survive because this area is lacking the resources they need to live, you must take a seat."

"Now one year has passed and summer is here, and it is a very hot and dry summer. Someone driving near the new housing development threw a cigarette out of their car window. It landed in this habitat patch. I need the species standing in this section to crowd into the rest of the habitat if you can fit, but anyone who touches the uninhabitable landscape will unfortunately be destroyed in the lethal (crown) fire and may take a seat"

Note: Fires can be good, but this was a lethal fire and it will take many years before the habitat is restored

5. Close the habitat into a smaller circle to represent the forest fire. Say:

   "Now a new road needs to be built through this forest to access the new mountain biking and hiking trails."

6. Ask Students to move from your designated road area and split the habitat/rope in half with scissors and arrange the habitat to make room for a road which should fragment a large piece of the habitat into 2 smaller habitats. Say:

   "Again, unfortunately any species on the new road can no longer survive because they were hit by a car, so you may take a seat."

   "Now our large connected landscape is looking quite small and fragmented. Do we have the same biodiversity we did in the beginning?"

   (students should say no, there is less biodiversity)

   Note: If you still have plenty of students, continue to invent more human activities that shrink and fragment your habitat patch. You should play the game till you have half or less of the students left on the fragmented landscape.

7. Count the number of species left in your habitat fragments. Record the new number of species left after habitat fragmentation (it should be a lot less than the original number). Calculate the percentage of species lost (e.g. (30 species on original large landscape - 15 species left on the small fragmented landscape)/ 30 species on original large landscape = 50 percent loss in biodiversity.) Say:

   "This smaller fragmented habitat has led to _ percentage extinction of species on our landscape.

   This is an example of what is currently devastating our world globally. Extinction rates are 1,000 times higher than historic rates documented in the fossil record. This loss in biodiversity is threating the survival of humans and wildlife. Healthy and intact ecosystems provide us with clean air, water, food, medicine, and other natural resources. It is our ethical and moral responsibility to prevent irreversible changes to Earth's system so that we do not harm other species and our own future generations."

8. So now what? Looking into the future. Say:

   "There are many human threats that continue to shrink habitats. What could we do to bring back our large habitat, or connect our fragmented landscape?"

(Students could say wildlife corridors, underpasses, overpasses, limits on development in a community, community planning to reduce urban sprawl, seasonal temporal closures on landscapes, reclamation and restoration of agricultural land to support wildlife while maintaining productivity for agriculturalists, or human-wildlife cohabitation measures (for example, ranching strategies outlined in the Oregon Department of Fish and Wildlife demonstrate non-lethal measures to minimize wolf-livestock conflict: https://www.dfw.state.or.us/Wolves/non-lethal_methods.asp. Some of these strategies could work with bears and other predators too.)

Note: You could extend this activity by moving the rope back to its original shape to represent habitat restoration and conservation practices. e.g. restoring mined or deforested land or building wildlife corridors. Say:

"What are some barriers to connecting or restoring fragmented landscapes?"

(Students should think of the opposition (private landowners, businesses, or public land users) or people who do not want to restore landscapes to support wildlife. This might be because of a variety of concerns such as that restoration will lead to job or economic decline and impair local livelihoods. Perception of public land rights may also be a barrier to restoration. Locals may believe the adjacent public lands are primarily for their use not the greater public good. This is not true because public lands are regulated for the sustained use of all wildlife and people. This means regulations on use such as park hours, types and extent of industrial uses (logging, natural resource extraction, etc.), grazing, motor vehicle use, and pet or agricultural access is either restricted or has limitations). Say:

"How could we approach communities, industry, and or individuals that are concerned about restoring habitat and corridors for large carnivores and increasing biodiversity?"

(Potential answers: First listen to the community's concerns. It is important to listen to stakeholders and interest groups because their perspective and support will help make conservation projects successful. After listening to and understanding concerns, land managers and conservation leaders may find common ground and ways to collaborate with local communities/industry/individuals to develop solutions, strategies, and tools that could restore habitats and build corridors. Maybe this means strategically talking and working with people in the community that are champions of conservation and already have trust in a concerned stakeholder, and collaborating with them on persuading and building awareness, support, and action towards conservation initiatives. Sometimes it takes time and trust between stakeholder and interest groups to build this vision of peaceful co-existence between humans and nature. Many times building connected habitat patches on working lands can also lead to greater productivity of the landscape which can be a win-win for the rancher and environment.) Say:

"What do you know about indigenous perspectives on large landscape conservation and habitat fragmentation?"

(Potential answers: Indigenous connection to land has been built up through generations of living in close contact with nature. Traditional Ecological Knowledge is now being considered by many conservation groups through integrating the knowledge indigenous people have about the local environment, how it functions, and ecological relationships, into conservation projects. Co-production of ecological knowledge uses western science and indigenous knowledge in project planning, resource management and environmental assessments.)" - http://www.learnalberta.ca/content/aswt/)

"When nature is healthy and thriving, humans are also healthy and thriving. What does this mean to you? What does nature provide for humans and wildlife?"

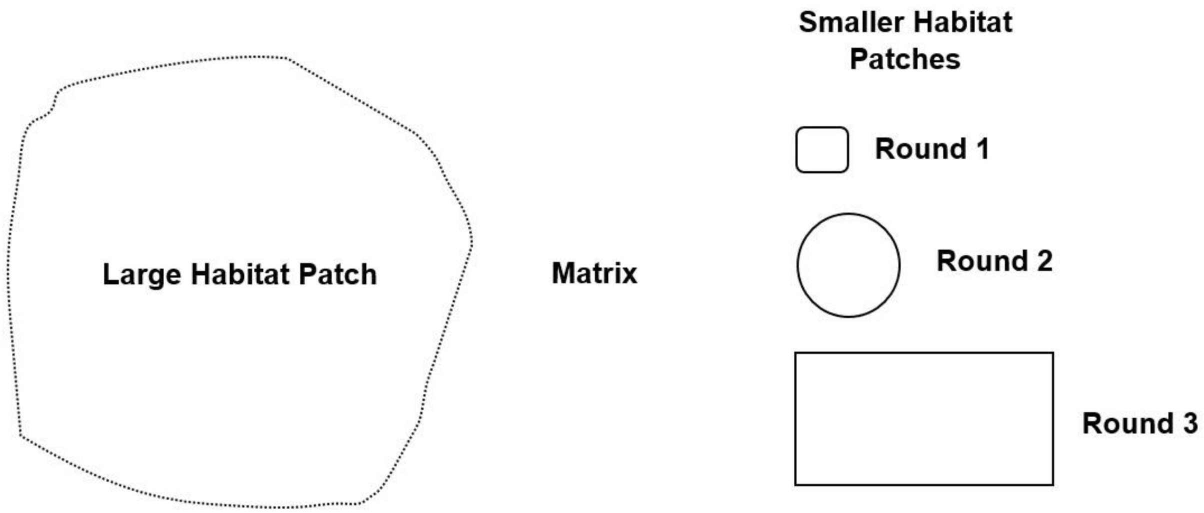
(Potential answers: Healthy air, water, soils, and less pollution is better for people as well as our environment. When people are healthy the environment is generally healthier too (less air pollution from cars, healthy food without chemicals is better for everyone!) At this point you can transition the conversation to environmental justice issues. How does environmental pollution, climate change, and habitat fragmentation disproportionately impact marginalized communities such as: low-income, lower-socio economic status, and racial minorities.)

9. At the end of the warmup activity, students can reflect on their learning by recording their responses to the questions above. Ultimately, students should be able to express that human activities fragment habitats, and smaller habitats lead to less diversity and more extinction events but connecting fragmented habitats can restore and strengthen biodiversity.

Main Activity

Part 1: Island Biogeography/Metapopulation Theory – Size/Area Effect

1. Set Up: Create a large habitat patch using rope (or draw it with chalk). The large patch does not have to be a perfect circle. Students will play 3 rounds of this activity, with different sized bins in each round. **Note**: Sizes should be tiny, medium, and large. About the size of an ice cream container, trash can, and large box. (approximately 220 cm^2, 500-1000 cm^2, and 2,000 cm^2) in size. Make sure to place the bins the same distance from the large habitat patch each round (an easy distance of about 1 or 2 meters would be best).



1. Say:

"Do you plan to always live at home?"

(Most will say no)

"The same is true from many wild animals. They need to leave their home to search for food, water, shelter, mates, or to socialize. Does anyone know what this is called?"

(answer: migration or dispersal)

2. Make sure the class knows the following key terms:

   Migration – seasonal movement of species in search of better living conditions or to breed (e.g. seasonal migration of elk from lower elevations in winter to higher elevations in summer to calf and to feed on new fresh snowmelt grass). Migration is essential for the survival of many species.

   Dispersal - the process of individuals leaving their residence, or home to look for a new place to live. This behavior can occur both within and between habitat patches. (e.g. male grizzly bear leaves home in search of a mate.) Say:

   "The difference between migration and dispersal is migrating animals generally return to the same habitats seasonally while dispersing animals find a new habitat to live in."

3. Say:

   "Today we will be analyzing the factors that influence successful dispersal of local species into new habitat patches. The roped area represents a large core habitat patch (can name after large local national park or protected area), and the smaller bins (receptacles) represent smaller isolated habitat patches (can name after smaller local parks). The area between the small habitats and large core habitat is the area of human development and activities such as roads, housing, agriculture, and industrial activities making it uninhabitable for wildlife.

   Note: Advanced Option – Before beginning the activity calculate and record the area of each bin. An example data table is in the handouts section.

   "You will all represent a large extinction resistant population of species. You can choose any wild species in the local area."

4. Give students time to choose species. **Note**: If students do not know the local animal species, make a list of species (with pictures) for them to choose from. Students can write their species on a sticky nametag for easy identification. After they have chosen their species say:

   "Wild species/students you may now stand in the large habitat patch called (name local national park or protected area). In this activity you represent parent animals. You and all the other species have a large, healthy family."

5. Gather scraps of recycled paper or printer paper and distribute it to the students (each student should have at least 10 pieces of paper). Say:

   "The paper will represent your offspring. Wad up the paper into balls."

   Note: As an option, have students mark their paper with their initials on the outside, or use some other distinguishing feature to identify each students (species) paper ball.

   "Your large habitat patch is becoming too crowded. It is reaching **carrying capacity** ~~(limit)~~. Your offspring need to leave the larger habitat because competition for space, resources (food and water), and mates is too high. The juvenile species will have a better chance of thriving and being healthy if they leave to find a better habitat."

"Where could your offspring go?" (answer – smaller habitat patches/bins)

"Yes, your offspring can travel to the isolated habitat patch which have lower species populations and plenty of food, water, and space. We will play 3 rounds to discover what size habitat patch is most suitable for your offspring."

"What is the barrier your juveniles will have to cross?" (answer - the uninhabitable landscape/human activity; roads, homes, mining, and other hazards)

How will you help your juveniles cross the human activities? – (yes, throwing them)

"When I call out 'disperse' you will have 1 minute to try and make as many shots into the isolated habitats as possible. You can try aiming for any habitat patch. Try your best to successfully disperse your offspring, and please no pushing or distracting other species!"

"Get mark, get set…DISPERSE"

Note: Give students the halfway and 10 second time indicator if they are taking their time with their shots.

6. When the timer is up, say:

   "Stop. Now calculate how many successful individuals you were able to disperse."

7. Say:

   "How many of your offspring made it to the new habitat? Hold up your fingers to indicate so we can all see the successful dispersal rates."

   (The students that are the most successful parent "throwers" or disperses are most likely to have their family genes occur in subsequent generations, so maybe your grandchildren will also be successful dispersers too.)

   "How many individuals in total did not successfully disperse?"

   "What happened to the juveniles that fell on the floor?"

   (answer – They did not successfully disperse because they fell into the uninhabitable landscape. Traveling through roads, ranches, and urban areas is hazardous. This is why juveniles of most species dispersing or searching for a new home have a high death rate.)

   "How many species in total successfully dispersed?"

   Note: Students can calculate the total species and give a percentage of unsuccessful/successful dispersal (e.g. 5 students, 50 individuals, 25 did not disperse = 50 percent death/success rate during dispersal)

8. Count the number of papers in the first bin and post the dispersal results for the class to see. You can use the table provided in the handout section.

9. Play again for 2 more rounds with different sized bins the same distance away from the students on the large habitat patch. Ensure students record their answers. **Note**: You can choose to put students in smaller groups if space or behavior is an issue.

10. The results should show that more individuals successfully dispersed to larger bins, while bins with smaller opening (or area size) received less species. Say:

    "Why did some bins receive a greater number of species than others?"

    (students should mention the size differences)

    "You have just discovered the area effect. Larger patches are more likely to be successfully reached by juveniles than smaller patches. This is because the probability of a juvenile to encounter a larger patch is higher than smaller patches. "

    Note – Students can also play a round to discover a species **dispersibility**, or the capability of an individual to disperse. For example, coyotes can disperse relatively well through the matrix, and their dispersal can be represented by a crumpled paper ball. But many frogs cannot survive through a human dominated matrix because they cannot travel far distances to disperse. Frogs could be represented with a flat piece of paper that students try and throw into the bins. Students will easily see the stark contrast in the differences of species dispersibility.

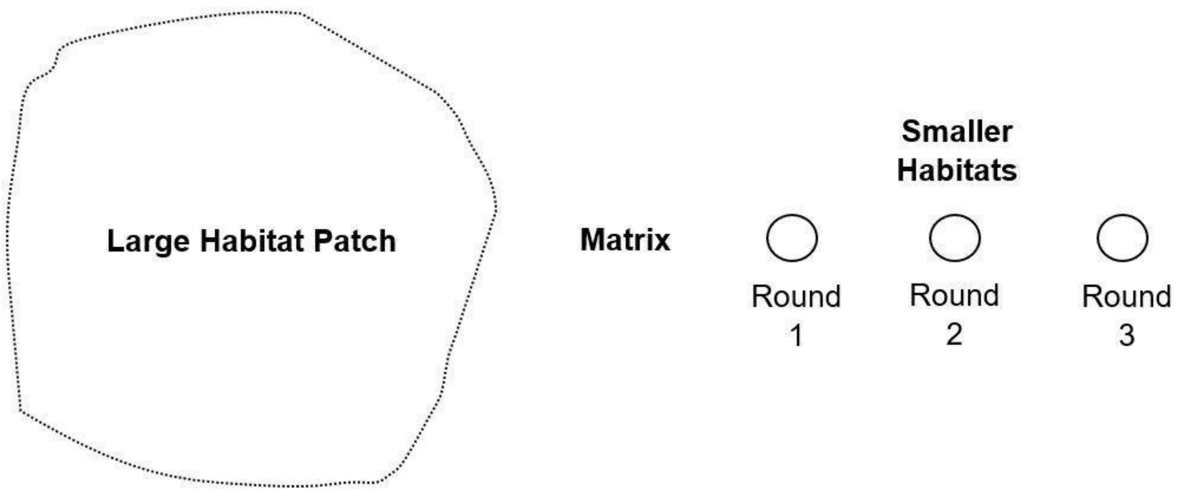
    Note: In real life an animal may not just make one dispersal – but could also travel back or to new habitat islands multiple times throughout its lifetime. There are also daily migrations that species make to access their food sources. And of course, animals also migrate annually or seasonally for mates or spawning, calving, or to give birth to their offspring

Advanced Option: Create a table with the number of individuals that successfully dispersed per student and per bin. Graph the relation between number of individuals colonizing a new habitat and area.

Note: you can visually represent a graph, by placing the paper balls (individuals) successfully dispersed beside each bin and using the rope to show how an increase in area leads to an increase in individuals dispersed.

Part 2: Island Biogeography/Metapopulation Theory - Distance Effect

11. Set up: This part will use 1 identical container of the same size in 3 different rounds. In each round you will move the container further away from the large/core habitat patch. Ensure that the final distance is far enough away that a student can rarely make a successful basket (more than 5 meters from large habitat patch).



12. Again, invite the students to the large habitat patch. Say:

    “This small habitat is experiencing genetic inbreeding because the population of species living in it is too low. Your juvenile offspring (or individual) will disperse to this patchy island in search of a mate. Again, you will have one minute to throw your offspring into this small habitat. When I say disperse you may begin.

    <u>Note</u>: Students may try to get as close to the end of your core habitat as possible, so you may wish to divide students into smaller groups of 4 of 5 to disperse their individuals and play different rounds with each group, or play the activity with 2 separate groups at the same time.

    “Get mark, get set…DISPERSE”

    <u>Note</u>: Give students the halfway and 10 second time indicator if they are taking their time with their shots.

13. When the timer is up, say:

    “Stop. Now calculate how many individuals you were able to disperse successfully.”

14. Say:

    “How many of your offspring made it to the new habitat? Hold up your fingers to indicate so we can all see the successful dispersal rates.”

    “How many species in total successfully dispersed?”

    “How many species in total did **not** successfully disperse?”

Note: Students can calculate the total species and give a percentage of unsuccessful/successful dispersal (e.g. 5 students, 50 species, 25 did not disperse = 50 percent death/success rate during dispersal)

15. Post the dispersal results for the class to see. You can use the table provided in the handout section to show the class results.

16. Repeat steps 12-15 for 2 more rounds, moving the small habitat (bin) further away from the core habitat in each round.

17. Post all 3 results for the class to see. They should show that the closer bins ~~closer~~ successfully dispersed a greater number of species, then the bins further away (distance effect). Say:

    "Why did some rounds receive a greater number of species than others?"

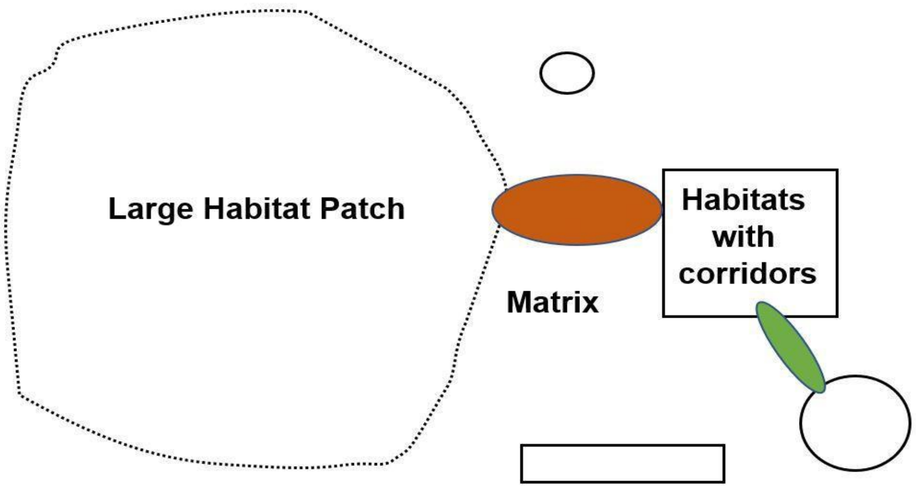
    (students should mention the distance differences)

    "You have just discovered the distance effect. Habitats closer to a core- habitat patch are more likely to successfully disperse species than ones further away. This is because closer habitat patches can be re-colonized by the larger population of species on the core-habitat/source sink. Habitats closer to each other have more successful dispersal and colonization rates."

    Note: Advanced Option - summarize your data in a table and plot your results on a graph. Sample graph is given in handouts section.

Part 3: Island Biogeography/Metapopulation Theory with Wildlife Corridors

18. Set Up: Use a rope to create a large habitat patch and spread the containers in the pattern shown below. (students can assist). Place five or more different sized containers at different distances from the large habitat patch. Use strips of paper or planks of wood to represent corridors which will be walked on by the students during the activity. You can choose to play this activity in different rounds adding and taking away corridors to show their impact on an individual's dispersal success. **Note**: The patches that are connected should have the highest dispersal rates out of all the examples presented.



19. Again, invite the students to the large habitat patch. Say:

    “The organization Yellowstone to Yukon Conservation Initiative (Y2Y) has the vision to connect wildlands and waters from the Yellowstone region in the U.S. to the Yukon in Canada. They have established wildlife corridors where different animal species can disperse between these habitat patches. The corridors are represented by (planks or newspaper/scrap paper) and they connect habitats creating one large healthy protected area that supports thriving wildlife and humans. Your juvenile offspring will disperse to the new habitats through these corridors.”

20. Demonstrate the activity by walking the corridors and dropping a paper into one of the bins. Say:

    “You will again have one minute to walk and drop your offspring into the smaller habitats. When I say disperse you may begin.” **<u>Note</u>**: It may be easier to play this portion in smaller groups.

    “Get mark, get set…DISPERSE”

21. When the timer is up, say:

    “Stop. Now calculate how many successful individuals you were able to disperse and into what bins.”

22. Say:

    “How many of your offspring made it through the corridor to the new habitat? Hold up your fingers to indicate so we can all see the number of successful dispersals.”

    “How many individuals in total successfully dispersed?”

    “How many individuals in total did **not** successfully disperse?”

    <u>Note</u>: Calculate the total species and give a percentage of unsuccessful/successful dispersal (e.g. 5 students, 50 species, 5 did not disperse = 10 percent death/ 90 percent success rate during dispersal)

23. Count the number of papers in each bin. And post the dispersal results (per bin) for the class to see. You can use the table provided in the handout section.

24. The results should show the best success rate out of the 3 scenarios. Corridors protect a wild animal’s ability to safely travel through the uninhabitable human activity. Say:

    “Why did this scenario produce the greatest dispersal success rates?”

    (students should mention how wildlife corridors such as overpasses or underpasses connect fragmented/isolated habitat patches and protect an animal’s ability to disperse)

    “You have just discovered how connectivity mitigates the island biogeography and metacommunity issue of too far and too small. Connecting landscapes through corridors increases a species chances of survival in a fragmented landscape. Connected habitats give wild species the ability to roam freely, disperse between metacommunities, and thrive alongside humans on fragmented and mosaic landscapes."

Note: Advanced Option - summarize your data in a table and plot your results on a graph. Compare findings of all 3 activities and determine which variable had the greatest effect on successful species dispersal.

Note: you can give students real world examples of Metapopulation Theory using the Yellowstone Grizzly Bear population as an example. Because they are so far away from the rest of the grizzly population in the Y2Y region they are at high risk of genetic inbreeding and eventual extinction.

Note: In real life wildlife corridors need to be a certain dimension, composition, location, and physical structure to be successfully used by species. Fencing is also used to train wildlife to use corridors, and certain species are sensitive to specific habitats and will only use underpasses or overpasses of specific structure and composition. Conservation scientists should also ensure careful consideration of the location of corridors, because they should be tailored to the ecosystem and focal species of the area.

25. Students can write a short paragraph to explain their findings and discovery during these activities. Their results should look similar to the conclusion paragraph.

Conclusion:

In this lesson students learned how larger habitat patches that are closer to fragmented habitat patches supported greater dispersal rates, higher numbers of species, and greater overall biodiversity.

Students learned the area and distance effect discovered by R.A. Macarthur and E.O. Wilson in the Theory of Biogeography, and in the theory of metapopulations. The area effect describes how smaller islands or habitat patches have less species diversity and lower numbers of individuals than larger islands. The distance effect describes how closer islands to large mainland habitats will experience greater numbers of species dispersal and biodiversity than islands further away.

Students also learned that the more connected a landscape is, the greater the ability of individuals to disperse and thrive in habitat patches. Connecting landscapes through corridors should be done with careful ecological monitoring and consideration to wildlife, human, and ecosystem needs.

Advanced option – compare the 3 graphs of area, distance, and connected patches to the number of species/individuals. Students should be able to recognize that the larger the area and closer the distance the greater the number of species that can colonize or disperse to a new habitat patch.

Teacher Reflections - How to improve for next lesson:

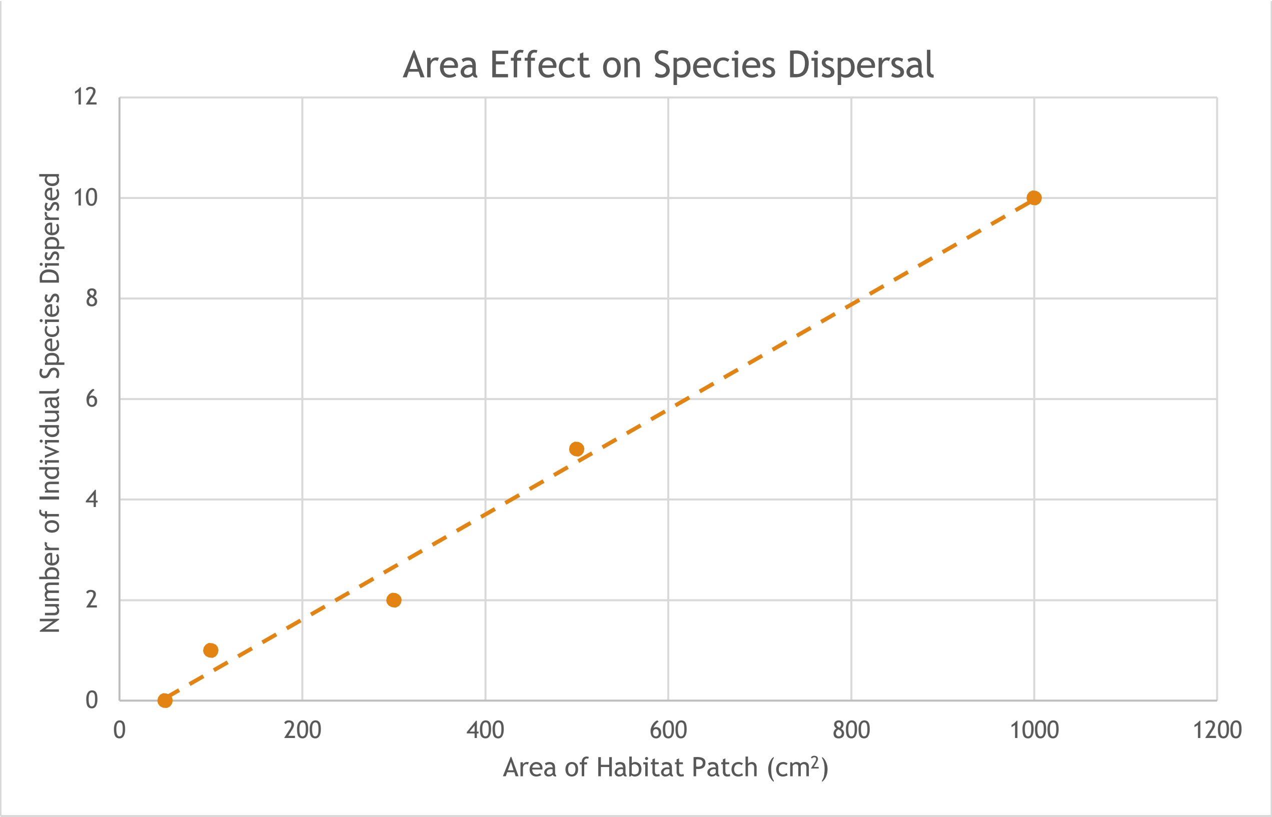
Handouts:

Example Table on habitat area effect on dispersal success

Different Sized Smaller Habitat Patches from Core-Habitat Patch			
	Area of 1st bin = _____cm^2	Area of 2nd bin = _____cm^2	Area of 3rd bin = _____cm^2
Name of Species	# of successful dispersals	# of successful dispersals	# of successful dispersals
e.g. Grizzly Bear			
Total			

Percentage of overall unsuccessful dispersal of species: ________

Example Graph of area effect on dispersal success

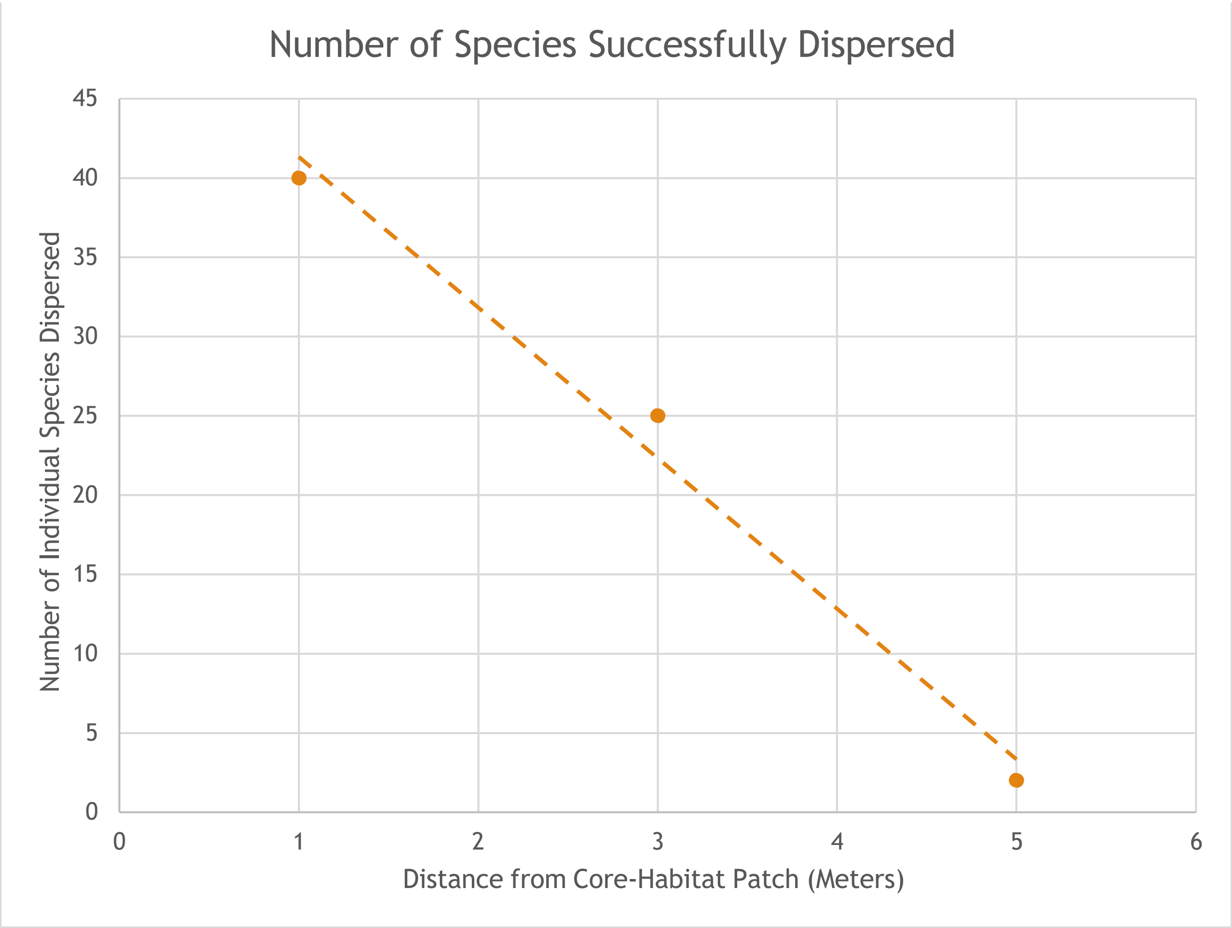


Example Table on habitat distance effect on dispersal success –

Distance of Smaller Habitats from Core-Habitat Patch			
	Distance of 1st bin = cm	Distance of 2nd bin = cm	Distance of 3rd bin = cm
Name of Species	# of successful dispersals	# of successful dispersals	# of successful dispersals
e.g. Grizzly Bear			
Total			

Percentage of overall unsuccessful dispersal of species: ________

Example Graph of distance effect on dispersal success



Example Table: Corridor effects on Dispersal Success –

	Connecting Smaller Habitat Patches to Core-Habitat Patch				
	1st bin (Corridor yes or no)	2nd bin (Corridor yes or no)	3rd bin (Corridor yes or no)	4th bin (Corridor yes or no)	5th bin (Corridor yes or no)
Name of Species	# of successful dispersals	# of successful dispersals	# of successful dispersals	# of successful dispersals	# of successful dispersals
e.g. Grizzly Bear					
Total					

Percentage of overall unsuccessful dispersal of species: ________

Appendix

Alberta Student Learning Targets:

Alberta Curriculum Connections	Outcomes
Science 7: Unit A (4)	Describe ongoing changes in biological diversity through extinction and extirpation of native species, and investigate the role of environmental factors in causing these changes *(e.g., investigate the effect of changing river characteristics on the variety of species living in the river; investigate the effect of changing land use on the survival of wolf or grizzly bear populations)* Evaluate the success and limitations of various local and global strategies for minimizing loss of species diversity *(e.g., breeding of endangered populations in zoos, development of seed banks, designating protected areas, development of international treaties regulating trade of protected species and animal parts)*
Science 7 skills (Analyzing and Interpreting)	Interpret patterns and trends in data, and infer and explain relationships among the variables *(e.g., interpret data on changing animal populations, and infer possible causes)*
Science (K-E) 8-9: Aboriginal Perspectives	Identify different perspectives on the nature of Earth and space, based on culture and science *(e.g., describe Aboriginal views of space and those of other cultures)* Stewardship: recognize that the traditional Aboriginal lifestyle supports a unique relationship with the environment
Science (K&E) 8-9	Skills: interpret patterns in data and explain relationships among the variables *(e.g., examine data on changing animal populations)*
Grade 9: Unit A (3)	Investigate human impact on diversity *(e.g., agriculture and habitat destruction)* Examine ongoing changes in biological diversity through loss of habitat and the extinction of species *(e.g., investigate the effect of changing land use on the survival of wolf or grizzly bear populations)* Examine local and global strategies for minimizing loss of species *(e.g., breeding of endangered populations in zoos).*
Science 10 Aboriginal Perspectives	Develop the concept of our connectivity to the natural world and the importance of caring for the environment
Science 10: Unit A (2)	The growth and interactions of life forms within their environments in ways that reflect their uniqueness, diversity, genetic continuity and changing nature; Includes ecosystems, biological diversity, the study of organisms,
Science 14:	Unit D: Investigating Matter and Energy in the Environment Estimate measurements *(e.g., collect quantitative data that demonstrate populations of organisms)*

Science 14-24: Unit A (2)	Analyze a local ecosystem in terms of its biotic and abiotic components, and describe factors of the equilibrium: Explain how various factors influence the size of populations; i.e., immigration and emigration, birth and death rates, food supply, predation, disease, reproductive rate, number of offspring produced, and climate change
Science 20: D3.3s	Demonstrate and assess the effect of environmental factors on population growth curves
Science 20-30:	Unit D: Changes in Living Systems
BIO 20-30:	Unit D: Changes in living systems them: energy, equilibrium change and systems
ENS 1010, 1020, 1040, 1110, and 1115	Outcomes: 2.1,2.2, 3.3 (cultural first nationals views to stewardship), 4.3 Fostering stewardship, living with the environment, natural resources, and natural resource management.

Next Generation Science Standards:

HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS4-6 Biological Evolution: Unity and Diversity

Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

Pre and Post Evaluation

Dispersal, Metapopulations, and Island Biogeography

Directions: Short answer responses (2-3 sentences)

1. What is the relationship between the Theory Island Biogeography and Metapopulation Theory?

2. What is habitat fragmentation and why is it a problem for biodiversity?

3. What is dispersal and why is it vital for population health?

4. What are some solutions to biodiversity loss?

Answer Key

1. Island Biogeography is a concept which explains the differences of biodiversity on ocean islands based on size and proximity of islands to other islands and the mainland. Metapopulation theory refers to terrestrial habitat (islands) patches, and expresses a similar concept that closer, larger, or connected patches experience greater biodiversity than smaller patches or habitats farther away from each other.
2. Habitat fragmentation is shrinking and dividing habitats typically through human activities such as roads, development, mining, and other industrial activities. These shrinking habitats are shrinking and isolating (separating) populations, weakening genetic pools. This is a problem because smaller habitat patches are leading to extinction events in species because they no longer have the range, resources, and space needed to survive.
3. Dispersal is when individual organisms move in search of a mate or more suitable habitat. Wildlife need to move freely or disperse across the landscape to sustain healthy ecosystems and support genetic diversity and resilience in populations. Without the ability to disperse, species suffer from genetic weakening and many times will risk their lives in inhospitable human dominated landscapes searching for mates. (example wolves or bears searching for a mate and being killed by ranchers, or hit by vehicles)
4. Corridors such as overpasses and underpasses connect landscapes and provide wildlife with more space and resources to sustain larger healthier populations. Through connected habitat patches species can disperse between different groups and increase genetic diversity within a metapopulation. And as climate continues to change ecosystems, corridors will give species the ability to adapt and move in search of more suitable habitats and climate conditions, mitigating against large scale species extinction due to climate change.