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| **Title:** | Genetic Rescue to the Rescue |
| **SubTitle:** | Preventing extinction through gene flow |
| **shortTitle:** | geneticRescue |
| **Module:** | conservationGenetics |

**Sponsored By** (blurb ~30 words):

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| The Lab of Sarah Fitzpatrick, PhD:  NSF? |

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| **Est. Time:** | 5-day unit (4-days +1 +1 add-ons) |
| **For Grades:** | 9-12 |
| **Target Subject:** | Science |
| **Lesson Hook:** | Florida panther conservation |
| **Driving Question(s):** | Can genetic rescue succeed in bringing a population back from the verge of extinction? |
| **Essential Question(s):** | * How do we use scientific methods to measure and address our negative impacts on the world? |
| **Learning Targets (I can):** | * Explain how genetic variation dictates an organism’s traits (phenotypes) and therefore its survival. * Explain how inbreeding leads to accumulation of recessive gene forms (alleles), leading to reduced survival and reproduction. * Explain what genetic rescue is (the introduction of genetic variation from a closely-related population) and how it can be applied to conservation. * Describe how model organisms (like guppies) can help scientists understand complex problems that are not practical to study in a species of interest (like endangered Florida panthers). |
| **Tags (up to 10):** | genetic rescue, genetics, conservation, fish, cat, natural selection, variation, evolution |

## Standards alignment notes:

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| NGSS Science  Target (guiding) standard. We will tailor the lesson to teach all the pieces of this.  **LS4.C-H1** Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.  What does 1 mean exactly? It’s kinda like *evolutionary potential*, but it says increase in number, not like adaptability. 2) Will be a big focus...need to give many opportunities for students to think about and absorb this. 3) This is weird that they don’t explicitly say natural selection here. 4) This is easy and makes sense.  These are also closely-tied target standards:  **LS4.B-H1** Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information–that is, trait variation–that leads to differences in performance among individuals.  LS4.C-H2 Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.  Target or connected standards?:  LS4.C-H5 Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species’ evolution is lost.  LS4.D-H2 Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. |

## **Loose Narrative**

(Just the gist; full procedure will go in meta/procedure.xlsx)

### **Part 1:** Saving a species: Genetic rescue and the Florida panther

1. Polymath Puzzle Warm-Up? Maybe a rebus? “Can we say+V the mountain lions of the southeast?” 🥫 🧑‍🤝‍🧑 🗣️+V the 🗻 🦁🦁 of the 🧭SE 🇺🇸 ?
2. Intro to the problem with first 1 min of this [Uproar documentary](https://www.youtube.com/watch?v=S98srPEViJs): Uno, a blinded panther as a charismatic story for a charismatic species; intro to different perspectives around cougars.
3. Brief Q&A: What voices/perspectives did you hear?
   1. Did everybody like panthers?
   2. What are some of the reasons you think people might like or dislike panthers?
4. Background, setting the stage for decline (1:30-2:52): ending with “If we lose them as a society...we lose.”
5. Scenario: The year is 1990. The Florida panther population has hit its lowest numbers on record?? What do you do? You are the head of \_\_\_\_\_\_ USFWS in Florida? Who makes the decision? You must choose what to do. 3 perspectives are being voiced:
   1. (No $, but Free??) Let them die...it’s hopeless anyway
   2. (?$$M) Bring them into captivity and do a selective breeding program
   3. (?$M) Employ “genetic rescue” and bring in panthers from another population to expand the gene pool
6. Immediate feedback: which one do you support & why (just take a few responses to not use up too much time in live classroom)
7. ->[Watch Vid 1.](#_heading=h.nvd4x2c7bmad) What is genetic rescue? Why is it necessary? Introduce kinked tails, infertile males. Will it work? What could go wrong?

#### After Vid 1:

Discussion Q: What species would you choose to test out genetic rescue (if you can increase a population’s fitness by introducing genetic variation)?

1. ->[Watch Vid 2.](#_heading=h.kv2vq4cmh7ig) More background (thru interactive video) on the parallels between Florida panthers and guppies.

#### After Vid 2:

Discussion Q: What are the advantages and disadvantages of using guppies to study genetic rescue as it applies to the Florida panther?

1. Dive into “genetic rescue:” what is it exactly? Go into inbreeding depression, deleterious mutations; variation and selection (will review in Part 2).
   1. In particular, focus on variation! (and keeping pace with environmental change
   2. Can’t have survival and evolution without variation.
2. Potential downsides (loss of local adaptation).
   1. example with Mountain ibex in Slovakia...when ibex from a different population that came from a different climate were introduced, the resulting fertile hybrids had babies at the coldest time of the year and the whole population went extinct :(
3. End: Tomorrow we’ll dive into the guppy study. We’re trying to answer the question: Can genetic rescue succeed in bringing a population back from the verge of extinction?

### Part 2: What do guppies have to do with panthers? Studying the unstudiable

1. Polymath Puzzle warmup?
2. Review. Question: Can we use genetic rescue to improve a population’s overall health?
3. Break it down: how do we test this?
   1. The simplest way to measure a species’ or a population’s health is to estimate population size. A “healthy” population has more individuals so a sudden disaster is unlikely to kill every individual. Large populations of sexually reproducing organisms also have more genetic variation, so when a new virus springs up, or if climate change causes the maximum summer temperature to be more intense, larger populations are more likely to have some resistant individuals.
   2. Population size in an isolated population like FL panthers that don’t get migrants is dictated by survival and reproduction rates.
   3. Q: Which of these scenarios would cause the population to increase?
      1. On average, each individual has 1 offspring in its lifetime
      2. On average, each individual produces 1.1 offspring in its lifetime
      3. On average, each individual produces 2 offspring in its lifetime
      4. Both II and III
   4. Heterozygosity is a measure of genetic variation. Low heterozygosity means most individuals are homozygous (an indicator that they’re inbred). If heterozygosity (having more versions of genes floating around in the population) increases population health, which of these relationships would you expect?
      1. Graph of positive relationship between heterozygosity and population size
      2. Graph of no relationship
      3. graph of negative relationship
   5. Setting Up predictions:
      1. Do we have them draw the curve?
      2. How does increase genetic diversity manifest? (In flashy fish, more genes may mean more color variants). In inbred cats, we expect the weird physical features to go away (kinked tails & cowlicks).
   6. Also expect increased phenotypic diversity. Do we have particular observable traits that directly affect survivorship? Or just color/pattern variability?
4. Introduction to the data. What are we gonna have them do exactly?
   1. Something to do with longevity and/or color data?
   2. testing the predictions from #3
5. Some kinda resolution that pivots back to applying the results to the panthers that we’ll get back to in Part 3

### Part 3:

1. Review how the guppy data inform what happened with the panthers (how they rebounded).
2. Are there caveats from the guppy data that also apply to the panthers? (i.e. something about particular idiosyncratic effects from the identity/level of divergence from the source population that can impact outcomes (i.e. leading to reduction in local adaptation or just some weird new trait))
3. Update what’s happened with panthers.
4. Introduction of habitat fragmentation as the new greatest threat to panthers (instead of sterility/ inbreeding depression)
5. Connect to cougar conflict in the Western US. Fragmentation, rancher conflict, collisions, etc.
6. [Have kids explore collision data in FL](https://geodata.myfwc.com/datasets/florida-panther-mortality/explore?filters=eyJEYXRlIjpbMTQ5Mzk2NDkyNzE4OS41NiwxNjA5NTQ1NjAwMDAwXX0%3D&location=26.491578%2C-81.497011%2C12.39). Make recommendations of which road(s) to prioritize?

Initial product ends at Part 3 (maybe all we can budget for at the moment, but we’ll see how it goes). Other “add-on,” modular lesson ideas

Part 4/extended project:

1. Make a curated list (modified from Fitz’s existing dataframe) of endangered/vulnerable species and have kids research which ones they would recommend for genetic rescue and why. Make a proposal for mitigation, given a budget and/or other constraints.

Part 5:

1. Another dive into a different set of guppy data to investigate a related question?

## Video Script Outlines

### Vid 1: What is genetic rescue? (2-3min)

Should be a standalone video which explains:

* BRIEFLY, what ***natural selection*** is
* That NS cannot work without variation in phenotypes
* Variation in ***phenotypes*** is generated by variation in ***genotypes***
* In panthers, we have reduced genetic variability by reducing and ***fragmenting habitats***
* The reduced genetic variability means:
  + accumulation of recessive genes
  + other random deleterious ***alleles*** that
  + generally, the population is less able to respond to ***selective pressures*** (hardship--from weather, predators, disease, whatever)
  + overall, inbreeding depression means the fitness (the number of offspring produced) of the whole population is reduced (show curve)
* ***Genetic rescue*** is based on the idea that we can rescue the population by introducing individuals from a different population that have other forms of genes (alleles) that can help the population be healthier, produce more offspring, and avoid extinction (show expanded peak of curve).
  + Downsides? (Make easy cut point for breaking up the video)
    - worst case = hybrid infertility
    - May make hybrid individuals be less locally adapted
    - May lose “uniqueness.” Abstract biodiversity question...what’s the value of these local variants?
  + In panthers, it’s risky...if you only have 20 individuals, if anything goes wrong, you could lose them. So...we study genetic rescue in a system that’s more manageable. To study genetic rescue, we need a system where we can:
    - selectively breed individuals to create (inbred lines) with reduced genetic variation
    - can be housed in a lab
    - are very common, cheap, and easy to work keep alive and breed
    - ideally small, and which can live in large groups without attacking each other so many can be stored in a small area
    - and which have been studied a bunch already, so we’re not starting from scratch
* What species would you choose to test out genetic rescue (if you can increase a population’s fitness by introducing genetic variation)?

->[After Vid 1](#_heading=h.kcp6v9xgqxjj)

### Vid 2. What do guppies have to do with panthers? (2 min)

Standalone video that explains the Fitzpatrick lab’s work thru consistent analogies to panthers.

* Video of guppies swimming in an aquarium which dissolves into a more abstract representation which will be used going forward to visualize guppies & gene flow
* Dr. Sarah Fitzpatrick is a researcher at Kellogg Biological Station at Michigan State University. Her lab uses Trinidadian guppies as a model for studying how reduced genetic variation leads to defects, low population fitness, and extinction. By using guppies, her lab group can experimentally test different strategies for genetic rescue and see how things like choice of what individuals are introduced affect outcomes—which you could not do in an endangered species that we’re trying to save.

Cut to video of Sarah talking, maybe showing off her lab and methods?? Next bit (if Fitz is willing) will be her narration.

* So, why guppies? They’re really easy to keep in the lab, thousands of papers have been used to study them. But in the wild, on the island of Trinidad in the Caribbean, there’s also a nice natural experiment (meaning an experiment that happens by chance in nature that scientists can take advantage of). So, whereas panthers used to range across pretty much the whole US, they’ve been hunted extensively and their habitat fragmented by roads, and deforestation and development, to the point where the Florida population was reduced to a few individuals in this tiny area.
* There’s an interesting parallel in Trinidadian guppies. They’re a super common fish that live in mountain streams on the island. Because they’re tiny little fish (not like salmon), any small waterfall over a rock can be a big barrier which prevents fish from encountering each other to mate, and limits gene flow. But occasionally, a few individuals will somehow jump up and make it into the higher pool and form a new colony. (This is like if a few panthers make it to one side of a busy highway and become effectively isolated from the rest). In each case, they have a small pool of individuals to mate with, which means inbreeding between cousins and siblings and quickly a lot of genetic disorders.
  + In panthers: kinked tails, infertile males, overall sickliness
  + In guppies: ??
* So our question is: if we start out with an inbred population, which has low survivorship and low fitness, can we rescue them by introducing new genetic variation?
* In both guppies and panthers, we would expect hybrid individuals to:
  + be more variable in appearance
  + to suffer less from recessive abnormalities
  + to have higher reproductive success
  + to survive longer than their parents
* At the population level, we expect the population size (number of individuals) to increase.
* If we see those patterns, this would support the effectiveness of genetic rescue as a way to conserve endangered species.

[-> After Vid 2](#_heading=h.ghx8w25yjsh5)

## Resources:

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| Media |
| * [Range map showing how weird the FL population is](https://en.wikipedia.org/wiki/Puma_(genus)#/media/File:Cougar_range_map_2010.png) |
| Explainers/Basic background: |
| * [USFWS Florida Panther Profile](<https://www.fws.gov/refuge/florida_panther/wah/panther.html>) * [Nat Geo: Planned roads could imperil Florida's panthers—and last remaining wilderness](<https://www.nationalgeographic.com/animals/article/florida-toll-road-threatens-wildlife-panthers?loggedin=true>) * [The Florida Panther: Past, Present and Future](<https://edis.ifas.ufl.edu/publication/UW402>) * [America’s cat is on the comeback](https://www.americanscientist.org/article/americas-cat-is-on-the-comeback) |
| Scientific papers: |
| * [Endangered Florida panther population size determined from public reports of motor vehicle collision mortalities](https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2664.12438) * [American Society of Mammologists notes on Florida panther species status](https://www.mammalsociety.org/uploads/committee_files/ASM-SCBNA%20Letter%20on%20Florida%20Panther%205-year%20Review.pdf) * [The impact of genetic restoration on cranial morphology of Florida panthers (Puma concolor coryi)](https://www.researchgate.net/profile/Kyle-Finn/publication/274814227_The_impact_of_genetic_restoration_on_cranial_morphology_of_Florida_panthers_Puma_concolor_coryi/links/5d108db4a6fdcc2462a039df/The-impact-of-genetic-restoration-on-cranial-morphology-of-Florida-panthers-Puma-concolor-coryi.pdf) * [De Novo Assembly and Annotation from Parental and F1 Puma Genomes of the Florida Panther Genetic Restoration Program](https://www.g3journal.org/content/ggg/9/11/3531.full.pdf) |
| Interactive widgets: |
| * [panther road mortality](https://geodata.myfwc.com/datasets/florida-panther-mortality/explore?filters=eyJEYXRlIjpbMTQ5Mzk2NDkyNzE4OS41NiwxNjA5NTQ1NjAwMDAwXX0%3D&location=26.491578%2C-81.497011%2C12.39) (possible fodder for Day 5/and/or project add-on??) |
| Possible Contacts/collaborators: |
| * [Madelon Van De Kerk](https://www.researchgate.net/profile/Madelon-Kerk-2) (maybe can get us Panther data and/or give feedback on lesson accuracy) * [Larisa De Santis of Vanderbilt](https://www.vanderbilt.edu/evolution/person/larisa-r-g-desantis/)...maybe can consult about Pizzlies as another example of the pros & cons of gene flow caused by climate change |

## Data:

Panthers

* [Survival of panther age/sex categories](https://docs.google.com/spreadsheets/d/1C_rDlJETi0ByvfBQfIz9eqCMh6twb3Xk_7TOwGcG3Is/edit?usp=sharing)
* [Heterozygosity and population size](https://docs.google.com/spreadsheets/d/14JzEVne6jCYenV3_nrUgQiCpEEaiTTulCK16i9D4IUQ/edit?usp=sharing)

Guppies

## Abstracts & Other Text Blocks

**Abstract (<250 words)**

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**Scientific Background (200–350 words)**

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| ### Scientific Background  Further Reading: Add links with markdown format: [*link text*](*link URL*)  - [A Puma Hunter Is Enlisted to Track Down and Help Save Florida Panthers [Excerpt]](https://www.scientificamerican.com/article/a-puma-hunter-is-enlisted-to-track-down-and-help-save-florida-panthers-excerpt/) |

**Lesson <-> Research Connections (200–350 words)**

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| ### Lesson Connections to this Research |