Think of this document as a sketch—a rough container for the titles, ideas, overall structure, links, and draft language for the lesson(s) we will be developing in the coming weeks.

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

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

| The Lab of Sarah Fitzpatrick, PhD:  NSF DEB 2016569 |
| --- |

[Client Goals Document](https://drive.google.com/open?id=14LiluzO0WscsMx0J0EOb0B-HeyBfqVIJ)

| **Est. Time:** | 5?-day unit |
| --- | --- |
| **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 develop solutions for our negative impacts on the world? |
| **Tags (up to 10):** | genetic rescue, genetics, conservation, fish, cat, natural selection, variation, evolution, extinction |

## Learning Goals:

### Linked from [alignment-reference\_all-standards\_GSheets](https://docs.google.com/spreadsheets/d/119Yqmty-yPtGfEcibUf76pre9gI7DkpL/edit#gid=1024605089)

| **Create Learning Goal (LG) Statements from Client Outreach Aims; LG# used in next tab to align to standards.** | |
| --- | --- |
| **LG#** | [**Learning Goal (Students Will Be Able To)**](https://tips.uark.edu/using-blooms-taxonomy/) |
| 1 | Provide examples of variation in genes, traits, and individual survival, and why each is important for a species to persist and evolve. |
| 2 | Predict how increasing genetic variation by introducing new individuals (i.e. by conducting genetic rescue) will impact population size. |
| 3 | Summarize how human activities fragment animal populations and how habitat fragmentation limits gene flow, reducing genetic variation. |
| 4 | Create a logic model showing how genetic rescue occurs; i.e. how the introduction of new individuals to a small, inbred population on the verge of extinction provides needed genetic variation for the population to survive and recover. |
| 5 | Demonstrate understanding of how reduction in both population size and genetic variation in endangered species lead to the "extinction vortex"—the increasing likelihood of small populations to blink out due to low population size and recessive genetics from inbreeding. |
| 6 | Propose a model organism to use for research on species that are endangered or intractible to study. |
| 7 | Interpret scatter plot data from a model organism (Trinidadian guppies) and compare to related data in an endangered species (Florida panthers) to draw broader conclusions about the effectiveness of genetic rescue. |
| 8 | Assess the potential risks and benefits of genetic rescue for a particular species, and propose a course of action. |

## Guiding Standard:

NGSS Science

We will tailor the lesson to teach all the pieces of this, while also hitting the other learning objectives.

**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.

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.

### See Full standard alignment summary in [**alignment-reference\_all-standards\_GSheets**](https://docs.google.com/spreadsheets/d/119Yqmty-yPtGfEcibUf76pre9gI7DkpL/edit#gid=1024605089)

## Lesson Outline

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

Part 1 (which will likely be 2-3 days/class periods) serves as a narrative hook and background refresher for relevant genetics concepts necessary to understand Dr. Fitzpatrick’s work. Sets up the bounding narrative of Florida panther genetic rescue to get students engaged in the topic, that will eventually segue to understanding model systems and analyzing parallel data in Trinidadian guppies (in Part 2). Part 1 is an “adapter” that engages and scaffolds student understanding in order to connect with Dr. Fitzpatrick’s work.

[Presentation 1](https://docs.google.com/presentation/u/0/d/1Zui07LwU041nPLQDNkwIAl-N1HXMm0e2e75h3XRQamM/edit)

1. Polymath Puzzle Warm-Up? 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. Background/review of related genetic concepts:
   1. inbreeding
   2. nucleotides
   3. alleles
   4. dominant/recessive
   5. etc.
6. Unhealthy cats section...recessive genetic problems
7. Role Play 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
8. Immediate feedback: which one do you support & why (just take a few responses to not use up too much time in live classroom)
9. End by saying we’ll go more into genetic rescue in depth tomorrow.

### Part 2: How do we save a species without risking its extinction? Studying the unstudiable

The purpose of this lesson is to transition from the bounding narrative of panthers to a worked example of studying genetic rescue in a model organism (Trinidadian guppies). Students will learn about the stakes (what can go wrong) with genetic rescue and think about why model organisms are important for studying species that are endangered or intractable to study. They will then analyze the parallel datasets in the guppy and panther systems to deepen understanding of what genetic rescue is and when/why it is important.

Links:

* [Presentation 2](https://docs.google.com/presentation/d/1Gnbn8YNfX2UTx9A85dIE-U0PN7Lp2fG6pp14AziPUT4/edit#slide=id.ge620142883_0_1)
* [Background scientific paper on genetic rescue in guppies for this lesson](https://onlinelibrary.wiley.com/doi/epdf/10.1111/eva.12356)
* GP Original Video 1: Intro to Genetic Rescue
  + [Script](https://docs.google.com/document/d/1w0RJd03dT2a13pcCw-NvqaQo2Wc-XvxjGXe0Nhs4Zn8/edit#)
  + [Storyboard](https://docs.google.com/presentation/d/1R2jbz4E0HfW7PVTEKuszyn7TeRIQTn7fyTEcMcLvEIA/edit#slide=id.ge7f7f5e6f7_0_9)
  + [**Rendered video segments**](https://drive.google.com/drive/folders/1JRTNxwFhWxbCC-GD5sZLX_XY8d0xBh1D)

### Learning Goals for this Part

2. Predict how increasing genetic variation by introducing new individuals (i.e. by conducting genetic rescue) will impact population size.

3. Summarize how human activities fragment animal populations and how habitat fragmentation limits gene flow, reducing genetic variation.

4. Create a logic model showing how genetic rescue occurs; i.e. how the introduction of new individuals to a small, inbred population on the verge of extinction provides needed genetic variation for the population to survive and recover.

5. Demonstrate understanding of how reduction in both population size and genetic variation in endangered species lead to the "extinction vortex"—the increasing likelihood of small populations to blink out due to low population size and recessive genetics from inbreeding.

6. Propose a model organism to use for research on species that are endangered or infeasible to study.

7. Interpret scatter plot data from a model organism (Trinidadian guppies) and compare to related data in an endangered species (Florida panthers) to draw broader conclusions about the effectiveness of genetic rescue.

1. Polymath Puzzle warmups
   1. Get students thinking about phenotypic variation and distinguishing variation within and across traits. This will provide a useful analog for discussing phenotypic and genetic variation.
2. Watch vid 1 ([storyboard](https://docs.google.com/presentation/d/1R2jbz4E0HfW7PVTEKuszyn7TeRIQTn7fyTEcMcLvEIA/edit#slide=id.ge971905975_0_3); [script](https://docs.google.com/document/d/1w0RJd03dT2a13pcCw-NvqaQo2Wc-XvxjGXe0Nhs4Zn8/edit#))
   1. Review of Day 1. What is genetic rescue? Why is it necessary? What could go wrong? What model organism could we use to study genetic rescue of endangered species without possibly leading to extinction?
   2. Interrupt the video with some *formative* discussion and/or worksheet prompt(s).
   3. For example, after the section on Extinction Vortexes, ask students to fill in the blanks for a logic model of genetic rescue. (Something like this on their Part 2 worksheet).



* 1. And have them think about an extinction vortex in graph terms.
  2. Potentially go over both as a class (i.e. embed correct worksheet responses in the powerpoint) to ensure understanding before moving on. (Assess deeper understanding of extinction vortex later).

1. Watch remaining part of video 1. Have students brainstorm in groups. What organism could meet the requirements?
   1. What model organism would you use to study genetic rescue?
      1. (Basically, we need to replicate the conditions of endangered species in a common species).
      2. Conditions for the model organism should be:
      3. Have inbred populations or can be selectively bred to create inbred lines with reduced genetic variation
      4. Affordable or common in nature
      5. Fast development (short time between generations; [e.g. days or months])
2. Share out/discuss student ideas (Teachers guide needs to have tips...how to support this discussion...mainly asking students if/how they meet the specs)
3. Watch vid 2 (2 min?) [See Script](https://docs.google.com/document/d/1w0RJd03dT2a13pcCw-NvqaQo2Wc-XvxjGXe0Nhs4Zn8/edit#heading=h.ld5nqvok1kc6)
   1. A list of common models for genetic rescue:
      1. fruit flies
      2. flour beetles
      3. nematodes
      4. yeast
      5. partridge pea
   2. We’re going to focus on Trinidadian guppies
   3. introduce Dr. [Sarah Fitzpatrick](mailto:sfitz@msu.edu), describing her study system.
   4. Then narrator (Stephanie) returns to pose another question to students: Making predictions. How can we know if genetic rescue worked?

**Overview of the rest of the lesson**

Rest of the lesson focuses on setting up and testing hypotheses. Goal is to test whether genetic rescue worked in the guppies. Make recommendations about the practicality of genetic rescue in other systems. Reveal what happened in the Florida panthers. Reflection questions/products that crystallize take homes for students.

* 1. Predicted relationships?
     1. (i.e. we expected population to increase significantly a generation or two after the new individuals are introduced)
     2. genetic variation (heterozygosity) should increase, and as a result, population should also increase (though not necessarily linearly).

1. Students are given 2 graphs and 2 data tables. Need to label axes and title from data table.
2. Interpret success of the experiment
3. Explore different parts of the data. (Was the population increasing rapidly at the end of the experiment?
   1. What would we have concluded if we had ended the experiment after the first year?
4. Reveal the panther data in the same way (have them label the graphs from the tables)
5. Was the panther genetic rescue successful? Was genetic variation successfully increased to the same degree as in the guppies?
6. Close with ending part of the [Video about Uno](https://www.youtube.com/watch?v=S98srPEViJs)?
7. Leave it with multiple endings for teachers
   1. Assign a reflection prompt
   2. Let students explore cat collision data and make
   3. Have them explore IUCN data to find a species they think might be a good candidate for genetic rescue?

Below are the main data/results we can have students investigate somehow. What should we do?

| Genetic Variation in both systems |
| --- |
|  |
|  |
| Population size in both systems |
|  |
|  |

1. Q for [pmarquez.zacarias@gmail.com](mailto:pmarquez.zacarias@gmail.com), what activity will we have them do with these data? Very interesting stuff here! (I will discuss this in our meeting)
2. Once they’ve set up predictions, have them do something to analyze the data. But what? Ideally something they can do on pen and paper, given that a lot of schools don’t have 1:1 laptops.
   1. The data files are here: [geneticRescue\_sci/data](https://drive.google.com/drive/folders/1xkG4UfaqzALPKRyo_feAEE27MyaIg449?usp=sharing)
   2. Break it down: how do we test this?
   3. 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
   4. 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).
   5. Also expect increased phenotypic diversity. Do we have particular observable traits that directly affect survivorship? Or just color/pattern variability?
3. Introduction to the data. What are we gonna have them do exactly?
   1. Something to do with longevity and/or color data?
   2. I think it might be good to have them read a slightly modified version of the main methods, and fill in blanks. This could help make sure they understand what was done. (And how hard it was).
   3. Should probably introduce Trinidad and the study site a little bit. (We’re focusing on the Taylor data [not Caigual]).
   4. Definitely want a question on how many generations passed.
   5. Maybe have them identify parts of the graph (population pulses from new births; declines)
   6. What’s causing the declines in guppy census estimates? Downstream migrations and deaths.
   7. They could look at the downward trend in heterozygosity and population size in both systems (before genetic rescue) and be asked to compare the plots and explain how the guppies are a good model for an “extinction vortex”. i.e. They have a small population size with low genetic diversity, just like the panthers. You could also provide some dummy graphs and say which of these data would be a better model for studying genetic rescue.
4. Some kinda resolution that pivots back to applying the results to the panthers that we’ll get back to in Part 3
5. Here are the actual results of genetic rescue in the 2 systems (plots are in assets/guppy-population\_before-after.png, etc)

### 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)

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:**

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.

### Future Extension(s) If the Alongside Wildlife Foundation funds our grant:

* Connect to cougar conflict in the Western US. Fragmentation, rancher conflict, collisions, etc.
* [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?
* Learn about latest genomic results on species concepts (controversy of protecting something that’s not really that genetically distinct)?
* Learn about persistent low genetic diversity (need for more genetic rescue)

## Video Script Outlines

### Vid 1: What is genetic rescue? (6min)

### 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:

| 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>) |
| Further Reading |
| * [Of kings and Alpine ibex: the amazing resurrection of a species from near-extinction](https://natureecoevocommunity.nature.com/posts/59792-of-kings-and-alpine-ibex-the-amazing-resurrection-of-a-species-from-near-extinction) |
| Scientific papers: |
| * **Main study the guppy data in the lesson comes from:** [Gene ﬂow from an adaptively divergent source causes rescue through genetic and demographic factors in two wild populations of Trinidadian guppies](https://onlinelibrary.wiley.com/doi/epdf/10.1111/eva.12356) * [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) * [Read this Science paper from 1892!](https://www.jstor.org/stable/1766860?seq=1#metadata_info_tab_contents) * [Puma genomes from North and South America provide insights into the genomic consequences of inbreeding](https://www.nature.com/articles/s41467-019-12741-1.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 project add-on?? Currently waiting on a funding decision for this extension) |
| 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

Extensions:

* [Dalmatian backcross project?](https://ckcusa.com/blog/2019/november/the-dalmatian-back-cross-project/)

## Abstracts & Other Text Blocks

**Abstract (<250 words)**

|  |
| --- |

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

| ### 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)**

| ### Lesson Connections to this Research |
| --- |