Bringing Research Data to the Ecology Classroom: Opportunities, Barriers, and Next Steps

Using Authentic Scientific Data to Improve Quantitative Reasoning in Ecology and Evolutionary Biology

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BEACON
An NSF Center for the Study of Evolution in Action

MICHIGAN STATE UNIVERSITY Founded 1855

Public Understanding of Science has never been more important

Speaking of Science

New Florida l
resident chall
taught in scie

By Sarah Kaplan July 1

"Academic freedom bills are now the new normal"

Glenn Branch, NCSE

NATIONAL CENTER for SCIENCE EDUCATION

https://www.washingtonpost.com/news/speaking-of-science/wp/2017/07/01/new-florida-law-lets-any-resident-challenge-whats-taught-in-science-classes/?utm_term=.2a55a9c51ed2

MARCH FOR SCIENCE

ge of Fighting cience

ings play out in people's everyday

A woman walks on the dried-up river bed in southwest China's Chongqing Municipality, August 16, 2006. (China Daily / Reuters)

JULIE BECK | JUN 24, 2017 | SCIENCE

The Atlantic

http://www.cnn.com/2017/04/22/health/global-march-for-science/index.html

We need to improve scientific literacy

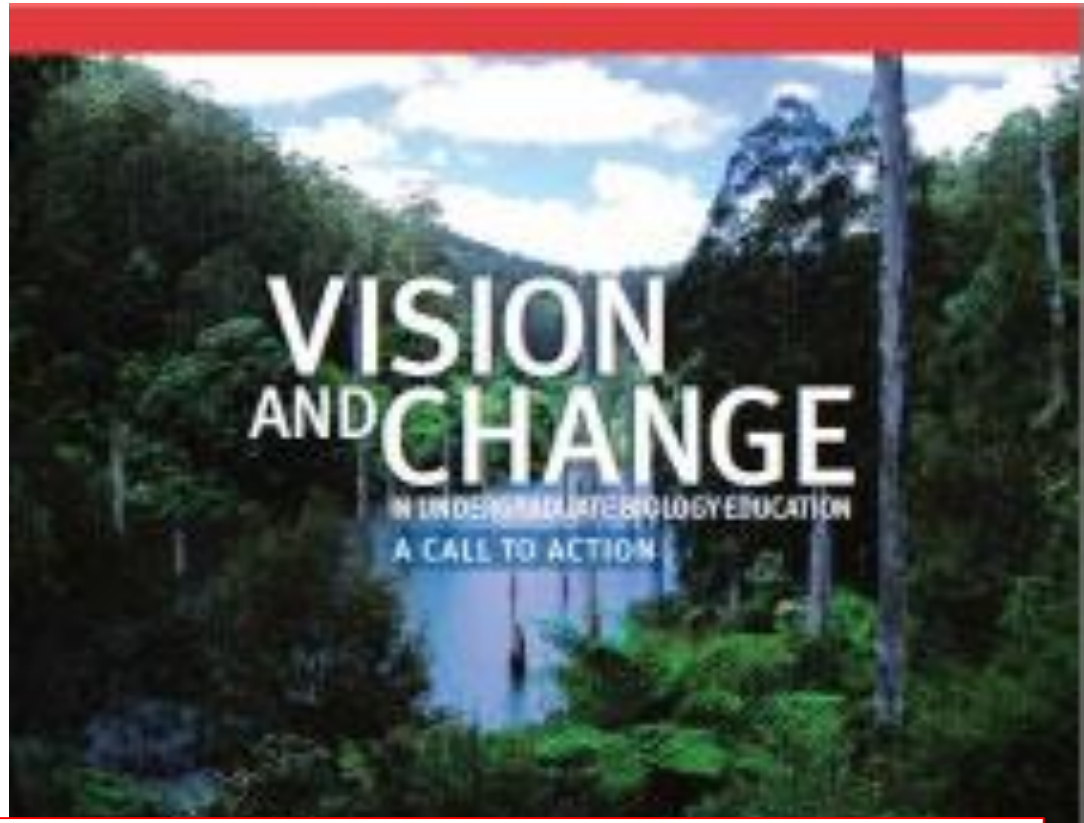
A scientifically literate person - understands what it means to do science

- **Critically evaluate claims and evidence**
- **Use and understand existing models.**
- Build models based on experimental evidence (physical, conceptual, and/or mathematical).
- Think of an experiment to test a particular question, hypothesis, or explanation.
- **Understand the importance and limitations of data to the scientific endeavor**.

Vision for Implementing Change

Integrate Core Concepts and **Competencies** throughout the Curriculum

Core Competencies: Focus on Student-Centered Learning



The eight practices of science and engineering that the *Framework* identifies as essential for all students to learn and describes in detail are listed below:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Current Goals

- Improving student understanding of how science relies on evidence (data) to support or reject claims

- Exposing undergraduates to real data, inquiry methods, and the use of models

- Engaging undergraduates in authentic research

To improve understanding of evolution

Current Projects

- Improving student understanding of how science relies on evidence (data) to support or reject claims

DATA Nuggets

Melissa Kjelvik and Liz Schultheis

DATA Nuggets

Activities that bring real scientific data into the classroom, guiding students through the entire process of science while building their quantitative abilities.

Search

Featured Data Nugget: Do salmon have the genes necessary to survive warming waters from climate change?

MAKE YOUR OWN DATA NUGGET!

STANDARDS ALIGNMENT

DATA NUGGET EXTENSIONS

DIFFERENTIATED INSTRUCTION

PUBLICATIONS AND RESEARCH

DATA NUGGETS WERE FOUNDED IN 2011 BY MSU SCIENTISTS AND TEACHERS IN THE GK-12 PARTNERSHIP. THEY ARE CURRENTLY FUNDED BY A DRK-12 GRANT FROM THE NATIONAL SCIENCE FOUNDATION.

RECENT NEWS & EVENTS

Data Nuggets at the National Academies Special Topics Summer Institute on Quantitative Biology

CONTACT US

Please feel free to email Liz (eschultheis@gmail.com) or Melissa (kjelvikm@gmail.com) with any questions you might have. If you would like to create your own Data Nugget, include Data Nuggets as a broader impact in an upcoming grant, or are using Data Nuggets in your classroom for the first time, let us

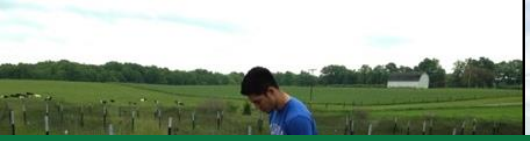
DATA NUGGETS BY THEME

adaptation agriculture algae animals behavior biodiversity biofuels birds climate change

DATA Nuggets

http://datanuggets.org

- Free activities that bring real data into the classroom, along with all its messiness & complexity
- Based on authentic ongoing research
- Designed to guide students through the process of science, including data analysis & interpretation
- Can easily be modified for use in undergraduate biology



DATA Nuggets

Activities that bring real scientific data into the classroom, guiding students through the entire process of science while building their quantitative abilities.

Search

MEET THE SCIENTISTS!

Want to know more about the scientists behind each Data Nugget? Click on their name for a link to their professional websites, or on their Data Nugget to learn more about their research!

Search:

	Name	Institution	About Me	Data Nuggets
	Mélanie Banville	Arizona State University	Since she was young, Melanie has had a keen interest for wildlife which led her to pursue a B.S. in Zoology at McGill University, Montreal, Canada. Shortly after her graduation, she left Canada to travel and work in the United States. She has been working as a professional wildlife biologist on a wide variety of wildlife-related projects for over a decade, eight of which were in the desert southwest. Melanie truly believes that a better understanding of urban ecology is of fundamental importance for the future of all living organisms as our urban boundaries expand and put more pressure on our ecological resources.	Lizards, iguanas, and snakes! Oh my!
	Tina Barbasch	Boston University	I first became interested in science catching frogs and snakes in my backyard in Ithaca, NY. This inspired me to major in Biology at Cornell University, located in my hometown. As an undergraduate, I studied male competition and sperm allocation in the local spotted salamander (Ambystoma maculatum). After graduating, I joined the Peace Corps and spent 2 years in Morocco teaching environmental education and 6 months in Liberia teaching high school chemistry. As a PhD student in the Buston Lab, I study how parents negotiate over parental care in my study system the clownfish (Amphiprion percula), otherwise known as Nemo.	Raising Nemo: Parental care in the clown anemonefish

Anatomy of a Data Nugget

Research background

Background information

Do insects prefer local or foreign foods?

Featured scientist: Elizabeth Schultheis from Michigan State University

Research Background:

Insects that feed on plants, called **herbivores**, can have big effects on how plants grow. **Herbivory** can change the size and shape of plants, the number of flowers and seeds, and even what plant species can survive in a habitat. For this reason, scientists study how insects and plants interact, and how much damage insects to do plants. A plant with more herbivore damage will most likely perform worse than a plant with less.

Native plants are those that naturally occur in an area without human interference. When a plant is moved from one area to another it is called an **exotic** plant. A small proportion of exotic plants become **invasive**, meaning they grow aggressively, take over habitats, push out native species, and harming human interests. What determines if an exotic species will become invasive? Scientists are very interested in this question because it could help control invasions underway and help stop new ones in the future.

Question and Hypothesis

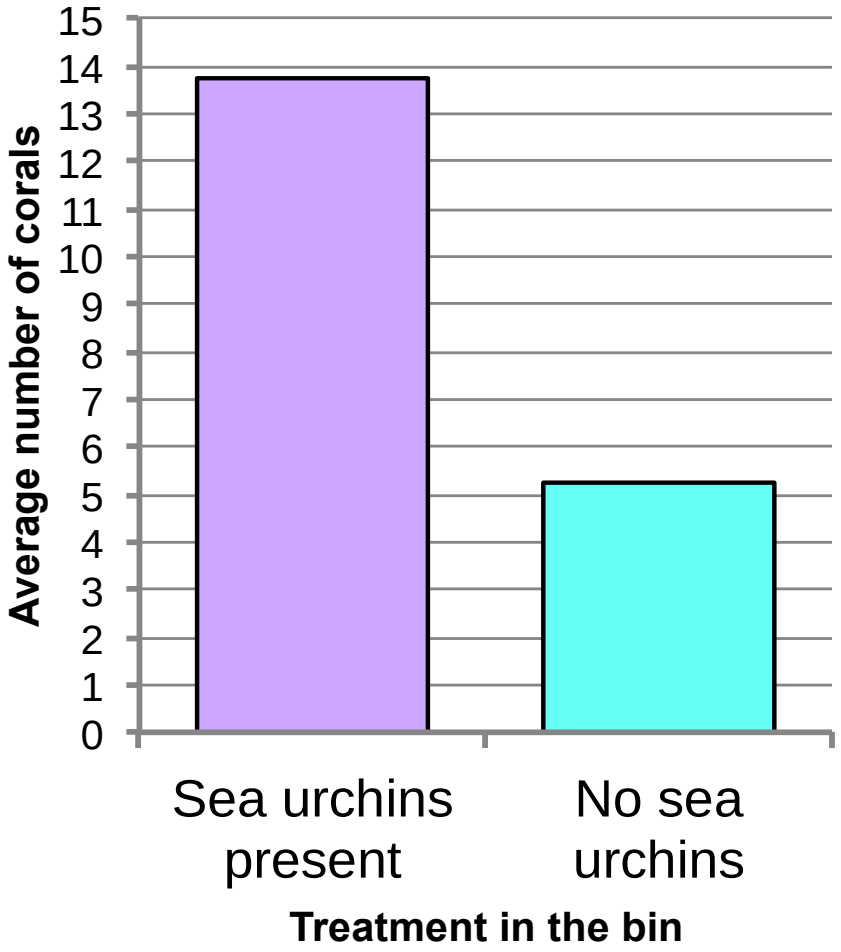
What is the hypothesis? Find the hypothesis in the background and underline it. A hypothesis is proposed explanation for an observation, which can then be tested with experimentation.

Scientific Question: Do invasive species receive less damage from herbivores compared to native and exotic species?

Data and data visualization

Treatment in the bin	Bin #	Number of corals on tile
Sea urchins present	1	8
Sea urchins present	2	12
Sea urchins present	3	10
Sea urchins present	4	25
No sea urchins	5	1
No sea urchins	6	3
No sea urchins	7	6
No sea urchins	8	11

Average number of corals on tile when urchins present	13.75
Average number of corals on tile when there are no sea urchins	5.25



Scaffolding & Differentiated Instruction

Type A graph provided	▪ Data: displayed on graph ▪ Axis labels and scale provided
Type B	▪ Data: student graphs data ▪ Axis labels and scale provided
Type C student creates graph	▪ Data: student graphs data ▪ Axis labels and scale not provided

Level 1	▪ Elementary and above
Level 2	▪ Middle School and above
Level 3	▪ High School and above
Level 4	▪ Advanced High School students ▪ College undergraduates

Constructing explanations

Interpret the data:

Make a **claim** that answers the scientific question.

What **evidence** was used to write your claim? Reference specific parts of the table or graph.

Explain your **reasoning** and why the evidence supports your claim. Connect the data back to what you learned about the system.

But do they work?????

Scientific Data in Schools: Measuring the efficacy of an innovative approach to integrating quantitative reasoning in secondary science

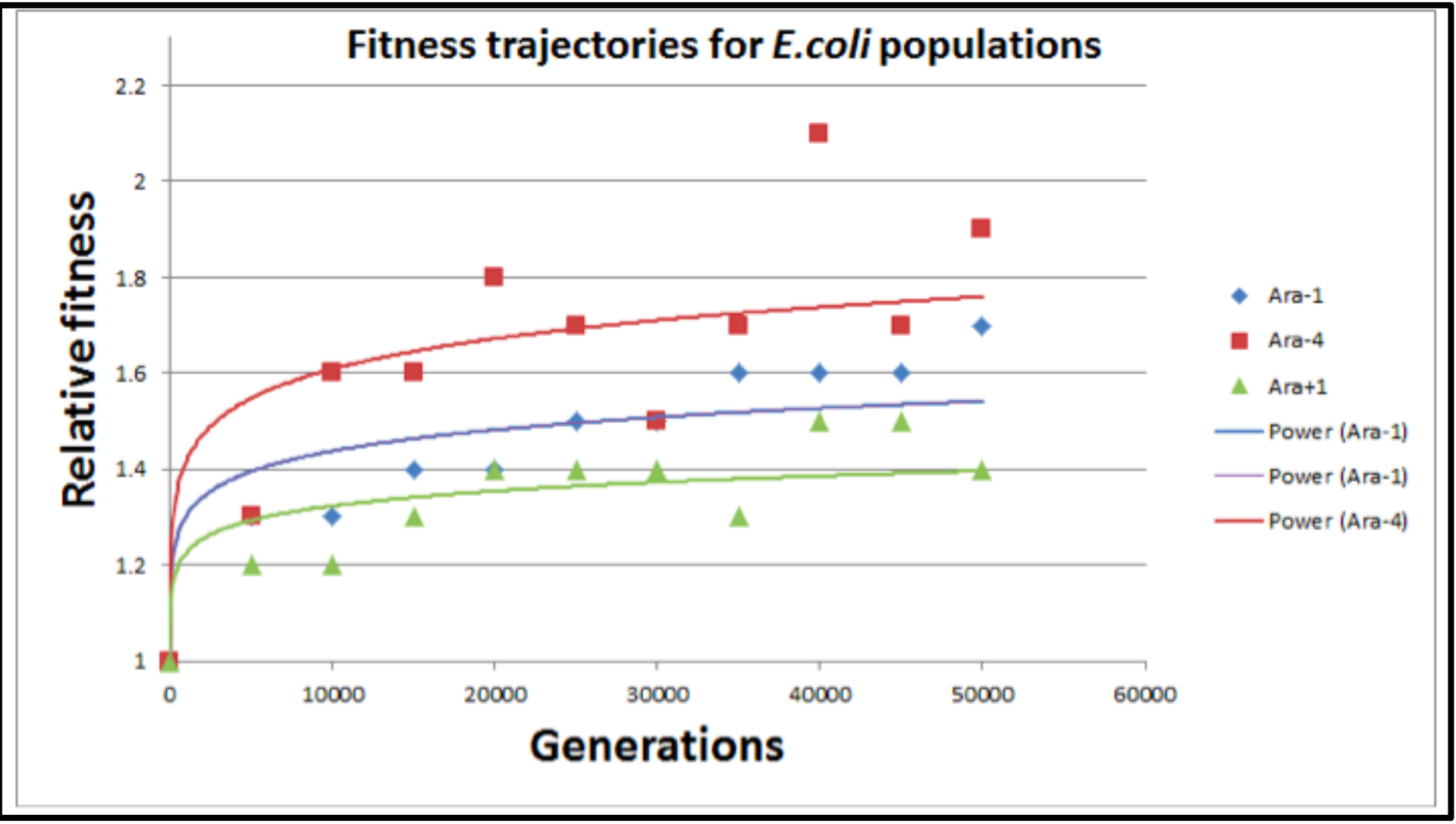
BSCS
A SCIENCE EDUCATION CURRICULUM STUDY

We want evidence...

Through the repeated use of Data Nuggets in the classroom, high school students will:

1. Understand that science is an active process and how we learn about the natural world.
2. Identify and differentiate between scientific questions, hypotheses, and predictions.
3. Build their quantitative skills by working with data, graphing, and interpreting quantitative information.
4. See science as an approachable and attainable career.

Using Data Nuggets in Undergraduate Biology to Teach Evolution



Usi… …uate

The

Evo

slide version 2

Use the data below to answer the scientific question:

Light Habitat		
	Number of Attacks	
Transect	Light Model	Dark Model
1		2
2		
3		
4		1
5		
6		
7		
8		
9	1	1
10		
11		1
12		
13		
14		
15	1	
16		
Total # of Attacks		
Sum of all attacks in habitat		
Proportion Attacks		

Dark Habitat		
	Number of Attacks	
Transect	Light Model	Dark Model
1	1	1
2		1
3		
4	1	
5	1	
6		
7	1	
8	1	1
9	1	
10	2	
11	1	
12	1	
13		
14	4	
15	1	1
16	1	1
Total # of Attacks		
Sum of all attacks in habitat		
Proportion Attacks		

Using Data Nuggets in Undergraduate Biology to Teach Evolution

… and critically evaluate claims

	Freezer Full of Fossils	Of Mice and Sand
Fall 2016	30%	36%
Spring 2017	38%	54%

Percentage of students who were able to use data correctly to provide evidence to support their claim

Current Goals and Projects

- Improve student understanding of how science

Avida-Ed Active Lens: Learning about Evolution and the Nature of Science using Evolution in Action

- Engage undergra tic research

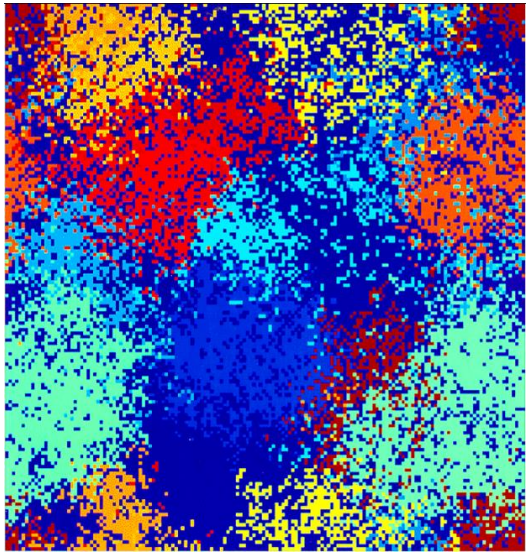
Rob Pennock
Jim Smith
Louise Mead
Mike Wiser
Cory Kohn
Diane Blackwood

Avida-ED is the education version of a digital evolution platform

bit.do/avida-ed

Avida-ED is the education version of a digital evolution platform

Population
of digital organisms



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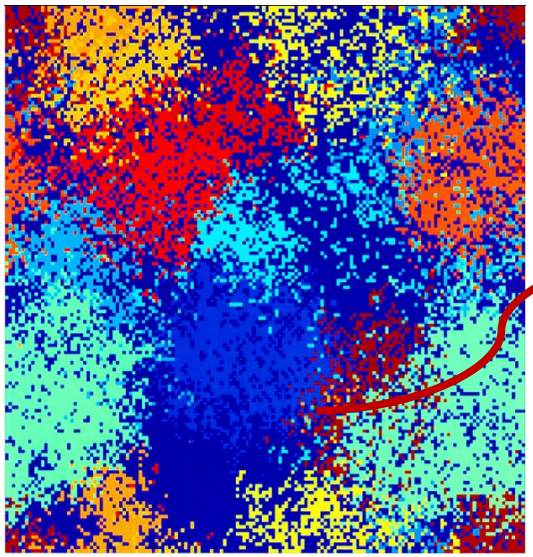
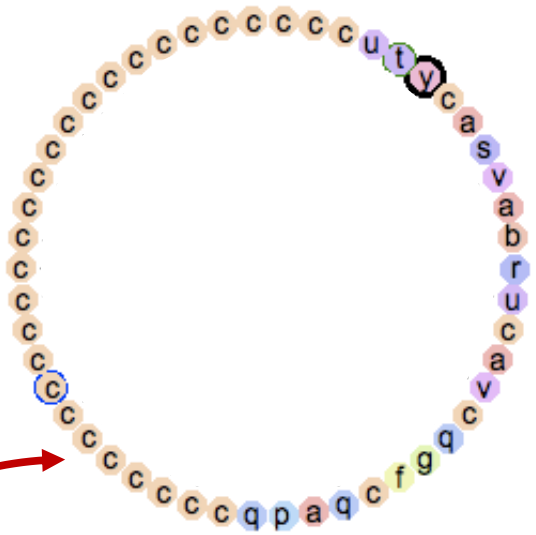
Population
of digital organisms





Computer code
genome

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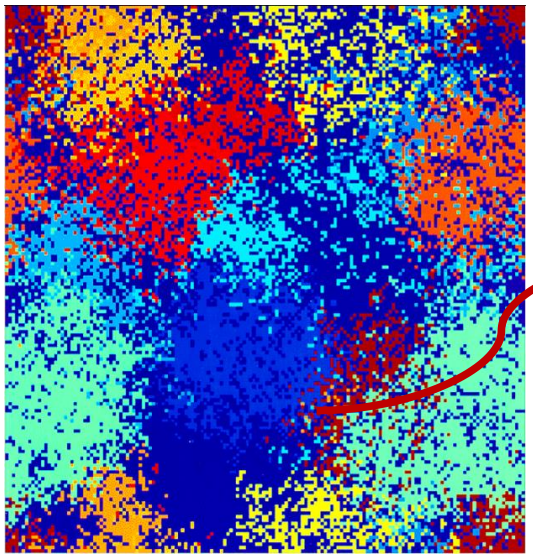
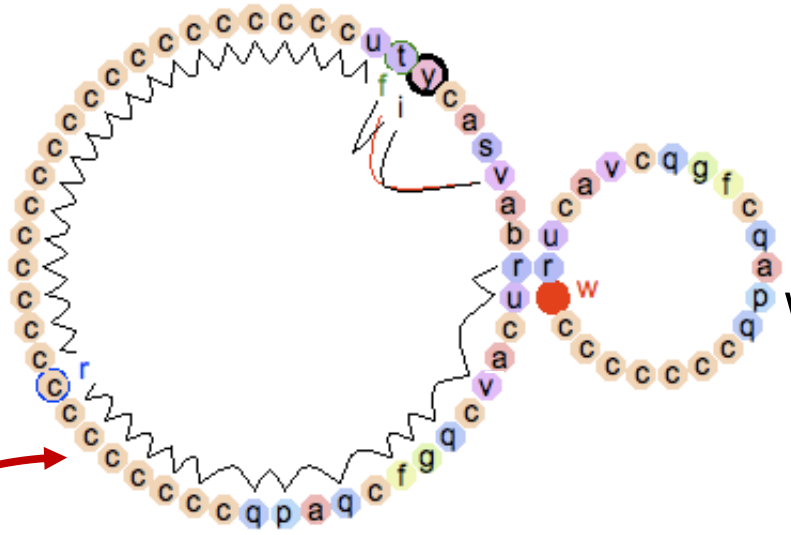
Population
of digital organisms





Computer code
genome
self-replicates
with probabilistic
mutation rate

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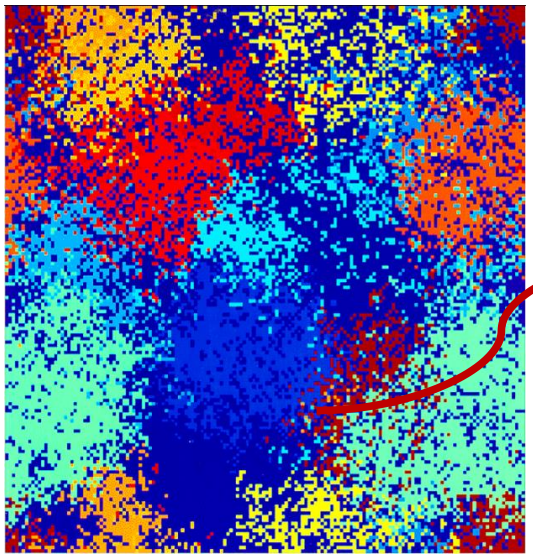
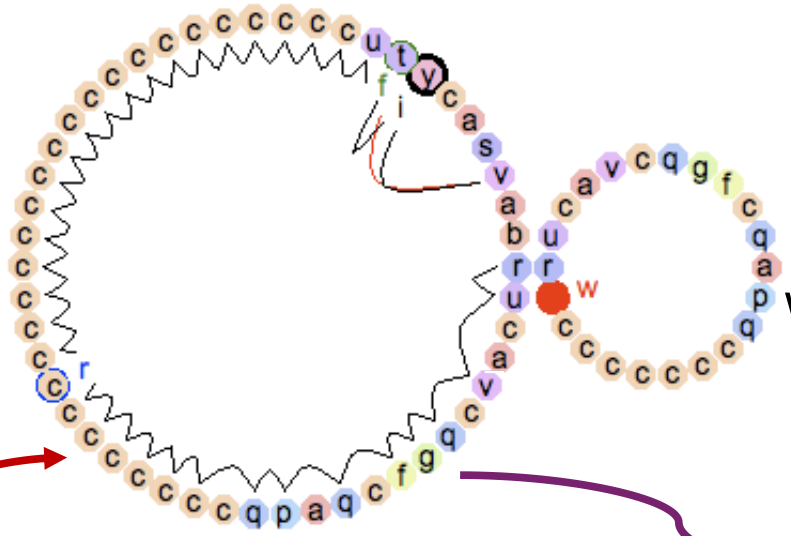
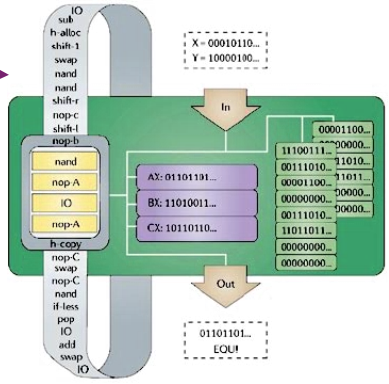
Population
of digital organisms





Computer code
genome
self-replicates
with probabilistic
mutation rate

Phenotype provides
reward depending
on environment



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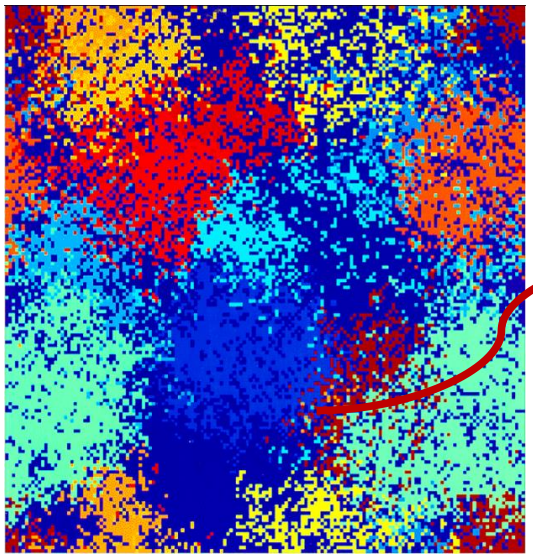
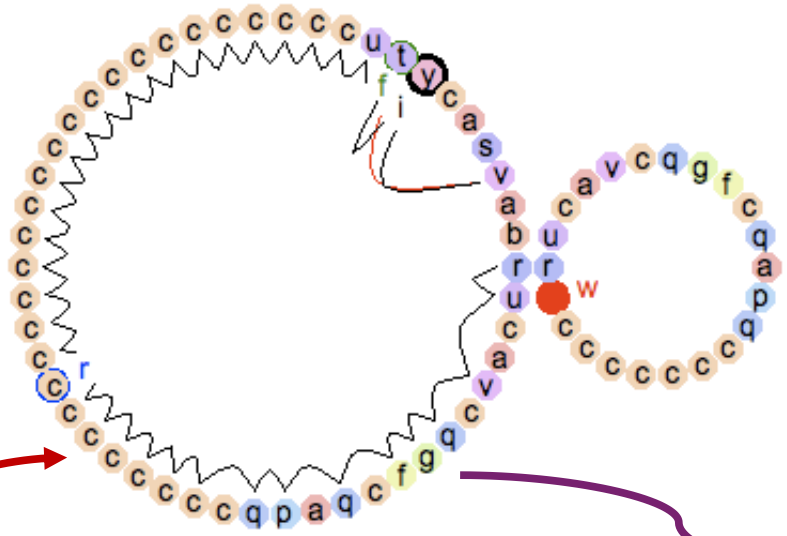
Population
of digital organisms

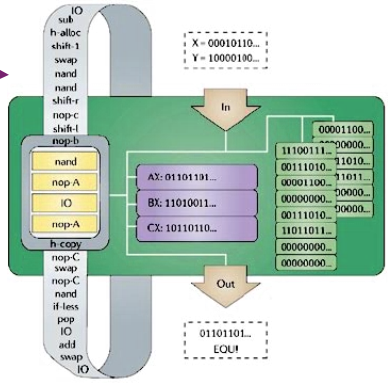




Heritability

probabilistic
mutation rate

Phenotype provides
reward depending
on environment



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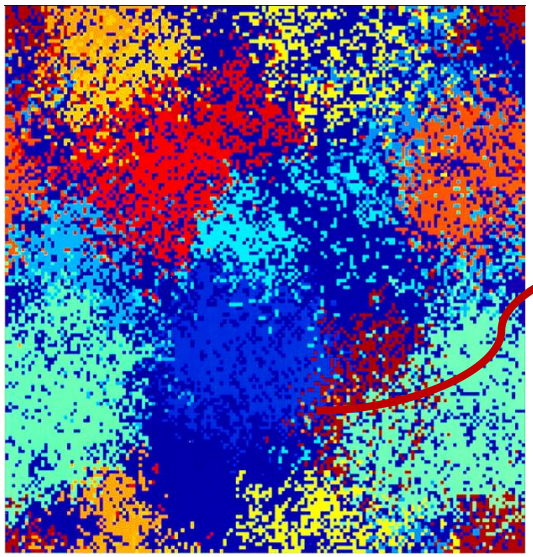
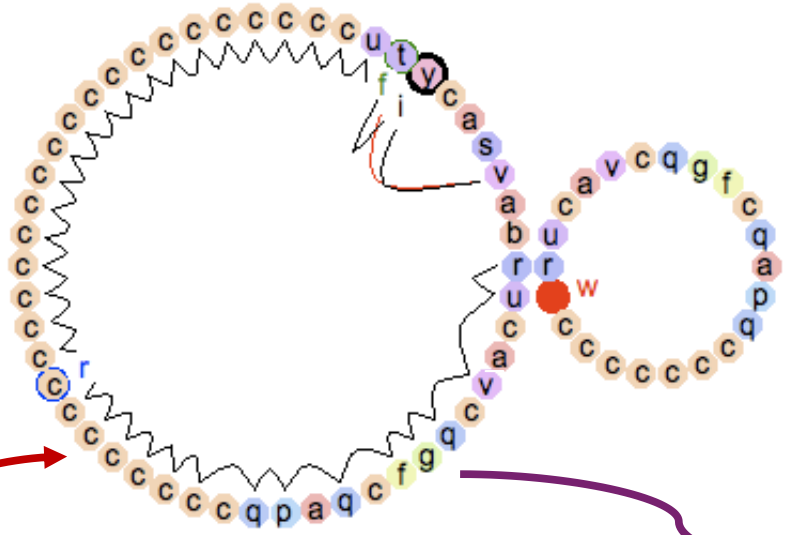
Population
of digital organisms

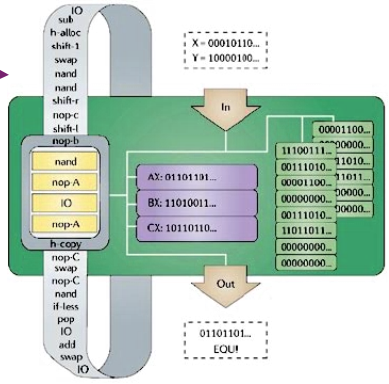




Heritability

Variation

Phenotype provides **reward** depending on environment



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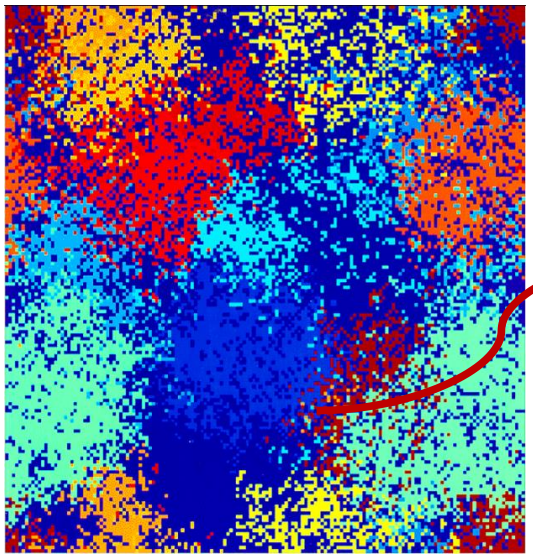
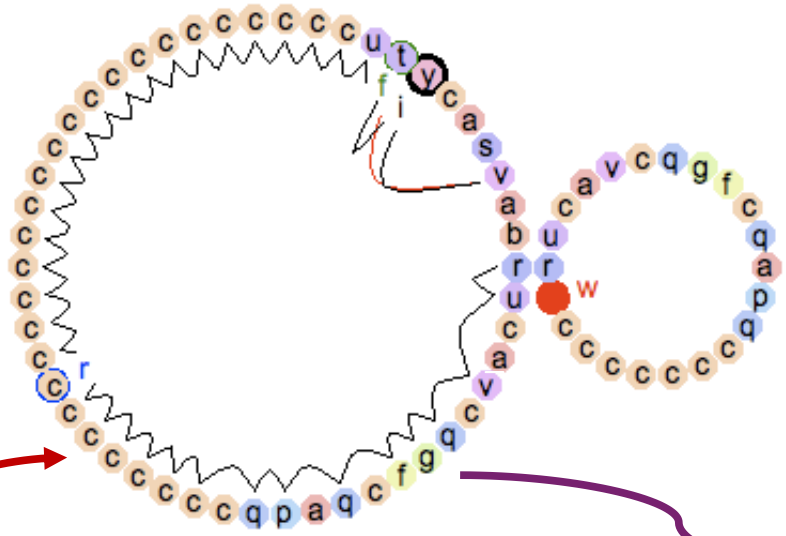
Population
of digital organisms

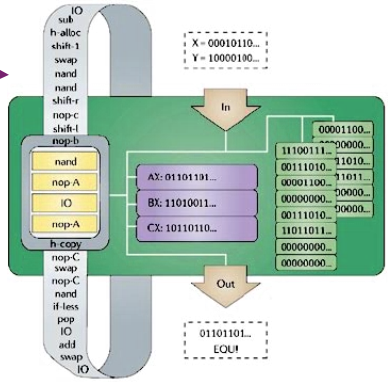




Heritability

Variation

Differential Fitness



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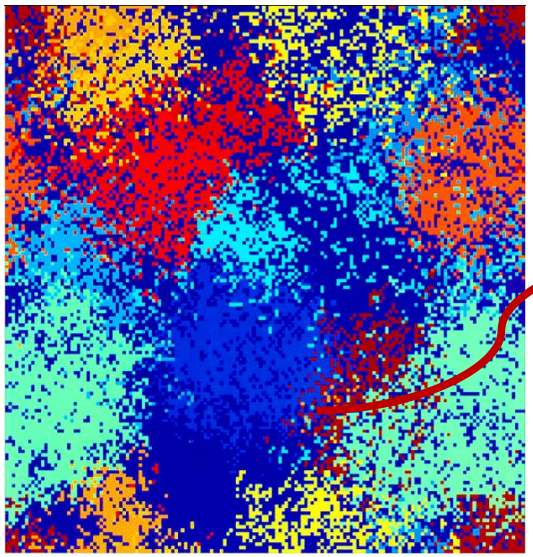
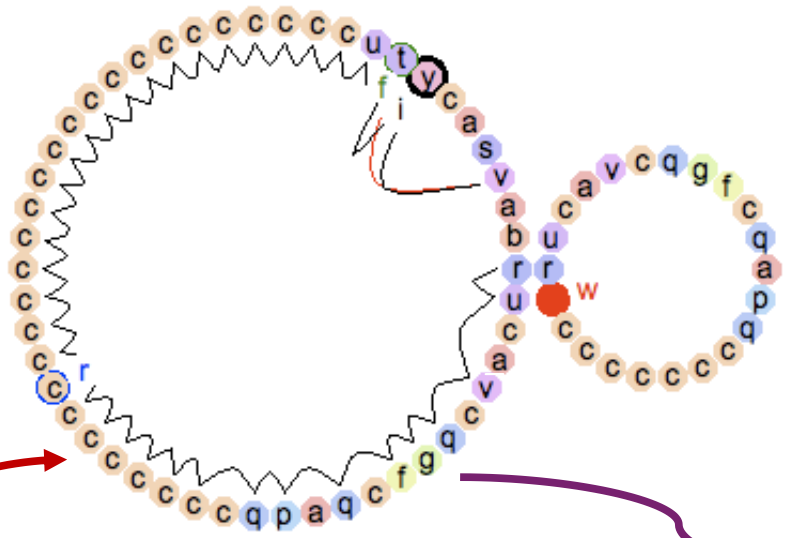
Population
of digital organisms

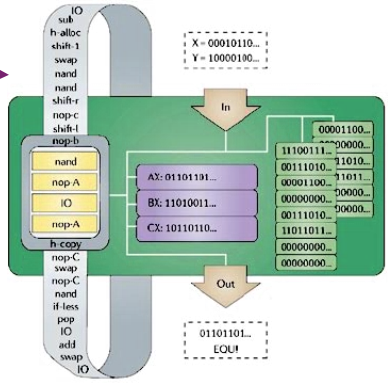




Heritability

Variation

Differential Fitness



Evolution

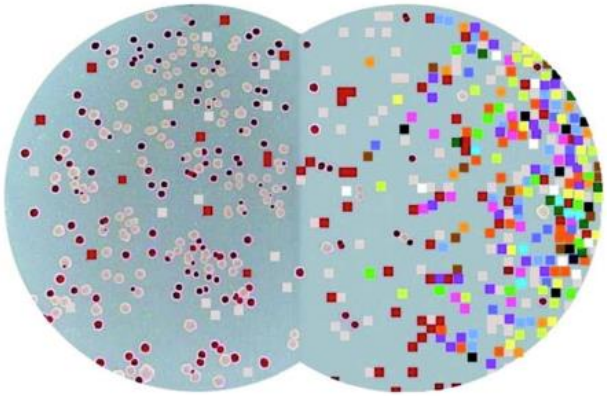
bit.do/avida-ed

Students complete a series of exercises and an independent research project

Investigate a biological phenomenon in Avida-ED

AVIDA-ED

Independent Research - Experimental Evolution Project



Two model evolutionary biology study systems:
E. coli bacteria (biological organisms) are on the left, while Avidians (digital organisms) are on the right.

Background

Some evolutionary biologists, such as Richard Lenski at Michigan State University, conduct experiments using microorganisms like *E. coli* to answer fundamental questions about evolutionary processes. Bacteria are useful model organisms because they reproduce quickly and their small size means that they don't take up much space in the laboratory. Lenski and his colleagues' work with *E. coli* has helped shed light on some important aspects of evolution and, having spanned over 25 years and 65,000 bacterial generations (and counting!), it is the longest-running investigation of its kind.

Population Size and Genetic Drift

MICHIGAN STATE UNIVERSITY

Introduction

Genetic drift is the change in frequency of a certain genotype within a population. The question that was asked was how does population size affect genetic drift?

It was believed that the introduction of resources will have a greater effect on smaller environments compared to the larger environments. It was thought that introducing resources to the environment will increase the frequency of the Avidians that can perform the nan function compared to the Avidians that cannot perform the function.

Methods

This experiment was run using Avida-Ed. In order to complete this experiment, three different environmental sizes were compared, each filled with 50% NAN performing Avidians, and 50% no function preforming Avidian. Figure 1 below is the population setup for the 10X10 environment size. The organisms highlighted in green are NAN preforming Avidians and the rest are no function preforming Avidians. A zero percent mutation rate was used to set a control of just NAN and no function preforming Avidian, disallowing the creation of other function preforming Avidians. Each environmental size ran 30 times with and without the Nanose resources available for a duration of 300 updates each.

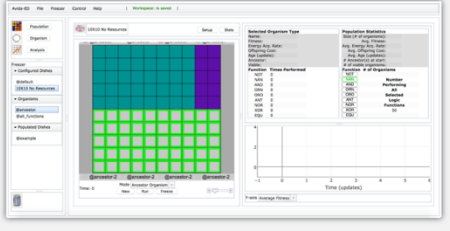


Figure 1: 10X10 setup

Results

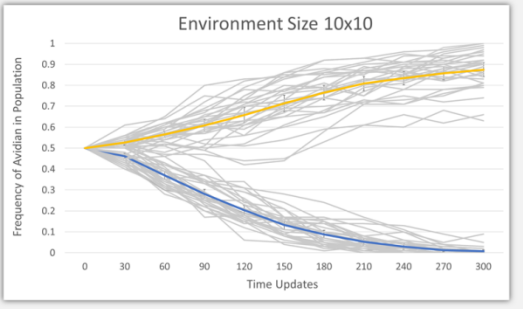


Figure 2: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 10x10 Environment

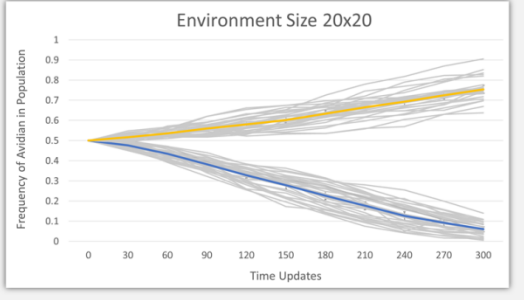


Figure 3: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 20x20 Environment

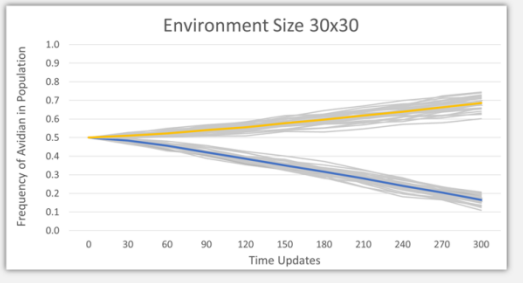


Figure 4: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 30x30 Environment

Figure 5: Comparing the response of the Avidian that can perform the NAN function when resources are turned off (bottom lines) and on (top lines) in all environments (corresponding environmental colors are shown in the key above)

Discussion

The data strongly supported the hypothesis made. As the environment size increases, the affects of genetic drift become less dynamic. It can be seen from the graphs that in the 10x10 environment, the NAN-performers were nearly completely wiped out when no resource were present or took over 90% of the population dish when resources were present. With the 30x30 environment, the NAN-performers were only reduced to ~15% of the population or took over an average of 60% of the dish when resources were present.

The reason there is worry about animals with very small populations going extinct has to do with genetic drift. A small population leads to less genetic variation which lowers its ability to adapt positively to its environment. This is evident in Cheetahs, which have 99% genetic similarity.

Population Size and Genetic Drift

Obtaining, evaluating, and communicating information

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Introduction

Genetic drift is the change in frequency of a certain genotype [illegible] that was asked was how does population size affect genetic drift?

Asking questions

It was believed that the introduction of resources will have a greater effect on smaller environments compared to the larger environments. It was thought that introducing resources to the environment will increase the frequency of the Avidians that can perform the nan function compared to the Avidians that cannot perform the function.

Methods

This experiment was run using Avida-Ed. In order to complete this experiment, three different environmental sizes were compared, each filled with 50% NAN performing Avidians, and 50% no function preforming Avidian. Figure 1 below is the population setup for the 10X10 environment size. The organisms highlighted in green are NAN preforming Avidians and the rest are no function preforming Avidians. A zero percent mutation rate was used to set a control of just NAN and no function preforming Avidian, disallowing the creation of other function preforming Avidians. Each environmental size ran 30 times with and without the Nanose resources available for a duration of 300 updates each.

Figure 1: 10X10 setup

Planning and carrying out investigations

Results

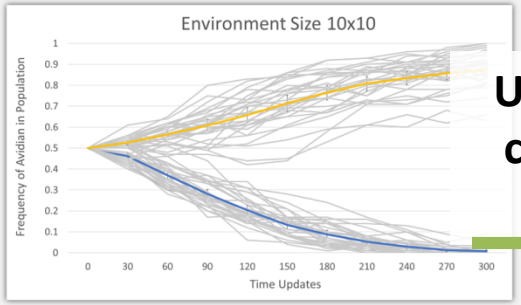


Figure 2: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 10x10 Environment

Figure 3: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 20x20 Environment

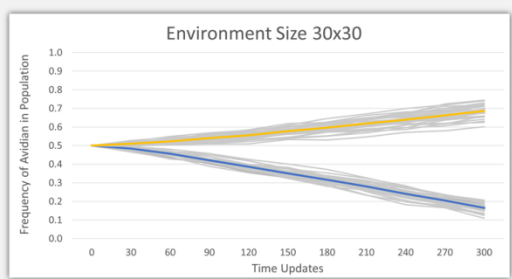


Figure 4: The response of the Avidian that can perform the NAN function when resources are turned off (blue line) and on (yellow line) in the 30x30 Environment

Analyzing and interpreting data

Using math and computational thinking

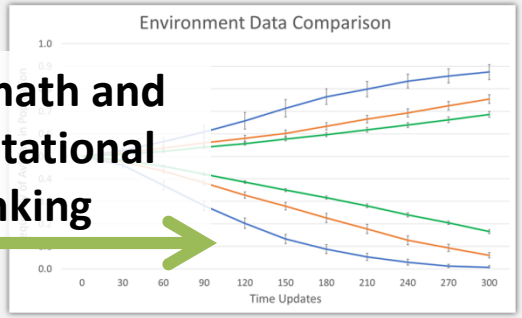


Figure 5: Comparing the response of the Avidian that can perform the NAN function when resources are turned off (bottom lines) and on (top lines) in all environments (corresponding environmental colors are shown in the key above)

Discussion

The d[illegible] strongly supported the hypothesis made. As the environment size increases, the affects of genetic drift become less dynam[illegible] the graphs that in the 10x10 environment, the NAN-performers were nearly completely wi[illegible] present or took over 90% of the population dish when resources were present. With the 30[illegible] NAN-performers were only reduced to ~15% of the population or took over an average of [illegible] of the dish when resources were present.

Engaging in argument from evidence

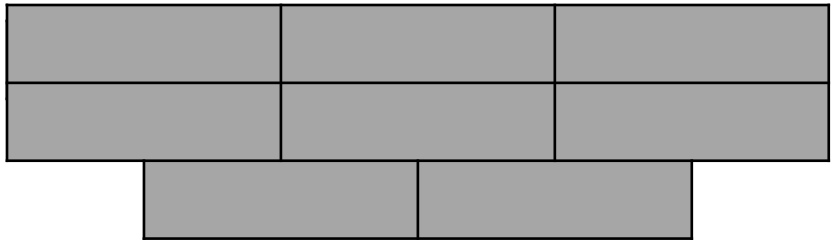
Developing and using models

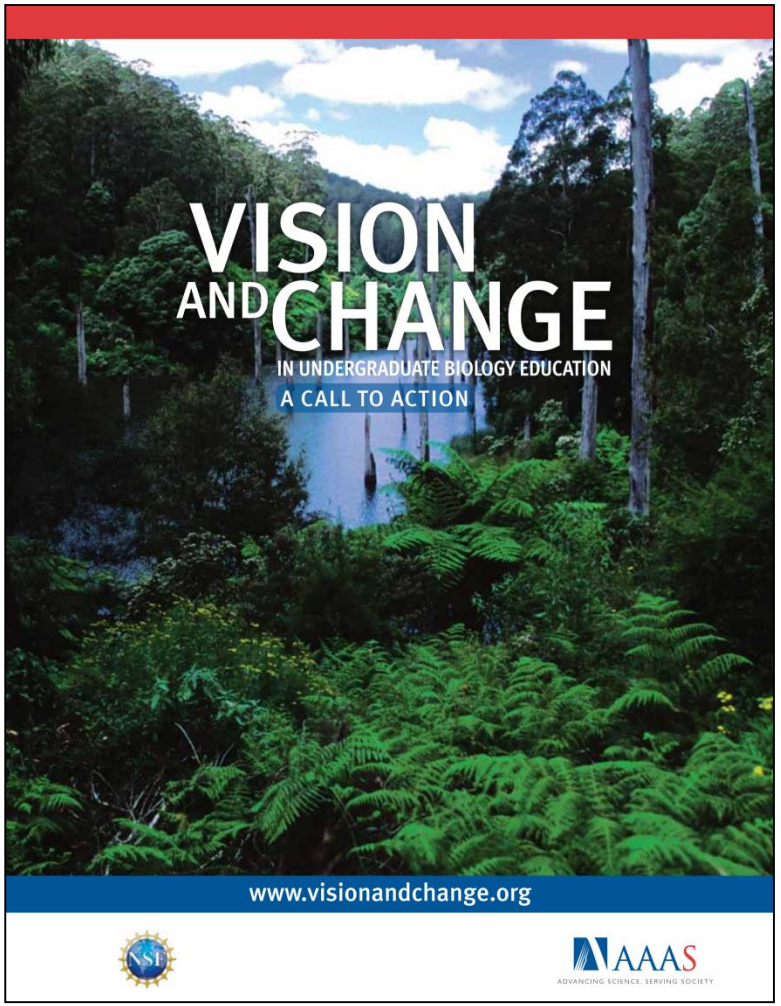
The reason there is worry about animals with very small populations goin[illegible] genetic drift. A small population leads to less genetic variation which lowers its ability to ad[illegible] This is evident in Cheetahs, which have 99% genetic similarity.

Constructing Explanations

Calls to Reform

Scientific Practices



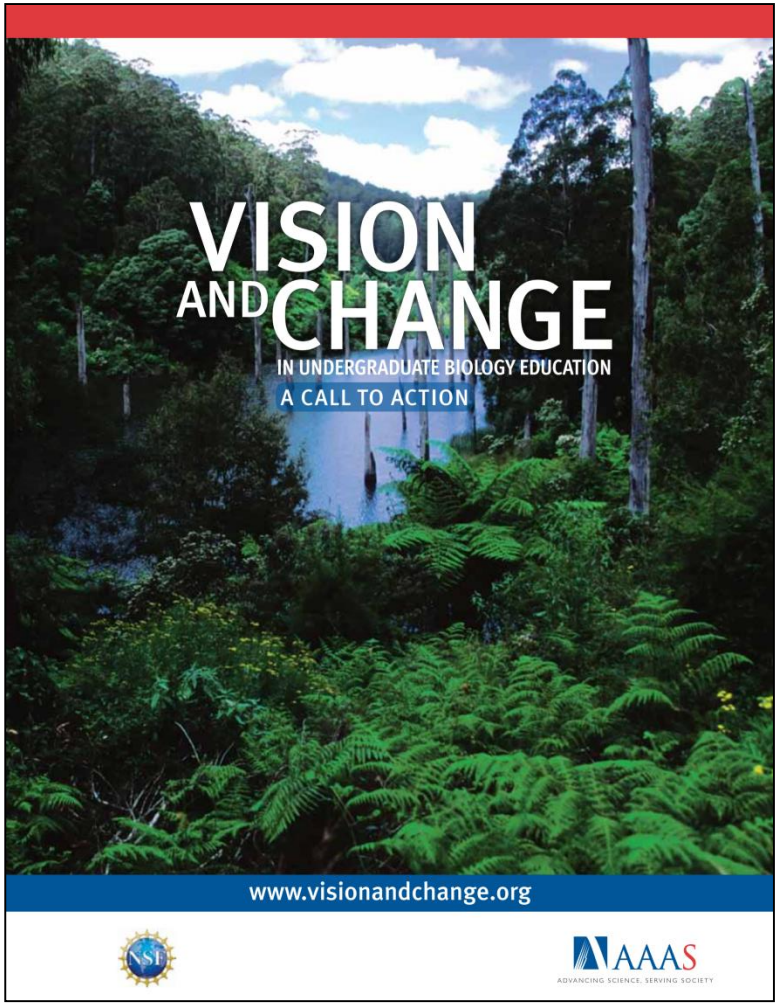


NRC. 2012. *Framework for K-12 Science Education*

AAAS. 2011. *Vision and Change*

Use of Avida-ED lab and Research

Addresses all the scientific practices



Brownell, SE et al. 2014. "BioCore Guide." CBE Life Sci Educ, 13:200-211.

NRC. 2012. *Framework for K-12 Science Education*

AAAS. 2011. *Vision and Change*

Goals and Current Project

- Improve student understanding of how science relies on evidence (data) to support or reject claims
- Expose undergraduates to real data, inquiry methods, and the use of models
- Engage undergraduates in authentic research

Salamander Population and Adaptation Collaboration Network

Evan Grant, David Miller, Chris Sutherland, David Munoz, Kristine Grayson, Caitlin Fisher-Reid, Alexa Warwick, Sarah Fitzpatrick, and others

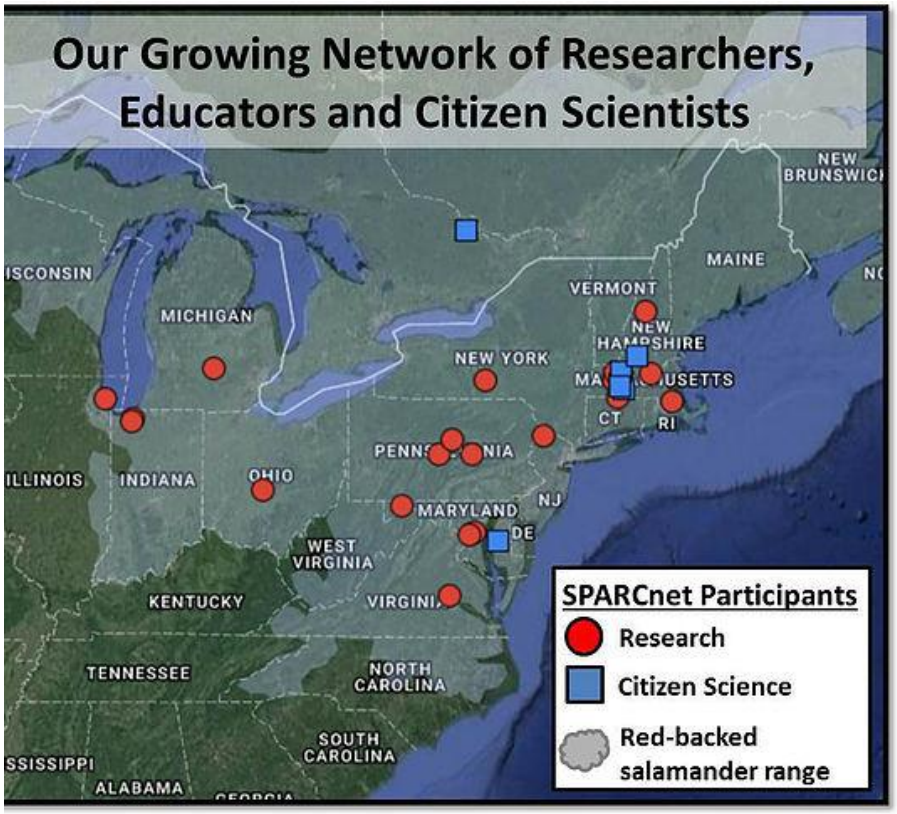
Goals

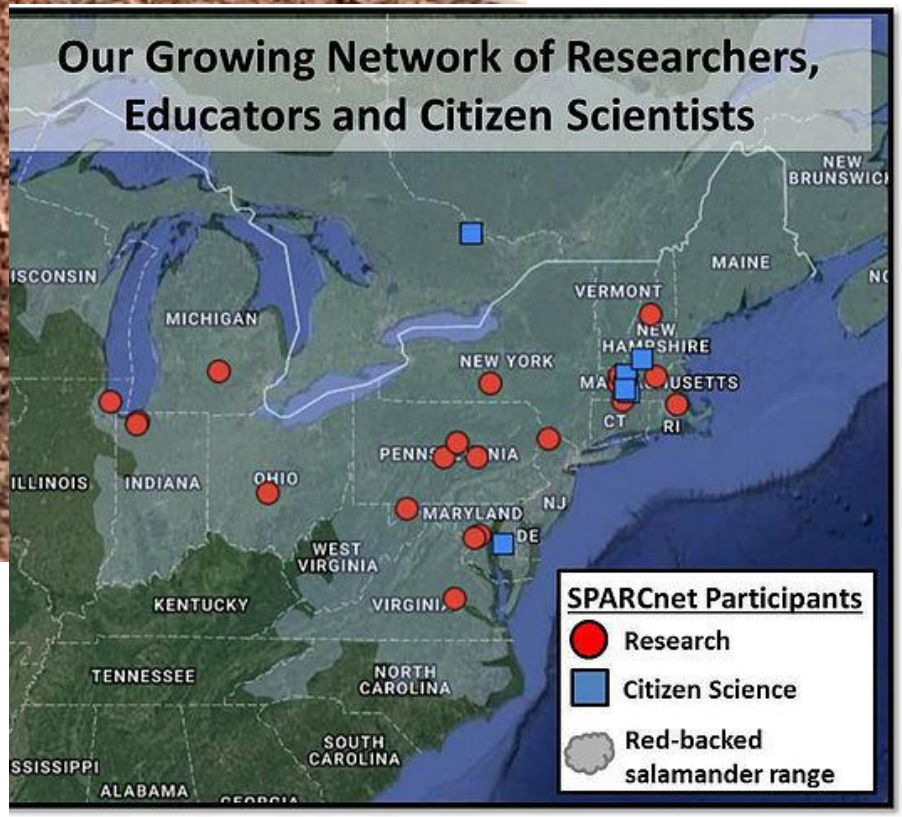
1) To understand the impacts of climate change

2) To develop models that describe the drivers of population dynamics

3) To understand the adaptability of salamanders

4) To develop an understanding and appreciation of salamander species




Our Growing Network of Researchers, Educators and Citizen Scientists
NEW BRUNSWICK
MAINE
VERMONT
NEW HAMPSHIRE
NEW YORK
MICHIGAN
ISCONSIN
ILLINOIS
INDIANA
OHIO
MARYLAND
NJ
DE
WEST VIRGINIA
KENTUCKY
VIRGINIA
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ALABAMA
CT
RI
SPARCnet Participants
Research
Citizen Science
Red-backed salamander range

Applying the CURE model to facilitate multi-institutional investigations across levels of biological inquiry using Eastern Red-Backed Salamanders

GOALS AND OBJECTIVES

The specific aims of this project are to:

- Develop CURE modules that address concepts across levels of biological inquiry using an established salamander research network.
- Implement modules in multiple institutions across the geographic network and create novel cross-course collaborations among students using a paired classrooms approach.

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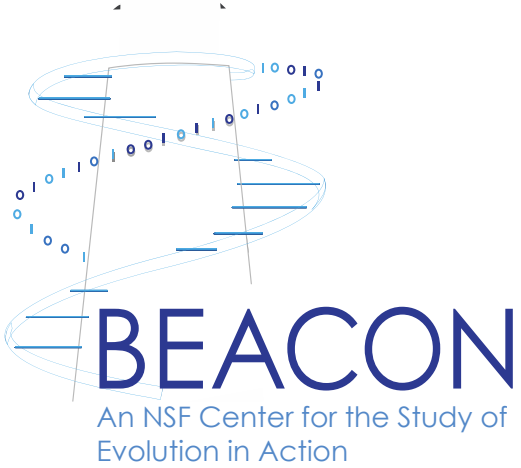

Science is a collaborative process

Science is a collaborative process