Computational Thinking Using Computer Simulations in High School Biology

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How familiar are you with computational thinking as used in science education?

0
Unfamiliar

2-3
Somewhat familiar

5
Very familiar

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Computational Thinking in Science and Engineering From *The Framework*…

Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

By the end of 12th grade, students should:

- Recognize that computer simulations are built on mathematical models that incorporate underlying assumptions about the phenomena or systems being studied.
- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

A Framework for Understanding Computational Thinking for Science (CT-S)

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The CT-S Framework

Each column is a type of interaction with a computational tool that gives rise to cognitive processes that CT is dependent on.

CT-S		Cognitive Processes		
		Reflective Use	Design	Evaluation
		of a computational tool for		
Science Activity	Data Collection			
	Data Processing			
	Modeling			
	Problem-Solving			

The cells of this table depict the intersection of each column with each row such that if an individual is engaged in an activity that is typified by at least one of these intersections, then that individual is engaged in CT-S.

Each row is a general category of science activity where computational tools are leveraged.

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Goal for today

To use a specific computational tool (computer simulation) and explore where its use fits in the landscape of computational thinking in science.

A Few Definition for the CT-S Framework

Computational Tool: an artifact that can compute, or carry out sequences of arithmetic, or logical operations, *automatically* in accordance with a well-defined model (e.g., an algorithm).

- automatically means that when an input is provided to the tool, an output will be provided by the tool. A slide rule *does* qualify.

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Cognitive Processes--examples

Reflective Use: a type of engagement with a computational tool where your goal is to figure out how to use the tool.

Example with **Data Collection**:

How can I use the time-lapse photography feature on my phone to collect data on how fast my plants grow?

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Cognitive Processes--examples

Design: one can engage in Design without actually constructing or programming the computational tool.

Example with **Data Processing**:

I have images that show the sun's height above the horizon from every day of the year from a given location taken at solar noon, what would I need software to do to help me find patterns related to seasonal changes?

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Cognitive Processes--examples

Evaluation: the focus of the evaluative activity is on the computational tool with respect to the science.

Example with **Modeling**:

Which aspects of this digital model accurately reflect natural selection, and which do not?

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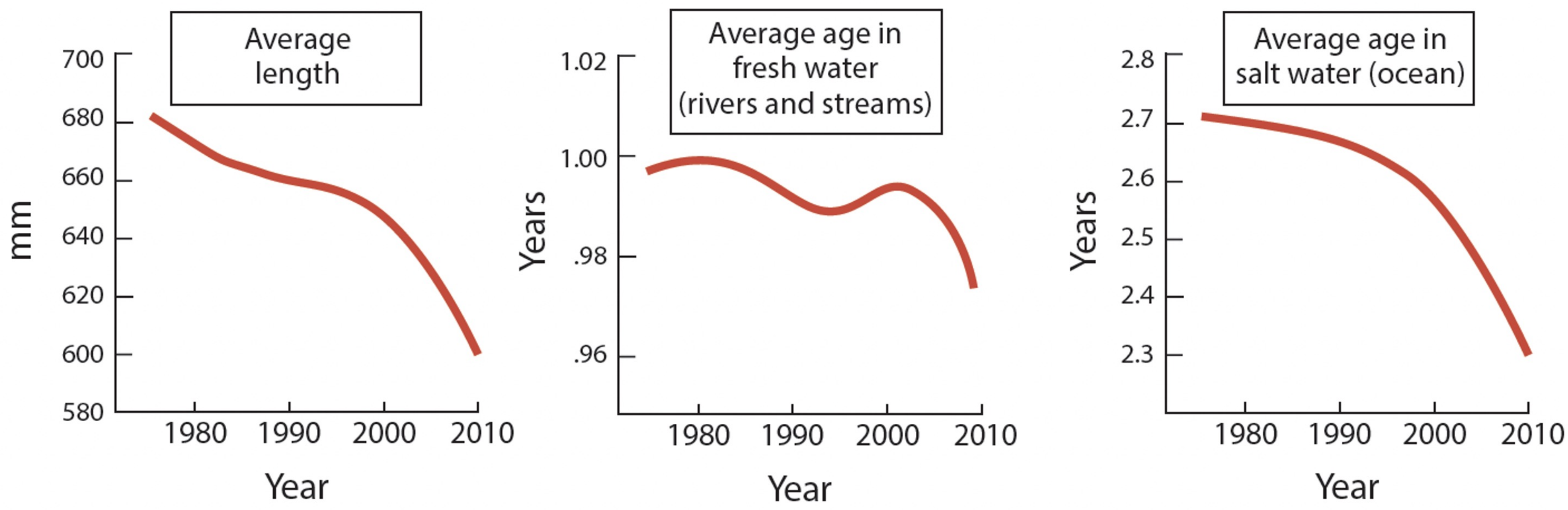
The Shrinking Salmon Problem

The Shrinking Salmon Problem (Part 1)



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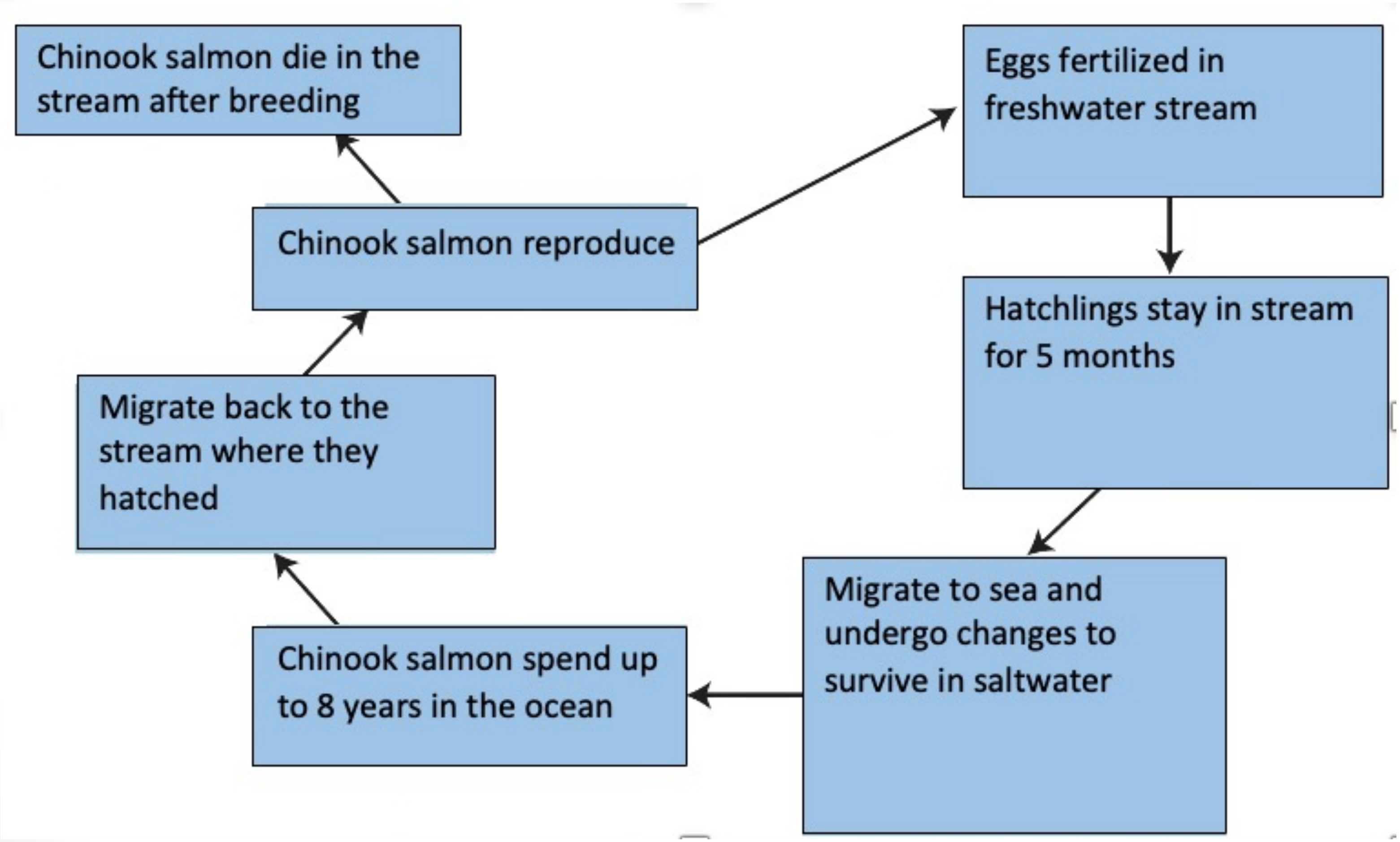
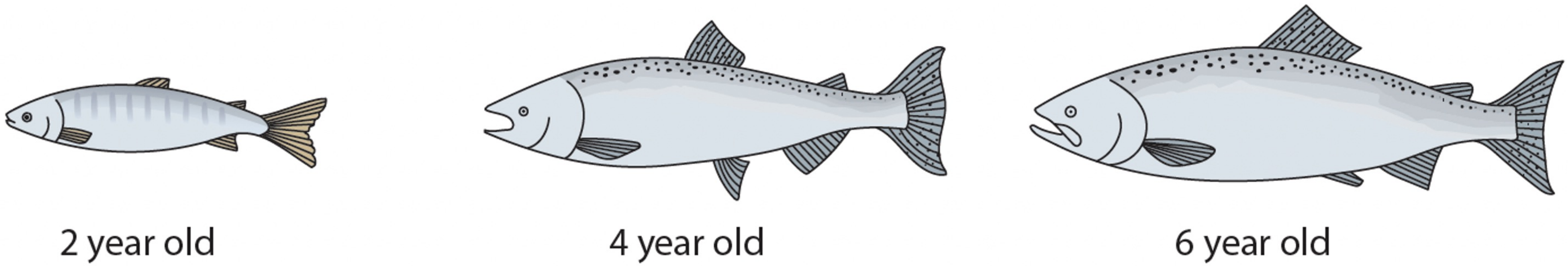
Chinook Salmon Life Cycle



Changing Selection Pressure

- Age and body size are highly correlated in salmon.
- Bigger salmon have higher reproductive success.
- In ~1990, Chinook salmon began returning to breed at a younger age.



2 kg

8.5 kg

14 kg

The Consequences

Researchers have calculated that between 1990 and 2010, there was a

- 16% reduction in Chinook salmon egg production
- 28% reduction in the flow of nutrients from salmon to other organisms
- 21% reduction in commercial fisheries earnings
- 26% reduction in meals for rural people

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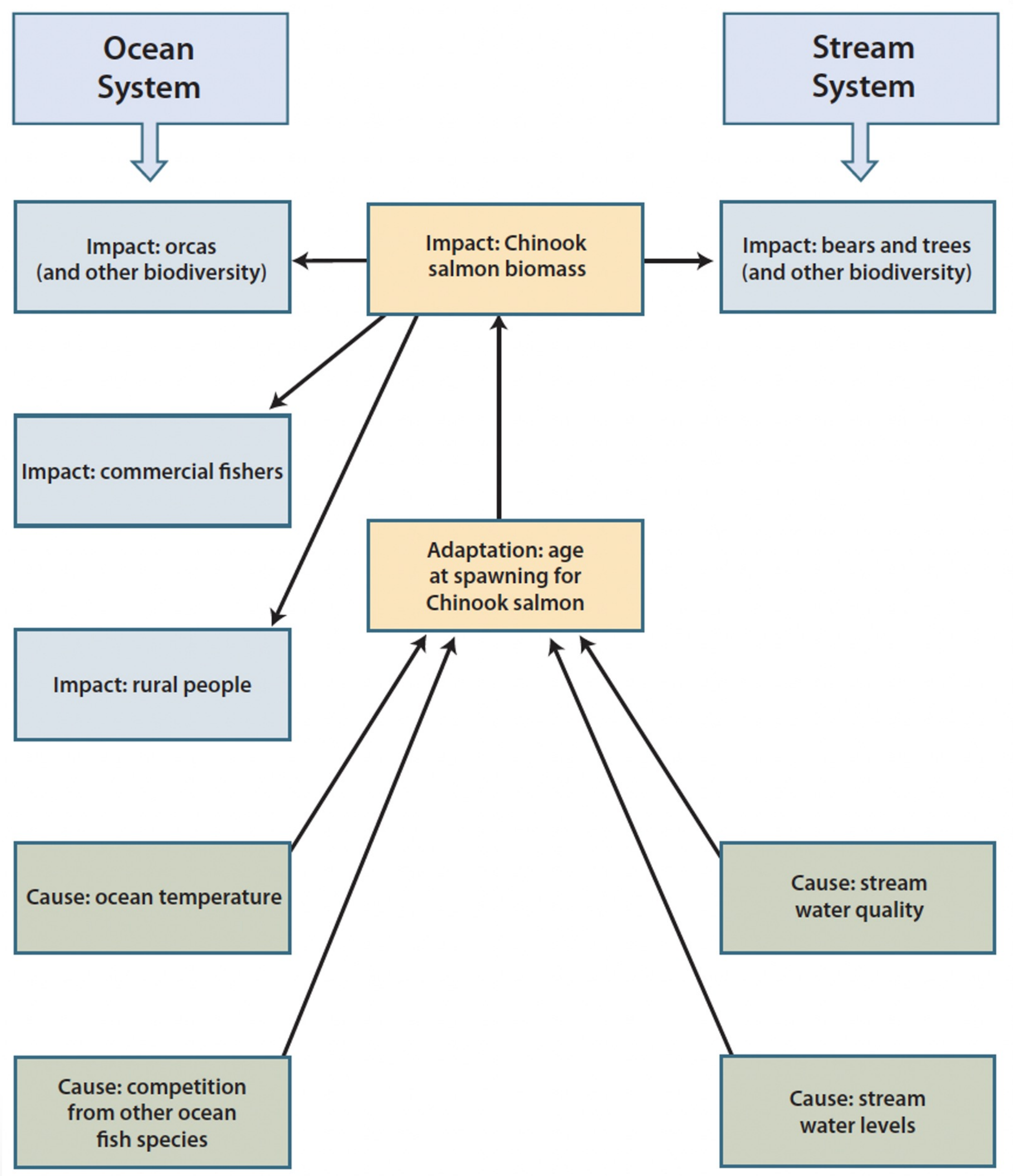
Modeling the System



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Addressing the Shrinking Salmon Problem

Using the system model, consider the following questions:

- What might happen if salmon body size continues to decline?
- What might be done to address one or more of the problems caused by declining salmon body size?
- What additional data or information would you want to gather to help you understand this complex real-world problem?

Solving the Problem (Part 2)

The Simulation

In the ocean, the environmental (independent) variables are

- Ocean temperature
- Level of competition from invasive species of fish and fish that have escaped from aquaculture pens.

In the stream, the environmental (independent) variables are

- Water quality (which is impacted by pollution from nearby towns)
- Water level (which is impacted by human development in wetland areas).

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The Simulation (cont'd.)

The salmon simulation provides data about changes in

- biomass
- distribution of size classes (small, medium, and large)

Over two time periods

- 1980 to 2020 based on past data
- 2020 to 2060 depending on future environmental conditions

3 Parts

- Part A examines a random sample of 1,000 salmon
- Part B examines the total population of salmon
- Part C allows for testing solutions based on the results in Parts A and B

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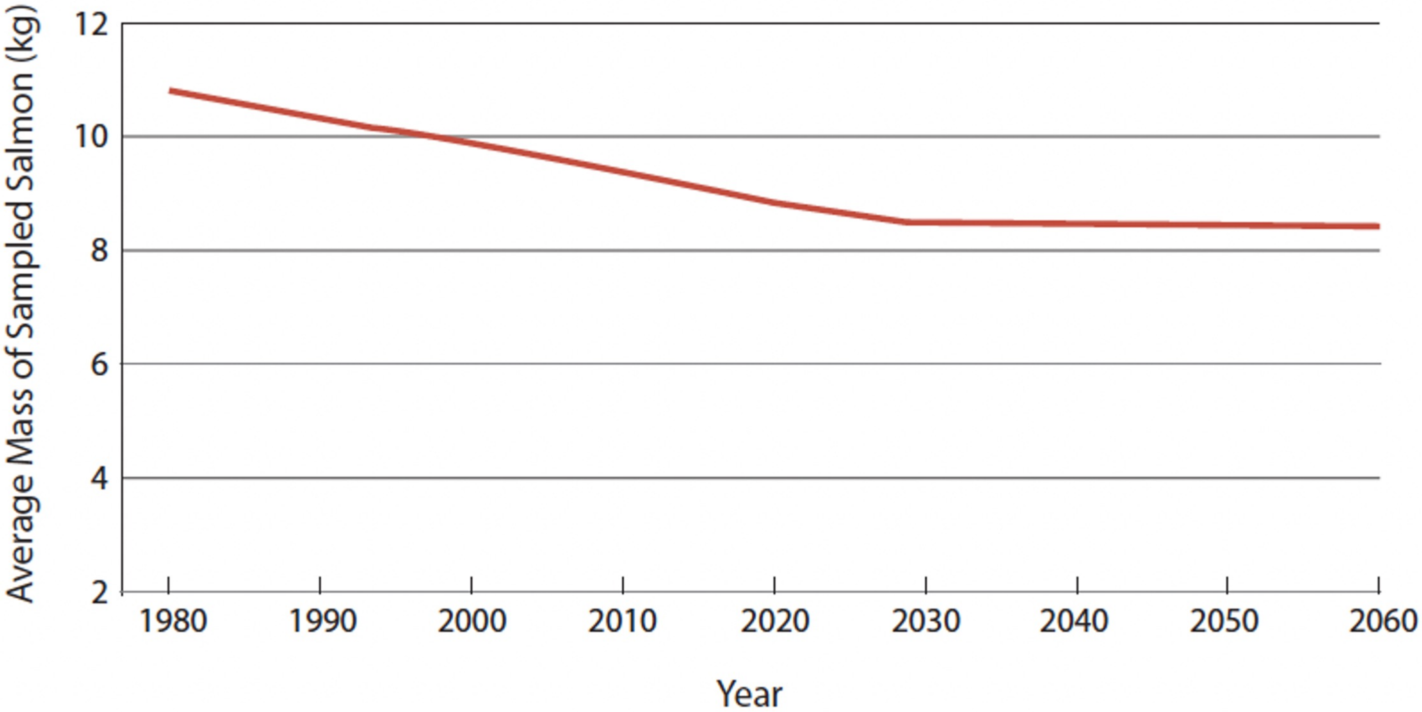
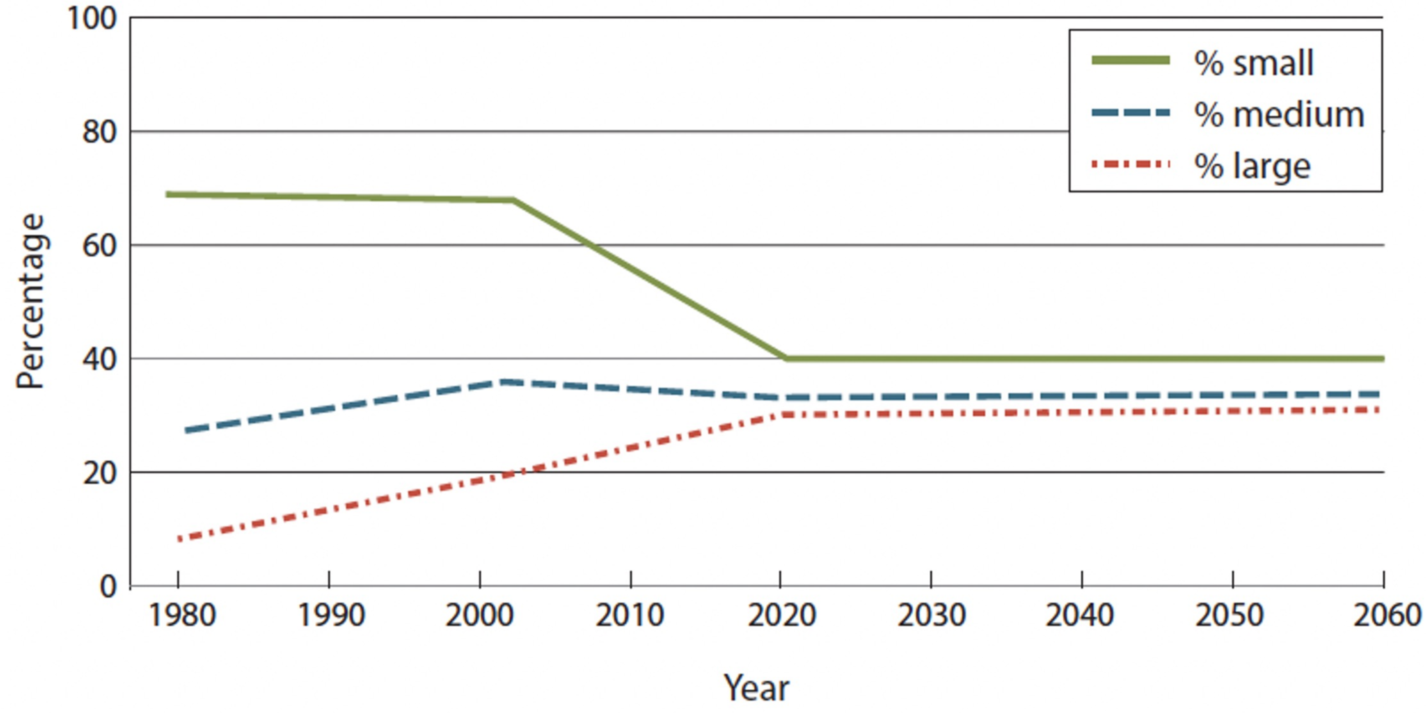
Getting started with the Simulation



Getting started with the Simulation



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The simulation

tinyurl.com/salmonsim

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Part A:
1,000 Randomly Sampled Fish

Part A: Random Sample

Condition	Biomass of 1,000 randomly sample salmon in 1980	Biomass of 1,000 randomly sampled salmon in 2060
Default	11.7K kg	8.8K kg
Ocean Warming	11.7K kg	3.66K kg
Stream Water Quality	11.7K kg	8.8K kg

Part A: Random Sample

Condition	Size class distribution of 1,000 randomly sampled salmon in 1980	Size class distribution of 1,000 randomly sampled salmon in 2060
Default	S: 7% M: 26% L: 67%	S: 29% M: 31% L: 40%
Ocean Warming	S: 7% M: 26% L: 67%	S: 81% M: 12% L: 7%
Stream Water Quality	S: 7% M: 26% L: 67%	S: 29% M: 31% L: 40%

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Analysis

Which condition has the greatest evolutionary impact on the age at which salmon return to spawn, and therefore salmon body size.

In other words, which environmental variable applies the strongest natural selection favoring salmon that return to spawn at a younger age?

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Part B:
Entire Population

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Part B: Total Population

Condition	Biomass of total population in 1980	Biomass of total population in 2060
Default	2.33M kg	1.19M kg
Ocean Warming	2.33M kg	497K kg
Stream Water Quality	2.33M kg	1.04M kg

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Part B: Total Population

Condition	Total population size in 1980	Total population size in 2060
Default	199 K	136K
Ocean Warming	199K	136K
Stream Water Quality	199K	117K

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Analysis

Which condition is having the greatest total impact on the salmon population?

That is, which environmental variable is having the greatest combined evolutionary impact and the greatest impact on the size of the salmon population?

Part C:
Possible Solutions

Part C: Possible Solutions

Solutions	Biomass of total population in 2020	Biomass of total population in 2020
No Action	1.4M kg	273K kg
Ocean Warming 100% improvement	1.4M kg	590K kg
Ocean Warming 25% improvement	1.4M kg	353K kg

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Part C: Possible Solutions

Solutions	Biomass of total population in 2020	Biomass of total population in 2020
No Action	1.4M kg	273K kg
Stream Water Quality 100% improvement	1.4M kg	321K kg
Stream Water Quality 25% improvement	1.4M kg	287K kg

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Analysis

Which solution seem to be the most effective based on Part C of the simulation? How confident you that your solution will solve the shrinking salmon problem.

So far you have considered only the effectiveness of a particular approach when designing a solution. But not all solutions are equally feasible, and the cost of the solution can vary tremendously. If money and feasibility are also issues, how would that impact your strategy?

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Revisiting the CT-S Framework

Where does this activity fit in this framework?

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Revisiting the NGSS

How does this activity address these goals?

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Performance Expectations

How does this activity address these PEs?

HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

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