PACIFIC SALMON FOUNDATION

Salmon Food Chain
Teacher's Guide

Presented by the Pacific Salmon Foundation

PSF.ca

OVERVIEW:

Students will watch a visually engaging presentation on the marine food chain of Pacific Salmon featuring images and videos of the different animal along the chain. We will take a look at what salmon typically eat and consider how environmental changes could influence salmon and the food chain. Students will also learn about how changes to one part of the chain can impact all other parts of the food chain. Based on the information provided in the video, students will then develop and share ideas/hypothesis as to how changes in the food chain could affect salmon and we will compare those to real world hypotheses developed by salmon scientists. We will then focus on two of the given hypotheses and use real-world data to create a variety of figures that may support or refute those hypotheses. The goal is for students to be able think critically about the connections between the different levels of the food chain and use scientific figures to support their ideas about those connections.

Artwork by Anish Parekh

Cover photos by: top - Eiko Jones, left - Mitch Miller, middle and right - Ryan Miller

ESSENTIAL QUESTIONS

- How are animals and plants dependent on one another?
- How does energy flow within an ecosystem?
- How does a change in one section of the food chain affect other sections?
- How might climate change create an unbalanced food chain?

CURRICULUM REQUIREMENTS

This lesson educates and engages students in the topic of energy flow and fits with the BC Environmental Science 11 curriculum. It allows students an opportunity to develop competency in the following areas:

Big Ideas:

- Complex roles and relationships contribute to diversity of ecosystems
- Changing ecosystems are maintained by natural processes
- Human practices affect the sustainability of ecosystems

Curricular Competencies	Content
• Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world • Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies • Construct, analyze, and interpret graphs, models, and/or diagrams • Use knowledge of scientific concepts to draw conclusions that are consistent with evidence • Analyze cause-and-effect relationships • Demonstrate an awareness of assumptions, question information given, and identify bias in their own work and in primary and secondary sources	• Levels of biotic diversity • Ecosystem complexity: > Roles > Relationships > Population dynamics • Energy flow through ecosystems • Human actions and their impact on ecosystem integrity

ADDITIONAL BACKGROUND FOR TEACHERS

Salmon

Pacific salmon hold tremendous ecological, cultural, and economic importance to communities in BC. They provide food for a wide array of animals and even plants, with their carcasses contributing important nutrients to the soil along the river banks when they return to spawn. The cultural, spiritual, and physical well-being of many First Nations communities is dependent on salmon. In addition, the commercial and recreational salmon fishing industries contribute millions of dollars to BC's gross domestic product and generate thousands of jobs. Over time, societal development has had negative effects on wild salmon and their habitats. Natural resource development such as logging and mining has resulted in significant habitat degradation, dams have blocked upriver migrations, and periods of voracious commercial fishing have led to overharvesting. In addition, climate change is altering their food supply and habitat, with warmer rivers and lakes and some systems drying out completely. Every year, more salmon populations are being recognized as being 'at risk'. Salmon populations are dwindling and although there remains much debate as to why and what to do about it, many scientists believe that changes to the marine food chain may be responsible.

There are five species of Pacific Salmon: Sockeye, Pink, Chum, Coho, and Chinook. Each have their own unique life history strategy, but generally, they spend a few months to a few years in streams, rivers, and/or lakes before migrating to sea. There, they will spend 1-4 years either migrating long distances throughout the North Pacific or staying closer to home. They eat mainly zooplankton and smaller fish, known as forage fish. Different species exhibit different feeding preferences: Sockeye, Pink, and Chum salmon are planktivores, consuming more zooplankton, while Chinook and Coho salmon are piscivores, consuming more fish.

Photo by Devan Johnson

BOTTOM-UP PRESSURES

In this lesson, we want students to see the complex connections between different levels of the food chain. What happens to one part of the food chain affects the entire food chain. Bottom-up pressures are those where changes at the base of the food chain (phytoplankton, the primary producers) cascade upwards throughout the rest of the food chain. Phytoplankton, being photosynthesizing organisms, require sunlight and nutrients to survive and generate energy. Therefore, they can only survive near the surface of the ocean where there's enough sunlight to photosynthesize. In years where there are unusually strong winds and storms, the ocean becomes highly mixed, and phytoplankton may not survive as they get pushed deep into the water column beyond the sun's rays. With less energy at the base of the food web, less energy can be transferred upwards, meaning fewer animals are supported.

TOP-DOWN PRESSURES

Conversely, changes at the top of the food chain can have cascading effects downwards on the other animals in the chain. In BC, there has been a significant increase in the numbers of harbour seals since seal culling was banned in the 1970s. Seals eat juvenile salmon when they first enter the ocean, and so an increase in seals means fewer salmon. Seals may also consume forage fish, an important prey for Coho and Chinook salmon, so an increase in seals is double bad news for salmon. Fewer salmon and forage fish may lead to there being more zooplankton, which will then graze down the amount of phytoplankton. These are the types of connections we want the students to see — that changes to one part of an ecosystem can have cascading effects in multiple and sometimes unexpected directions.

Photo by Lucy Quayle

ENVIRONMENTAL CONDITIONS

Climate change is rapidly breaking down what were once stable states and relationships in marine ecosystems. There is more variability than ever before, meaning things are less predictable. Animals have evolved to have key life cycle events correspond with times of favourable environmental conditions. However, the seasonal cycles of production and growth that have evolved over millennia are falling out of sync. A phytoplankton bloom (where longer days and warmer temperatures lead to a rapid multiplication of phytoplankton in the surface waters) may happen earlier in the year. Zooplankton populations closely follow those of their food source, and so they will become more abundant earlier in the year as well. Salmon migrations have evolved so that juveniles enter the ocean when their prey are most abundant, however in such years where zooplankton peak early, salmon may be late to the game and not be able to grow as big or survive as well as in other years. This is just one example of how important environmental change is to the marine food chain.

VOCABULARY

Photosynthesis: the process of using the sun's energy to convert carbon dioxide and water into carbohydrates and oxygen

Primary producer: an organism that makes organic material from inorganic material. E.g. plants, phytoplankton, some bacteria

Secondary producer: an animal that eats plants (a herbivore) and is food for a predator.

Phytoplankton: microscopic algae that live in water and play a key part as primary producers at the base of the food chain. Derived from Greek words *phyto* (plant) and *planktos* (wanderer or drifter)

Zooplankton: the animal component of the plankton, including small animals and immature stages of larger animals. Derived from Greek words *zoo* (animal) and *planktos* (wanderer of drifter)

Trophic: of or relating to food or nutrition

Trophic level: the hierarchical position an organism occupies in the food chain, comprised of organisms that share the same function

Trophic cascade: indirect effects on other animals when a trophic level in a food chain or food web is reduced or removed

Photo from Pacific Salmon Foundation

OUTLINE

Video:

PSF Biologist, Sam James, will guide students through the salmon food chain. Below is an outline of the topics covered, key content in each topic, as well as potential questions for teachers to ask. Sam asks some of these questions in the video, which would be ideal times for you to pause the video and do a round of think, pair, share with the students before continuing.

Topic	Content	Potential Questions
Salmon life cycle	• Quick overview of salmon life cycle • Introduce salmon's dilemma of finding food vs avoiding predators and how that influences their life cycle	**Q: Why do salmon spend part of their lives in freshwater and part in the ocean** A: Because the ocean provides more food, allowing them to grow bigger. If you look at kokanee (land-locked sockeye salmon in lakes), they don't grow anywhere near as big as their migrating counterparts! Also salmon choose to spawn in nutrient-poor streams and rivers since these habitats typically cannot support year-round predator populations big enough to heavily reduce numbers of salmon.
Introduce the marine food chain with a diagram	• Food chain = a hierarchical series of organisms each dependent on the next as a source of food (Oxford dictionary) • Energy is produced at the bottom and transferred and accumulated up the food chain as animals consume animals below them in the food chain. There are also important fatty acids that can only be consumed by organisms at the bottom of the food chain and then bio-accumulated upwards. • Salmon are in the middle: they eat the animals 1-2 levels below them, but are also consumed by predators above. • The abundance and health of organisms at each level determines how stable that ecosystem is during environmental stress and how many other species it can support.	
Phytoplankton	• Microscopic, plant-like organisms that perform photosynthesis (use sunlight as energy to take in carbon dioxide and produce organic carbons that they use to create their body parts — oxygen is a bi-product • Conduct 50% of all photosynthesis on earth and produce 50% of all oxygen • Base of largest food web in the world • Require sunlight and nutrients — vulnerable to environmental change • "Spring bloom" = when phytoplankton rapidly increase in abundance in the spring due to longer day length and increased sunlight	**Q: If phytoplankton bloom and are most abundant in the spring, how does that affect the abundance of other animals that feed on them?** A: Zooplankton, the secondary producers in the marine food chain that we will talk more about in next, closely follow their food supply. They cannot grow and reproduce without enough food (i.e. phytoplankton) available to them, so they don't increase in numbers until phyto-plankton increase in number. Similarly, higher levels of the food chain rely on an abundant source of zooplankton to feed on, so they too will become more abundant once zooplankton are more abundant, and so on.

Zooplankton	• Microscopic animals, including the young of larger invertebrates such as crabs, as well as larval fish and jellyfish • Drifters that cannot swim against the current • Many shapes and forms, special adaptations • Introduce herbivores and carnivores • Discuss prey quality, energy content, some are more nutritious than others	**Q: Do you think some zooplankton could be more nutritious than others? How does this impact salmon and other fish that need energy to grow and survive in the ocean?** A: The quality of zooplankton as food for fish depends on a number of things, such as the amount of lipids or fatty acids they carry and the number of calories they provide when consumed. In colder waters, you tend to find bigger, fatter copepods with more lipids. Conversely, in warmer climates, you tend to find much smaller copepods with very little lipids. Jellyfish are largely made up of water and so are not very nutritious for salmon at all! As the waters off the BC coast warm, we are starting to see more warm-water (less nutritious!) zooplankton becoming more abundant, which means less good quality food for salmon. **Q: How might climate change be affecting the types of zooplankton (e.g. big juicy cold water species vs small warm water species) on the coast of BC?** A: Over the past few years, we've experienced warming ocean temperatures, with some extreme warming events creating "The Blob" – a mass of warm water in the Northeast Pacific Ocean. As a result, we're seeing an increase in the number of warm water species and a decrease in the numbers of cold water species. Generally speaking, warm water species are less nutritious for salmon.
Forage fish	• Small schooling fish • Some (i.e. Pacific herring) most abundant fish species in BC's coastal waters • Important link and transfer of energy between zooplankton and higher trophic levels (including salmon) • Support fisheries and important to First Nations • Many spawn on beaches and so are susceptible to habitat loss due to climate change and urban development	
Salmon	• Briefly describe the 5 species and compare planktivores to piscivores • Importance of growth in early marine life phase	**Q: How do we know what salmon eat?** A: Collect them in the field and either pump their stomachs or bring them back to the lab for dissection. Sort food into different categories, identify them under a microscope and count them.

Predators	• Introduce different types of predators, incl birds, pinnipeds, whales, bears, and other fish • Where in life cycle are predators exerting top-down pressures: describe how some target juveniles outmigrating while others target adult returns • Show how salmon abundance correlated with mortality indices of killer whales	Q: What impact would an increase in predators have on salmon, and the rest of the food chain? A: (provided later in the video when we demonstrate what a top-down trophic cascade looks like) More predators will need more food, therefore they will eat more salmon. Fewer salmon will then have other effects on the lower trophic levels.
Recap	A visual summary of the food chain and trophic levels	
Top-down, wasp-waist, and bottom-up trophic cascades	• Types of interactions: if one species becomes too abundant, competition will result in a collapse, but also, if that species decreases dramatically, it leaves a gap in the food chain and energy cannot be transferred upward beyond that level, also leading to collapse. • Types of trophic cascades when one level of the food chain becomes unbalanced: > Top-down: Changes in the numbers of animals at the top of the food chain have cascading effects on the lower levels of the food chain (e.g. increase in predators) > Wasp-waist: Changes to the middle of the food chain (e.g. decrease in forage fish) have cascading effects both upwards and downwards through the food chain > Bottom-up: changes in the population of primary producers at the bottom of the food chain will affect all other organisms at higher trophic levels in the chain.	
Wrap up	• Introduce the marine food web and discuss importance of the relationships we've just learned about, highlighting news headlines related to the food chain.	

Photo by Sam James

ACTIVITY: EAT OR BE EATEN

Objectives:

Students will develop research questions about the salmon food chain and predict what the answers might be (i.e. develop hypotheses). They will then be able to compare their ideas to those of PSF scientists to see where they overlap or how hypotheses (their own or PSF's) could be improved. Students will be able to look at data from PSF Scientists and graph the relationships between salmon migration and prey availability. They will create a circle graph to show best location for food availability, plot the relationship between forage fish and juvenile salmon and understand the impacts of release timing of juveniles with the abundance of zooplankton.

Materials Needed:

Eat or Be Eaten handout. Pens (at least 2 different colours would be helpful)

Essential Questions:

1. Do salmon always eat the same thing or does it change depending on the habitat they are in? What might be the impact of juvenile salmon migrating through an area with low food availability or poor food quality?

2. Do the types of prey eaten by salmon influence their growth rates? What's the importance of having a faster growth rate?

3. Why is the timing of the spring phytoplankton bloom important to salmon and how might climate change trigger bottom-up trophic cascades?

Procedure:

Go through the 'Eat or Be Eaten' worksheet with the students. There are two parts:

Part 1: Get the students asking questions about the salmon food chain and coming up with their own predictions in response to their questions. Compare students' ideas to those of real-world scientists.

Part 2: Students are provided with 3 datasets pertaining to salmon and the food chain and are asked to create 3 different types of graphs and interpret them.

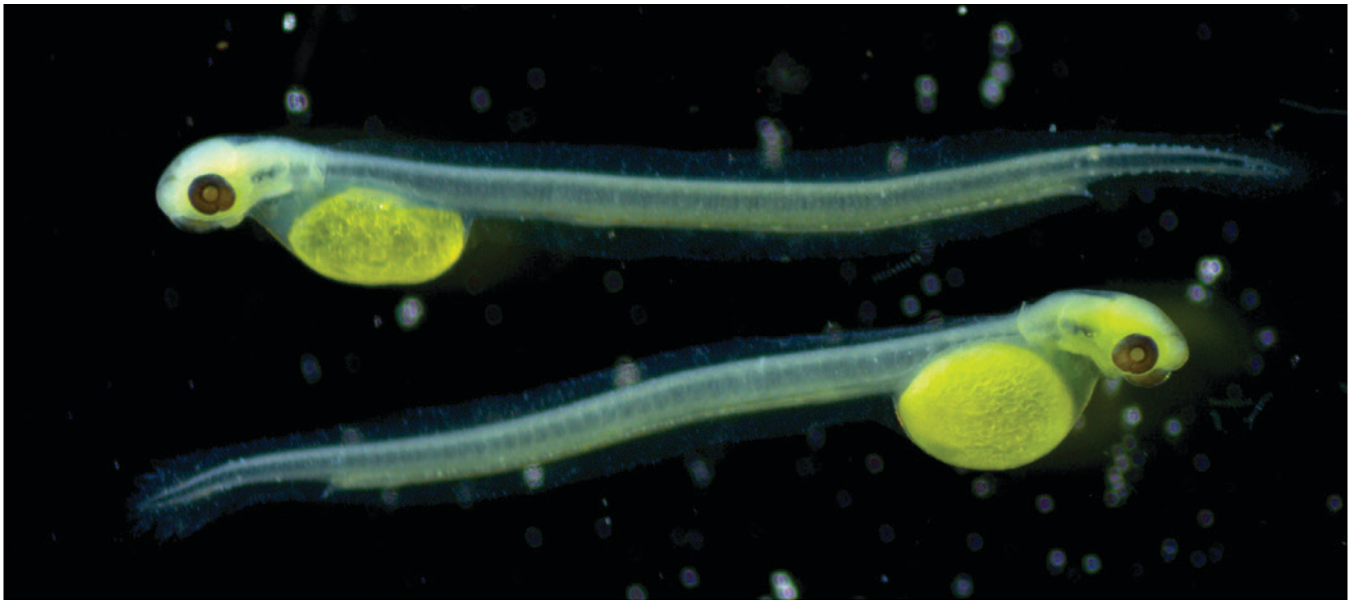

Photo by Natalie Mahara

DATA SOURCES

1. Killer whale mortality indices: Ford et al. 2009

2. Salmon diet data based on research by Sam James

3. Herring abundance and salmon growth data loosely adapted from Journey et al. 2020

4. Zooplankton timeseries and salmon returns loosely adapted from Chittenden et al. 2010

MEDIA

1. Drawings by Anisha Parekh

2. Phytoplankton images and video by Devan Johnson and Svetlana Esenkulova

3. Zooplankton images by Natalie Mahara and Will Duguid

4. Predator images (sea lions, killer whales, eagles, cormorants) by Lucy Quayle

5. Sand lance by brewbooks

6. Lion's mane video by hauntedLuminous

7. Images without attribution are from the public domain

REFERENCES

Chittenden CM, Jensen JLA, Ewart D, Anderson S, Balfry S, et al. 2010 Recent salmon declines: A result of lost feeding opportunities due to bad timing? PLoS ONE 5(8): e12423. doi:10.1371/journal.pone.0012423

Ford, JKB, Wright, BM, Ellis, GM, and Candy, JR. 2010. Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p.

Journey, ML, Neville, C, Young, G, Trudel, M, Beckman, BR. 2020. Spatial and interannual variability of juvenile coho salmon growth in the Strait of Georgia (2012-2015). Mar Ecol Prog Ser 646: 145-160.

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