STREAM STRESSORS, IMPACTS, AND RESTORATION

TEACHER'S GUIDE

Photo credit: Eiko Jones

Prepared by Maria Catanzaro and Kyla Sheehan

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PACIFIC SALMON FOUNDATION

PACIFIC SALMON FOUNDATION
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OVERVIEW

Students will begin this lesson by revisiting what makes good freshwater salmon habitat. They will learn about stressors and impacts to freshwater ecosystems, including erosion, culverts and other barriers to natural stream flow, forestry practices, run-off pollution, and climate change. Students will explore how these stressors can impact Pacific salmon health and survival. Some of these impacts include: loss of fish passage and habitat connectivity, excess sediment and pollution contamination that can affect salmon health, lack of shady riparian habitat for shelter, the reduction or elimination of appropriately sized spawning gravel, and decreased flow and increasing stream temperatures that can prevent successful upstream migration. Students will be invited to think critically about the "drivers" for these stressors and will be introduced to the field of ecological restoration - "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration). Students will look at multiple methods of ecological restoration that can help improve freshwater habitat, including exploring two case studies. Students will also have the opportunity to think critically with an activity involving graphing stream temperature datasets and making observations about what they see and hypotheses for broader implications.

ESSENTIAL QUESTIONS

- Review: What habitat components do Pacific salmon depend upon?
- What are some anthropogenic stressors that impact freshwater environments (rivers, streams, creeks)?
- How do these stressors impact salmon?
- How does climate change specifically impact freshwater salmon habitat?
- What are some ways to tackle these stressors?

CURRICULUM REQUIREMENTS

This lesson educates and engages students in the topic of the natural world, impacts from anthropogenic stressors, and how this impacts Pacific salmon survival. This lesson fits with the BC Science and Math 7 curriculum. It allows students an opportunity to develop competency in the following areas:

Big Ideas

- Earth and its climate have changed over geological time
- Contributing to community and caring for the environment

<table>
<tr><td>Curricular Competencies</td><td>Content</td></tr>
<tr><td>
Science
Questioning and predicting

Demonstrate a sustained intellectual curiosity about a scientific topic
Make observations aimed at identifying their own questions about the natural world
Identify a question to answer or a problem to solve through scientific inquiry
Formulate alternative “If…then…” hypotheses based on their questions
Make predictions about the findings of their inquiry

Processing and analyzing data and information

Experience and interpret the local environment
Construct and use a range of methods to represent patterns or relationships in data, including tables, graphs, keys, models, and digital technologies as appropriate
Use scientific understandings to identify relationships and draw conclusions

Planning and conducting

Measure and control variables (dependent and independent) through fair tests

Communicating

Communicate ideas, findings, and solutions to problems, using scientific language, representations, and digital technologies as appropriate

</td><td>
Biology
Survival needs

Students will learn about the key habitat components that make for a hospitable environment for Pacific salmon. We will discuss factors that impact survival, such as stream warming (thermotolerance), sediment load, and barriers to migration (which can lead to stranding).

Earth/Space
Evidence of climate change over geological time and recent impacts of humans

Discussion of warming temperatures, increased droughts due to changes in precipitation patterns and melting of glaciers.
Identifying human-caused impacts on freshwater ecosystems such as increased sediment load and reduced shading from removal of riparian vegetation and logging, and impeded migration by installation of structures like dams and non salmon-safe culverts.

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</table>

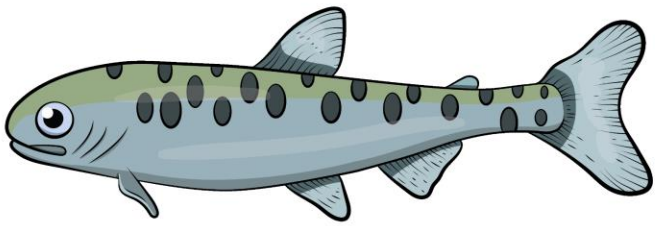
Core competencies: Critical thinking and Reflective thinking • Questioning and Investigating • Analyzing and Critiquing	
Math • **Connecting and Engaging with others** – Questioning and Investigating – Analysing and Critiquing • **Reasoning and Analyzing** – Use tools or technology to explore and create patterns and relationships, and test conjectures • **Understanding and solving** – Reflect on mathematical thinking	**Data and probability** *Discrete linear relations, using tables and graphs &* *Cartesian coordinates and graphing* ● students will create two graphs of temperature over time, plotting data for two streams provided by PSF. ● students will analyze the changes in temperature over time and hypothesize reasons for those changes in the habitat.
Arts • **Exploring and creating** – Intentionally select and apply materials, movements, technologies, environments, tools, and techniques by combining and arranging artistic elements, processes, and principles in art making	*Processes, materials, movements, technologies, tools, strategies, and techniques to support creative works* ● In the 'Building a Secchi Disc' activity, students consider the purpose of each component of the device, and how it contributes to the overall functioning of the secchi disc tool.

ADDITIONAL BACKGROUND FOR TEACHERS

Salmon (written by Sam James)

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.



Freshwater Habitat Stressors

In this lesson, we want students to explore how freshwater habitat can be impacted by human activity, including how these stressors impact Pacific salmon during their early juvenile life stage and during terminal migration to spawn. There are many habitat features that are important to salmon for them to successfully spawn, to grow and to find refuge and shelter. The morphology of the river creates these habitat features, and they shift and change naturally (season changes in precipitation) as well as through other impacts (climate change). There are a wide range of anthropogenic stressors that salmon face, one critical one being barriers to fish passage from perched culverts, dikes, and dams, and another being forestry practices. In respect to forestry practices, many streams and rivers are impacted: clearcuts increase sediment loading in waterways (as rain falls it collects sediment and runs off into streams instead of permeating through the soil), windfall near clearcuts can cause riparian trees to fall, collect and create barriers for salmon, slopes can become unstable causing landslides and mass wasting, and sediment can bury spawning substrate (salmon species require specific substrate to spawn in). Climate change is another stressor for freshwater salmon habitat - which compounds existing non-climate stressors such as ones named above.

As our climate continues to change we can expect more precipitation to fall in the form of rain rather than snow, for this precipitation to increase flow during winter months, for stream temperatures to increase except for areas with glacial influence, and drought will decrease water levels. This results in impacts to salmon survival - such as causing stress to salmon as they navigate warmer streams or increasing the duration of time that salmon must wait during their terminal migration to spawn while water levels rise again and while water temperatures are suitable.

We want students to see the connection between human activity, the impact to the environment, and the responses by salmon, including how our changing climate compounds it. We want to encourage creative and big thinking for tackling these environmental impacts and to explore different methods of habitat restoration and other stewardship activities we can do to help keep our waterways healthy.

More details on Stream Temperature: Stream temperature is influenced by many variables including, variables at a catchment scale (e.g., drainage, area), macroclimate scale (e.g., air temperature, precipitation), and reach-scale (e.g., shading by riparian vegetation) (Moore 2006). Whether water flow is regulated or not can also influence stream temperature. Stream temperatures can be documented over time to understand temperature regimes and find temperature -sensitive streams (Moore 2006). This can help with assessing whether a habitat is suitable for salmon species and can also help with the restoration decision-making process and how to prioritize urgent actions.

VOCABULARY

Anadromous: Anadromous fish spend part of their lives in salt water and part in freshwater. Salmon, for instance, are anadromous and start their lives in freshwater, then make their way to the ocean to grow up, then return to freshwater to spawn and complete their life cycle.

Alevin: Juvenile salmon that have just emerged from their egg sacks from the gravel beds of streams, rivers and creeks. Alevin will still have a yolk sac attached to their bodies for nutrients as they grow.

Bankfull Width: The width of the channel, measured from the level on either bank where the highest level of water would be found. This is essentially the width of the channel during a typical high flow event (i.e. after a big rainfall). The point on either bank is indicated by the start of permanent (rooted) vegetation like grasses, shrubs and trees.

Cascade: Freshwater flowing over a steep drop - a waterfall.

Channel: A wide strait or waterway between two landmasses that lie close to each other.

Channelization When the morphology of streams and other water courses are altered and straightened by human-made infrastructure.

Culvert: A structure that channels water, usually under obstructions like roads or bridges

Ecological Restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

Erosion: Erosion occurs when sediment is picked up and transported away from a particular site. Erosion occurs naturally, but high erosion events can take away too much beneficial sediment, leaving behind only large rocks.

Estuary: Areas where incoming fresh water (rivers) meet salt water (ocean). Estuaries are unique habitats, and are critical areas for juvenile salmon to grow before entering the open ocean and beginning their migration.

Fish-ways: Human-made structures that help fish migrate past barriers like dams and other structures along the course of a river. Often, fish ways are stepped, allowing fish to get past areas that would be too steep for them to traverse on their own. Also known as fish ladders.

Fry: Once the alevin lose their yolk sac, they must leave their gravel nests and enter the river to find food. These salmon that emerge from the gravel are called fry. Fry develop dark bars along the sides of their bodies called parr marks to better camouflage in their new environment.

Glide: A stretch of a channel with smooth, laminar flow (no riffles or pools).

Gradient: Refers to the slope of the channel.

Large Woody Debris (LWD): Trees, logs, large branches or root wads that extend into the bankfull channel and influence the flow or shape of that watercourse. LWD is usually at least 2 meters in length and at least 10 cm thick.

Life Stage: A life stage is a period of the life cycle where an organism has distinct physical characteristics and/or habitat requirements. An example of a salmon life stage is the ‘fry’ stage.

Live staking: A restoration practice where cuttings are taken from fast growing tree species like red-osier dogwood and alder and planted directly in the streambanks. Once the cuttings start to root into the soil, they help to stabilize the banks, and their branches and foliage help to shade the stream.

Mass Wasting: Natural and human-driven events of slope failure. I.e. stream banks and riparian slopes can fail during storms, high flow events, and when vegetation is removed.

Migration: A migration is a long journey that is completed as a normal part of a species life cycle. Salmon smolts travel many kilometers from the freshwater where they are born down to estuaries and out to the ocean. Some salmon species migrate long distances in the ocean as well as they grow. Once they're ready, they start their migration back up those same rivers to spawn.

Pool: A pool is a deep (relative to the average depth of the river) pocket of a river where the water flows at low velocity. A scour pool is a particular type of pool, where water flows against a partial channel obstruction like a piece of large wood, or the channel bank and the sediment buildup behind that structure gets washed out or eroded by the flow. A dammed pool occurs when there is an obstruction that extends across the entire channel width. The pool develops behind the obstruction, as the flow scours away sediment behind it.

Riffle: A relatively shallow area of a river, creek or stream where water flows over rocks near the surface. The flow of the water over these rocks is audible.

Riparian: The vegetated area adjacent to the channel. This riparian area provides many ecosystem functions like regulating the temperature of the channel by shading out the sun, adding organic matter and nutrients from falling leaves/branches, and contributing terrestrial invertebrates (insects) to the channel.

River: A large natural course of flowing freshwater that extends from inland to meet an ocean/sea at the coastline or lake or channelized fresh watercourse.

Runoff: Substances accumulating on land that are washed into waterways. E.g., agricultural pesticides and fertilizers, effluent from cars. When water from rain, irrigation or even washing your car flows over paved surfaces, it collects all the materials including harmful chemicals from those surfaces as it flows into storm drains and directly into waterways.

Secchi disk: A tool to measure water turbidity.

Sediment load: The amount of eroded sediment or solid particles that are suspended and carried in a waterway.

Smolt: Fry transform into smolts when they are ready to begin their migration downstream into the open ocean. Smolts undergo physiological changes like losing their parr marks and slowly change to be more silver in colouring, as well as changing internally to prepare for the salt water environment.

Spawning Gravel/Redds: Redds are the nests of spawning fish like Pacific salmon. Adult salmon select areas in their natal streams where the substrate (sediment) is suitable for them to lay their eggs. Depending on the species and their preferences for gravel size, water depth and water flow, we can describe their ideal spawning grounds and identify areas where there are appropriate beds of spawning gravel.

Substrate: In the video, we refer to the floor of the river and the substrate or 'bed materials' of which it is made up. The substrate is usually described as the type of material or size of sediment, e.g. sand, rock, cobble.

Thalweg: The deepest part of the channel, which also happens to be where the flow will be fastest. The thalweg is not always in the centre of the channel, and often is skewed to one side when channels bend or curve.

Turbidity: The measure of relative clarity in water. Reflects the amount of suspended particles in the water column.

Velocity: The speed at which something or someone travels. In this case, we refer to the stream velocity, or the speed at which the water is moving, usually measured in metres per second (m/s).

Watershed: The area over which freshwater drains over the landscape to reach its final destination (the ocean or sea).

Wetted Width: The width of the channel, measured from the point on either bank where the water level sits at the time it is recorded.

Windfall: Trees or other vegetation falling over during a high wind event – downed trees from windfall often end up in the river as large woody debris.

Anadromous: Anadromous fish spend part of their lives in salt water and part in freshwater. Salmon, for instance, are anadromous and start their lives in freshwater, then make their way to the ocean to grow up, then return to freshwater to spawn and complete their life cycle.

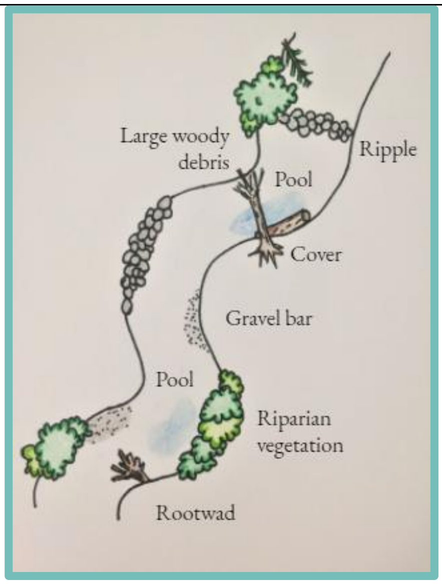
Photo by: Maria Catanzaro

OUTLINE

Video

PSF Biologists, Kyla Sheehan and Maria Catanzaro, will begin by guiding students through a review of what habitat requirements are needed by Pacific salmon in their early juvenile life stage and during their terminal migration, followed by stressors and impacts due to human activity, and finishing with ways we can combat these stressors with ecological restoration. Below is an outline of the topics covered, key content in each topic, as well as potential questions for teachers to ask. Kyla and Maria ask 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
Habitat Requirements for Pacific Salmon	A brief review of habitat features that are critical for Pacific salmon during their freshwater stages.	Pause video at Slide 3 to discuss Q: What makes a good habitat for salmon? A: Food sources (from insects feeding on large woody debris or riparian vegetation), complex habitat such as a good mixture of riffles, pools and glides, as well as cover (from the hot sun and protection from predators).

		 Illustration by Maria Catanzaro
Freshwater habitat stressors	Human induced stressors that impact freshwater ecosystems. Discussion of cause and effect of a driver that prompts a stressor. E.g., an eroding bank is caused by something greater – climate change, or forestry, or both combined.	Pause video at start of Slide 5 to discuss Q: Can you think of some examples of stressors that could impact our streams, rivers and creeks? A: Eroding banks, lack of/removed riparian vegetation, fish passage blockages (e.g, perched culverts), climate change (e.g., drought, flooding), pollution, natural events (landslides), upstream inputs (sediment, pollution). Drivers cause stressors, such as forestry and climate change.
Stressors to salmon in their freshwater life stages: Overview	There are many stressors that can impact salmon – both of natural origin, and anthropogenic (human-caused). Some of these stressors include: runoff from agriculture or	Pause video at end of Slide 5 to discuss Q: What are some ways that these can impact salmon? A: Salmon will experience more stressful environments, they may experience barriers to successful migration, lack of adequate temperatures, lack of adequate shelter and cover from predation, physiological stress from increased sediment and

	pollution from industry, perched culverts, removed riparian vegetation from forestry, and erosion.	reduced oxygen, and impediments to successfully spawn to produce the next generation.
Perched culverts	Perched culverts are major barriers for salmon, since they sit above the level of the water in the stream and often are made of materials that make it difficult for salmon to move through.	
Unwanted stream inputs (pollution/runoff)	Runoff is all the material that gets washed off of surfaces like roads, rooftops and driveways when it rains, and makes its way to the ocean, rivers or streams. There are lots of unwanted pollutants that we use on land that will be washed into the waterways, impacting habitat for Pacific Salmon and many other species.	**Pause video at slide 12 to discuss** Q: What are some ways that we can reduce runoff of unwanted substances from our homes? • wash your vehicle over a grass or gravel surface so the water infiltrates into the ground instead of running off of hard surfaces such as a paved driveway • do not use herbicides or pesticides in your garden • use natural soaps and detergents for dish washing and laundry
Riparian Vegetation	Riparian vegetation helps filter runoff prior to entering waterways as well as helps to stabilize stream banks. The trees and shrubs in riparian areas also provide shade and protective cover to waterways.	**Pause video at slide 13 to discuss** Q: What happens when riparian areas are removed? A: Bank destabilization, loss of cover, loss of food sources, loss of shelter and refuge (shade and cooler waters for salmon).
Sediment Loading, Secchi disk and turbidity	We can describe waters that look muddy from carrying sediment as 'turbid'. And we can	**Pause video at start of Slide 18 to discuss** Q: If it's natural for large rivers to be turbid, why is it an issue in smaller streams?

<table>
<tr><td></td><td>compare the muddiness of water, or how easily light shines through it, by its ‘turbidity’. A Secchi disk is a tool that scientists use to measure turbidity.</td><td>A: It can impact the health of salmon. Fine sediments prevent oxygen flow and can bury spawning gravel.</td></tr>
<tr><td>Climate Change</td><td colspan="2">Climate change is altering natural habitats globally. Increasing intensity of storm events, and rising temperatures have major impacts to stream flow, and exacerbate the existing stressors to freshwater habitats.</td></tr>
<tr><td>Ecological restoration</td><td>We discuss the science of ecological restoration – the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society of Ecological Restoration).

We discuss that natural processes should be reinstated and to determine the drivers causing the degradation in the first place.

Some examples are: Live staking, Riparian planting, Slope stabilization, Installing LWD structures, Replacing migration barriers, Installing fish-ways, Diverting pollution/runoff</td><td>Discussion/Review question for after video

Q: What is ecological restoration?

A: the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society of Ecological Restoration).

Q: What are drivers?

A: What is causing the stressor to begin with. E.g., forestry practices.

Q: What do you think could be done to culverts to make it safer and increase migration ability for salmon?

A: Open-bottom culverts, so they cannot be perched and cause migration barriers.

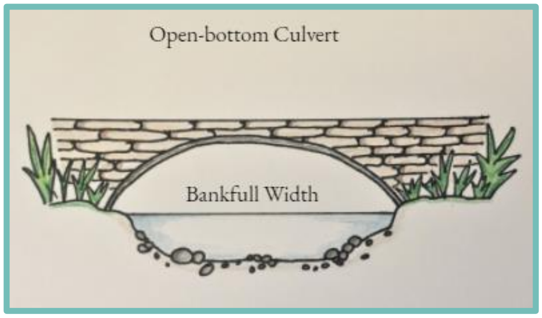

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		Illustration by Maria Catanzaro Q: How can restoration practitioners add complexity to streams? A: Adding large woody debris, which can also encourage new habitat development through new water movement, such as new pool habitat.
Case A Removed Riparian Vegetation	At this site, the riparian vegetation has been removed, and the banks of the stream have been eroded.	**Pause at slide 24 to discuss** Q: What can we do about this? (the removal of riparian vegetation) A: Replanting the riparian area to increase shade and stabilization. You can use native plants like red osier dogwood, willow or black cottonwood for live-staking.
Case B Perched culverts and dams in streams/rivers	Perched culverts are major barriers to fish migration, but are necessary because they allow water to flow through a channel underneath infrastructure like roads. We can replace perched culverts with more salmon-friendly structures like open-bottom culverts.	**Bonus question: Pause at the end of Slide 31 to discuss** Q: What do you think is the difference between a regular culvert and an open-bottom culvert? (Look at illustration and photos to compare) A: The open-bottom culvert allows water to flow through more naturally, rather than regular culverts that can scour the sediment below and become perched (making it a barrier for salmon to swim up)
Case C: Stream lacking habitat complexity	In this case, the stream is functioning, but has a low ratio of pools to riffles. We can add LWD structures and large boulders to help encourage the stream to shift its sediment around the structures, adding	**Pause at the end of slide 36** Q: What other benefits would installation of LWD have in a stream like this? As the LWD softens and rots in the stream, it acts as a substrate for other trees and shrubs to grow out of. This adds to the riparian vegetation, increasing the amount of overhanging vegetation close to or even in the stream. Decaying LWD and the new riparian growth attracts insects to the new habitat, which will fall into the stream, providing a food source for Pacific

	complexity by forming more pools and riffles.	salmon.
Student Activity: Graphing Stream Temperatur e	Stream temperature was recorded at two sites every hour for a whole day. The photos are of the two locations where stream temperatures were taken.	**Activity (slide 37):** 1) Graph each dataset separately. 2) Compare both graphs of stream temperature over time. (Ask students to think about it, then to discuss with another student). They can ask the questions below to one another, then they can be discussed as a class. Q: What do you notice? Q: Which stream has higher water temperatures? Q: Compare the photos of stream A and B. Do you see any stressors that we talked about? Q: Which stream would you expect to have a higher temperature? Match the dataset with the stream.

ACTIVITY: GRAPHING STREAM TEMPERATURE

Student Worksheet and Teacher Answer Key in separate documents.

Objectives

Students will plot the given data of stream temperature over time. There are two sets of data; one for each of the streams pictured on the slide. Students will be asked questions about both datasets and to make predictions.

Materials Needed

Ruler, two different coloured pencil crayons, either graph paper and pencil, ruler, or excel spreadsheet. Data provided.

Essential Questions

1. What factors influence the temperature of a stream?
2. Why is it important that streams don't get too hot?

Procedure

- Look at the data as a class - explain how to read the dataset outputs from BC Hydro.
- Explain that their first step is to ask them to transfer the BC Hydro data to the tables provided.
- Review how the graph will be laid out:
    - x-axis = time of day (24 hour period)
    - y-axis = temperature
    - units for the y-axis = degrees celsius (℃)
    - each value is a data point and put into a line for each dataset, in the same graph for easy comparison
- Note: If using excel
    1. Have students create three columns (time- beginning at 14:00 PM going clockwise, dataset #1 values, dataset #2 values)
    2. Highlight all the columns, including the headings above them.
    3. Click on Insert on the drop down menu, then select line graph - specifically "Line with Markers"

Photo by Kyla Sheehan

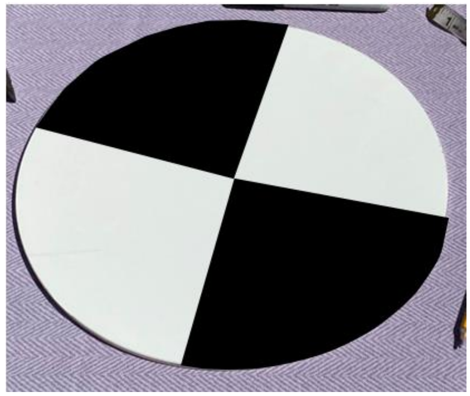
SUPPLEMENTAL ACTIVITY: BUILDING A SECCHI DISC

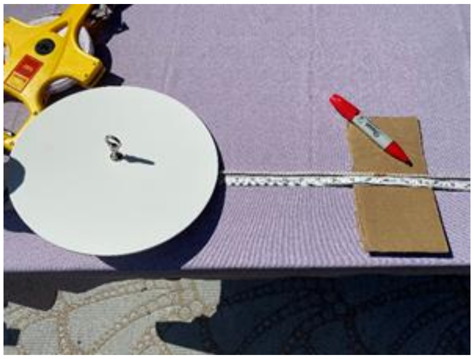
Materials

- 1 round plastic disc (can be specially ordered or can use a 5-gallon bucket lid or ice cream bucket lid)
- Black paint
- Permanent felt pens (black and red)
- 0.75 lb lead weight/1lb lead cannonball
- white poly rope (ideally < 20 m long)
- stainless steel eye bolt with shoulder and eye nuts[1]
- Foam pool noodle or piece of wood dowel.

Instructions

1. Divide the disc into four equal quadrants by drawing two lines crossing at a 90 degree angle to identify the quadrants. 2. Use painters tape to mark out the quadrants.	

3. Paint the first quadrant white (if your disc is not white already) 4. Paint the next quadrant black. Leave the next quadrant white. Paint the final quadrant black. You should have two black quadrants and two white quadrants. Q: Why do we paint half of the quadrants black? A: As we drop the secchi disc into the water, the difference between the black and white quadrants will become more difficult to distinguish as we lower it further, or if the water is turbid. This is a *visual tool* to help us measure the clarity of the water.	
5. At the centre of the disc (where the quadrants meet) drill a hole big enough for the eye bolt to fit through. *note: you can also use a hammer and a nail to create a hole if you are using a bucket lid or softer plastic.	

6. Screw the eye bolt through the centre hole in the disc. 7. Screw the washer and eye nut onto the other side* 8. Tie 20 m of poly rope to the top eye bolt. *It is important that you get the eye nut so you can put a weight on one side and the rope on the other.	
9. Measure and mark out ½ m and 1 m increments along the rope (starting from the disc). *Use red felt for ½ metre and black felt for 1 m.	
10. Wrap the poly rope around a chunk of foam pool noodle or piece of wood dowel. 11. Using a carabiner attach the lead weight or cannonball to the bottom eye bolt	

MEDIA

1. Drawings by Anisha Parekh
2. Secchi Disc photos by Nicole Frederickson

REFERENCES

1. Secchi Disc Activity organized by Nicole Fredrickson.

Photo credit: Eiko Jones

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