Science Learning Packet

BIO B:

Population Ecology, Lessons 4-6

science learning activities for SPS students during the COVID-19 school closure.

Seattle Public Schools is committed to making its online information accessible and usable to all people, regardless of ability or technology. Meeting web accessibility guidelines and standards is an ongoing process that we are consistently working to improve.

While Seattle Public Schools endeavors to only post documents optimized for accessibility, due to the nature and complexity of some documents, an accessible version of the document may not be available. In these limited circumstances, the District will provide equally effective alternate access.

Due to the COVID-19 closure, teachers were asked to provide packets of home activities. This is not intended to take the place of regular classroom instruction but will help supplement student learning and provide opportunities for student learning while they are absent from school. Assignments are not required or graded. Because of the unprecedented nature of this health crisis and the District’s swift closure, some home activities may not be accessible.

If you have difficulty accessing the material or have any questions, please contact your student’s teacher.
How to use this PowerPoint

- Work at your own pace. Your health and your family come first.
- If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
- You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
- Read through the slides one at a time. Take your time to explore the images and any links.
- If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
- When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Identify the goals in the Orca Task Force Recommendations.
2) Identify supporting recommendations within the goals.
3) Interpret the requirements on “4 Orca Project Rubric for Distance Learning.”
4) Choose a goal and supporting recommendation that you would like to focus on your project.

Planning for the Unit Project

- Review “4 Orca Project Rubric for Distance Learning.”
- Skim “4 Orca_Recovery_Task_Force_Recommendations.”
  - What are the goals suggested by the Orca Task Force?
  - Choose a goal that you find interesting to read more closely. What are the supporting recommendations for that goal?
  - What questions do you have about the Orca Task Force document?
- Reach out to a peer in your class, if possible, to see if they would like to partner on the project.
- Choose a goal and recommendation that you would like to study further.
Check Your Understanding

1) Identify the goals in the Orca Task Force Recommendations.
2) Identify supporting recommendations within the goals.
3) Interpret the requirements on 4 Orca Project Rubric for Distance Learning.
4) Choose a goal and supporting recommendation that you would like to focus on your project.

What's Next?
Make an entry in your Learning Tracking Tool titled “4 Project Introduction.”
Orca Project Rubric

NAME(S):______________________________

**Background:** In Biology we studied the transfer of matter and energy in ecosystems and populations. Throughout this unit you have researched several problems that are causing the orca population in the Puget Sound to decrease. You saw how different stakeholders are involved in helping to solve the problem to increase the orca whale population.

**Question:** Which recommendation from the Orca Task Force will protect orca populations in the future?

**The Challenge:** Select a Goal and Supporting Recommendation from the Orca Task Force Recommendations. Create a scientific argument that will support their recommendation. The argument can take shape in a variety of ways - open letter to stakeholder, infographic/poster, video commercial, podcast, PowerPoint to share with stakeholder, and many more!

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Check-off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task Force Recommendation:</strong></td>
<td>□ Identify Goal and Recommendation from the Orca Task Force</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Explain why you think this Goal and Recommendation are important to focus on</td>
<td></td>
</tr>
<tr>
<td><strong>Quantitative Data:</strong></td>
<td>□ Provides quantitative data (numbers) to support the Goal and Recommendation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ There is a clear connection between the data and the Orca Task Force Goal and Recommendation</td>
<td></td>
</tr>
<tr>
<td><strong>Predict Biodiversity of Puget Sound:</strong></td>
<td>□ Predict how the Goal and Recommendation will support orcas and Puget Sound biodiversity at <strong>two</strong> different scales (large scale, macro, micro or atomic-molecular – refer to Activity 2 Who Are the Orcas?)</td>
<td></td>
</tr>
<tr>
<td><strong>Scientific Concept:</strong></td>
<td>□ List a scientific concept learned in this unit that connects to the Goal and Recommendation (example: biodiversity, bioaccumulation, food chains, keystone species)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Explain how the scientific concept connects the Goal and Recommendation</td>
<td></td>
</tr>
<tr>
<td><strong>Revision to Recommendation:</strong></td>
<td>□ Suggest at least one revision to the Recommendation that will help mitigate adverse effects of human activity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Explain how your revision will support biodiversity of the Puget Sound</td>
<td></td>
</tr>
<tr>
<td><strong>Sources Cited</strong></td>
<td>□ Cite sources using MLA formatting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Bibliography is included in project</td>
<td></td>
</tr>
</tbody>
</table>
Southern Resident Orca Task Force Draft Report and Recommendations

*A simplified guide to the draft recommendations and how to provide public input.*

After many months of incredibly hard work, dedication and collaboration, the revised draft recommendations for action to recover the Southern Resident orcas were posted on the Governor’s website October 24. These recommendations were generated by the Orca Task Force based on input from the three working groups to the Orca Recovery Task Force for consideration. Public input received via this Survey Monkey will be provided to the Task Force for further consideration and finalization at the November 6 meeting.

The full October 24 Southern Resident Orca Task Force Draft Report and Potential Recommendations can be found [here](#) and the Survey Monkey link [here](#).

This guide is laid out in the same order as the survey, which will ask you to rank your level of agreement or disagreement with each potential recommendation. We have laid out which actions we feel will have the greatest impact on Southern Resident orca recovery, and encourage you to reinforce support for these actions.

*Public comment period is open until midnight on October 29, 2018.*

**Simplified Draft Recommendations**

**Goal 1: Increase Chinook abundance**

1. **Draft recommendation 1:** Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.  
   **STRONGLY SUPPORT**

2. **Draft recommendation 2:** Immediately fund acquisition and restoration of nearshore habitat to increase the abundance of forage fish for salmon sustenance.  
   **STRONGLY SUPPORT**
**STRONGLY SUPPORT**

4. Draft recommendation 4: Immediately strengthen protection of Chinook and forage fish habitat through legislation that amends existing statutes, agency rulemaking, and/or agency policy.  
**STRONGLY SUPPORT**

5. Draft recommendation 5: Develop incentives to encourage voluntary actions to protect habitat.  
**SUPPORT**

6. Draft recommendation 6: Increase hatchery production and programs to benefit Southern Resident orcas consistent with sustainable fisheries and stock management, available habitat, recovery plans, and the Endangered Species Act. Hatchery increases should be done in concert with increased habitat protection and restoration measures.  
**SUPPORT**

7. Draft recommendation 7: Prepare an implementation strategy to re-establish salmon runs above existing dams, increasing prey availability for Southern Resident orcas.  
**STRONGLY SUPPORT**

8. Draft recommendation 8: Increase spill to benefit Chinook for Southern Residents by adjusting Total Dissolved Gas allowances at the Snake and Columbia River dams.  
**STRONGLY SUPPORT**

9. Draft recommendation 9: Determine whether removal of Lower Snake River Dams would provide benefits to Southern Resident orcas commensurate with the associated costs, and implementation considerations.  
**STRONGLY SUPPORT**

**NEITHER SUPPORT NOR OPPOSE**

**SUPPORT**

12. Draft recommendation 12: Direct the appropriate agencies to work with tribes and NOAA to determine if pinniped predation is a limiting factor for Chinook in Puget Sound and along Washington’s outer coast and evaluate potential management actions.  
**SUPPORT**

**NEITHER SUPPORT NOR OPPOSE**

14. Draft recommendation 14: Reduce populations of non-native predatory fish species that prey upon or compete with Chinook.  
**SUPPORT**

15. Draft recommendation 15: Monitor forage fish populations to inform decisions on harvest and management actions that provide for sufficient feedstocks to support increased abundance of Chinook.  
**STRONGLY SUPPORT**

16. Draft recommendation 16: Support the Puget Sound zooplankton sampling program as a Chinook and forage fish management tool.  
**STRONGLY SUPPORT**

**Goal 2: Decrease disturbance of orcas from vessels and noise and increase orcas’ access to prey**

17. Draft recommendation 17: Establish a statewide “go-slow” bubble for small vessels and commercial whale watching vessels within half a nautical mile of orcas.  
**STRONGLY SUPPORT**

18. Draft recommendation 18: Establish a limited-entry whale-watching permit system for commercial whale-watching vessels and commercial kayak groups in the inland waters of Washington to increase acoustic refuge opportunities for the orcas.  
**STRONGLY SUPPORT**

19. Draft recommendation 19: Require an annual “Be Whale Wise” certification for all recreational boaters on the inland marine waters, and ensure that all boaters are educated on how to limit boating impacts to orcas.  
**STRONGLY SUPPORT**

20. Draft recommendation 20: Increase enforcement capacity and fully enforce regulations on small vessels to provide protection to Southern Residents.  
**STRONGLY SUPPORT**

**STRONGLY SUPPORT**

**STRONGLY SUPPORT**

23. Draft recommendation 23: Reduce noise from the Washington State ferries by accelerating the transition to quieter and more fuel-efficient vessels and implementing other strategies to reduce ferry noise when Southern Residents are present.  
**STRONGLY SUPPORT**

24. Draft recommendation 24: Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.  
**STRONGLY SUPPORT**

25. Draft recommendation 25: Coordinate with the Navy in 2019 to discuss reduction of noise and disturbance affecting Southern Resident orcas from military exercises and Navy aircraft.  
**STRONGLY SUPPORT**
26. Draft recommendation 26: Revise RCW 77.15.740 to increase the buffer to 400 yards behind the orcas.  
**STRONGLY SUPPORT**

27. Draft recommendation 27: Determine how permit applications in Washington State that could increase traffic and vessel impacts could be required to explicitly address potential impacts to orcas.  
**STRONGLY SUPPORT**

**NEITHER SUPPORT NOR OPPOSE**

Goal 3: Reduce the exposure of Southern Resident orcas and their prey to contaminants

29. Draft recommendation 29: Accelerate the implementation of the ban on PCBs in state purchased products and make information available online for other purchasers.  
**STRONGLY SUPPORT**

30. Draft recommendation 30: Identify, prioritize and take action on chemicals that impact orcas and their prey.  
**STRONGLY SUPPORT**

31. Draft recommendation 31: Reduce stormwater threats and accelerate clean-up of toxics that are harmful to orcas.  
**STRONGLY SUPPORT**

32. Draft recommendation 32: Improve effectiveness, implementation and enforcement of National Pollutant Discharge Elimination System (NPDES) permits to address direct threats to Southern Resident orcas and their prey.  
**STRONGLY SUPPORT**

33. Draft recommendation 33: Increase monitoring of toxics substances in marine waters; create and deploy adaptive management strategies to reduce threats to orcas and their prey.  
**STRONGLY SUPPORT**

Additional draft recommendations

34. Draft recommendation 34: Provide sustainable funding for implementation of all recommendations.  
**STRONGLY SUPPORT**

35. Draft recommendation 35: Conduct research, science and monitoring to inform decision-making, adaptive management and implementation of actions to recover Southern Residents.  
**STRONGLY SUPPORT**

**STRONGLY SUPPORT**

TOP PRIORITIES

37. What are the top 5 things that you think should be done?
   
   **Draft recommendation 1:** Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.  
   **Draft recommendation 3:** Enforce laws that protect habitat.  
   **Draft recommendation 17:** Establish a statewide “Go-slow” bubble for small vessels and commercial whale watching vessels within half a nautical mile of orcas.  
   **Draft recommendation 24:** Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.  
   **Draft recommendation 31:** Reduce stormwater threats and accelerate clean-up of toxics that are harmful to orcas.

COMMENT BOX

38. Please use this space to share any comments about the draft recommendations.

**PERSONALIZE ANY ADDITIONAL COMMENTS YOU WISH TO INCLUDE.**

Copy and Paste:  
It is essential that the suite of final recommendations for action are comprehensive and that they address all the threats facing the Southern residents orcas—food, noise, and pollutants. The actions should not be limited to a short list that are easier or more convenient for people. They must be bold and represent a balance of actions throughout the state, in both rural and urban communities.  

The reality is that most of these proposed actions can be done under existing authorities—our state simply must prioritize the hard work needed to protect and restore salmon and to reduce pollution. Let’s get started implementing these actions and continue the work to refine actions for the final set of recommendations from the task force.

Thank you for submitting a public comment in support of solutions that will help the recovery of our Southern Resident orcas!
5.1 Orca Food Webs PowerPoint lesson

**How to use this PowerPoint**

- Work at your own pace. Your health and your family come first.
- If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
- You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
- Read through the slides one at a time. Take your time to explore the images and any links.
- If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
- When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

**Goals**

After reviewing this PowerPoint, you should be able to:

1) Identify biotic and abiotic factors that affect the Puget Sound ecosystem and orcas
2) Create a Puget Sound food web that includes both resident and transient orcas
3) Explain how removing organisms from the food webs may impact the biodiversity of the entire ecosystem.

**5.1 What role(s) do orcas serve in their ecosystem?**

Gathering information for argument: biotic and abiotic factors affecting orcas

**Marine Food Web**

**Goal**: Identify biotic and abiotic factors that affect the Puget Sound ecosystem and orcas

**Task**: Create a Puget Sound food web that includes both resident and transient orcas
Ecosystems include Two Different Factors:
1. Biotic (living)
2. Abiotic (non-living)

**Biotic Factors**
- Competition
- Access to prey
- Predators

What are some other examples of biotic factors?

**Abiotic Factors**
- Waves
- Substrates (rocks, sand, etc.)
- Chemicals in our food web

Remember - Biomagnification – the top predator in the food web will accumulate the most amount of toxins

Are there other examples of abiotic factors?

**Example of a Food Web**
1. Arrows show the connection between two organisms.
2. The direction of the arrow indicates what organism ate the other.

Example: The fox ate the rabbit.
Marine Food Web

Materials: Paper, pencil and Organism Cards (next 4 slides or separate file for printing)

Task: Create a marine food web using the organisms on the next four slides. You can print and cut the cards to organize them OR you can just write the names of the organisms on a piece of paper.

Show the relationship between each organism with an arrow pointing to the consumer. This may take some research to figure out feeding relationships!

You may check your work with the last slide of this ppt.
Food Web Analysis Questions

1. How are the roles that the transient and resident orca have in the food web similar? How are they different?

2. How will the web change when one organism is removed? Try removing one organism and reviewing the food webs. Explain how this changed the ecosystem. Repeat for an additional organism and explain.

3. Recall Biodiversity from lesson 3.2 - the number of different ecosystems, types of species, and the genetic diversity of the individuals in the region. Explain how removing organisms may impact the biodiversity in the ecosystem.

4. List abiotic factors that might affect the marine food web.

5. List different roles orcas serve in their ecosystem.
How do populations affect each other?

If wolf populations go down, what happens to moose? Trees?

If moose populations go down, what happens to wolves? Trees?

Check Your Understanding

1) Identify biotic and abiotic factors that affect the Puget Sound ecosystem and orcas
2) Describe the food web a resident orca whale.
3) Explain how removing organisms from the food webs may impact the biodiversity of the entire ecosystem

What’s Next?
Make an entry in your Learning Tracking Tool titled “What role(s) do orcas serve in their ecosystem?”
## 5.1 Orca Food Web - cards for cutting out

<table>
<thead>
<tr>
<th>Image</th>
<th>Species</th>
<th>Photo Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Blue Heron" /></td>
<td>Blue Heron</td>
<td>nwbirding.com</td>
</tr>
<tr>
<td><img src="image2.png" alt="Marine Bacteria" /></td>
<td>Marine Bacteria</td>
<td>blog.coralwonders.com</td>
</tr>
<tr>
<td><img src="image3.png" alt="Harbor Seal" /></td>
<td>Harbor Seal</td>
<td>eopugetsound.org</td>
</tr>
<tr>
<td><img src="image4.png" alt="Zooplankton: Copepod" /></td>
<td>Zooplankton: Copepod</td>
<td>buzzmarinelife.blogspot.com</td>
</tr>
<tr>
<td><strong>PHYTOPLANKTON</strong></td>
<td><strong>SEA OTTER</strong></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Photo credit: buzzmarinelife.blogspot.com</td>
<td>Photo credit: eopugetsound.org</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SALMON</strong></th>
<th><strong>RESIDENT ORCA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo credit: washington.edu</td>
<td>Photo credit: conservationbiology.uw.edu</td>
</tr>
</tbody>
</table>
PROTOZOA
Photo credit: buzzmarinelife.blogspot.com

TRANSIENT ORCA
Photo credit: visitsanjuans.com

HERRING
Photo credit: washington.edu

BULL KELP
Photo credit: uvic.ca
<table>
<thead>
<tr>
<th>Sea Urchin</th>
<th>Eelgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo credit: salishseanews.blogspot.com</td>
<td>Photo credit: nps.gov</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Krill (Zooplankton)</th>
<th>Grey Whale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo credit: pugetsoundblogs.com</td>
<td>Photo credit: digitaljournal.com</td>
</tr>
</tbody>
</table>
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
• Read through the slides one at a time. Take your time to explore the images and any links.
• If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Define keystone species.
2) Identify several examples of keystone species and explain why they are keystone species.
3) Describe the role of Chinook salmon as a keystone species.

5.2 Keystone Species

Gathering information for argument: How do species in a food web influence each other?

Keystone species:

a species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically.
Watch these videos on keystone species

Example: Purple Sea Stars
https://www.youtube.com/watch?v=hRGg5it5FMI
(0-8:45)

Example: Yellowstone Wolves
https://www.youtube.com/watch?v=ysa5OBhXz-Q

What other types of species are keystone species?

Think back to your food webs. Would removing certain species have a large impact on other species?

Here are several examples of keystone species:
• Ecosystem engineers like beavers
• Species that create habitats for other organisms like eelgrass
• Important prey species like herring
• Species with important jobs like bees that pollinate plants

Top predators are often keystone species because they free lower trophic levels from predation (trophic cascade).

With Sea Otters

Without Sea Otters

Northern California Kelp Beds
Chinook Salmon are a keystone species

- Chinook salmon influence marine (ocean), aquatic (river/stream), and terrestrial (land) ecosystems.
- Chinook salmon are a major food source for orcas, bears, seals, and birds of prey.
- When salmon swim upstream to spawn and then die, their bodies return nutrients to the surrounding ecosystem.

Check Your Understanding

1) Define keystone species.
2) Identify several examples of keystone species and explain why they are keystone species.
3) Describe the role of Chinook salmon as a keystone species. Explain why Chinook salmon are important to Southern Resident Orca populations.

What’s Next?
Make an entry in your Learning Tracking Tool titled “5.2 Keystone Species.”
[CARROLL:] From jungle to desert, from forest to plain, from mountaintops to the sea shore, the Earth is home to many habitats. And every habitat contains a community of plants and animals. Each community is populated by different species. And each species is present in different numbers.

[CARROLL (narrated):] So what determines how many species live in a given place? Or how large each population can grow?

[CARROLL:] The answers to such basic questions about how nature works eluded biologists for a long time. Until on this rocky Pacific shore in 1963, young zoology professor Robert Paine pried a purple starfish off the rocks and threw it out into the bay. And so began one of the most important experiments in the history of ecology.

[PAINE:] It was a lovely day. The old zoology building in Ann Arbor had a courtyard. In that courtyard, there was a tree which was beginning to bud out.

[PAINE:] And he said "Class, I want you to think about this... Why is that tree green?" And someone said... [FEMALE STUDENT:] Chlorophyll.

[PAINE:] Fred said, "What keeps the leaves there?"

[CARROLL (narrated):] Although technically, chlorophyll is what makes trees green, Fred Smith was asking a bigger question. He was thinking about food chains.

[PAINE:] You obviously had producers. They are the energy suppliers to whatever lives off of them. Then you have consumers on top of that, and then, we know, the herbivores.

[CARROLL (narrated):] The popular idea at the time was that the number of producers limits the number of herbivores. In turn the number of herbivores limits the number of predators that feed on them. Every level was regulated by the amount of food from the bottom of the food chain going up.
But this view didn’t explain why herbivore populations don’t simply grow to the point where they eat all the leaves on the tree. Professor Smith had discussed this conundrum with two colleagues: Nelson Hairston and Lawrence Slobodkin. They proposed a new idea. The number of herbivores must be controlled not only from the bottom up, but also from the top down.

[PAINE:] The herbivores had the capacity of destroying the plant community. Trees could be defoliated, and why weren’t they defoliated? And the answer was, because there weren’t enough insects around to do that, and that was the role of predators.

[CARROLL (narrated):] The world is green because predators keep herbivores in check. This was a radical concept that became known as the "Green World Hypothesis." Up until that time, no one thought predators had any role in regulating ecosystems.

[PAINE:] His class was the first public vetting of the Green World Hypothesis.

[CARROLL (narrated):] And one of Smith’s students, Robert Paine, would be the one to put this idea to the test.

[music plays] A few years later, as a new professor at the University of Washington, Paine went looking for a system where he could study the role of predators.

[PAINE:] I discovered the Pacific Ocean, and this magnificent array of organisms which lives along its margins. There it was, spread out in front of me. It was nirvana.

[CARROLL (narrated):] He began by identifying all the organisms. And then he started mapping out who eats who.

[PAINE:] There were carnivorous gastropods feeding on barnacles. There were sea urchins feeding on algae. There was a lot of pattern.

[CARROLL (narrated):] His observations showed that a species of large, purple and orange starfish, called *Pisaster ochraceus*, was at the top of the food chain.

[dramatic music] Starfish may seem like unlikely predators, but speed time up a bit and you'll see deadly hunters.

[PAINE:] If a starfish is feeding, you turn it over and you see what the starfish is eating. They were eating mussels. They were eating a lot of other things as well, but they were eating mussels...

[CARROLL (narrated):] So Paine asked, what happens when you remove the predator starfish from a single outcrop?

[PAINE:] You have to surprise them, because a starfish clamps down. It takes a strong wrist and a pry bar. I would then scale them as I could, and in those days, I could throw a starfish 60 or 70 feet, out
into deeper water. There were always starfish marching in, so during the summer months, I would drive the 350 miles round-trip, hit the area at low tide, do my removals, take other data, and then return to Seattle.

[CARROLL (narrated):] The ecosystem started to change rapidly.

[PAINE:] Within a year and a half, I knew that I hit ecological gold.

[CARROLL (narrated):] Although the top predator had been removed, surprisingly, the number of species on the rock actually decreased from 15 to 8.

[PAINE:] After three years, it went down to seven. But then by another seven years, it simplified itself 'til it was basically a monoculture. I'd changed the nature of the system.

[CARROLL (narrated):] As the experiment continued, the line of mussels advanced down the rock face, monopolizing almost all of the available space, and pushing all other species out. Paine had discovered that one predator could regulate the composition of an entire community. He coined a term to describe the power a single species can exert on an ecosystem.

[PAINE:] I know very little about architecture, but if you build an arch, you have to get the two sides of it to put pressure against one another, and therefore, at the apex of the arch you have a keystone. You pull the keystone out, and the structure collapses.

[CARROLL (narrated):] Many predators, like Pisaster starfish, turn out to be keystone species.

[PAINE:] These keystone species have a huge impact which extends well beyond the species they primarily prey on.

[CARROLL (narrated):] Most species do not have large impacts. In other experiments, Paine had removed various species, but that had little or no effect on the ecosystem as a whole.

[PAINE:] "All animals are equal, but some animals are more equal than others." And that expresses the fact that all species don't have the same impact on the system they're in. It takes experiments to tease that out, and that's often not easily done.

[CARROLL (narrated):] Paine's pioneering experiments and the concept of keystone species, sent ripples through the field of ecology, and turned thinking about the regulation of communities upside down.

[PAINE:] You remove the predator, the system simplifies itself. This is an ecological concept which is general and global.

[CARROLL (narrated):] As Paine continued his studies a little further from shore, he noticed another striking pattern.
[PAINE:] There were a lot of tide pools. And some of the tide pools were dominated by urchins, some weren't.

[CARROLL (narrated):] In the tide pools with lots of urchins, there was much less kelp. Paine suspected the urchins were keeping the kelp from growing.

[PAINE:] And I said to myself, that's my next round of experiments.

[CARROLL (narrated):] Paine removed all the urchins by hand from some pools and left nearby pools untouched. Again, the results were dramatic. In the pools where he removed urchins, the kelp started growing almost immediately.

[PAINE:] Urchins control the kelp; therefore, it's a total violation of the Green World Hypothesis.

[CARROLL (narrated):] The urchins in Paine's pools were eating all of the kelp. So why was nothing regulating the urchin populations? The answer would come from a fortuitous meeting, on a remote island in Alaska's Aleutian Island chain. There, Paine would cross paths with another scientist. In 1971, James Estes was an ambitious young graduate student.

[ESTES:] At the time that Bob and I met, I was just beginning to try to think my way through what it was I was going to do.

[PAINE:] We met in a bar after a movie. I was interested in sea urchins and Jim, I think, was doing a study on sea otter physiology.

[ESTES:] I was explaining to him what it was that I was thinking of trying to do, which was somehow understand how an ecosystem like the one at Amchitka Island could support such a high abundance of predators, and do that through an understanding of production and the efficiency of energy and material flow upward through the food web. And Bob's explicit or implicit reaction to that was "that's just not very interesting." And "have you ever thought about what these animals might be doing to the system?"

[CARROLL (narrated):] Paine realized if Estes focused on what sea otters were doing from the top down, rather than the kelp from the bottom up, he might discover the role otters play in the organization of nature.

[ESTES:] And so I thought, why not? Let's go out and have a look.

[CARROLL (narrated):] Paine was suggesting an approach similar to his starfish-throwing experiment: Remove otters from the ecosystem and test the impact that had on other species.

[ESTES:] I don't think at that time that Bob had any perception of how that might be done. But I did, because I knew quite a bit about the history of the otters. They were abundant across the North
Pacific. And then the Pacific Maritime fur trade began in 1741, and over the subsequent 150 years, otters were hunted to the brink of extinction. In 1911 or 1912, further take was prohibited, and a few of those colonies survived and served as the seed for the recovery of the species.

[CARROLL (narrated):] But the sea otter recovery was spotty.

[ESTES:] They had completely recovered from the fur trade at a number of island systems across the Aleutian archipelago, of which Amchitka is a part. There were other island systems where they had not yet recovered.

[CARROLL (narrated):] The experiment was simple: Compare ecosystems with otters to those without. He began with his home island of Amchitka.

[ESTES:] I knew a lot about what Amchitka looked like. I knew that sea urchins were common but very small.

[CARROLL (narrated):] The next step was to arrange for a dive at nearby Shemya Island, a location with no otters.

[ESTES:] The most dramatic moment of learning in my life happened in less than a second. And that was sticking my head in the water at Shemya Island. It was just green with urchins and no kelp. And it all sort of fell into place in just an instant, that the loss of otters from that system had completely reorganized that system from which kelps had probably been very abundant before the loss of otters, to one in which the sea urchins now had become abundant in the absence of the otters and had eaten all the kelp.

[CARROLL (narrated):] It was a striking demonstration of the Green World Hypothesis. Sea otters, the predators, were controlling the urchins that fed on the kelp. Remove the sea otters and the kelp forests disappear. Paine called these cascading effects of one species downward upon others "trophic cascades."

[PAINE:] A trophic cascade is when you have an apex predator controlling the distribution of resources, and they lead to these cascades of indirect effects. Lots and lots of indirect effects. You have fewer sea otters, you have more sea urchins, you have fewer kelp.

[ESTES:] I expect every coastal species is probably impacted in one way or another by the presence or absence of kelp. Kelp forest fishes depend a lot on kelp. There are birds that feed in the kelp forests, there are invertebrates that feed in the kelp forest. Virtually everything that lives in the coastal zone depends upon that system in some way.

[CARROLL (narrated):] So sea otters are another keystone species. They regulate the structure of this coastal marine community.
The results are unambiguous. Sea otters drive this system from the top down. You know, the message is clear, and it's been enormously important in how ecologists tend to view the world.

Estes returned regularly to Alaska to study otters. Some twenty years later, he noticed something strange was happening.

We were capturing otters, having a devil of a time catching enough, and that was peculiar, because I'd never had trouble catching otters.

Otter populations seemed to be declining. He tried to think of every possible explanation.

And we essentially lined up all of the hypotheses that we could think of that could be causing this population decline.

He ruled out starvation. He ruled out disease. And then a third hypothesis emerged.

Tim Tinker, who is a technician, called me one day in the winter and said, "you know, I'm starting to wonder if it might be killer whales." And I said, "you're crazy. You know, I mean, this just couldn't happen. They don't eat otters." And he said, "yes, they do. I've seen them eat a couple."

But how could he test it? Once again, nature provided an ideal site.

We went into a place called Clam Lagoon. It provided us a site that orcas could not get to. We had no problem catching about 30 animals in two or three days. And the fact that that little population did not decline when everything else did that orcas had access to, helped me become convinced that it was a viable hypothesis.

Why were the orcas now eating otters? Orcas generally eat whales, not otters.

There were a lot of whales around after World War II. After World War II, the Japanese and the Russians started reducing those whales, and by the late 1960s, they had been depleted by 90%. And the stripping of all these big whales out of the system shocked these killer whales and forced them to broaden their diet and start feeding on these other species. What had happened is that we had taken this three-level trophic cascade and the orcas had added a fourth trophic level, and it made that system behave just like theory predicted.

With the orcas eating otters, urchin populations increased and kelp disappeared.

To me, the amazing part of that was the notion that something like whaling, that started in the middle of the 20th century, way out in the oceanic realm of the North Pacific, could affect something like urchins and kelp in the coastal ecosystem. It was mind-boggling to even conceive of something... it was almost like science fiction.
[CARROLL (narrated):] To Robert Paine, this was a satisfying confirmation.

[PAINE:] It provided an example of how the concept of a trophic cascade functions in nature, and it's Jim's work in the Aleutians which in fact sold the case.

[CARROLL:] As ecologists explored other habitats with new eyes, they discovered keystone species and trophic cascades in many places.

[CARROLL (narrated):] And just as with otters, the removal of predators, such as wolves, sharks, and lions, has had profound effects on the number and variety of other species, and on ecosystems as a whole. These fundamental insights have changed the way we look at the world. And they've given ecologists and conservationists a new set of tools.

[ESTES:] It has turned us from a fundamental view of nature that was bottom-up. More than any other single ecologist, he was the one that transitioned our thinking to the importance of top-down forcing.

[PAINE:] Well, thank you. [ESTES:] No, it's the truth.

[CARROLL (narrated):] But from Paine's vantage point, humans still have much to learn.

[PAINE:] To ignore the fact that there are top-down effects is to invite mistakes. One ignores at one's own risk what role apex predators play.

[wolf howls]

[music plays]
How to use this PowerPoint

• Work at your own pace. Your health and your family come first.
• If possible, you might find it helpful to go through activities at the same time as a peer. Then you can communicate through text, email, or a call if you have questions or to share ideas.
• You might find it helpful to have a piece of scrap paper and a pencil or pen to record questions or ideas.
• Read through the slides one at a time. Take your time to explore the images and any links.
• If you come across something you don’t understand, make a note of which slide you are on and come back to it after you go through the whole PowerPoint. If you are still confused, feel free to email your teacher with a question. You could also ask someone in your household or reach out to a peer through text, email, or a call.
• When you finish, consider sharing what you learned with someone in your household or a friend through text, email, or a call. Explaining your thinking will help you to retain and make sense of the information.

Goals

After reviewing this PowerPoint, you should be able to:
1) Plan your Orca Project.
2) Present your Orca Project to someone you know.
3) Submit your Orca Project to your teacher.

Planning for the Unit Project

• Use “6.1 Orca Project Planning Worksheet” and answer the questions.
• Review “4 Orca Project Rubric for Distance Learning” and “4 Orca_Recovery_Task_Force_Recommendations.”
• Remind yourself about which Goal and Recommendation you plan to explore further.
• Reach out to your partner, if you chose to work with a peer.
Completing the Unit Project

- Decide how you will complete your project: infographic, poster, podcast, video, etc. If you aren’t sure what to do, feel free to email your teacher for ideas or to ask questions.
- Use your completed “6.1 Orca Project Planning Worksheet” to guide your work.
- Use resources from the unit as evidence for your scientific argument. You may also do additional research. Remember to make a bibliography!
- Remember to refer back to “4 Orca Project Rubric for Distance Learning” and to use it like a checklist as you complete your project.

Presenting the Unit Project

- When your project is ready, present it to someone you know. This could be an in-person presentation to someone in your household or an electronic presentation to someone using video chat. You could also email your presentation to someone and then explain it to them over the phone or play your podcast for someone over the phone.
- Take questions and answer them.
- Invite their feedback and make revisions based on their suggestions.

Check Your Understanding

1) Does your project meet all of the criteria on the rubric? If not, edit your presentation so that it does!
2) Have you presented your project to someone you know? Have you made edits based on their feedback? If not, do!
3) If you worked with a partner, did you communicate and collaborate?

What’s Next?
You may need to submit your finished project to your teacher. Please follow the directions provided by your teacher.
Orca Project Planning Document

Answer the following questions using complete sentences to help plan your project.

1. Task Force Recommendation:
   ➢ Which Goal and Recommendation from the Orca Task Force Assessment will you focus on in your project?
     ➢ Why did you choose this Recommendation?

2. Quantitative Data:
   ➢ What quantitative data will you use in your project?
     ➢ How does this data support the Recommendation you chose to discuss in Part 1?

3. Biodiversity of Puget Sound:
   ➢ How do you think the Goal and Recommendation you chose in Part 1 will affect the biodiversity of the Puget Sound?
     ➢ One scale that will be affected: _______________________
       How that scale will be affected:

     ➢ Another scale that will be affected: _______________________
       How that scale will be affected:

4. Scientific Concept:
   ➢ What is a scientific concept from this unit that connects to the Goal and Recommendation you chose in Part 1?
5. Revision to Recommendation:
   ➢ What is one revision (adjustment/addition) to the Orca Task Force Recommendation that might help mitigate (reduce) the effects of human activity?

   ➢ How will your revision increase the biodiversity in the Puget Sound?

6. Sources:
   ➢ What sources are you using to support your scientific argument? Make sure these are in MLA format in your final document!
# KEY Learning Tracking Tool for Population Ecology:
Why has the orca population declined in Puget Sound? How can we protect orca populations in the future?

<table>
<thead>
<tr>
<th>Lesson</th>
<th>What did we do?</th>
<th>How can our learning be used to explain the phenomenon?</th>
<th>Self-Assess: Where am I with my understanding of the phenomenon?</th>
<th>What questions do I have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Population Ecology Initial Ideas</td>
<td>The graphs and figures indicate that the Southern Resident Orca population has declined. Few calves have been born and survived in recent years.</td>
<td>Students MIGHT say: Orcas may be thinner and struggling with loss of critical habitat.</td>
<td>Many options! Example: Ready to explain, starting to get it, need more information</td>
<td>Many options! Example: Who are the orcas?</td>
</tr>
<tr>
<td>2 Who Are the Orcas?</td>
<td>Orcas are mammals with similar traits/behavior to humans. There are several types of orcas, including Northern and Southern Resident, transient, and offshore orcas. Orcas vocalize to communicate and use echolocation to hunt.</td>
<td>Students MIGHT say: Orcas have been negatively impacted by chemicals like PCBs which bioaccumulate in their bodies and biomagnify up the food chain. Noise pollution also interferes with communicate and echolocation.</td>
<td>Many options! Example: Who are the stakeholders and what is their connection to the orca population?</td>
<td></td>
</tr>
<tr>
<td>3.1 Stakeholder Articles</td>
<td>Stakeholders include local indigenous people, tourists, commercial fisherman, environmental groups, scientists, industries, government and students.</td>
<td>Students MIGHT say: The main issues causing the decline in the Southern Resident Orca population are food, specifically salmon, chemical pollution, and noise pollution. Many groups are interested in trying to protect Southern Resident Orca populations, including tribes and government agencies.</td>
<td>Many options! Example: How do humans impact ecosystems and orcas?</td>
<td></td>
</tr>
<tr>
<td>Lesson</td>
<td>What did we do? What did we figure out?</td>
<td>How can our learning be used to explain the phenomenon?</td>
<td>Self-Assess: Where am I with my understanding of the phenomenon?</td>
<td>What questions do I have?</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------</td>
<td>------------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>3.2 HIPPCO</td>
<td>HIPPCO is an acronym to remember the key impacts humans have on ecosystem: climate change, habitat loss, invasive species, pollution, human population growth, and overharvest.</td>
<td>Students MIGHT say: All of the impacts in CHIPPO can affect the Southern Resident Orca population.</td>
<td>Many options! Example: What is being done to protect orcas?</td>
<td></td>
</tr>
<tr>
<td>4 Project Introduction</td>
<td>The Orca Task Force Recommendations include goals and specific recommendations aimed at protecting Southern Resident Orcas in Puget Sound. The goals include increasing Chinook salmon abundance, decreasing noise pollution, and reducing exposure to chemical pollutants.</td>
<td>Students MIGHT say: The goals overlap with the issues we identified that impact the orca population. The Orca Task Force lists specific recommendations to solve the problems orcas face.</td>
<td>Many options! Example: what roles do orcas serve in ecosystems?</td>
<td></td>
</tr>
<tr>
<td>5.1 Orca Food Web</td>
<td>Although orcas are the top predator in their ecosystems, resident orcas primarily feed on salmon while transient orcas eat marine mammals like seals. Orcas are connected to other Puget Sound organisms through the food web. If one organisms is removed from a food web, others are impacted.</td>
<td>Students MIGHT say: Southern Resident Orcas need more salmon to eat.</td>
<td>Many options! Example: Which species do orcas depend on the most?</td>
<td></td>
</tr>
<tr>
<td>5.2 Keystone Species</td>
<td>Keystone species are organisms that have a large impact on their ecosystem. If they were removed, there would be major changes in the rest of the ecosystem. Examples: beavers, eelgrass, sea stars, wolves, bees, herring, and salmon</td>
<td>Students MIGHT say: Chinook salmon are a keystone species. Southern Resident Orca whales depend on Chinook salmon as a major food source. Several other Puget Sound species are keystone species. Maintaining their populations is important for the preservation of biodiversity in Puget Sound.</td>
<td>Many options! Example: Which recommendation from the Orca Task Force will protect orca populations in the future?</td>
<td></td>
</tr>
</tbody>
</table>