How can we evaluate ecosystem health to determine if restoration is needed?		
HIgh School	Life Science	Time: 2-3 50 min class periods

Lesson Level Performance Expectation (teacher-facing):

Investigate past and current ecosystem restoration projects and build a framework that could be used to determine ecosystem stability after a human disruption to decide if restoration efforts are needed or if the ecosystem can rebound without intervention.

Snapshot: High school students, as scientists, investigate an ecosystem after a human disruption and evaluate cleanup efforts and restoration plans. By studying previous disruptions, students will develop a framework that could be used to evaluate ecosystem health after a disruption and work to develop and propose a restoration plan. The purpose of this lesson is to make students aware that ecosystem destruction is not always permanent; nature is resilient and we can help that process along through restoration. To gain this understanding, students will evaluate a range of impacts, intentional and accidental, humans have on the Earth's environments, and the efforts that are taken to restore these environments.

Phenomenon: Ecosystem restoration of Prince William Sound, Alaska after the Exxon Valdez oil spill.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models ● Develop, revise, and/ or use a model based on evidence to illustrate and/ or predict the relationships between systems or between components of a system. **Developing Explanations and Designing Solutions**	**LS2.C Ecosystem Dynamics, Functioning, and Resilience** ● A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is	**Cause and Effect** ● Changes in systems may have various causes that may not have equal effects. **Stability and Change** ● Much of science deals with constructing explanations of how things change and how they remain stable.

● Apply scientific ideas, principles and/ or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	resilient) as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions for the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. ● Anthropogenic changes induced by human activity in the environment- including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change can disrupt an ecosystem and threaten the survival of some species. **LS4.D Biodiversity and Humans** ● Biodiversity is increased by the formation of new species and decreased by the loss of species ● Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of an invasive species, and climate change. Thus, sustaining biodiversity so that the ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. **ETS1.B Developing Possible Solutions** ● When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental	

	impacts.	

This lesson could be one in a series of lessons building toward:

HS-LS2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [**Clarification statement:** examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a season of flood, and extreme changes, such as volcanic eruption or sea level rise.]

HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [**Clarification statement**: examples of human activities can include urbanization building dams, and introduction of invasive species.]

Materials

Student Materials

- Reading, *What is Ecological Restoration*, from the Society for Ecological Restoration (SER)
- NOAA's Restoration Atlas (https://www.habitat.noaa.gov/apps/restoration-atlas/)
- SER's Project Database (https://www.ser-rrc.org/project-database/)

Optional Activity Resources

- Then & Now: 30 Years After the Exxon Valdez Oil Spill (reading)
- Lessons From Valdez: 25 Years After (video)

Teacher Materials

- The Exxon Valdez Oil Spill Flashback from NBC News (https://www.youtube.com/watch?v=A7hfQ8mTVrU)
- (Optional) History Pod - 24th March 1989: The start of the Exxon Valdez oil spill disaster in Alaska's Prince William Sound (https://www.youtube.com/watch?v=J1VdQEMEju8)
- Habitat Restoration at NOAA: 25 Years (https://www.fisheries.noaa.gov/topic/habitat-conservation#how-we-restore)
- Timeline of species recovery - NOAA infographic: (https://response.restoration.noaa.gov/sites/default/files/exxon-valdez-timeline-of-recovery-5jun14_noaa.pn

Resources for Building Teacher Content Knowledge and/or Pedagogy

Student Discourse:

- **Talk Science Primer**
- **Checklist: Goals for Productive Discussion and 9 Talk Moves**

Cross-Cutting Concepts

- **Stem Teaching Tool #41**

• 20 Years After the Exxon Valdez: Preventing--and Preparing for--the Next Oil Spill Disaster (reading) • Restoration Plan 2014 Update • 1994 Restoration Plan https://evostc.state.ak.us/media/7576/evostc-1994-restoration-plan-rev83021.pdf	g)	

Teacher Preparation

Driving Question: How can we evaluate ecosystem health to determine if human intervention through restoration is needed?

What Students Will Figure Out (Student Facing Objective)

- Analyze and use data from a previous human disruption to an ecosystem to determine what information is needed to evaluate ecosystem health.
- Obtain information from a variety of sources to learn more about ecosystem resilience and restoration.
- Develop and use an evaluation tool that can assist in determining if a restoration plan is needed to restore an ecosystem.

Required Student Prior Knowledge

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfer of matter into and out of the physical environment occurs at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS-LS2-5)

Teacher Content Knowledge

This lesson is driven by the ideas that students analyze and use data to inform their development of an ecosystem evaluation framework. By researching human-caused disruptions and their short- and long-term impacts students can start to make informed decisions about ecosystem restoration. The stability of ecosystems is influenced by many factors and the interactions between the components of the ecosystem help determine the stability and resilience of an ecosystem.

Experience the Phenomenon or Experience the Problem

Summary: In this section students watch a video of the Exxon Valdez oil spill and the cleanup efforts that happened after. Students make observations, develop questions and share their questions publicly to guide their learning. They examine whether cleanup and restoration are the same thing and use other examples of restoration projects to determine if/how they might be different.

1. **Introduce the phenomena to students and allow them to make observations and ask questions.**

   Introduce students to the 1989 oil spill in Prince Williams Sound, Alaska. Explain that this oil spill was the largest of its kind at the time and spurred a national awareness of habitat destruction and restoration efforts. To build context and create a common

shared experience for students, play the following video clips of the spill. Students should record at least three observations and two questions about the spill and the clean up efforts as they watch.

- The Exxon Valdez Oil Spill Flashback from NBC News (https://www.youtube.com/watch?v=A7hfQ8mTVrU)
- (Optional) History Pod - 24th March 1989: The start of the Exxon Valdez oil spill disaster in Alaska's Prince William Sound (https://www.youtube.com/watch?v=J1VdQEMEju8)

Assign students to small groups and have them discuss their observations and questions. Next, facilitate a class discussion to allow all students to share observations and record them in a common space. Once all the observations have been shared, have them share their questions.

As students share questions, group similar questions together. Common questions may include:

- Why did they get so little oil cleaned up?
- Is there still oil there since more time has passed?
- How does the oil that is still there affect the ecosystem?
- How long will it take for all the populations to come back?
- Does cleaning the animals with dish soap really help them if they have to go back into oiled water?
- Did using other chemicals (dispersants) for cleanup hurt the ecosystem more?
- What kinds of things did people do to help restore the sound?
- Are people still cleaning up the area?

Students will have many questions about the lingering oil and how it has (and still is) effecting restoration efforts. Focus on the questions about restoration efforts and say, "There are several questions here about the clean up and restoration efforts; can someone tell me more about what you mean? Do we think cleanup and restoration are the same things or are they different?"

Allow students to share their ideas about cleanup versus habitat restoration.

Additional Guidance:

- Showing the videos provides a common shared experience; this anchors student learning allowing opportunities for them to share and discuss. The introduction of phenomenon is vital to three-dimensional teaching and learning and should not be skipped.
- Allowing students to share in small groups first, before making their ideas public, allows them time to formulate their ideas and practice speaking them before sharing with the class. This allows reluctant speakers to get more comfortable sharing ideas allowing them more access to participate in class.
- Acknowledging student ideas and questions (free of judgment, at this point) allow for all students to have a voice. It is

important that all students participate in the class discussion to share one observation and one question. Recording what students say brings validation to their ideas and questions and also allows for other students to see that they share similar ideas.

2. **Students review some other restoration projects to figure out the difference between cleanup and restoration.**

   Tell students you have a short video about some restoration projects that have taken place since the Exxon Valdez oil spill. Play the video, Habitat Restoration at NOAA: 25 Years (https://www.fisheries.noaa.gov/topic/habitat-conservation#how-we-restore) then have students read, *What is Ecological Restoration*, from the Society for Ecological Restoration (SER) individually or in pairs.

   To make students aware of some of the current restoration project have them explore one or both of the sites:

   - NOAA's Restoration Atlas (https://www.habitat.noaa.gov/apps/restoration-atlas/)
   - SER's Project Database (https://www.ser-rrc.org/project-database/)

   As students explore the data, encourage them to look for patterns. Patterns they may notice include:

   - Spills happen in many different places, but many happen along waterways.
   - North America seems to have the most restoration projects.
   - Eastern Europe does not have any projects.
   - There are a lot of restoration projects on land and along waterways.

   Now that students have some information on different restoration projects, ask them to consider the differences between a cleanup initiative and a restoration project. Students should conclude, restoration means humans help the ecosystem recover from a disruption. Sometimes this includes a clean up effort, like Exxon Valdez and some of the other examples. Other times it means removing a man-made structure, like a dam, to allow a habitat to be restored. Clean up means just that, clean up and does not include human intervention to restore the ecosystem.

Ask students, “How do we determine if an ecosystem needs restoration?” Have students do a quick chat with a partner and then share their ideas with the class. Students' ideas will vary, but capitalize on ideas that they need a system to measure the extent of a disruption.

Investigate the Phenomenon

Summary: In this section students will use the cross-cutting concept of stability and change and prior knowledge of ecosystem interactions to figure out what they could use as indicators of the health of an ecosystem. Students will brainstorm a list of examples of human disruption and identify patterns they notice when it comes to restoring these ecosystems. Students use these ideas to develop a framework for evaluating ecosystems that could be used to determine what actions need to be taken to restore the ecosystem.

3. **Students develop a framework of indicators they can use to determine ecosystem health and stability.**

   Explain that before we can figure out if harm has come to an ecosystem, we first need to figure out what kind of data to collect and evaluate to determine stability and/or change within an ecosystem.

   Have students work in small groups to come up with a list of ecosystem indicators they can use as criteria for their evaluation framework. Explain that these criteria need to include both components and interactions that could be investigated to determine if an ecosystem is healthy. Look for students to identify:

   - Predator/prey interactions
   - The idea of food chain/webs/, energy pyramid and/or tertiary levels
   - Living and non-living factors (water, air, space)
   - Energy flow and matter cycling
   - Different amounts of organisms
   - Human activity and/ or disruption

- Reproduction of organism

Have a brief discussion about the indicators to ensure everyone is on the same page, then prompt students to think about data collection and measurement necessary to determine if an ecosystem is being disrupted. Have students come up with some ideas in small groups before sharing with the class.

Allow students to share their ideas but press on them to go deeper when sharing, if needed. For example, a student may say, “the ecosystem will change”, however ecosystems are always changing and fluctuations in the ecosystem are normal. Consider using prompts such as:

- Can you tell me more about what you mean by “change”?
- What I think I hear you saying is (repeat student statement)
- Does anyone want to add onto that or have something similar to suggest?

Record all student ideas to your common space highlighting examples of stability and change. Common indicators of that can be used to determine if there is cause for concern are:

- Species population decline
- A decline in biodiversity
- An increase in population of a certain species (developing into a less diverse system)
- The introduction of a new species
- Destruction of an ecosystem (natural or human)

If students do not surface all of these ideas during this discussion there will be other opportunities to add them to the board later in the lesson. You will also want to refrain from giving these ideas to students as you want them to build science ideas based on their experiences.

Additional Guidance:

- Having students make a list of ecosystem indicators can be used as a formative assessment opportunity to determine background knowledge and prior experience. This small group discussion will also allow students to share their ideas and get feedback before making them public.

4. **Students research a previous oil spill to learn more about human impacts, clean up efforts, and restoration of ecosystems.**

   Ask, “What do you think happens to the ecosystem once something like this happens? What actions, if any, need to occur?” Have students discuss this question with a partner. Have a few students share and then ask, “What do we know about ecosystems and how they react to change?” Use this prompt to surface student background knowledge and prior experiences with ecosystem resilience. Student answers will vary, but listen for examples that could include:

   - When left alone, things just seem to grow back like when I mowed my mom's flowers.
   - The high winds blew over a bunch of trees and other plants just started growing around them and on them.
   - Humans stopped planting crops to allow the natural prairie to be restored in some places.
   - We built a barrier along the shore to help bring back aquatic life.
   - We planned a pollinator garden to help bring back wildlife.
   - After the forest fire, stuff just started growing again all by itself.
   - We planted ground cover to help keep all our soil in place.

   After students share some examples, ask them if they notice a pattern in their examples. Students should realize that some examples express small disruptions to an ecosystem and others are larger and more damaging. Some of the examples included human interactions and other examples did not.

   Acknowledge the differences in the examples, then have student discuss the following in small groups:

   - What do these examples tell us about ecosystems?
   - How would we know when an ecosystem is considered recovered from a disruption?

   Students should conclude that when ecosystems are left alone after a disruption that eventually they will return to a stable state but it might not look exactly the same. To figure out if an ecosystem has recovered, look for students to come up with a list of indicators that could include:

   - What the ecosystem looked like before the disruption
   - What and how many organisms lived there before then after (biodiversity and populations)
   - Check it at different times - some ecosystems might come back quickly and others may take more time.

- Look at the rate of change. When change slows down we think the ecosystem might be more stable.

Bring students back to the oil spill example, explain that the Exxon Valdez oil spill devastated Prince William Sound, Alaska and triggered a deep dive into oil practices (transporting, spills and clean up, and environmental clean up efforts). As this spill was the first major spill of its kind, many things were unclear, however it spurred on the development of new laws and independent citizen efforts to protect ecosystems in the future.

Inform students that due to the size of the spill a massive clean up effort was implemented, and it was also clear that a restoration plan needed to be put in place. Tell students that in 1994 a restoration plan was approved. Have students look at the plan (https://evostc.state.ak.us/media/7576/evostc-1994-restoration-plan-rev83021.pdf) starting on page 35, Chapter 5: Goal, Objectives and Strategies. Summarize the overview in chapter 5 to give students a general idea about how they measured recovery status.

Assign each group or pair of students a set of resources or services to investigate. Tell students to jot down or highlight important information including: type and extent of damage to the resource or service, recovery objective, restoration strategy and any other information they would like to share. Groups should also be prepared to share what they learned about their resources to the class.

Key ideas that should surface in class discussion:

- The spill impacted resources differently.
- Recovery objectives were all very similar.
- Restoration Strategies varied between resources. Some resources were left to recover through natural means and others received more help. Some resources needed further study as scientists were unsure why restoration strategies were not working to increase populations.

Inform students in 2014 the restoration plan was revisited. Have students predict the recovery of resources (fully recovered, partially, not at all) then project this infographic to help facilitate a discussion about continued restoration. Have students share anything that surprised them about the information and share any questions they have. Conclude the discussion by asking students what this scenario tells us about ecosystem disruptions and restoration efforts.

Key Take-Aways

- Ecosystems can be restored even after a huge disruption

- When a disruption happens, not all things recover at the same time or rate.
- Different resources and services need different restoration strategies.
- Some resources may never recover.
- Although some populations may become stable, that does not mean the ecosystem is stable and vice versa.

(**Optional Extension Activity**) To figure out more about how clean up, prevention efforts, and current oil spill status have students do a jigsaw using the following materials. As they investigate the materials have them consider the following prompts:

- What was the condition of the ecosystem before?
- What was the condition of the ecosystem after?
- What data could you use to determine the severity of the disruption?
- How did the disruption affect the stability of the ecosystem?
- What data could you use to determine if an ecosystem has recovered from a disruption?

Assign each group a resource or two and have them note what they think is important information or other facts they would like to share. They should also note any information or facts that were surprising to them as they researched.

- Then & Now: 30 Years After the Exxon Valdez Oil Spill (reading)
- Lessons From Valdez: 25 Years After (video)
- 20 Years After the Exxon Valdez: Preventing--and Preparing for--the Next Oil Spill Disaster (reading)
- Restoration Plan 2014 Update

When students have completed their research, rearrange the groups so that each student shares information about a separate resource. Explain that each member of the group should summarize their findings and then work as a group to compile their information to develop a model to help them build an explanation for what happened in the Prince William Sound ecosystem.

5. **Students develop an ecosystem evaluation framework using what they figured out from the Exxon Valdez oil spill.**

Tell students to consider what they have figured out about ecosystems and restoration and use that information to develop a framework that could help them determine ecosystem health after a human disruption**.** Provide each group with a whiteboard or chart paper to make a draft of their criteria.

As they work, walk around and ask probing questions to ensure they consider all the different factors. For example, students may have a population of organisms as a criteria, however it will also be important to include birth rates of new organisms. Consider having a set of “back-pocket questions” to use to help students think more deeply about the criterion they need to build their evaluation tool. Example probing questions could include:

- When looking at the population of animals, what other things should you consider when determining how fast the population can increase?
- What other factors do you need to consider when thinking about what plants need to grow?
- If the ground is contaminated, how might that affect the animals living there?

Students may also bring up questions about the population of organisms and where to find ‘before’ data. Explain that often there will not be ‘before’ data for an ecosystem, in this instance prompt students to think of other ways they could determine the severity of a human disruption. Students should remember that some of the data collected during Exxon Valdez and other disruptions included:

- Number of dead organism
- Size/Area of contamination
- Growth rate of vegetation after the disruption

Engage students in a gallery walk to see what other groups have developed and to record similarities and differences in their evaluation frameworks. Have a consensus discussion to develop a class framework by combining the ideas of the small groups. Ask students to first share similarities they noticed. These could include:

- Tracking energy flow (from sunlight, food webs, vegetation growth)
- Differences in biodiversity (before/after population data)
- Population numbers (rates of change, births/deaths, area affected)
- Resources affected (water, air, soil, space)

Once students come up with the components they need to collect data on, prompt them to think of what they need to know about these components. Students should conclude that they would need some way to track changes in the ecosystem to

determine the severity of the damage. This could include “before” data however, many times that is not available. Prompt students to think about other ways they could determine how an ecosystem has been affected by a human disruption. Students' ideas will vary, but focus on ideas that include monitoring change. Students should also surface the idea that in some cases the changes are immediate, like an oil spill, but the effects of other disruptions may take longer to notice.

Once the evaluation framework has been developed, have each student group make a copy of the agreed upon criteria. Explain that students will use this framework to evaluate an ecosystem however, as this is a first draft they should also note where revisions might be necessary to improve the tool in the future.

Determining the need for clean up efforts and restoration

Last, ask students to consider how they might determine if an ecosystem needs a restoration plan or if it can be left to restore itself. Remind students of what they figured out in step 2 about the differences between cleanup and restoration and the different scope and scales of restoration efforts. To resurface these ideas ask,”How might the restoration plan for the oil spill in Alaska look very different than a restoration plan for a city park that might have a small fuel spill along their shoreline?”

Have students share their ideas and what they know about other restoration projects, these could include large scale projects like the reintroduction of wolves to Yellowstone National Park or small scale projects like planting a pollinator garden to help restore natural plant species to help butterflies, bees, and other pollinators.

Facilitate a class discussion to add a final piece to the frame around restoration of the affected ecosystem. Have students consider criteria and constraints of restoration projects versus allowing the ecosystem to heal itself. Considerations could include:

- Extent of ecosystem damage
- Type of ecosystem
- Affected components (how fast do they reproduce, how many of the population is left)
- Cost of the project
- Prediction of outcomes
- Implementation and monitoring

Additional Guidance:

- Co-construction of the evaluation framework allows for student voice and also provides reflection opportunities. As students use the evaluation framework they developed together they can also reflect on its usefulness to determine where revisions are needed. This helps to normalize the development process and reinforces the idea that ideas and tools do not have to be perfect the first time - development takes time and critical feedback.
- Gallery Walks are commonly used as a strategy for allowing students to share their ideas with others and get feedback on their work. If you have a protocol for Gallery Walks in place, continue to use it for this activity. If you are not familiar with this strategy consider using the “1 stay, 3 stray” method. One person from the small groups stays to answer clarifying questions and the other group members make observations and/or provide feedback to the other groups.

Designing Solutions

Summary: In this section, students will use the framework to evaluate another ecosystem that has been disrupted by human actions. Students will determine how well the tool works

6. **Have students test their framework by using it to evaluate a local (or other ecosystem) to determine ecosystem health.** To give students ideas about other restoration projects, show them the short film from UCLA, Ecosystem Resilience, before breaking them into work groups.

   Individually or in groups, have students apply their evaluation framework to an ecosystem. This could be a local ecosystem that has been damaged or another ecosystem that has been disrupted/damaged by human impacts.

   When students have finished, have students share what they found and what they determined about their given ecosystem. This could be done as presentations or as a gallery walk.

   After presentations, engage students in a discussion that would allow them to share any patterns they noticed in the restoration projects. Students should recognize the cause-and-effect relationships in both the human disruptions and the restoration efforts.

7. **Have students evaluate the use of the framework to determine the need for revisions.**

   Have a discussion about the usefulness of the evaluation framework and make suggestions for revisions. Ask students if it provided enough data for them to be able to make a decision about the ecosystem they were investigating. Some possible prompts to consider could be:

   - Did the tool provide all the information you needed to consider when evaluating your ecosystem?
   - Are there additional items you might want to add to the tool?
   - Is the tool flexible enough to be used for different ecosystems?
   - Was the format of the tool easy to use, or are there suggestions for change?

   Explain that when tools like this are developed it usually has to be used and revised several times before it is made final. If time permits, allow students to make revision to the tool.