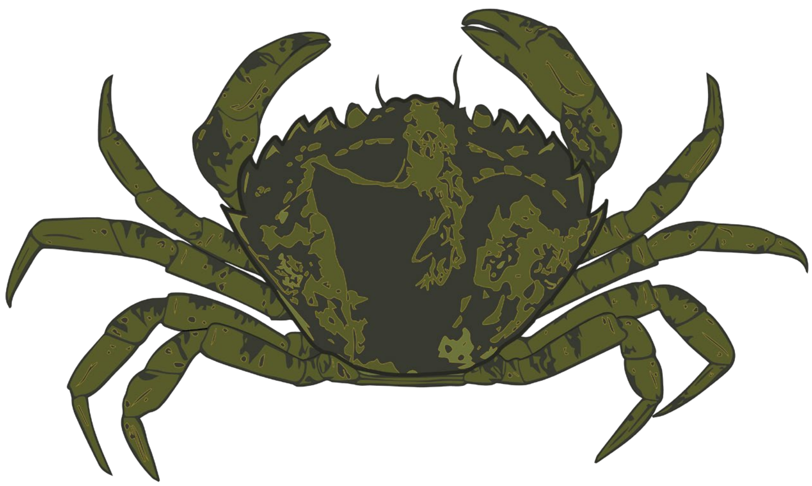
Green Crab Alert: Invasion in Washington's Waters

7Th grade mini unit



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Appreciations

This lesson bundle has been designed to facilitate alignment with the Next Generation Science Standards (NGSS). It is structured to allow students to engage in sense making around a real-world fish and wildlife conservation issue as a central phenomenon. Each lesson incorporates a disciplinary core idea (DCI), a cross cutting concept (CCC), and a science and engineering practice (SEP) to allow for three-dimensional learning.

At the time of this writing, Washington is responding to a declared state of emergency due to growth in populations of invasive European green crabs on the Washington Coast and in areas of the Salish Sea. This lesson could not have been written without the collaboration and review from partners. We would also like to thank Dr. Brian Turner, WDFW Aquatic Invasive Species (AIS) research scientist, and the Portland State University Department of Environmental Science and Management for providing some of the content to this unit plan. Finally, we want to express our immense appreciation to all the residents of Washington who are working hard to protect our environment, economy, and natural and cultural resources from invasive European green crabs.

The Washington Department of Fish and Wildlife (WDFW) conservation education team hopes you and your students enjoy, engage, and become engineers in this mini unit.

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Introduction and Overview

European green crabs *(Carcinus maenas)* are considered to be one of the world's worst invasive species. In 2021, the Washington Department of Fish and Wildlife (WDFW), tribes, and partners identified an exponential increase of invasive European green crabs (EGC) in areas on Washington's outer coast, including Makah Bay, Grays Harbor, and Willapa Bay, as well as within the Lummi Nation's Sea Pond near Bellingham. This poses a growing threat to Washington's economic, environmental, and cultural resources.

In January of 2022, governor Jay Inslee issued an emergency proclamation that directed WDFW to implement measures to control European green crabs, and to coordinate with other state agencies as well as tribal nations and organizations such as the University of Washington's Sea Grant program. Emergency measures to control invasive European green crabs are now underway.

Under the governor's emergency order, WDFW leads an Incident Command System (ICS) that aids coordination amongst agencies, tribes, and partners. The ICS is an approach developed by the United States Federal Emergency Management Agency (FEMA) to standardize emergency management across the country. In Washington, the European Green Crab Emergency ICS is led by WDFW and includes representatives from other state and federal agencies, tribes, and other partners.

Experts believe European green crabs will never be fully eradicated due to large populations in neighboring states. The goals of the ICS are to reduce European green crab populations to levels that do not harm environmental, economic, or cultural resources. This includes coordinating field efforts to remove crabs, conducting scientific research and environmental monitoring, and issuing regular reports, communications, and outreach. Washington also provides grant funding and other support to tribes, shellfish growers, and partners trapping the green crabs. The main control method used by responding entities is trapping, with more than 1,000 traps deployed in 2023. For more information about this issue please visit the WDFW European green crab webpage and review the relevant talking points.

Throughout this unit, students will explore why European green crabs are such a concerning invasive species, how they may impact the biodiversity of Washington's estuaries, and what options are available for controlling their population. Perhaps most importantly, students will understand how they can help by learning how to identify and report European green crabs to support efforts to control them and limit their harm.

This mini unit is designed to be able to stand alone, or to supplement OpenSci Ed unit *7.5 Ecosystem Dynamics:* **"**How does changing an ecosystem affect what lives there?". To ensure this unit is easily implemented, the unit has been designed to replicate the processes and procedures utilized by OpenSci Ed.

The lesson plans and materials provided help guide students through an exploration of estuary ecosystem dynamics, and the changes that occur when an invasive species occupies an ecosystem and competes for resources with native species. Students are then tasked with learning about relevant control methods considered for use on European green crabs and are asked to choose a control method they believe should be implemented and write Claim-Evidence-Reasoning (CER) to support their choice. Through the implementation of this unit, students and teachers anchor learning in a place-based phenomena and engage with a current environmental issue.

Standards

Next Generation Science Standards (NGSS)
This mini unit is designed to support learning towards the following performance expectations:

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Other performance expectations that are supported through this unit include:

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Materials needed for unit

- Additional materials downloaded from WDFW unit plan website:
    - PowerPoint: European Green Crab Unit PowerPoint
    - Lessons 3 and 4 excel spreadsheets.
    - Lessons 2-4 species chips.
- Media for showing videos with sound to class (laptop, projector, TV, etc.)

- Printer
- Scissors or paper cutter
- Laminator (optional)
- Something large to write on like a white board, chalk board, or smart board
- Chart paper
- Markers
- Pencils
- Envelopes
- Dice
- Coins
- Background Information StoryMap: wdfw-egc-hub-wdfw.hub.arcgis.com/pages/background-information

Learning Objectives

Students will…

- Discuss the anchoring phenomena of European green crabs found in Washington.
- Develop initial model of how European green crabs are a threat to estuary ecosystems.
- Describe what an estuary is and learn about other organisms who live there.
- Develop a model of a healthy estuary food web.
- Make predictions of what will happen to an estuary food web with the introduction of European green crabs.
- Collect data through an estuary survey simulation.
- Observe normal population fluctuations in a healthy estuary ecosystem over time.
- Combine individual survey data into class data set and compare data through graphs.
- Simulate the effects of the introduction of European green crabs to a healthy estuary ecosystem.
- Determine the biodiversity index of the simplified estuary ecosystem before and after the introduction of European green crabs.
- Read and evaluate an article detailing the impacts of European green crabs on shellfish industries in Maine.
- Compare the results of their simulation and the effects of European green crabs on ecosystems on the east coast.
- Describe the invasion curve and how it is used to help guide scientists and policy makers in determining the best method of management for invasive species.

- Evaluate the methods considered to control the populations of European green crabs in Washington state.
- Construct a Claim Evidence Reasoning (CER) on the control method they believe would be most effective.
- Brainstorm ways they could take action to help control the spread of European green crabs throughout the coast and estuaries of Washington.

Essential questions

- Why are people trying to control invasive European green crabs in Washington?
- Who is the European green crab and why are they so concerning to Washington?
- How can European green crabs impact the estuary food web?
- How do populations of some species in a healthy estuary fluctuate?
- How do population dynamics of specific species change after the introduction of European green crabs to the estuary?
- How have European green crabs been a problem in other locations?
- What are the options for controlling European green crab populations? What are pros and cons of these options?

Vocabulary

- **Biodiversity**: The full range of life in all its forms. This includes the habitats in which life occurs, the ways that species and habitats interact with each other, and the physical environment and the processes necessary for those interactions.
- **Co-management**: Tribes with treaty rights and the State of Washington, through the Washington Department of Fish and Wildlife (WDFW), are jointly responsible for managing certain fisheries and hatchery programs, and they collaborate in efforts to recover depleted fisheries resources. -
- **Control**: Taking actions to reduce the population or limit the spread of an invasive species.
- **Emergency order**: An order issued by a leader, like the governor, under their authority provided by law or regulation in response to an existing or imminent emergency.
- **Endangered species**: A species of animal or plant that is seriously at risk of extinction.
- **Estuary**: The place where fresh water from the land meets salt water of the sea; may include river mouths, deltas, mudflats, sloughs or shallow areas of brackish water.
- **Intertidal zone**: The area on a beach or estuary that is the region between the area's high and low tides. - National Geographic

- **Invasive species**: A plant, animal, or other organism introduced to an area outside of its native range, usually by humans, which negatively impacts the economy, environment, and health. Not all non-native species are considered invasive.
- **Natural resource management**: The ways in which societies manage the supply of or access to the natural resources upon which they rely for their survival and development.
- **Organism**: Any living creature such as a plant, animal, fungus, bacteria.
- **Primary consumer**: An organism that eats producers.
- **Producer**: An organism that produces food from inorganic compounds, usually through photosynthesis; typically, a plant.
- **Secondary consumers**: An organism that eats other consumers.

Lesson plan summary

Lesson	Essential Questions	Standards	Learning Objectives	Assessment
1: European Green Crab Emergency Order Duration: 3 class periods	Why are people trying to control invasive European green crabs in Washington state?	MS-LS2-4	Students will: • Discuss the anchoring phenomena of European green crab found in WA, and the subsequent Emergency order created by Governor Inslee. • Develop initial model of how European green crabs threaten estuary ecosystems.	European green crab (EGC) brain map EGC emergency worksheet and map Wonder Wall Driving Question Board
2: What is an estuary and why is it important? Duration: 1-2 class periods	How may European green crabs impact the estuary food web?	MS-LS2-3	Students will: • Describe what an estuary is and learn about some of the organisms that live there. • Develop a model of a healthy estuary food web. • Predict what will happen to an estuary food web with the introduction of European green crabs.	Student food web models Food web model questions (could be used as summative assessment, or as tool to guide student learning)
3: Healthy estuary dynamics Duration: 1-2 class periods	How do populations of some species in a healthy estuary fluctuate?	MS-LS2-1	Students will: • Collect data through an estuary survey simulation. • Observe normal population fluctuations in a healthy estuary ecosystem over time. • Combine individual survey data into class data set and compare data through graphs.	Estuary survey simulation Class data set Biodiversity index

Lesson	Essential Questions	Standards	Learning Objectives	Assessment
4: Invasion of the European green crab in Washington Duration: 2-3 class periods	How do population dynamics of specific species change after the introduction of European green crabs to the estuary? Who are European green crabs, and why are they so concerning to Washington?	MS-LS2-1	Students will: • Simulate the effects of the introduction of European green crabs to a healthy estuary ecosystem. • Determine the biodiversity index of the simplified estuary ecosystem before and after the introduction of European green crabs. • Read and evaluate an article detailing the impacts of European green crabs on shellfish industries in Maine. • Compare the results of their simulation, and the effects of European green crabs on ecosystems on the east coast.	Estuary survey simulation Class data set Biodiversity index Article and worksheet: European green crabs in Maine
5: Evaluating solutions to the European green crab problem Duration: 2-3 class periods (more if students engage in action item)	What are options for controlling European green crab populations? What are their pros and cons?	MS-LS2-5	Students will: • Describe the invasion curve, and how it is used to help guide scientists and policy makers in determining the best management method for invasive species. • Evaluate methods considered to control the populations of European green crabs in Washington state. • Create an argument based on evidence to construct a CER on the control method they believe would be most effective. • Brainstorm ways they could take action to help control the spread of European green crabs throughout the coast and estuaries of Washington.	Student page: Controlling European green crabs Control methods CER Optional action project

Lesson 1: European Green Crab Emergency Order

Science Standards

<table>
<tr><td colspan="3">Performance Expectation:
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.</td></tr>
<tr><td>Science and Engineering Practices</td><td>Disciplinary Core Ideas</td><td>Crosscutting Concepts</td></tr>
<tr><td>Asking Questions and defining problems
Ask questions o that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
Developing and Using Models
Developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.</td><td>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</td><td>Cause and Effect
Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td></tr>
</table>

Essential Question

Why are people trying to control European green crabs in Washington?

Learning Objective

Students will…

- Discuss the anchoring phenomena of European green grab found in WA, and the subsequent emergency order created by Governor Inslee.
- Develop initial model of how European green crabs are a threat to Washington estuary ecosystems.

Anchoring Phenomenon

To anchor this mini unit, the following are used together: European green crabs in the news and European green crab emergency order. Through this lesson students:

- Engage with the anchoring phenomena by observing European green crabs in their habitats,
- Unpack news headlines that feature European green crabs,
- Create a brain map to model their thinking about this new information,
- Reading about the emergency order issued by Governor Inslee, and
- Map where in Washington these species are a concern.

In each subsequent lesson, aim to lead students through the OpenSciEd Navigation routine steps 1-3 in which the class begins a lesson by asking "What brought us to this point?" Throughout the lesson check in by asking "Where are we now?", and close the lesson by asking "Where are we going?"

Materials

- Copies of news headlines
- Copies of "Worksheet: European green crab emergency order"
- European green crab unit PowerPoint
- (optional) Copies of base map of Washington state coastline and estuaries
- Chart paper
- Markers

Lesson Procedure

Part 1: Introducing the anchoring phenomena.

1. Begin the unit by telling students that you have seen an unusual topic show up in the news recently, and you want them to help you make sense of it.
2. Open slideshow to slide 2 and play short video. The video should begin at 0:33 to skip straight to the crabs. As video plays, ask students to identify the animal in the clip. Ask, "have any of you heard any news about green crabs recently?" Discuss if they answer yes.
3. Place students in small groups or pairs and pass out "news headlines" slips to each small group or pair. Have students work together to paraphrase their news headline.
4. Bring up slide 3 and have students present their paraphrase of the headline to the rest of the class. Ask, "Just by looking at these headlines, what information can we gather about this animal and the issues that surround it?"

a. As students present, compile student ideas onto class brain map with "European green crabs" at the center.
b. Ask students to consider the headlines and think about what questions these headlines make them wonder about. Have students record their questions on a sticky note and add the questions to a section of the brain map titled "Wonderings".

> **Teacher Note:** Students will be able to ask questions and build up a "wonder wall" in part three.

5. Identify vocabulary words or phrases that are in the headlines that need to be investigated. Add spaces on the class brain map for the following terms:
    i. Invasive species
    ii. Emergency order
6. To introduce or revisit the concept of invasive species, play the video on slide 4: "Uninvited: the spread of invasive species" from the start to 6 minutes 45 seconds. Add information about invasive species to brain map.
7. Show slides 5-8 and discuss the European green crab as a kind of invasive species that is of particular concern to Washington.
8. Ask, "Do you know of any other related phenomena where a new species being introduced to an ecosystem caused negative changes to that ecosystem?"
9. Add additional phenomena and student thinking to European green crab brain map.

Part 2: Mapping Washington estuaries and emergency order

This section has students engage with data about European green crabs presented through a map and through an article about the governor's emergency order.

1. Open the PowerPoint and walk students through slides 10-12 to help orient students to the locations of interest for European green crabs in Washington. Help students decode the map on slide 12: "Washington state Shoreline Map."

> **Teacher Note:** You may wish to print a copy of the base map for each student and have them add information to the map as you read the emergency order and advance through the PowerPoint presentation.

2. Walk students through decoding the map.
    a. Locate and identify the cardinal directions.
    b. Locate and decode the map key.
    c. Locate and identify the scale of the map.

d. Locate key cities/roads/rivers/mountains etc.
e. Find and mark the general location of your school.

3. Pass out the article "Governor Inslee issues Green Crab Emergency Order". As a class, read through the article and advance through the slides.

> **Teacher Note:** The text of the article can be found below and is annotated to show where to advance through slide show. This is intended to help support the reading through visual representations of the data shared. Discussion questions can be found in the notes on each slide.

Governor Inslee Issues Green Crab Emergency Order

Governor Jay Inslee issued an emergency order to increase the state's response to a concerning increase in European green crabs in some areas of Washington state. These areas include Makah Bay, Grays Harbor, Willapa Bay, and the Lummi Nation's Sea Pond near Bellingham.

Advance to next slide

According to the Washington Department of Fish and Wildlife, European green crabs were first found in Washington in 1998. They were found in Willapa Bay and Grays Harbor.

Advance to next slide

Since 2016, green crabs have been found in Padilla Bay, Sequim Bay, Dungeness Spit, and the San Juan Islands.

Advance to next slide

*European green crabs first arrived on the East Coast of the United States in the mid-1800s. In the early 1900s they spread north. They are thought to have contributed to the decline of a major clam fishery on the East Coast. In 1989, green crabs were found on the West Coast, in San Francisco Bay. They then made it to Oregon, Washington, and British Columbia **estuaries** in the late 1990s, helped by warm ocean currents that pushed crab larvae north.*

Advance to next slide

*The European green crab is one of the world's worst **invasive species**. If they become permanently established, they can harm the environment and **endangered species**, damage resources that are important to coastal communities, and impact small businesses.*

The emergency order directs the Washington Department of Fish and Wildlife to carry out emergency actions to prevent the establishment of the European green crab in Washington state. The order also directs other state agencies to help and asks the Washington Legislature to increase funding for the effort as soon as possible.

The order became effective immediately and will remain in effect until canceled.

4. After reading through the article and looking through the slides, have students answer the questions on the worksheet. You may have students continue to work in their small groups or work individually.
5. As a class, discuss the emergency order and add information to the European green crab brain map.
6. Ask students to consider the maps and the emergency order and write down any questions they have. Have students record their questions on a sticky note and add the questions to a section of the brain map titled "Wonderings".

Part 3: Creating wonder wall and driving questions board.

In this section students will generate questions related to the issues surrounding European green crabs and will use those questions to create a driving question board (DQB). For more information about creating a Driving Question Board refer to this on demand teacher support from OpenSciEd.

This section of the lesson will follow the procedures from sections 13 and 14 of lesson 1 from OpenSci Ed unit 7.5 Ecosystem Dynamics. "7.5 Ecosystem Dynamics" by OpenSciEd is licensed under CC BY 4.0.

1. Return to the European green crab class brain map and review the information students have gathered about European green crabs so far.
2. Refer to the "wonderings" section of the brain map and read out some of the questions that students added to it in part one.
3. Explain that students are now going to work together to identify some questions we have about what is going on with European green crabs and will create a driving questions board (DQB) to help organize our learning.

> **Teacher Note:** For more information on how to help students generate and improve their questions, check out the Question Formulation Technique (QFT) created by the Right Question Institute.

4. Have students work in small groups to write as many questions as they can about European green crabs and their impact on the ecosystems they are invading. Remind students we are trying to create open-ended questions that can help guide our learning.
5. After allotted time has ended, have students identify the questions they think are the most important, and write those down on sticky notes. Make sure the question is written in marker, is large enough to read from a few feet away, and has the student initials on the back.
6. Gather students back together and introduce the blank Driving Questions Board (DQB). (This can be a piece of chart paper, a bulletin board in the classroom, or even a virtual bulletin board).
7. Follow the procedures from OpenSci Ed outlined below to have students add to and organize their DQB.

Instruct students to share their questions, one by one, with the whole group.
Explain to students how you will create the DQB:

- The first student reads their question aloud to the class, and then posts it on the DQB.
- Students who are listening should raise their hands if they have a question that relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads their question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- The student selects the next student.
- Continue until everyone has at least one question on the DQB.

∗ If the question is a new question and doesn't fit with any questions that are already on the board, students should create a new cluster.

8. If time allows, you may continue engaging with the DQB by having students brainstorm the following:
    a. What information will we need to gather to be able to answer these questions?
    b. What kinds of investigations could we perform to answer these questions?

Area of interest for European green crab invasion

Invasive European green crabs threaten Northwest shellfish industries **–Oregon Public Broadcasting** Jan 04, 2024

Over 400K invasive crabs trapped, killed as fight goes on **-Kitsap Sun** Jun 14, 2023

Governor issues emergency order over green crab infestation **–AP News** Jan 19, 2022

Invasive crab threatening shellfish industry, salmon found in another western Washington bay -King 5 Nov 09, 2022

Washington takes emergency action to stop thousands of invasive green crabs -Bellingham Herald Jan 09, 2022

"Efficient predator": Invasive European green crab found in new area of Washington state -CBS News May 20, 2022

Article: Governor Inslee Issues Green Crab Emergency Order, January 21, 2022

This article is adapted from an article originally published by KXRO on January 21, 2022: https://www.kxro.com/gov-inslee-issues-green-crab-infestation-proclamation/

Governor Jay Inslee issued an emergency order to increase the state's response to a concerning increase in European green crabs in some areas of Washington state. These areas include **Makah Bay, Grays Harbor, Willapa Bay, and the Lummi Nation's Sea Pond near Bellingham.**

According to the Washington Department of Fish and Wildlife, European green crabs were first found in Washington in 1998. They were found in **Willapa Bay and Grays Harbor.**

Since 2016, green crabs have been found in **Padilla Bay, Sequim Bay, Dungeness Spit, and the San Juan Islands.**

European green crabs first arrived on the East Coast of the United States in the mid-1800s. In the early 1900s they spread north. They are thought to have contributed to the decline of a major clam fishery on the East Coast. In 1989, green crabs were found on the West Coast, in San Francisco Bay. They then made it to Oregon, Washington, and British Columbia **estuaries** in the late 1990s, helped by strong ocean currents.

The European green crab is one of the world's worst **invasive species**. If they become permanently established, they can harm **endangered species**, damage resources that are important to tribes and native peoples, and impact small businesses.

The emergency order directs the Washington Department of Fish and Wildlife to carry out emergency actions to prevent the establishment of the European green crab in Washington state. The order also directs other state agencies to help and asks the Washington Legislature to increase funding for the effort as soon as possible.

The order is effective immediately and will remain in effect until canceled.

Vocabulary

- **Estuary**: The place where fresh water from the land meets salt water of the sea.
- **Invasive species:** A plant, animal, or other organism introduced to an area outside of its native range, usually by humans, which negatively impacts the economy, environment, and health. -
- **Endangered species:** A species of animal or plant that is seriously at risk of extinction.

Worksheet: European green crab emergency

1) List three things you learned about invasive European green crabs:

    1. ____

    ____

    2. ____

    ____

    3. ____

    ____

2) What is an “emergency order”? What does it do?

____

____

3) Why did Governor Inslee make an emergency order about European green crabs in Washington state?

____

____

4) According to the article, why are European green crabs one of the “world’s worst invasive species”?

____

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Lesson 2 What is an estuary and why is it important?

This lesson was adapted from a lesson plan developed by Dr. Brian Turner, WDFW AIS research scientist at the Portland State University Department of Environmental Science and Management.

Standards

Performance Expectation: MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.	*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.	*Cause and Effect* Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Essential Question

How may European green crabs impact the estuary food web?

Learning Objectives

Students will…

- Describe an estuary and learn about some of the organisms who live there.
- Develop a model of a healthy estuary food web.
- Use their model to make predictions of what will happen to an estuary food web with the introduction of European green crabs.

Anchoring Phenomenon Connections

To anchor student learning to the storyline started by the anchoring phenomenon, we begin the lesson by referring to the driving questions board (DQB). **For this lesson, we identify and highlight student questions that have to do with the ecosystem or habitat European green crabs live in.**

In each lesson, we aim to lead students through the OpenSciEd Navigation routine steps 1-3 in which the class begins a lesson by asking "What brought us to this point?". Throughout the lesson check in by asking "Where are we now?", and close the lesson by asking "Where are we going?"

Materials

- European green crab unit PowerPoint
- Something large to write on like a white board, chalk board, or smart board.
- Copies of the estuary food web instructions and information
- Species tokens (printed, cut, and laminated). These can be found on the unit plan website (link this when up on site)
- Envelopes to organize species tokens

Lesson Procedure

Part 1: What is an estuary and who lives there?

1. To connect to the anchoring phenomenon, explain to students that today we will continue exploring the problem presented to Washington ecosystems by the appearance of European green crabs, and we will try to answer some of the questions we identified in our DQB.
2. Refer to any questions in the DQB related to ecosystems, habitats, what crabs eat, etc.
3. Have students create a T-chart with the following information:
    a. Heading: What is an estuary and who lives there?
        i. Left side: living
        ii. Right side: non-living
4. Pull up the European green crab unit PowerPoint and have students watch the short video on slide 20: "Estuaries. More than meets the eye."

> **Teacher Notes:** Be sure to pause frequently throughout the video to allow students to catch up with note taking.

5. After the video refer to student T-chart notes, and work to co-create a definition for the term "Estuary". Add the term and definition to the driving questions board.
6. Explain that today we are going to build a model of the food web for organisms that live in an estuary ecosystem, and to be able to do so, we need to learn more about the needs of those organisms.
7. Explore some of the organisms that live in an estuary through slides 21-28

Part 2: Estuary food web

Before the lesson, print and laminate a set of species tokens for each student. Store the tokens in an envelope to help with organization.

> **Teacher Note:** Depending on the class, teachers may want to review what food webs are and the concepts of "producer," "primary consumer," and "secondary consumer."

1) Watch the video "Estuaries" made by the city of Bellingham. (Slide 30)
2) Lead students in discussion about food chains and food webs and show examples on slides 31 and 32. Discussion questions can be found in the notes.
3) Pass out species tokens (each student should get one envelope), large sheets of paper, and markers for labeling their models.
4) Have students work independently or in small groups to create a model food web using the information on the estuary food web worksheet and the slide show, then fill out the estuary food web model questions 1-3.
   a) You may want to guide students through brainstorming answers to question three.

Part 3: Food web impacts of European green crabs

Part 3 of the lesson has students use their food web model to predict potential changes to the food web caused by the introduction of European green crabs into the estuary.

1. Show slide 34 depicting information about the dietary habits of European green crabs.
2. Have students rearrange their food web to include the European green crab.
3. Lead class discussion about the following question (shown on slide 33) "How could the introduction of European green crabs impact the estuary food web?"
4. Finish the activity by having students complete questions 4 and

The estuary food web instructions and information

<u>Tasks</u>

1. Use the information below and from the slide show to arrange the native species cards into a food web model.
2. Label **producers, primary consumers, secondary consumers, tertiary consumers, and apex consumers** where appropriate.
3. Draw arrows to indicate the direction of energy flow.
4. Label non-living components of the food web.
5. Using your food web, answer the questions.

<u>Food web information</u>

Common loons migrate through Washington's estuaries and eat small fish and crabs, including Pacific herring and hairy shore crabs. Phytoplankton, a kind of microscopic alga, float in the water or form large clumps on hard surfaces. When floating in the water, phytoplankton get sucked up and eaten by clams like the littleneck clam. When the phytoplankton is in large clumps, animals such as hairy shore crabs will find and eat it. Pacific herring also find phytoplankton to be a delicious snack.

The hairy shore crabs have many predators, including Pacific herring who like to lay their eggs in eelgrass. Herring is very important to the ecosystem and provides a nutritious meal to young Chinook salmon. People also like to eat many of the animals that live in the estuary, including the littleneck clams, herring, and Chinook salmon.

The European green crab is a hungry newcomer. Not very picky, the green crab will eat anything smaller than it, including eelgrass, clams, and even shore crabs. European green crab zoea (the form of crabs right after they hatch) will even eat phytoplankton. But there is always someone bigger than you! Common loons and Pacific herring may eat baby European green crabs, and bigger European green crabs like to eat the smaller European green crabs.

<u>Vocabulary</u>

- **Organism**: Any living creature such as a plant, animal, fungus, or bacteria.
- **Producer**: An organism that produces food from inorganic compounds, usually through photosynthesis; typically a plant.
- **Primary consumer**: An organism that eats producers.
- **Secondary consumer**: An organism that eats other consumers.
- **Estuary**: The place where fresh water from the land meets salt water of the sea.

Estuary food web model questions

1) What are three non-living parts of an ecosystem that living organisms in an estuary need to survive?

   a) ______________________________

   b) ______________________________

   c) ______________________________

2) Our model is missing a key trophic level: D=decomposers. What do decomposer do, and why are they an important part of the food web?

   ____

   ____

3) This food web model does not fully represent the variety of species that live in an estuary. Look at your T-chart and identify other organisms that are missing from our model?

   ____

   ____

Washington residents are concerned that the European green crab, an **invasive species**, may be harmful to native species such as Dungeness crabs, hairy shore crabs, and salmon. Each native species plays an important part of local **estuary** ecosystems. Some of these native species are also **endangered species**, including some Chinook salmon populations.

4) Based on the food web, what organisms might be affected by the presence of green crab? How?

   ____

   ____

   ____

5) Does the food web provide information that could be used to help remove green crabs? How might you get rid of the green crabs?

   ____

   ____

Lesson 3 Healthy Estuary Dynamics

Standards

Performance Expectation: MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.	*LS2.C Ecosystem Dynamics, Functioning, and Resilience* Ecosystems are dynamic in nature; their characteristics can vary over time. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	*Stability and Change* Small changes in one part of a system might cause large changes in another part. *Cause and Effect* Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Essential Questions

How do scientists evaluate the health of an estuary ecosystem?

How do populations of some species in a healthy estuary fluctuate?

Learning Objective

Students will…

- Collect data through an estuary survey simulation.
- Observe normal population fluctuations in a healthy estuary ecosystem over time.
- Combine individual survey data into class data set and compare data through graphs.
- Determine the biodiversity index of the simplified estuary ecosystem before and after the introduction of European green crabs.

Anchoring Phenomenon Connections

To anchor student learning to the storyline started by the anchoring phenomenon, we begin the lesson by referring to the driving questions board (DQB). **For this lesson we identify and highlight student questions that have to do with the estuary ecosystem, how scientists find European green crabs, how we gather information about ecosystems, etc.**

In each lesson, aim to lead students through the OpenSciEd Navigation routine steps 1-3 in which the class begins a lesson by asking "What brought us to this point?" Throughout the lesson check in by asking "Where are we now?", and close the lesson by asking "Where are we going?"

Materials

- Copy of Willapa Bay survey sites
- Ten sets of species chips printed, cut, and laminated. (one per survey site). Found on the unit plan website.
- One die (singular of dice) per group
- Copies of simulation instructions (one per group)
- Copies of simulation data sheets (one per group)
- Class data Excel Spreadsheet (used by teacher to easily record data from all groups)

Lesson Procedure

Part 1: Introducing estuary survey simulation

1. Refer to the DQB Identify student questions that have to do with the estuary ecosystem, how scientists find European green crabs, how we gather information about ecosystems, etc. Explain that in today's lesson we are going to be conducting a simulation of an estuary survey.
2. Discuss the term survey, and work to co-create a definition. Add the term and the definition to the DQB.
3. Present PowerPoint slide 36 showing the location of our simulated survey site: Willapa Bay. Have students identify where Willapa Bay is located on their maps from lesson one.
4. Bring up slide 37 or pass out Willapa Bay survey sites map. Explain that in this simulation we are going to be working in small groups to collect data about a specific survey site. Discuss how scientists use data collected from multiple survey sites to get an idea of the health of a larger ecosystem as a whole.
5. Pass out estuary health survey simulation instructions and open the Excel estuary health survey data spreadsheet. Model conducting the survey simulation. Be sure to model recording their

data into the corresponding sheet on the Excel spreadsheet and show how their data will automatically be imported into the class data sheet.

> **Teacher Note:** The simplest way to record data from the simulation is to add it directly the survey site sheets on the excel document. A printable data sheet has also been provided, but the data will need to be transferred to the Excell spreadsheet to interpret the class results.

2. As you present each scenario, lead discussion on why these changes would occur. For example, scenario 2 says, "This year's Chinook salmon are coming back to spawn, and if there are lots of herring to eat, they will stop in the estuary before heading to their home stream. If you have at least three herring, **subtract three herring and add two Chinook salmon.** Otherwise, their numbers stay the same." Potential discussion questions could include:
    a. Why does the population change in the scenario depend on the number of herring present in the estuary?
    b. What would happen if there weren't enough herring present?

> **Teacher Note:** It is important to ensure students understand why changes occur in each scenario, otherwise the survey simulation won't support the crosscutting concept of Cause and Effect.

Part 2: Estuary health survey simulation

1. Divide students up into small groups. The simulation has 10 potential survey sites, so up to 10 groups can be created.
2. Assign each group a survey site (1-10) and have them identify the location of the site on the map of Willapa Bay.
3. Pass out species token card sets to each group.
4. Have students set aside the European green crab tokens for this simulation. They will be used in future simulations.

> **Teacher Note:** Students should observe fluctuations in the populations of individual species in the estuary but should not see a total population collapse.

5. Distribute dice, data sheets, and simulation instruction sheets to each group.

6. Have students begin their simulation by reading through the first paragraph on the simulation instructions sheet and recording the numbers of each species in their data sheet.
7. Model rolling a die (singular of dice) and determining which scenario corresponds to the number on the die. Model adding and removing the appropriate tokens from their "survey site" and recording their data on the data sheet.
8. Have students work in their small groups to record 10 weeks of survey data.

Part 3: Class data

1. When the simulation is complete and all weeks have been recorded, have students report out their numbers or add their data directly to the corresponding sheet on the excel spreadsheet provided with unit. Spreadsheets can be found on the European green crabs unit page on the [unit plan webpage.]
2. Lead students through analyzing and interpreting the data presented in the graph. Make observations about population fluctuations over the course of the survey season.
3. Guiding questions for discussion
    a. Did any population change dramatically over the course of the survey season?
    b. How do you think this simulation might represent the real changes in an estuary ecosystem over time?
    c. What would you predict would happen if you carried out the simulation for longer?
    d. Was there anything missing from the scenarios?
    e. The scenarios didn't have reproduction occurring very often. Do you think adding reproduction of all the organisms in the survey site could change the outcomes? How?
    f. Did any week of the survey have an unexpected outcome?

Part 4: Biodiversity in the estuary

Adapted from "Schoolyard Biodiversity Investigation Educator Guide An Introduction to Biodiversity Concepts and Outdoor Investigations" from the Association of Fish and Wildlife Agencies and Pacific Education Institute

1. Introduce the term "Biodiversity" and discuss definition on slide 39.
2. Show image on slide 40 and have students try to estimate the number of different species presented. Details about the poster and the artist can be found in the notes on the slide.
3. Explain that by counting the number of different species in an ecosystem, the students just calculated the "species richness". Discuss definition on slide 41.

> **Teacher Note:** The Excell spreadsheet has been set up with the equation to automatically generate the simplified Biodiversity index.

4. Walk students through slides 42-43 on determining biodiversity and using a simplified index to calculate the biodiversity of our simulated estuary using our survey data.
5. Discuss how to evaluate the simplified biodiversity index (closer to zero is less diverse, closer to 1 is more diverse), and show students how their data has generated a simplified biodiversity index for the Willapa Bay survey site.
6. How biodiverse was Willapa bay at the beginning of the survey?
7. How biodiverse was Willapa bay at the end of the survey?

Willapa Bay Survey Sites

Estuary Health Survey

Represents possible survey sites.

**Does not represent actual survey sites used by WDFW*

Estuary health survey simulation instructions

Step 1: Read the paragraphs below and fill out the first empty column of Table 1 with how many species chips you have for each species. This represents the number of species observed in your survey site on week one.

It's a normal season in the estuary. Lush meadows of eelgrass provide shelter and protection from predators to Pacific herring. Phytoplankton float along in the water, brushing up against the sides of swimming Chinook salmon. Littleneck clams are burrowed in the estuary's muddy bottom, and little shore crabs skitter back and forth. A few people are harvesting clams on the beach or fishing for salmon. Common loons are flying overhead and the scene is calm.

Set aside the following numbers of chips for each species: 15 eelgrass, 15 phytoplankton, 5 littleneck clams, 5 hairy shore crabs, 5 Pacific herring, 3 Chinook salmon, 2 people, and 2 common loons. These represent the plants and animals that were just described to be in the estuary. Let's see what happens to their populations over time.

Step 2: You are now going to explore how the number of each species changes over time as different events happen. You should have one die (singular of dice) and find a list of six events below. The numbers below correspond to each side of the die. For example, if you roll a four, then the event corresponding to number four happens. Record the number of each species after the event, adding or subtracting as directed. Roll the dice nine times and add the date to Table 1 for each species.

1. The eelgrass and phytoplankton have all the sunlight and nutrients they need to grow and reproduce – **add three eelgrass** and **three phytoplankton**. Wait, there's more! With more eelgrass, the herring have more places to lay their eggs – **add two herring.**

3. This year's Chinook salmon are coming back to spawn, and if there are lots of herring to eat, they will stop in the estuary before heading to their home stream. If you have at least three herring, **subtract three herring and add two Chinook salmon.** Otherwise, their numbers stay the same.

3. Both hairy shore crabs and littleneck clams eat phytoplankton. If you have at least four phytoplankton, **add one shore crab and one littleneck clam**. Then, **subtract four phytoplankton.**

4. Some common loons are migrating by. For them to stop, they need food to eat. If you have any Pacific herring or hairy shore crab, **add one common loon**. Then, **subtract two shore crabs and two herring**.

5. A person comes to the beach and is looking for clams. While they are looking for clams, they trample some eelgrass along the way– **subtract three eel grass.** If the people find clams, they

will tell their friends and more people will come to visit. If you have at least two clams, **subtract two clams** and **add one person.** Otherwise, their numbers stay the same.

6. Just like us, plants and animals can get sick. Both the Chinook salmon and the common loons get sick with bacteria and some pass away. **Subtract one Chinook salmon and one common loon**. With fewer Chinook and common loons to eat them, the herring and shore crab populations can grow. **Add two shore crabs and two herring.**

Estuary Health Survey Simulation Data Sheet

Survey Site: _____________

Read the paragraph on the simulation sheet, and record how many species chips you have for each species in the first empty column of Table 1. This represents the number of that species observed in your survey site.

Table 1.

Species	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Eelgrass										
Phytoplankton										
Littleneck clams										
Hairy shore crabs										
Pacific herring										
Chinook salmon										
People										
Common loons										

Lesson 4 Invasion of European green crab in Washington

Standards

Performance Expectation:
MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, evaluating, and communicating information Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.	*LS2. A Interdependent Relationships in Ecosystems* Growth of organisms and population increases are limited by access to resources. *LS2.C Ecosystem Dynamics, Functioning, and Resilience* The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. *LS2.D Biodiversity and Humans* Changes in biodiversity can influence humans' resources	*Stability and Change* Small changes in one part of a system might cause large changes in another part. *Cause and Effect* Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Essential Question

How do population dynamics of specific species change after the introduction of European green crabs to the estuary?

Learning Objectives

Students will…

- Simulate the effects of the introduction of European green crabs to a healthy estuary ecosystem.
- Determine the biodiversity index of the simplified estuary ecosystem before and after the introduction of European green crabs.

- Read and evaluate an article detailing the impacts of European green crabs on shellfish industries in Maine.
- Draw comparisons between the results of their simulation, and the effects of European green crabs on ecosystems on the east coast.

Anchoring Phenomenon Connections

To anchor student learning to the storyline started by the anchoring phenomenon, we begin the lesson by referring to the Driving Questions Board (DQB). **For this lesson, we identify and highlight student questions that have to do with how European green crabs change the ecosystems they invade.**

In each lesson, aim to lead students through the OpenSciEd Navigation routine steps 1-3 in which the class begins a lesson by asking "What brought us to this point?". Throughout the lesson check in by asking "Where are we now?", and close the lesson by asking "Where are we going?"

Materials

- Copy of Willapa Bay survey sites
- Sets of species chips printed, cut, and organized into sets. (1 per student) Found on the [unit plan website.]
- One die (singular of dice) per group
- Copies of simulation instructions (1 per group)
- Copies of simulation data sheets (1 per group)
- Class Data Excel Spreadsheet. Found on the [unit plan website.]

Lesson Procedure

Part 1: Video and discussion

1. The prior lesson focused on the ecosystem dynamics of a healthy estuary. In this lesson, we aim to simulate what could/has happened in estuaries where the European green crab has invaded. Explain that we are going to repeat our simulation from the prior lesson, but today we will have some new variables introduced with European green crabs. (Show slide 45 with the European green crab in Willapa bay).
2. Open PowerPoint and watch the video clip on slide 46 "The true cost of European green crabs"
3. Lead students through discussion about information presented in the video.

a. Based on the information from the video, what do you predict will happen in our estuary health survey simulation?
b. How do you think biodiversity will be affected by the introduction of European green crab to our simulation?

Part 2: Estuary health survey simulation

1. Have the students reform their groups from Lesson three.
2. Distribute dice, data sheets, and simulation instruction sheets to each group.
3. Have students begin their simulation by reading through the first paragraph on the simulation instructions sheet and recording the numbers of each species in their data sheet.

> **Teacher Note:** To account for the introduction of European green crabs, the simulation will add an additional step: Flip a coin to determine which set of scenarios to use, then roll the die to determine which scenario number.

4. Model flipping a coin and referring to the appropriate scenario sheet- Heads or Tails. Then, model rolling a die (singular of dice) and determining which scenario corresponds to the number on the die. Model adding and removing the appropriate tokens from their "survey site" and recording their data on the data sheet.
5. Have students work in their small groups to record 10 weeks of survey data.
6. When the simulation is complete and all weeks have been recorded, have students report out their numbers or add their data directly to the corresponding sheet on the excel spreadsheet provided with unit. Spreadsheets can be found on the European green crabs unit page on WDFW's website.

Part 3: Class data

7. Once the class data has all been added, use Excel to create a graph of the populations of individual species in the Willapa Bay Estuary.
8. Lead students through analyzing and interpreting the data presented in the graph. Make observations about population fluctuations over the course of the survey season.
9. Guiding questions for discussion
   c. With the introduction of European green crabs, did any species' population change dramatically over the course of the survey season?
   d. What would you predict would happen if you carried out the simulation for longer?

e. Based on the data alone, what are your predictions about the change to the biodiversity of our simulated estuary after the introduction of European green crabs?

Part 4: Biodiversity in the estuary

1. Return to the PowerPoint slides on determining biodiversity and using a simplified index to calculate the biodiversity of our simulated estuary using our survey data from the previous lesson.
2. Compare the final biodiversity index from the healthy estuary to the final biodiversity index from the simulation with European green crabs.
   a) Guide students through discussion of biodiversity and what simplified index numbers tell us about the health of an ecosystem.
   b) How did the biodiversity of the simulated estuary change?
   c) What behaviors from the European green crabs contributed to the changes in biodiversity in the estuary observed in the simulation?

Part 5: The European green crab problem

1. Pass out the article, "The Green Crab Invasion…" and lead students through reading, decoding, and discussing the article. Discussion questions could include:
   a. How did our estuary health survey simulation reflect what happened in Maine with the invasion of European green crabs?
   b. What traits or behaviors does the article point out that allow European green crabs' to outcompete native species for resources?
   c. Think about Washington. Who do you think should be/is concerned about the introduction of European green crabs?
2. Have students work independently or in pairs to answer the questions on the worksheet "European green crabs in Maine".
3. Lead students through PowerPoint slides 50-52 and add information to their European green crab brain map. Potential discussion questions:
   a. What other industries could the invasion of European green crabs impact?
   b. Are there any marine species we can think of that have cultural importance to Washingtonians that may be impacted by the invasion of European green crabs?

Teacher Note: The information on these slides is intended to support student thinking about the impacts of the introduction of European green crabs to the environment, and to the economic and cultural health of the state.

Estuary health survey simulation instructions: Invasion of European green crab in Washington

It's another normal season in the estuary. You will find that you have ***15 eelgrass, 15 phytoplankton, 5 littleneck clams, 5 hairy shore crabs, 5 Pacific herring, 3 Chinook salmon, 2 people, and 2 common loons****. These represent the plants and animals that are living in the estuary.*

Oh no! Two European green crabs have been introduced to the estuary! Maybe they were brought in by accidentally by ships, or maybe somebody released them on purpose. However the case, they are here. ***Add 2 European green crabs****. The European green crabs are happy to be in the beautiful estuary. There's lots of food for them to eat! Let's see what happens to the biodiversity of the estuary and the numbers of the other species now that green crabs have arrived.*

You are now going to explore how the number of each species changes over time as different events happen. You should have one die (singular of dice), a coin, a list of six scenarios corresponding with "heads," and a list of six scenarios corresponding with "tails".

First, flip the coin to determine which list to use. Then, role the die to see which event happens.

For example: You flip the coin and get "tails" and roll the die and get four. To find the correct scenario you would turn to the scenario sheet titled "TAILS" follow instructions from scenario.

Record the number of each species after the event, adding or subtracting as directed. Repeat the "simulated survey" nine more times. Make sure to record your data on the population of each species on Table 1 for each "simulated survey".

HEADS survey simulation instructions

1) The eelgrass and phytoplankton have all the sunlight and nutrients they need to grow and reproduce – **add three eelgrass** and **three phytoplankton**. Wait, there's more! With more eelgrass, the herring have more places to lay their eggs – **add two herring.**

2) This year's Chinook salmon are coming back to spawn, and if there are lots of herring to eat, they will stop in the estuary before heading to their home stream. If you have at least three herring, **subtract three herring and add two Chinook salmon.** Otherwise, their numbers stay the same.

3) Both hairy shore crabs and littleneck clams eat phytoplankton. If you have at least four phytoplankton, **add one shore crab and one littleneck clam**. Then, **subtract four phytoplankton.**

4) Some common loons are migrating by. For them to stop, they need food to eat. If you have any Pacific herring or hairy shore crab, **add one common loon**. Then, **subtract two shore crabs and two herring**.

5) A person comes to the beach and is looking for clams. While they are looking for clams, they trample some eelgrass along the way– **subtract three eel grass.** If the people find clams, they will tell their friends and more people will come to visit. If you have at least two clams, **subtract two clams** and **add one person.** Otherwise, their numbers stay the same.

6) Just like us, plants and animals can get sick. Both the Chinook salmon and the common loons get sick with bacteria and some pass away. **Subtract one Chinook salmon and one common loon**. With fewer Chinook and common loons to eat them, the herring and shore crab populations can grow. **Add two shore crabs and two herring.**

TAILS survey simulation instructions

1) European green crabs find the littleneck clams – **take away 2 littleneck clams per European green crab.** With fewer clams, fewer phytoplankton will get eaten- **add three phytoplankton**. Because there are fewer clams, people stop visiting the estuary to go clamming - **subtract one person.**

2) The bigger and stronger European green crabs find the hairy shore crabs and eat them up– **take away one hairy shore crab per European green crab.** Without as many shore crabs, fewer common loons want to stay in the neighborhood – **subtract one common loon.** With enough food resources, the European green crabs can grow and take up more space. They burrow into the muddy shoreline and pull up some eelgrass. **Subtract one eelgrass per green crab.**

3) European green crabs have found all the resources they need and have enough energy to spawn. The water temperature is warm enough for the European green crab eggs to hatch, and the tiny zoea (the planktonic form of crabs when they hatch) drift in the water and eat some of the phytoplankton. **Double the number of European green crabs** in the estuary **then subtract one phytoplankton per green crab.**

4) Some bigger European green crabs decide some of the smaller green crabs and hairy shore crabs would be a good snack. **Subtract one European green crab, then subtract one hairy shore crab per remaining green crab.**

5) The European green crabs like eelgrass – both to eat and to burrow into. **Subtract one eelgrass per European green crab.** With less abundant eelgrass to hide in, young herring are easily spotted and eaten. **Subtract two herring**. The European green crabs are doing well – **add two European green crabs.**

6) The European green crabs discover delicious herring eggs on the eelgrass and eat them. **Subtract two herring**. With fewer herring, Chinook salmon don't have as much to eat and so fewer stay in the estuary – **subtract two Chinook salmon.** With plenty of resources available to them, the European green crabs are able to grow and reproduce. **Add two European green crabs**.

Survey Simulation Data Sheet

Survey Site: _______________

Read the paragraphs below and record how many species chips you have for each species in the first empty column of Table 1. This represents the number of that species observed in your survey site.

Table 1.

Species	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Eelgrass										
Phytoplankton										
Littleneck clams										
Hairy shore crabs										
Pacific herring										
Chinook salmon										
People										
Common loons										
European green crabs										

Worksheet: European green crabs in Maine

Read the article and answer the following questions:

1) Give two examples of why the European green crab is such a successful invasive species.

   a) ______________________________

   b) ______________________________

2) Name two ways the European green crab has harmed Maine's environment and seafood industries.

   a) ______________________________

   ____

   b) ______________________________

   ____

3) Do you think the European green crab could do similar damage to Washington's environment and seafood industries? Explain:

   a) ______________________________

   ____

Article: The Green Crab Invasion: Will this invasive crab destroy Maine's $15 million soft-shell clam industry?

This article is adapted from an article originally published by DownEast: https://downeast.com/uncategorized/green-crab-invasion/ Published January, 2014

Chad Coffin, president of the Maine Clammers Association, looks out over Recompense Cove in Freeport, Maine. Just a few years ago the **intertidal zone** was thick with mussels and eelgrass. Now there is just gray mud and green crabs.

"Everything is being systematically eaten," Coffin says.

Dr. Hilary Neckles, a U.S. Geological Survey scientist, calls the green crab an "ecological catastrophe" for Maine. Neckles describes what clammer Chad Coffin has witnessed over the past five years as "an absolute cascade" — scallops disappear, mussels disappear, clams disappear, sea grass disappears. With them goes the seabirds and fish that depend on them for food and habitat. Clammers just hope they won't be next to disappear.

Sometimes called "cockroaches of the sea," European green crabs eat a lot, as many as forty clams a day each. They also reproduce quickly, with females laying as many as 185,000 eggs a year. The crabs appear to prefer estuaries, where freshwater mixes with saltwater. Freeport has a lot of estuaries.

The threat of green crabs to Maine's $15 million soft-shell clam industry and the livelihoods of local clam harvesters is big news, but it's nothing new.

"Since 1949," noted a 1961 U.S. Department of the Interior report, "the green crab has been the most serious clam predator in Maine. In 1951, an experimental clam farm in Scarborough. . . was completely destroyed. . . by green crabs."

European green crabs were first reported in Casco Bay around 1900 and spread to the northernmost part of Maine by the 1950s. Their rise is linked with a decline in Maine clam harvests. The largest Maine clam catch was thirty-eight million pounds in 1977 and then went into a long, slow decline to around eleven million pounds a year today.

Warmer water temperature is the most cited cause of the fast growth of the green crab population. Whatever the causes, the impacts of the green crab invasion are clear — loss of shellfish, loss of sea grass, and soil erosion where the crab burrows undermine the shore.

The hope is that enough green crabs can be trapped, fenced out, or otherwise deterred so that the clams can rebound. The question on everyone's mind – is it too late?

Vocabulary

- **Intertidal zone**: The area on a beach that is region between the high and low tide of an area. - National Geographic

Lesson 5 Evaluating solutions to the European green crab problem

Standards

Performance Expectation: MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute a solution to a problem.	*LS2.C: Ecosystem Dynamics, Functioning, and Resilience* Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. *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.	*Stability and Change* Small changes in one part of a system might cause large changes in another part.

Essential Question

What are the options for controlling European green crab populations? What are their pros and cons?

Learning Objectives

Students will...

- Describe the invasion curve, and how it is used to help guide scientists and policy makers in determining the best method of management for invasive species.

- Evaluate the methods considered to control the populations of European green crabs in Washington.
- Engage in argument with evidence to construct a CER on the control method they believe would be most effective.
- Brainstorm ways they could take action to help control the spread of European green crabs throughout the coast and estuaries of Washington.

Anchoring Phenomenon

In each lesson, aim to lead students through the OpenSciEd Navigation routine steps 1-3 in which the class begins a lesson by asking "What brought us to this point?". Throughout the lesson check in by asking "Where are we now?", and close the lesson by asking "Where are we going?" This routine helps guide students in analysis and sense-making connections between previous lessons and future investigations.

As this is the final lesson in the mini unit, the goal is to synthesize all of the information students have gathered about European green crabs, understanding why European green crabs have been in the news, and why they are problematic enough to warrant a gubernatorial emergency order to manage them. Students will use that background information to help evaluate possible solutions to managing European green crab populations in the state.

Be sure to close out the Driving Questions Board with students at the end of the lesson by going over all the questions they had from the beginning of the unit and adding that information to the brain map about European green crabs. The optional closing activity in this unit asks students to work together to identify an action they could take to help support the efforts to curb the spread of European green crabs throughout the coasts and estuaries of Washington. The brain map created throughout the unit can be used as a resource during this activity.

Materials

- European Green Crab Unit PowerPoint Slides 53-81
- Copies of "Worksheet: European green crab control methods"

Lesson Procedure

Part 1: Introduction to invasive species management

1. Open the PowerPoint slide show to slide 54 and watch the short video about invasive species.

2. Lead class discussion about the species presented in the video, and how they are similar to European green crabs.
    a. How do European green crabs outcompete the native species in the estuary for resources?
    b. How did the species in the video outcompete the native species in the ecosystems they invaded?
3. Lead students through understanding and decoding the graphic, The Invasion Curve" on slide 55. Continue through slide 61 and evaluate the different levels of the invasion curve and the kinds of control methods associated with them. The different control methods students will evaluate all work toward management at the eradication, containment, and management/suppression stages of the invasion curve.

Part 2: Management Plan for the European Green Crab

For more information on different control options, please review the following report submitted by the Green Crab Control Committee to the Aquatic Nuisance Species Task Force: https://www3.epa.gov/region1/npdes/schillerstation/pdfs/AR-317.pdf.

Once enough green crabs have arrived at a location, it may be difficult to get rid of them, but still desirable to reduce their numbers. The fewer European green crabs, the less harm they can cause to the environment and coastal economy (like the shellfish industry).

Fast action is needed to increase the likelihood of successful control of European green crab populations. There are four main types of control – selective harvest, chemical control, biological control, and genetic and molecular control. We are only going to focus on the first three methods, however, as there are no successful genetic and molecular control options yet.

1. Pass out the Management Options sheet to each student.
2. Read through the control options on the student sheets while leading students through slides 63-69.

> **Teacher Notes**: The text from the student pages can be found on the notes for the slides on each control option. Slide 65 allows you to model brainstorming the benefits and drawbacks of control option one.

3. For each control option, have students brainstorm the benefits and drawbacks of the method on their student page.
4. Allow students time to discuss the control options presented. Then, have them fill out the remaining parts of the student page where they are asked to choose a control option and

brainstorm some evidence that supports their claim. Remind students that there are no wrong answers.

5. Have students take their notes and use them to craft a formal Claim Evidence Reasoning paragraph arguing for the use of their chosen control option. Remind students that the reasoning piece of a CER is how the evidence supports the claim.

Part 3: What is Washington doing in 2024?

> **Teacher Notes**: This is an ongoing emergency and management strategies may change over time. For up-to-date information please visit https://wdfw.wa.gov/species-habitats/invasive/carcinus-maenas

1. Lead students through the remaining slides in the PowerPoint, pause often for discussion.
2. The control method adopted by Washington state is selective harvest/trapping to achieve "functional eradication". This means reducing European green crab populations to levels that do not harm environmental, economic, or cultural resources.
3. One of the primary ways WDFW and co-management partners can identify new locations of European green crabs is from members of the public reporting a sighting.
4. Community science is a great way to get involved in monitoring green crabs and could be something students and their families do if they have proximity to an estuary or coastline.

Part 4: Take action

1. Have students brainstorm possible ways they could take action with the information they have learned about European green crabs through the course of this mini unit.

> **Teacher Notes**: If using this lesson in conjunction with the OpenSciEd unit 7.5 Ecosystem Dynamics, refer to Lesson 19: How can we inform others in our community about the palm oil problem and convince them to take action?

2. Students could create an informational poster, write and act in a Public Service Announcement, install a temporary piece of public art depicting the issues associated with European green crab invasion…etc.
3. If you are interested, research who is working on the European green crab issue in your area and see if they are willing to speak with your class. Contact ais@dfw.wa.gov if you need help finding a connection.

Teacher Notes: However students decide to take action on this issue, we want to hear about it! Photos or videos of completed projects can be submitted to WDFW at wdfw.wa.gov/share. Be sure to indicate if you are willing to have them shared on social media pages and blog posts!

Controlling European Green Crabs

Use the information in the texts below and from the presentation to identify some of the benefits and drawbacks of each control option.

Control Option 1: Selective harvest/trapping

Selective harvest usually uses traps to catch European green crabs in specific areas. Using traps is the easiest initial control method because it has few environmental concerns and requires little up-front research. The traps can specifically target European green crabs, causing little harm to other marine animals. Selective harvest can be very expensive, however, as it requires money to fund the trapping efforts, including buying traps, bait, and paying and training people doing the work.

Benefits	Drawbacks

Control Option 2: Chemical control

The use of chemicals such as pesticides to control European green crabs has been suggested as it would kill many crabs very quickly. Chemical control, however, has significant environmental concerns. The biggest concern is that all existing chemicals that would kill European green crabs would also kill other species, harming the local ecosystem. Because of these concerns, use of a chemical to control green crabs would require extensive environmental review which takes a lot of time and money. Additionally, a huge amount of the chemical would need to be used across the state. It could be very challenging to get enough supplies and may need to be done repeatedly.

Benefits	Drawbacks

Control Option 3: Biological control

Biological control is when a natural predator is introduced to control an invasive species population. A biological control would only reduce the impact or population of European green crabs, but they will never eradicate them. One of the biggest issues with biological controls is making sure that they don't harm other organisms in addition to the European green crab. So far, no biological control has been found that effectively controls the European green crab population without harming other organisms. For biological controls to become an option, further research is needed, which requires funding.

Benefits	Drawbacks

If you were tasked with trying to control the invasion of European green crabs, which control method(s) would you choose to implement?

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____

What evidence from the text or presentation can you use to support that choice?

Resources

If reading a printed version, scan QR code for the unit resource links.

WDFW online resources and videos

- European green crab plain language talking points
- European green crab WDFW webpage
- Video: Estuaries. More than meets the eye.
- European green crab poster

Videos used in Lessons

- Green crabs Anchor Video
- Uninvited: The Spread of Invasive Species
- "Estuaries" made by the city of Bellingham.
- True Cost of European Green Crabs Clip
    - True Cost of European Green Crabs Full Video
- Invasive species 101 National Geographic
- Northwest Now Digital First European Green Crabs FIX
- UW Research on European Green Crabs
- What's Molt Search?

Additional Resources

- Question Formulation Technique (QFT)
- Background Information StoryMap: https://wdfw-egc-hub-wdfw.hub.arcgis.com/pages/background-information
- Don't let it loose campaign from Washington invasive species council. https://invasivespecies.wa.gov/campaigns/dont-let-it-loose/

Standards

MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to provide evidence for phenomena.	**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. • 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. • Growth of organisms and population increases are limited by access to resources.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students organize the given data (e.g., using tables, graphs, and charts) to allow for analysis and interpretation of relationships between resource availability and organisms in an ecosystem, including:	
		i.	Populations (e.g., sizes, reproduction rates, growth information) of organisms as a function of resource availability.
		ii.	Growth of individual organisms as a function of resource availability.
2	Identifying relationships		
	a	Students analyze the organized data to determine the relationships between the size of a population, the growth and survival of individual organisms, and resource availability.	
	b	Students determine whether the relationships provide evidence of a causal link between these factors.	
3	Interpreting data		
	a	Students analyze and interpret the organized data to make predictions based on evidence of causal relationships between resource availability, organisms, and organism populations. Students make relevant predictions, including:	
		i.	Changes in the amount and availability of a given resource (e.g., less food) may result in changes in the population of an organism (e.g., less food results in fewer organisms).
		ii.	Changes in the amount or availability of a resource (e.g., more food) may result in changes in the growth of individual organisms (e.g., more food results in faster growth).
		iii.	Resource availability drives competition among organisms, both within a population as well as between populations.
		iv.	Resource availability may have effects on a population's rate of reproduction.

MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] *[Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]*

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to describe phenomena.

Disciplinary Core Ideas

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. Transfers of matter into and out of the physical environment occur 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.

Crosscutting Concepts

Energy and Matter

- The transfer of energy can be tracked as energy flows through a natural system.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components, including:	
		i.	Organisms that can be classified as producers, consumers, and/or decomposers.
		ii.	Nonliving parts of an ecosystem (e.g., water, minerals, air) that can provide matter to living organisms or receive matter from living organisms.
		iii.	Energy
	b	Students define the boundaries of the ecosystem under consideration in their model (e.g., pond, part of a forest, meadow; a whole forest, which contains a meadow, pond, and stream).	
2	Relationships		
	a	In the model, students describe* relationships between components within the ecosystem, including:	
		i.	Energy transfer into and out of the system.
		ii.	Energy transfer and matter cycling (cycling of atoms):
			1. Among producers, consumers, and decomposers (e.g., decomposers break down consumers and producers via chemical reactions and use the energy released from rearranging those molecules for growth and development).
			2. Between organisms and the nonliving parts of the system (e.g., producers use matter from the nonliving parts of the ecosystem and energy from the sun to produce food from nonfood materials).
3	Connections		
	a	Students use the model to describe* the cycling of matter and flow of energy among living and nonliving parts of the defined system, including:	

		i.	When organisms consume other organisms, there is a transfer of energy and a cycling of atoms that were originally captured from the nonliving parts of the ecosystem by producers.
		ii.	The transfer of matter (atoms) and energy between living and nonliving parts of the ecosystem at every level within the system, which allows matter to cycle and energy to flow within and outside of the system.
	b	Students use the model to track energy transfer and matter cycling in the system based on consistent and measureable patterns, including:	
		i.	That the atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
		ii.	That matter and energy are conserved through transfers within and outside of the ecosystem.

MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-4. **Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science disciplines share common rules of obtaining and evaluating empirical evidence.	**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.	**Stability and Change** • Small changes in one part of a system might cause large changes in another part.

Observable features of the student performance by the end of the course:			
1	Supported claims		
	a	Students make a claim to be supported about a given explanation or model for a phenomenon. In their claim, students include the idea that changes to physical or biological components of an ecosystem can affect the populations living there.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence (e.g., evidence from data, scientific literature) needed for supporting the claim, including evidence about:	
		i.	Changes in the physical or biological components of an ecosystem, including the magnitude of the changes (e.g., data about rainfall, fires, predator removal, species introduction).
		ii.	Changes in the populations of an ecosystem, including the magnitude of the changes (e.g., changes in population size, types of species present, and relative prevalence of a species within the ecosystem).
		iii.	Evidence of causal and correlational relationships between changes in the components of an ecosystem with the changes in populations.
	b	Students use multiple valid and reliable sources of evidence.	
3	Evaluating and critiquing the evidence		
	a	Students evaluate the given evidence, identifying the necessary and sufficient evidence for supporting the claim.	
	b	Students identify alternative interpretations of the evidence and describe* why the evidence supports the student's claim.	
4	Reasoning and synthesis		
	a	Students use reasoning to connect the appropriate evidence to the claim and construct an oral or written argument about the causal relationship between physical and biological components of an	

		ecosystem and changes in organism populations, based on patterns in the evidence. In the argument, students describe* a chain of reasoning that includes:	
		i.	Specific changes in the physical or biological components of an ecosystem cause changes that can affect the survival and reproductive likelihood of organisms within that ecosystem (e.g., scarcity of food or the elimination of a predator will alter the survival and reproductive probability of some organisms).
		ii.	Factors that affect the survival and reproduction of organisms can cause changes in the populations of those organisms.
		iii.	Patterns in the evidence suggest that many different types of changes (e.g., changes in multiple types of physical and biological components) are correlated with changes in organism populations.
		iv.	Several consistent correlational patterns, along with the understanding of specific causal relationships between changes in the components of an ecosystem and changes in the survival and reproduction of organisms, suggest that many changes in physical or biological components of ecosystems can cause changes in populations of organisms.
		v.	Some small changes in physical or biological components of an ecosystem are associated with large changes in a population, suggesting that small changes in one component of an ecosystem can cause large changes in another component.

MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. *(secondary)*

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)*

Crosscutting Concepts

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Observable features of the student performance by the end of the course:			
1	Identifying the given design solution and supporting evidence		
	a	Students identify and describe*:	
		i.	The given competing design solutions for maintaining biodiversity and ecosystem services.
		ii.	The given problem involving biodiversity and/or ecosystem services that is being solved by the given design solutions, including information about why biodiversity and/or ecosystem services are necessary to maintaining a healthy ecosystem.
		iii.	The given evidence about performance of the given design solutions.
2	Identifying any potential additional evidence that is relevant to the evaluation		
	a	Students identify and describe* the additional evidence (in the form of data, information, or other appropriate forms) that is relevant to the problem, design solutions, and evaluation of the solutions, including:	
		i.	The variety of species (biodiversity) found in the given ecosystem.
		ii.	Factors that affect the stability of the biodiversity of the given ecosystem.

		iii.	Ecosystem services (e.g., water purification, nutrient recycling, prevention of soil erosion) that affect the stability of the system.
	b	Students collaboratively define and describe* criteria and constraints for the evaluation of the design solution.	
3	Evaluating and critiquing the design solution		
	a	In their evaluations, students use scientific evidence to:	
		i.	Compare the ability of each of the competing design solutions to maintain ecosystem stability and biodiversity.
		ii.	Clarify the strengths and weaknesses of the competing designs with respect to each criterion and constraint (e.g., scientific, social, and economic considerations).
		iii.	Assess possible side effects of the given design solutions on other aspects of the ecosystem, including the possibility that a small change in one component of an ecosystem can produce a large change in another component of the ecosystem.