Managing Whales at Risk

How does population genetics inform marine policy and management?

Overview
In recent years, an increasing number of large whales have become entangled by crab trap lines off the U.S. Pacific coast. Wildlife managers are interested in knowing whether the whales are from threatened or endangered populations. In this lesson, students will learn how whale populations are defined, and how population genetics can be used to help inform marine policy and management.

Learning Goals
Students will learn the following:

- *Genetic data provides information that can help researchers and resource managers identify and protect populations that are at greatest risk.*
- *Genetically distinct populations of organisms can exist in the same area during certain periods of the year.*
- *Knowing the status of the population to which an impacted individual whale belongs can inform how managers respond to threats.*

Introduction
Research has shown that humpback whales observed off the Oregon coast are made up of individuals from three genetically distinct populations. Scientists use research techniques known as genotype panels and mitochondrial haplotypes to distinguish the populations. Each whale population uses one of three different breeding grounds, located in Hawaii, Mexico, or Central America. Although scientists estimate the Hawaii population to be approaching 20,000 individuals, there are many fewer humpback whales in the populations that breed offshore Mexico and Central America. The Mexico and Central America populations are listed as threatened and endangered, respectively.

Image: Ed Lyman/NOAA

Whales from the three populations mix to an unknown degree when migrating and feeding. Since the breeding grounds fall under different jurisdictions for species management, effective management of humpback whale populations requires international, cooperative practices.

Authors
Dr. Micki Halsey Randall & Stephanie Razmus
Blanchet Catholic School
Slade Sapora
Tillamook High School
Karen Lohman
Oregon State University

Grade Level
9-12

Anchoring Phenomenon
Managing Whales at Risk

Driving Question
How does population genetics inform marine policy and management?

Time
13 – 18 class periods

Standards
Next Generation Science Standards
LS21.A – Structure and Function
LS3.A – Inheritance of Traits
LS3.B – Variation of Traits
ESS3.C – Human Impacts on Earth Systems
ETS.1B – Developing Possible Solutions

Common Core Math Standards
HS.S-ID.5
HS.S-ID.6
HS.S-IC-1

Learning Objectives

Students will be able to:

1. *Characterize the humpback whale populations that visit the U.S. Pacific Coast, including life history events, population status, and threats.*
2. *Analyze genetic evidence to determine the population to which an individual belongs.*
3. *Use genetic evidence to inform policy proposals that could protect whale populations that are most at risk.*

The anchoring phenomenon of this lesson begins with the observed problem of humpback whale entanglement in crabbing gear off the U.S. Pacific coast. Obviously, this is a problem for the individual whales, but what impacts might these deadly occurrences have for populations that are threatened or endangered? To investigate the issue, students first learn about the life history, migration patterns, and populations of different humpback whales that spend time off the U.S. Pacific coast. They learn how researchers use genetic evidence to determine to which population an individual belongs, and they practice using data to make population identifications for given individuals. Once students determine the degree to which whales from endangered populations are affected by gear entanglement, they propose policy solutions to address the problem.

Essential Questions

- *What is a genetic population?*
- *How do scientists determine to which population an individual whale belongs?*
- *Which populations are impacted by whale entanglements off the U.S. Pacific Coast?*
- *How can threats to whales be managed?*

Curriculum Maps

This ORSEA lesson was piloted in different courses, including a general biology course (Randall) and a marine biology course (Sapora). To see which components were used in each course, as well as the order and timing of lessons as they were implemented, view the two examples in this Curriculum Maps document .

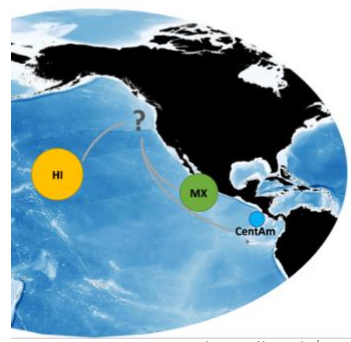
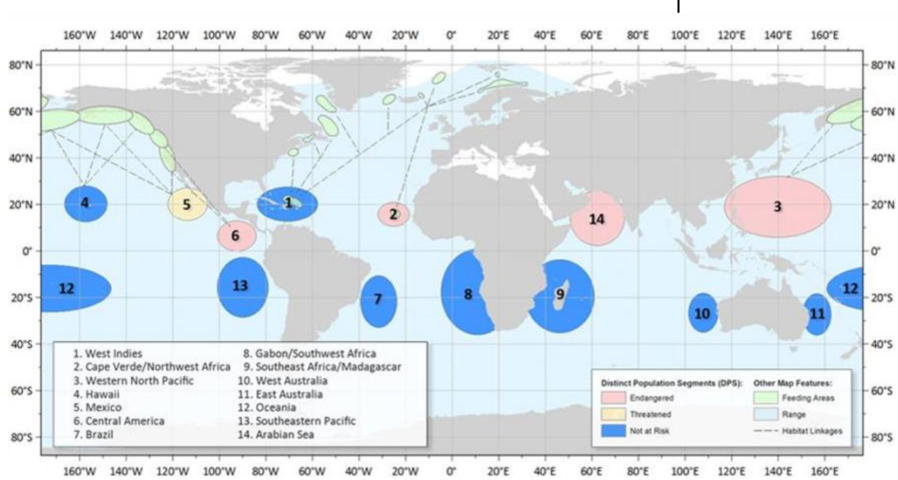


Image: Karen Lohman

Image: NOAA



Humpback whale population chart, with "not at risk" groups shown in blue. Credit: NOAA

Lesson Procedure

ENGAGE

Use the *Save the Whales!* presentation (slides 5-9) to guide the lesson in this section.

Activity: Introduce the problem of whale entanglement
Show students a video of a *Whale Disentanglement* without providing commentary. After watching the video, ask the students: What is going on here? What is the whale caught in? What kind of whale is it? Where is this? What was the whale doing when it got itself all caught up?

Next, play the *Teaming Up for Entangled Whales* video from NOAA Fisheries. Towards the end of this video, the narrator uses the term “population” several times - write POPULATION on the board and have students discuss what this word means - in general, and specifically in regard to whales.

The “Population vs Species” slide (#7) shows global whale populations on a map with color bubbles indicating population status. If we are going to SAVE THE WHALES, which whale populations should we prioritize in our protective efforts? How would we identify these different populations when they all get to mixing it up here on the Oregon coast?

EXPLORE

In this section, students explore resources to learn about humpback whales, their populations, and the entanglement risks they might encounter. The teacher may decide at this time to preview the expectations for the culminating Town Hall event that will take place at the end of the unit.

Activity: Humpback Whale Background
Students explore recommended websites to learn about humpback whale biology and answer questions on the worksheet *Exploring Humpback Whales.* Using a blank map of the North Pacific Ocean, students follow instructions in the *Mapping Locations of Humpback Whales* to plot data and respond to questions about the patterns they observe. In addition, students research and respond to questions about the *Endangered Species Act* and how it is applied to humpback whales.

Activity: Entanglement Risk Reading and Discussion
Have students read the *2018 West Coast Whale Entanglement Summary* and take notes (15 min). Then, engage the class in a discussion using *Guided Discussion Prompts*.

LESSON RESOURCES

Presentation:
- *Save the Whales!*

Videos:
- *Whale Disentanglement*
- *Teaming Up for Entangled Whales*

Image: Bryant Anderson / NOAA Fisheries

Humpback Whale Background:
- *Exploring Humpback Whales*
- *Mapping Locations of Humpback Whales*
- *Endangered Species Act*

Entanglement Risk:
- *2018 West Coast Whale Entanglement Summary*

Guided Discussion Prompts:
- *What are the numbers of entangled animals, what are the locations of entanglement reports, what species are involved, what sources of entanglement have been identified, what are the responses and outcomes, and what is being done to address the issue?*
- *Given the known and potential sources of humpback whale entanglements, brainstorm possible solutions. Look for existing, alternative methods or gear that could reduce entanglements. How could knowledge of the timing and location of entanglements inform possible solutions?*
- *What implications does the Endangered Species Act have on management of humpback whales?*

EXPLAIN

Continue the rest of the *Save the Whales!* presentation in sections over the course of the unit. Refer to the *Curriculum Maps* for examples of pacing for slides.

Humpback whale populations have been identified through genetic analysis. In this section, students first learn about DNA profiling and extraction, and then they use a dataset to match individuals with their population group.

Activity: HHMI DNA Profiling

This multipart activity from HHMI is designed to give students a firm understanding of genetic profiling using short tandem repeats (STRs), which is a process used by forensic labs around the world. Use with interactive activity: *CSI Wildlife* (click on "Launch Interactive" to begin the activity). Over two days, students complete the interactive *Analyzing Genetic Evidence* packet (4pgs)

Activity: Strawberry DNA Extraction Demo

Demonstrate the process for extracting DNA from a strawberry.

Activity: Data Analysis

In this activity, students use the *North Pacific Whale Data Set* to complete *NP Whale Genotype Matches worksheet #1*.
They will use whale entanglement data to figure out which population each entangled whale comes from.

Next, students use the same *NP Whale Data Set* to complete the *Calculating Probability of Identification* worksheet. Given genotype data, students calculate the relative frequencies of key alleles in humpback whale populations, and then use the relative frequencies to calculate the probability of identification for individual whales.

ELABORATE

In this section, students use their data calculations to inform their Policy Proposals. Using *NP Whale Genotype Matches worksheet #2*, they calculate Potential Biological Removal (PBR), compare PBR figures to the number of entanglements in the dataset, and describe how their calculations should be used to manage humpback whales off the U.S. Pacific Coast.

DNA Biointeractives from HHMI

- *DNA Profiling Activity*
- *CSI Wildlife Activity*
- *Analyzing Genetic Evidence packet* (4pgs)

DNA Extraction Demo

- *Strawberry DNA Extraction*
- *Student worksheet*

Data Analysis

- *NP Whale Data set*
- *NP Whale Genotype Matches* worksheet #1
- *Calculating Probability of Identification* worksheet
- *Genetic Marker Quiz*

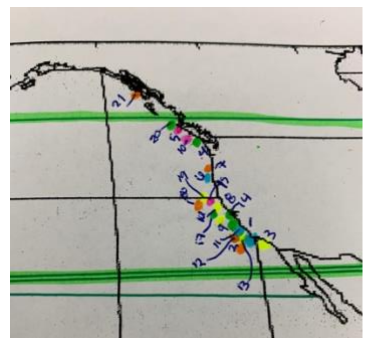


Image: Micki Halsey Randall

Field Experiences for Students

- *Marine Discovery Tours - whale watching*
- *Hatfield Marine Science Center - lab*
- *Whale Watching Center*

Policy Proposals

- *NP whale Genotype Matches* worksheet #2

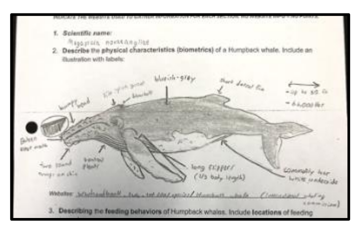


Image: Micki Halsey Randall

EVALUATE

The lesson concludes with students identifying the stakeholders who are impacted by this population genetics research.

Activity: Town Hall

Assign students to research and represent a stakeholder role and position to share at a culminating in-class Town Hall event. Example stakeholder roles might include: commercial fishers (crabbers), resource managers (ODFW, NOAA), local tourism industry (whale watching), academic/government scientists, conservation organizations, etc. Share the *Town Hall Rubric and Template* with students so they will know what they are expected to produce and how they will be evaluated.

On the day of the event, each student will turn in a single-page, stakeholder document that contains a summary paragraph stating the problem and the student's suggested solution (see *Template*). The document will include a graph of data, and a written summary of the graph that supports their argument. Following the Town Hall, students will answer three *Student Assessment* questions which will be turned in at the end of the period.

The student stakeholder documents and participation in the Town Hall will be evaluated by the teacher according to the *Town Hall Rubric*. The teacher will also evaluate the students' written policy proposals from the *NP Whale Genotytpe Matches worksheet #2*.

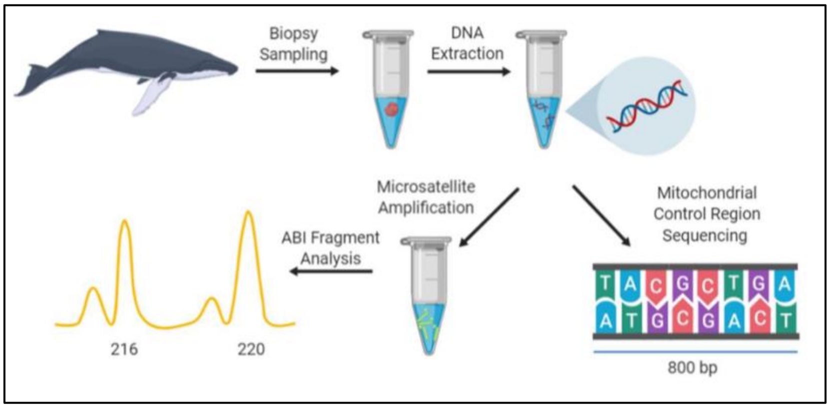


Image: Karen Lohman

Town Hall Meeting

- *Town Hall Rubric and Template*
- *Student Assessment* worksheet

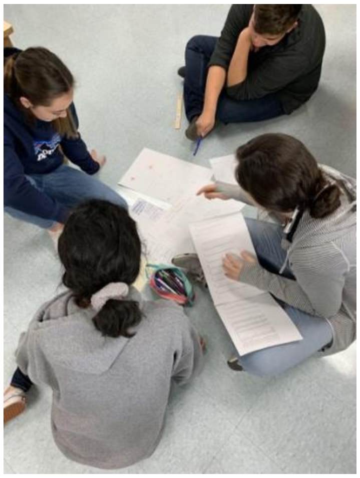


Image: Micki Halsey Randall

Image: Doug Perrine, NOAA Permit #88

Next Generation Science Standards

Performance Expectations:
HS-LS3-1 - Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
HS-LS3-3 - Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
HS-ESS3-4 - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ETS1-3 - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Science & Engineering Practices:
Asking Questions and Defining Problems
Analyzing and Interpreting Data
Constructing Explanations and Designing Solutions

Disciplinary Core Ideas:
LS1.A - Structure and Function
LS3.A - Inheritance of Traits
LS3.B - Variation of Traits
ESS3.C - Human Impacts on Earth Systems
ETS.1B - Developing Possible Solutions

Crosscutting Concepts:
Cause and Effect
Scale, Proportion and Quantity
Stability and Change
Influence of Science, Engineering, and Technology on Society and the Natural World

Math Practices:
MP.1 - Make sense of problems and persevere in solving them.
MP.3 - Construct viable arguments and critique the reasoning of others.
MP.5 - Use appropriate tools strategically.

Math Standards:
HS.S-ID.5 - Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data. Recognize possible associations and trends in the data.
HS.S-ID.6 - Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
HS.S-IC.1 - Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

Acknowledgments
The 2019-20 ORSEA materials are based upon work supported by Oregon Sea Grant and the Oregon Coast STEM Hub, as well as the National Science Foundation Regional Class Research Vessels under Cooperative Agreement No. 1333564 Award: OCE-1748726. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

See more lessons on the [ORSEA webpage]