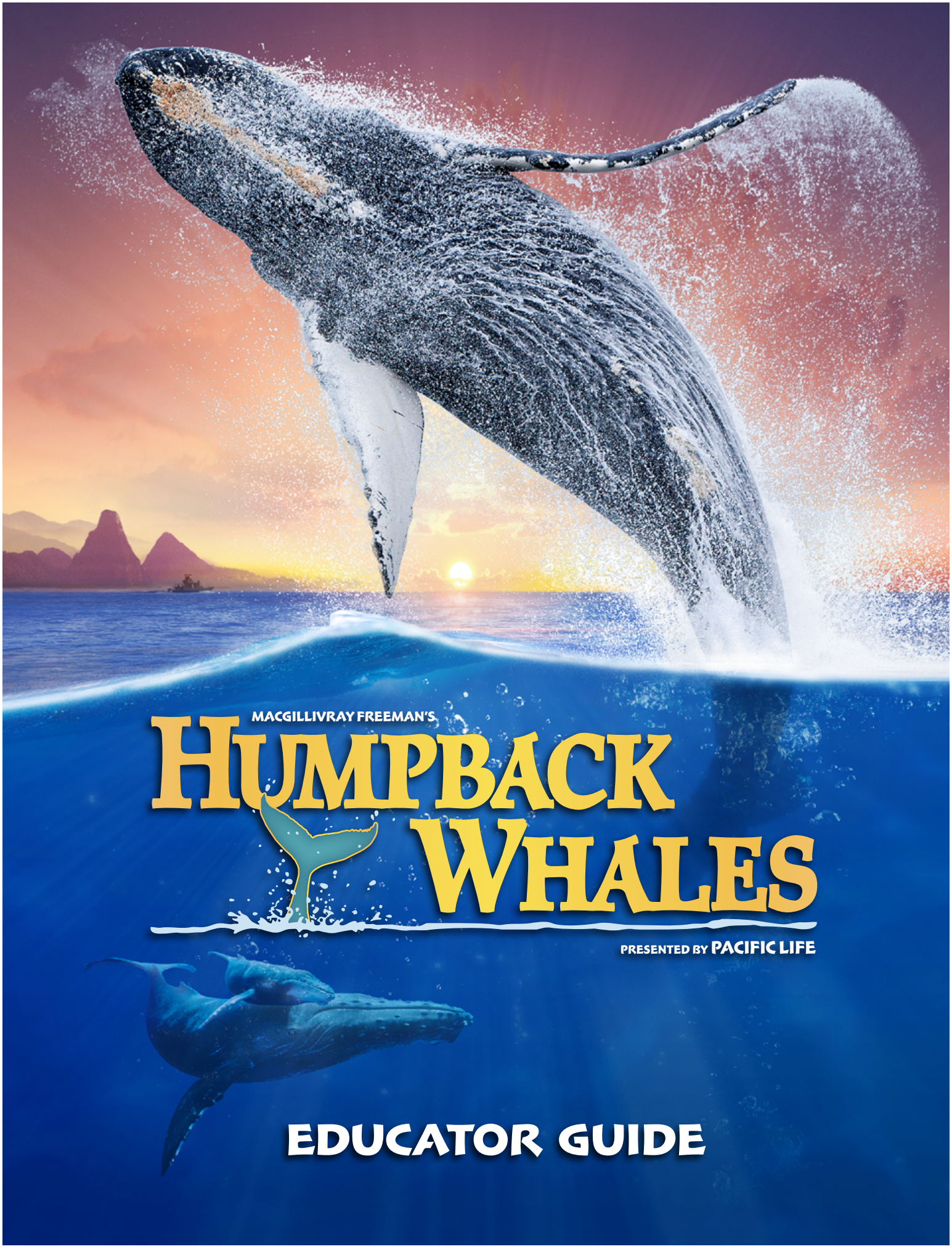

MACGILLIVRAY FREEMAN'S
HUMPBACK WHALES
PRESENTED BY PACIFIC LIFE
EDUCATOR GUIDE

LESSON **4**

Bioaccumulation: It All Adds Up

OBJECTIVE

In this lesson students will create a representation of how energy flows and cycles through a food web containing a humpback whale. Using magnets of various sizes they will swim and feed through an ocean food chain and after each feeding session count the quantity of toxins attached to their predator (large magnet). By recording these numbers they will see the numeric accumulation of toxins, representing bioaccumulation.

LESSON LENGTH

60 minutes

IN THE FILM

In the film we hear how the future of humpback whales in the Southern Ocean depends on the health of the Antarctic ecosystem. We learn that having a healthy whale calf population now is what makes possible a healthy and abundant whale population in the future. One concern is how the abundance of toxins in the food chain can negatively impact the health of whales as well as humans who consume seafood.

MATERIALS

Each student group will need:

- ☐ One large bowl or baking pan with sides to hold a box of BBs
- ☐ One small bowl to hold large magnets
- ☐ Each student (or each pair of students) needs one large magnet
- ☐ Steel BBs that are coated with copper or brass to prevent rust. These will act as the lower trophic level organisms (such as bait fish) in the activity.
- ☐ Internet availability and projector to view websites, or individual student devices
- ☐ A copy of the Food Pyramid and Bioaccumulation worksheet and the Ocean Food Web worksheet (optional).

TEACHER PREP NOTES

Students will learn the concept of food chains and the linear relationship and order of who eats whom in the ocean. They will also learn the concept of bioaccumulation in that it takes thousands of plankton to create a small fish and then hundreds of thousands of small fish to create an adult humpback whale. Each student group needs one medium -to-large (2 to 3- inch) magnet to represent a consumer. The BBs represent the toxins in the ocean that are absorbed by producers or ingested by consumers. (Online retailers sell small cartons of BBs and various sizes of magnets.) It is recommended to complete *Lesson 3: Anatomy and Adaptation* before this lesson as there is an in-depth introduction to plankton as the base of the food web.

KEY WORDS

Food Chain—A group of organisms linked in order by the food they eat, from producers to consumers and decomposers.

Food Web—A food web consists of all the food chains in a single ecosystem.

Producer—Organisms that make their own food and do not depend on any other organism for nutrition. In the ocean these are single-celled plant-like plankton (phytoplankton) and algae.

Consumer—An organism that eats another organism, with the food choice being plant or animal.

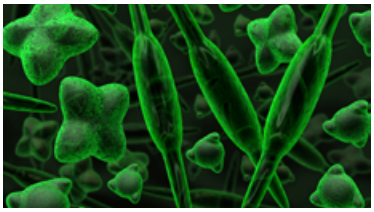
Decomposer—An organism that breaks down dead plant and animal material, releasing the minerals and nutrients from organic material and recycling them back into the food web.

Bioaccumulation—A process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical.

BACKGROUND

Bioaccumulation of toxic chemicals in ocean life comes from humans introducing chemicals through runoff pollution directly from land into the ocean or rivers. Once in the food chain, toxicity increases as energy moves up the food chain. If a medium size fish eats 10 small fish, then toxins in the medium fish can accumulate 10 times. Some of the most harmful toxins to humans and ocean animals such as whales include mercury, pesticides, and persistent organic pollutants (POPs). POPs stay in the environment for decades and in humans have been linked to impaired immune systems and developmental problems in young children. In the activity below students will write their data in an upside down triangle, which is the opposite of how we usually see food pyramids. Instead, this version shows the accumulation of toxins in the top predator. This activity also begins with a discussion of food chains and the roles organisms play in the food web. Consumers are organisms that eat primary producers and can be arranged in levels based on their prey choice. Primary consumers feed on producers, secondary consumers feed on the primary consumers, and tertiary consumers feed on secondary consumers. Examples include:

- **primary producer**—organisms, like plants, that produce food. Examples: phytoplankton, algae
- **primary consumer**—an animal that eats primary producers. Examples: krill, small fish, mussels



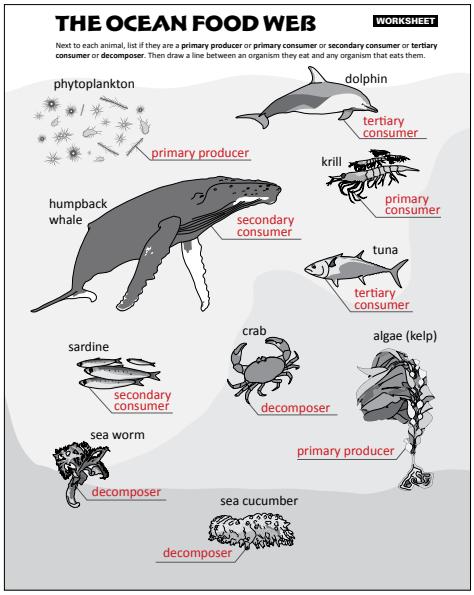

Microscopic organisms called phytoplankton (left) and zooplankton (right) form the base of several aquatic food webs. They provide food for many different sea creatures.

- **secondary consumer**—an animal that eats primary consumers. Examples: humpback whale, sardines
- **tertiary consumer**—an animal that eats secondary consumers. Examples: shark, dolphin, tuna
- **decomposer**—organisms that break down dead plant and animal material and wastes and release it again as energy and nutrients in the ecosystem. Examples: bacteria, sea cucumbers, worms, crabs

TO DO

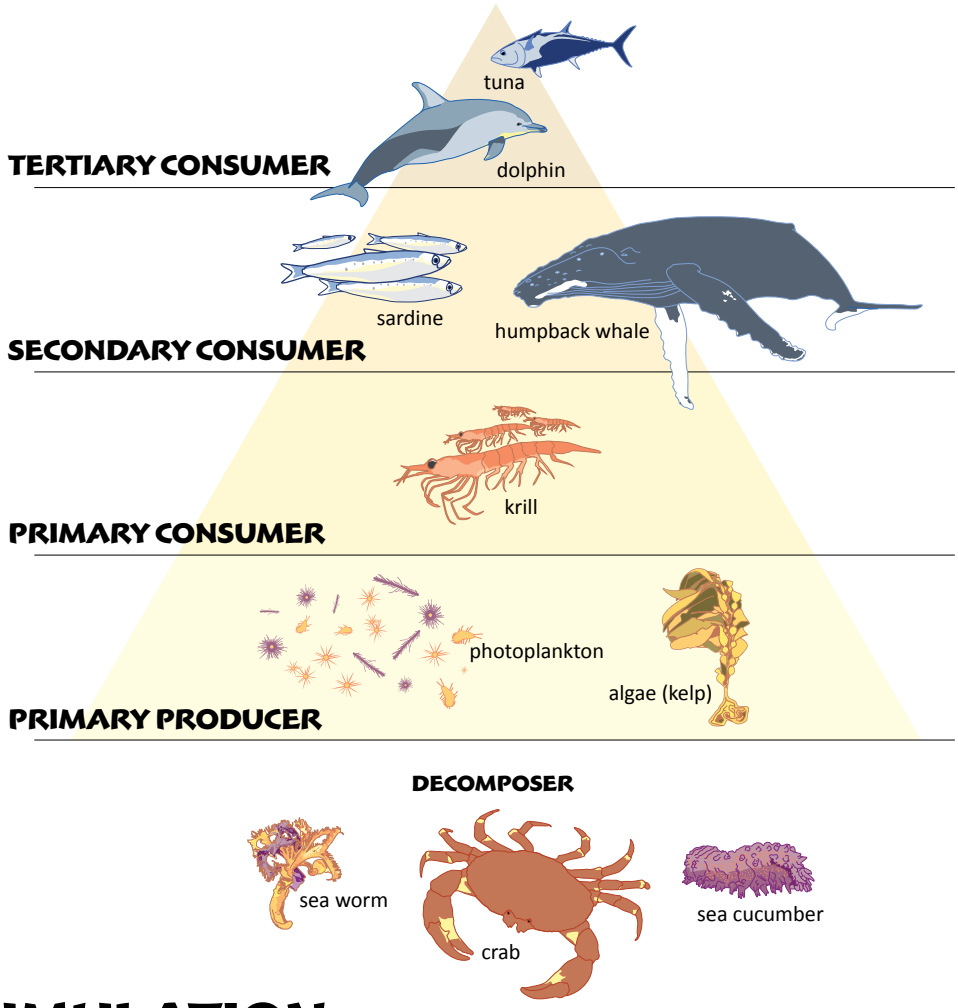
1. Lead discussion on food chains and write student examples on the board (it can be terrestrial if that is most familiar to students). Ask students to give examples of "who eats whom" starting with plants and moving up to the final consumer.
2. Ask students to give the same examples of food chains found in the ocean. Review the Food Pyramid and Bioaccumulation worksheet for examples of primary producers, primary consumers, etc.
3. (Optional) Hand out the Ocean Food Web worksheet and ask students to complete it.
4. Instruct students to take one large magnet (a krill) and swim through the water with the BBs (the ocean where they feed on plankton).
   - Count the number of BBs attached to the large magnet. These represent the number of plankton and the number of toxins ingested.Write the number on the bottom (point) section of the pyramid on the Food Pyramid and Bioaccumulation worksheet. (1 swim through ocean = 1 krill eating phyto-plankton).
5. Repeat using the steps below:
   - Swim the magnet through the BBs 3 times and record the number of attached BBs in the middle section of the pyramid. (3 swims through the ocean = 1 small fish eating lots of krill)
   - Swim the magnet through the BBs 5 times and record the number of attached BBs in the top of the pyramid. (5 swims through the ocean = humpback whale eating thousands of small fish or krill)
6. Lead the discussion asking: How many fish do you think humpback whales eat a day during the feeding season? Several hundred? Several thousand? (Whales can eat up to 2,000 pounds of food a day). How about the fish eating plankton? How many a day?
7. Instruct students to take the numbers in the pyramid and multiple by 100 as an estimate of daily minimum feeding requirements.
8. Discuss: What are examples of toxins? Where do they come from? How do they get in the ocean? Which animals have the highest number? The pyramid shows the quantity of plankton it takes to feed the top predator and others on the food pyramid. It also shows the amount of toxins that are now in the body of each animal, showing the concept of bioaccumulation. Why did we draw an upside down pyramid? (to show the amount of toxins that accumulate in the top predator). What impact might this have on humpback whales' health? To the health of calves born to mother whales feeding on fish with higher toxins? Who else eats fish? Is there the potential for this to impact humans that eat seafood?
9. Go to the *One World One Ocean.com* website and locate the *Sustainable Seafood: Why It's Good for Your Health* infographic. (Go to *Media*, then *Infographics*) (www.oneworldoneocean.com/blog/entry/seafood_and_your_health_infographic)
10. Project the image on the board and discuss as a conclusion to the activity:
    - What toxins are harmful to humans?
    - In what seafood choices are those toxins found?
    - What are the better choices of seafood to make for your own health?
11. To view and discuss impacts of toxins and diseases on marine mammals, visit the website home page for *Voices in the Sea* and select the videos section *Issues in Focus* and watch the short video titled *Unusual Mortality Events* (cetus.ucsd.edu/voicesinthe-sea_org/index.html).

ANSWER KEY:

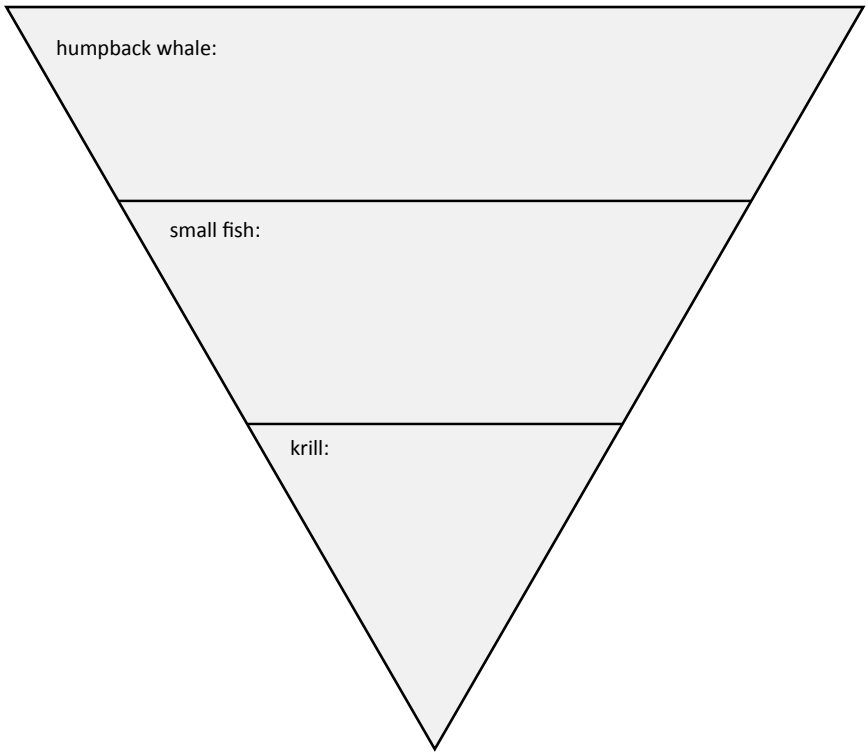


FOOD PYRAMID

WORKSHEET



BIOACCUMULATION



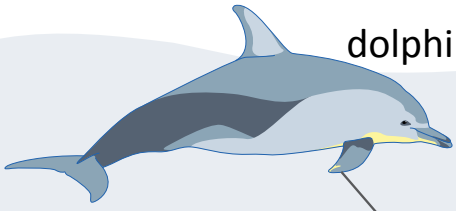
THE OCEAN FOOD WEB

WORKSHEET

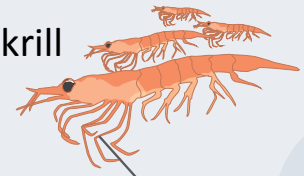
Next to each animal, list if they are a primary producer or primary consumer or secondary consumer or tertiary consumer or decomposer. Then draw a line between an organism they eat and any organism that eats them.

phytoplankton

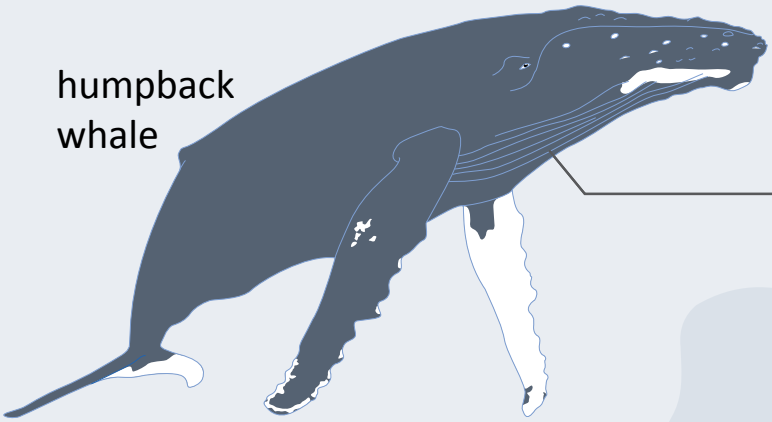
dolphin



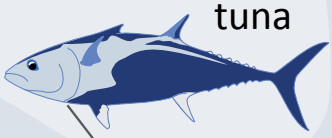
krill



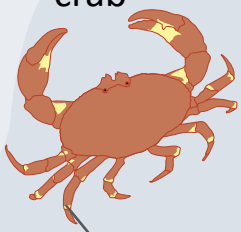
humpback whale



tuna



crab

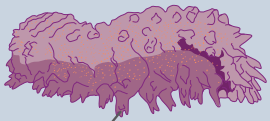


algae (kelp)

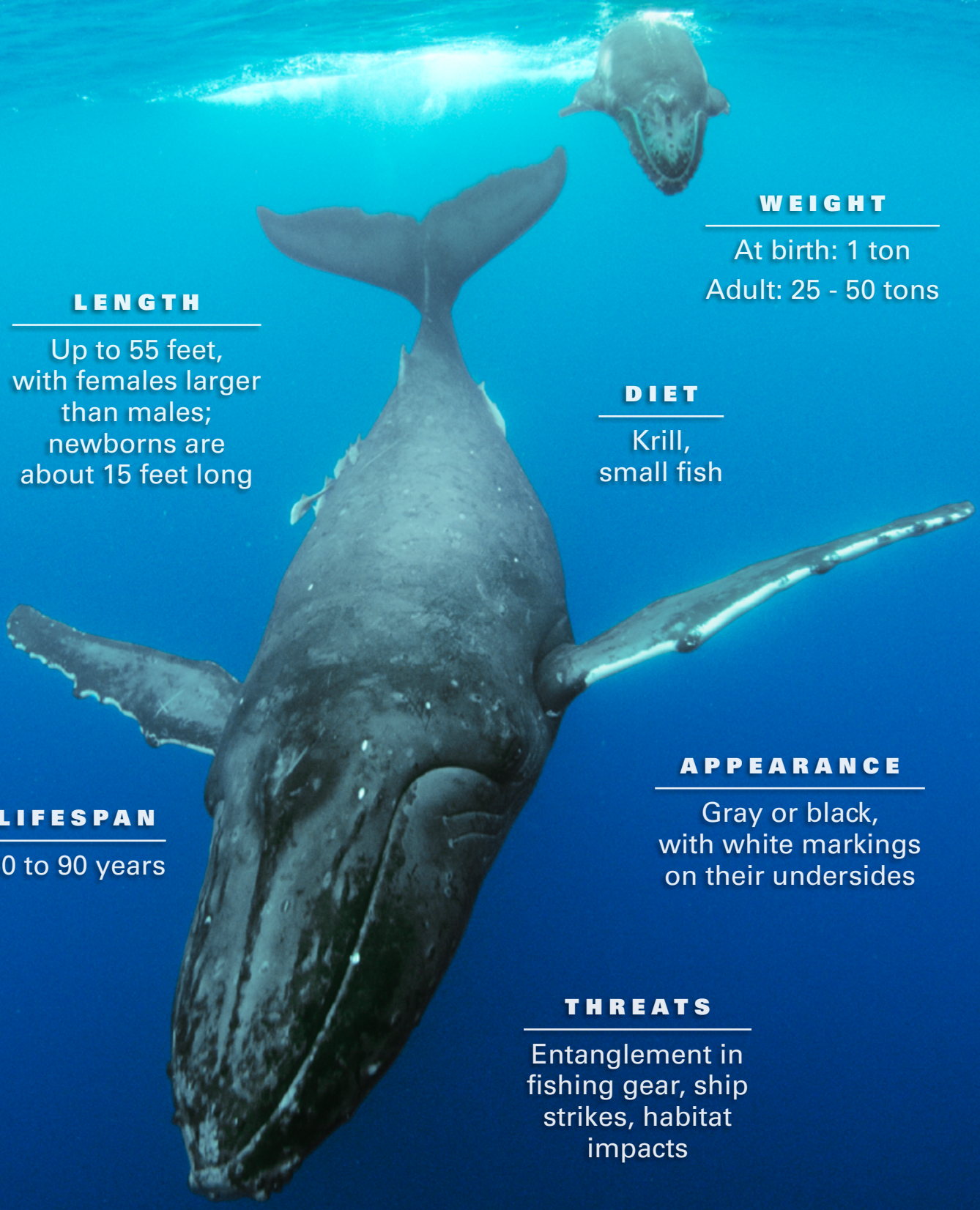
sardine

sea worm

sea cucumber



HUMPBACK FUN FACTS



LENGTH

Up to 55 feet, with females larger than males; newborns are about 15 feet long

WEIGHT

At birth: 1 ton

Adult: 25 - 50 tons

DIET

Krill, small fish

APPEARANCE

Gray or black, with white markings on their undersides

LIFESPAN

50 to 90 years

THREATS

Entanglement in fishing gear, ship strikes, habitat impacts

Resources to Learn More

ALASKA WHALE FOUNDATION
alaskawhalefoundation.org

The Alaska Whale Foundation (AWF) was founded in 1996 by a team of passionate individuals who wanted to shed light on the amazing behaviors of the endangered humpback whales in Southeast Alaska. AWF continues to study humpbacks and their habitat, but with greater resources, established scientists, and ambitious graduate and undergraduate student participants.

AMERICAN CETACEAN SOCIETY
acsonline.org

The American Cetacean Society believes that the solution to threats facing cetaceans begins with education. Whales, dolphins, and porpoises (collectively known as 'cetaceans') have an exceptional ability to inspire people and serve as ambassadors for marine conservation. And yet they face more threats today than ever before—from entanglement in marine debris and fishing gear, ship strikes, noise pollution, climate change, ocean acidification, contaminants, loss of habitat and whaling.

DISCOVERY OF SOUND IN THE SEA (DOSITS)
dosits.org

The Discovery of Sound in the Sea website will introduce the science and uses of sound in the sea. There are several major sections on the site such as The Science of Sound in the Sea, People and Sound in the Sea, and Animals and Sound in the Sea. The Discovery of Sound in the Sea website has been developed by the University of Rhode Island's Graduate School of Oceanography in partnership with Marine Acoustics, Inc. of Middletown, RI.

HAWAIIAN ISLANDS HUMPBACK WHALE NATIONAL MARINE SANCTUARY
hawaiihumpbackwhale.noaa.gov/explore/humpback_whale.html

The Hawaiian Islands Humpback Whale National Marine Sanctuary was created by Congress in 1992 to protect humpback whales and their habitat in Hawaii. The sanctuary, which lies within the shallow (less than 600 feet), warm waters surrounding the main Hawaiian Islands, constitutes one of the world's most important humpback whale habitats. Through education, outreach, research and resource protection activities, the sanctuary strives to protect humpback whales and their habitat in Hawaii.

INTERNATIONAL WHALING COMMISSION
iwc.int/home

The International Whaling Commission (IWC) is the global intergovernmental body charged with the conservation of whales and the management of whaling. It was set up under the International Convention for the Regulation of Whaling signed in 1946. The Commission has a current membership of 88 governments from countries around the world. The pages on this website provide detailed information about the Commission, its meetings, decisions and its current work to conserve and manage whale populations throughout the world.

NATIONAL MARINE MAMMAL LABORATORY
afsc.noaa.gov/nmml/species/species_humpback.php

The National Marine Mammal Laboratory (NMML) conducts research on marine mammals important to the mission of the National Marine Fisheries Service (NMFS) and the National Oceanic & Atmospheric Administration (NOAA), with particular attention to issues related to marine mammals off the coasts of Alaska and the North Pacific. Research projects focus on ecology and behavior, population dynamics, life history, and status and trends.

NOAA FISHERIES
nmfs.noaa.gov/stories/2012/10/noaa_fisheries_education.html

NOAA Fisheries is responsible for the stewardship of the nation's ocean resources and their habitat. The resilience of our marine ecosystems and coastal communities depend on healthy marine species, including protected species such as whales, sea turtles, corals, and salmon. Under the Marine Mammal Protection Act and the Endangered Species Act, NOAA Fisheries works to recover protected marine species while allowing economic and recreational opportunities.

ONE WORLD ONE OCEAN CAMPAIGN
oneworldoneocean.com

MacGillivray Freeman Films, producer of the giant-screen film *Humpback Whales*, has created a multi-platform campaign that uses the power of film, television and new media to inspire, educate and connect millions of people worldwide in a common purpose: to protect and restore the health of the ocean. The goals of the campaign include: educate and inspire people to buy sustainable seafood; reduce plastic pollution in the ocean; and expand protected areas to 10% of the planet's ocean. MacGillivray Freeman Films and the One World Ocean Campaign are located in Laguna Beach, California.

THE HAWAIIAN ISLANDS DISENTANGLEMENT NETWORK
hawaiihumpbackwhale.noaa.gov/res/rescue_network.html

The network was formed in 2002 in an attempt to free endangered humpback whales and other marine animals from life-threatening entanglements and at the same time gather valuable information that will help mitigate the issue of marine debris and future entanglement. The network is part of the larger Pacific Islands Marine Mammal Response Network headed by NOAA's Pacific Islands Regional Office.

VOICES IN THE SEA
voicesinthesea.org

Voices in the Sea is an interactive multimedia exhibit and companion website created by the Pacific Life Foundation and the Whale Acoustics Lab at Scripps Institution of Oceanography that seeks to bring educational content about the natural history, acoustics, and conservation of whales to aquarium visitors, students, and the general public. The educational content is available online and includes 37 short videos featuring on-camera interviews with more than 20 leading whale scientists, resource managers and community leaders.

WHALE TRUST
whaletrust.org

Whale Trust Maui is a nonprofit organization dedicated to scientific research and public awareness of whales and their environment. Based on the Hawaiian Island of Maui, they conduct and support marine research and education programs around Maui and elsewhere throughout the Pacific Ocean.

National Academic Standards

Next Generation Science Standards

LS: Life Science
ESS: Earth and Space Science
PS: Physical Science
ETS: Engineering, Technology, and Applications of Science

Lesson 1: Seeing Songs in the Sea

Third Grade
- 3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
- 3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
- 3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
- 3-LS4 Biological Evolution: Unity and Diversity (LS4.B and LS4.D)

Fourth Grade
- 4-LS1 From Molecules to Organisms: Structure and Processes (LS1.D)

Fifth Grade
- 5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
- MS-PS4 Waves and Their Application in Technologies for Information Transfer (PS4.A)
- MS-LS1 From Molecules to Organisms: Structures and Processes (MS-LS1.B)
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS.A and MS-LS2.C)

Lesson 2: Migration Match

Third Grade
- 3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
- 3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
- 3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
- 3-LS4 Biological Evolution: Unity and Diversity (LS2.C and LS4.B and LS4.D)

Fourth Grade
- 4-LS-1 From Molecules to Organisms: Structures and Processes (LS1.D)

Fifth Grade
- 5-PS3 Energy (LS1.C)
- 5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
- MS-LS1 From Molecules to Organisms: Structures and Processes (MS-LS1.B)
- MS – LS1 Science and Engineering Practices (MS-LS1-8)
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS2.A and LS2.C)
- MS-LS3 Heredity: Inheritance and Variation of Traits (LS1.A and LS1.B)

Lesson 3: Anatomy and Adaptations

Third Grade
- 3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
- 3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
- 3-LS3 Heredity: Inheritance and Variation of Traits (LS3.A and LS3.B)
- 3-LS4 Biological Evolution: Unity and Diversity (LS2.C and LS4.B and LS4.C and LS4.D)

Fourth Grade
- 4-LS-1 From Molecules to Organisms: Structures and Processes (LS1.A and LS1.D)

Fifth Grade
- 5-PS3 Energy (LS1.C)

Middle School
- MS-LS1 From Molecules to Organisms: Structures and Processes (MS-LS1.B and MS-LS1.C)
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS2.A and LS2.C)
- MS-LS4- Biological Evolution: Unity and Diversity (LS4.B and LS4.C)

Lesson 4: Bioaccumulation: It All Adds Up

Third Grade
- 3-LS1 From Molecules to Organisms: Structures and Processes (LS1.B)
- 3-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.D)
- 3-LS4 Biological Evolution: Unity and Diversity (LS2.C and LS4.C and LS4.D)

Fourth Grade
- 4-LS-1 From Molecules to Organisms: Structures and Processes (LS1.A)

Fifth Grade
- 5-PS3 Energy (LS1.C)
- 5-LS1 From Molecules to Organisms: Structures and Processes (LS1.C)
- 5-LS2 Ecosystems: Interactions, Energy, and Dynamics (LS2.A and LS2.B)
- 5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
- MS-LS1 From Molecules to Organisms: Structures and Processes (MS-LS1.C)
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS2.A and LS2.B and LS2.C and LS4.D)
- MS-ESS3 Earth and Human Activity (ESS3.A and ESS3.C and ESS3.D)

Lesson 5: "Whale Safe" Engineering Challenge

Third Grade
- 3-LS4 Biological Evolution: Unity and Diversity (LS2.C and LS4.D)

Fifth Grade
- 5-ESS3 Earth and Human Activity (ESS3.C)
- 3rd – 5th Engineering Design (ETS1.A and ETS1.B and ETS1.C)

Middle School
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS2.A and LS2.B and LS2.C and LS4.D and ETS1.B)
- MS-ESS3 Earth and Human Activity (ESS3.C)
- Middle School Engineering Design (ETS1.A and ETS1.B and ETS1.C)

Lesson 6: Whaling to Whale Watching

Third Grade
- 3-LS4 Biological Evolution: Unity and Diversity (LS2.C and LS4.D)

Fourth Grade
- 4-ESS3 Earth and Human Activity (ESS3.A)

Fifth Grade
- 5-ESS3 Earth and Human Activity (ESS3.C)

Middle School
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics (MS-LS2.A and LS2.C and LS4.D and ETS1.B)
- MS-ESS3 Earth and Human Activity (ESS3.C and ESS3.D)

Ocean Literacy Principles

Lesson 1: Principles 5 and 6
Lesson 2: Principles 1, 5 and 6
Lesson 3: Principles 1, 4 and 5 and 6
Lesson 4: Principles 1, 5 and 6
Lesson 5: Principles 5, 6 and 7
Lesson 6: Principles 5, 6 and 7

Ocean Literacy Principles
1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean made Earth habitable.
5. The ocean supports a great diversity of life and ecosystems
6. The ocean and humans are inextricably interconnected
7. The ocean is largely unexplored

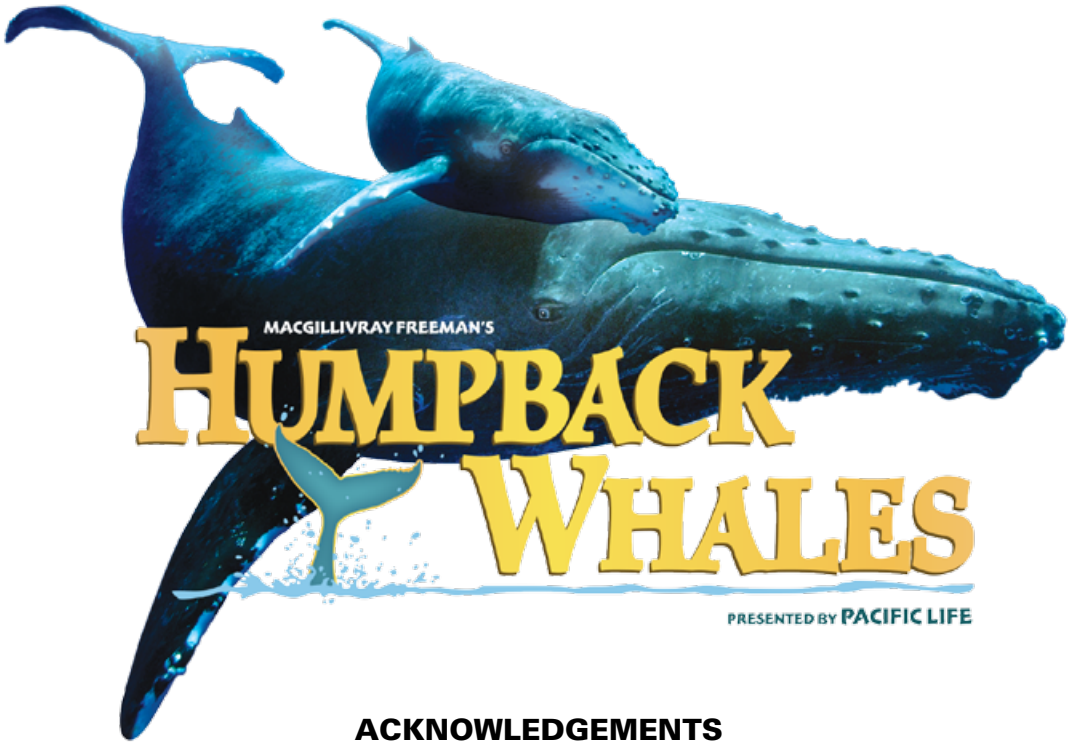
National Geography Standards

Lesson 1: Standards 4 and 5
Lesson 2: Standards 1, 3, 4, 5 and 6
Lesson 3: Standards 4
Lesson 4: Standards 4 and 5
Lesson 5: Standards 2, 4 and 5
Lesson 6: Standards 2, 4 and 5

National Geography Standards
1. The world in spatial terms
2. Places and regions
3. Physical systems
4. Human systems
5. Environment and society
6. The uses of geography

Common Core Language Arts

Reading Informational Text—Lesson 2, 4 and 6
Writing—Lesson 5 and 6
Speaking and Listening—All lessons



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MACGILLIVRAY FREEMAN FILMS EDUCATIONAL FOUNDATION

Orange County Community Foundation

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